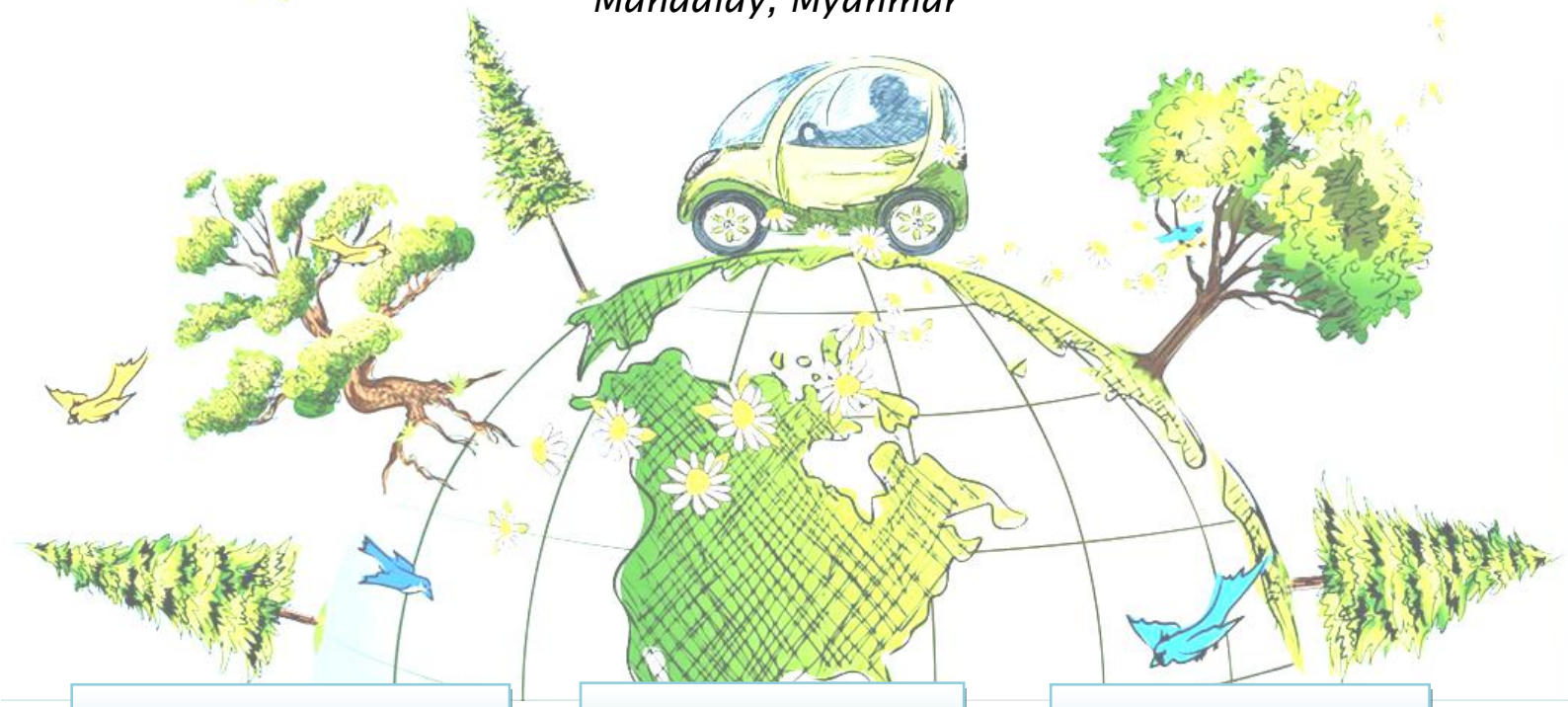
PROCEEDINGS

THE 8TH GMSARN INTERNATIONAL CONFERENCE 2013 ON

Green Growth in GMS: Energy, Environment and Social Issues

18-20 December 2013
Sedona Hotel
Mandalay, Myanmar



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About GMSARN

The Greater Mekong Subregion (GMS) consists of Cambodia, China (Yunnan & Guangxi Provinces), Laos, Myanmar, Thailand and Vietnam.

The Greater Mekong Subregion Academic and Research Network (GMSARN) is composed of sixteen of the region's top-ranking academic and research institutions. GMSARN carries out activities in the following areas: human resources development, joint research, and dissemination of information and intellectual assets generated in the GMS. GMSARN seeks to ensure that the holistic intellectual knowledge and assets generated, developed and maintained are shared by organizations within the region. Primary emphasis is placed on complementary linkages between technological and socio-economic development issues.

The GMSARN current member institutions are the Asian Institute of Technology, Pathumthani, Thailand; The Institute of Technology of Cambodia, Phnom Penh, Cambodia; Kunming University of Science and Technology, Yunnan Province, China; National University of Laos, Vientiane, Laos PDR; Yangon Technological University, Yangon, Myanmar; Khon Kaen University, Khon Kaen Province, Thailand; Thammasat University, Bangkok, Thailand; Hanoi University of Technology, Hanoi, Vietnam; Ho Chi Minh City University of Technology, Ho Chi Minh City, Vietnam; The Royal University of Phnom Penh, Phnom Penh, Cambodia; Yunnan University, Yunnan Province and Guangxi University, Guangxi Province, China; Nakhon Phanom University, Nakon Phanom Province, Thailand; and Ubon Ratchathani University, Ubon Ratchathani Province, Thailand and another associate members are Mekong River Commission, Vientiane, Laos PDR. These institutions together with the Asian Development Bank are being represented in the GMSARN Board by their respective Rectors, Presidents and Representatives.

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Greetings from Conference Chair

It is my great pleasure to chair "the Eight GMSARN International Conference 2013 on "*Green Growth in GMS: Energy, Environment and Social Issues*". On behalf of organizing committee, I take this opportunity to welcome you all to this prestigious international conference.

A Green Economy is the vital links between economy, society, and environment taking into account the transformation of production processes, production and consumption patterns, while contributing to a reduction per unit in reduced waste, pollution. The use of resources, materials, and energy in an environmental friendly manner will revitalize and diversify economies, create well-mannered employment opportunities, promote sustainable trade, reduce poverty, and improve equity and income distribution. With the growing technologies surrounding the internet there is a good opportunity to build a firm network that would contribute to promote Subregional Sustainable Development.

It is my pride that the Greater Mekong Subregion Academic and Research Network (GMSARN) Secretariat is situated in Asian Institute of Technology, Thailand. GMSARN through its Research and Education Project seeks to ensure that the holistic intellectual knowledge and assets generated, developed and maintained are shared by organizations within the Subregion. Network consists of 15 premier universities and research institution in the Subregion spreading over six member countries. GMSARN platform can also be used to develop *joint academic, research, and outreach programs* within member institutes.

The conference is organized by Greater Mekong Subregion Academic and Research Network (GMSARN) and co-organized by Asian Institute of Technology (AIT), Yangon Technological University (YTU) and Mandalay Technological University (MTU). In organizing this conference, GMSARN has been assisted and guided by our International Advisory Committee. The cooperation has been given by our co-organizers, colleagues, and friends from institutions in GMS and beyond words of appreciation.

I take this great honor to thank the co-organizers, sponsors, for their esteemed support and cooperation. Finally, I would like to thank once again the participants of the conference and wish that you enjoy the conference, your stay in Mandalay city.

Prof. Worsak Kanok-Nukulchai
Interim President
Asian Institute of Technology
P.O. Box 4, Klong Luang,
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Conference Purposes

GMS regions are facing various common problems - water & food, energy, environment and social issues. GMS countries are to achieve the global green growth with sustainability. The concept of green growth from Ministerial Conference on Environment and Development (MCED) is a strategy for achieving sustainable development. It is focused on overhauling the economy in a way that synergizes economic growth and environmental protection, building a green economy in which investments in resource savings as well as sustainable management of natural capital are drivers of growth. To address these critical issues, the International Conference 2013 on "***Green Growth in GMS: Energy, Environment and Social Issues***" is a three-day platform for knowledge dissemination by a diverse group of researchers and participants.

The rationale of the GMSARN 2013 is to initiate and stimulate international discussion and enhance research networking. The conference can be used as a platform on a regional and global level. Thus, it can contribute to sustainable development, and solve transboundary issues related to energy, environment and social development. The GMSARN International Conference is a multi-disciplinary conference which is problem oriented focus. In this aspect, GMSARN Conference is unique hosting a wide range of disciplines that would generate shared solutions to existing problems, regionally and globally. In addition, the conference aim is to provide a forum to disseminate the research and development findings on various sustainable developments in the GMS. It is also envisaged that the conference will be able to generate shared solutions beneficial to the GMS and the findings and recommendations should also be useful for GMSARN education and research programs.

Contact Address

The 8th GMSARN International Conference 2013 on "*Green Growth in GMS: Energy, Environment and Social Issues*".

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Venue

The conference venue will be held at Sedona Hotel, Mandalay, Myanmar.

Itinerary for Visiting Mandalay

Thursday 19 December 2013

Morning Session

03.30 – 03.45 am. Meet at Hotel's Lobby

04.00 am. Arrive at **Mahamuni Pagoda** for ritual of washing the Face of Maha Muni Image

06.00 am. Go back to the Hotel & Breakfast

08.30 am. Meet at Hotel's Lobby and leave to Pier

09.00 am. Go to **Mingun** by boat (11km up river) from Mandalay on the opposite bank of Ayeyarwaddy River. Tour highlights includes the huge unfinished Mingun Pagoda, Mingun Bell which weighs 90 tons, and Myatheindan Pagoda with seven concentric terraces at the base.

Lunch

12.00 pm. Luncheon at the Mya Nandar River View restaurant

Afternoon Session

13.00 pm. Visit **Mandalay Royal Palace**, **Shwe Nandaw Monastery** (Golden Palace) where you can marvel the superb example of Myanmar traditional woodcarving.
After that, go to **Kuthodaw Pagoda** known as World's Biggest Book for its 729 marble slabs engraved with Buddhist scriptures.

17.00 pm. Enjoy the sunset and panoramic view of **Mandalay Hills**.

Dinner

18.30 pm. Dinner at Oriental House

20.30 pm. Go back to Hotel

Remark: *English-speaking tour guide service & transportation (Bus & Boat) are provided. The programs maybe change without prior notice.*

Design and Feasibility Analysis of Solar Water Pumping System for Irrigation

Aye Chan Myae and Myat Myat Soe

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Patheingyi, Mandalay, Myanmar

Abstract— *This paper presents the solar water pumping system to provide irrigation purpose for a number of innovative applications. The main objective of this paper is to design the centrifugal pump and to observe the flow analysis in the centrifugal pump with the aids of SolidWork software. The focus has been to supplement the water for 1 acre paddy field and the total head against which the pump has to work as 5m by using centrifugal pump. The flow rate of this pump is 0.0143 m^3/s and the motor speed is 1500 rpm. The flow analysis of centrifugal pump is carried out after designing the dimensions of centrifugal pump.This study focused on utilizing renewable energy, in particular solar energy, to supply water in irrigation system. The main contribution is to investigate the solar water pumping system to transport water for irrigation. According to solar radiation data of dry zone in Myanmar, system is analyzed to fulfill about 413 Wh/m^2. This system consists of one 1.1 kW centrifugal pump, photovoltaic(PV) panel(2013 OPAI 300W polycrystalline PV panels each having 300W power output together with a controller(320A) and battery(2P1101Ah lead acid battery) storage system.*

Keywords— **Centrifugal pump, electrical energy, flow analysis, irrigation**

1. INTRODUCTION

Renewable energy system converts energy from sunlight, wind, falling water and other resources into usable form like electrical energy. Nowadays, solar water pumping systems have been used in many countries as they offer several advantages: fewer costs for operation and maintenance because of the operation of the system without the use of fossil fuel. The use of solar energy also results in reduction of greenhouse gases and avoids local pollution of the air, soil and of the well itself [3]. If so, everywhere away from national grids, people can enjoy the electricity generated by solar energy and can easily carry water or store water without waste of our time and energy since we can run the water pump directly from the solar panel without any difficultly. The main objective is to obtain for converting solar energy into electrical energy in a simple, cheap and safe way. The main components of solar water pumping system are centrifugal pump, solar PV array, storage batteries, inverter and motor. Photovoltaic modules only represent the basic element of a solar power system. From the side of centrifugal pump, the main components are the impeller and the volute casing. The impeller is a rotating component and the casing is a stationary component. Centrifugal pumps are widely used for irrigation, water supply plants, stream power plants, sewage, oil refineries, chemical plants, food processing factories and mines. Moreover, they are also used extensively in the chemical industry because of their suitability in practically any service and are mostly used in many applications such as water pumping project, domestic water raising, industrial waste water removal, raising water from tube wells to the fields [7]. This paper has demonstrated the use of solar water pumps to reduce grid-connected electricity use in pumping water for domestic consumption, thereby decreasing carbon dioxide emissions and allowing to reduce the electricity costs [5].

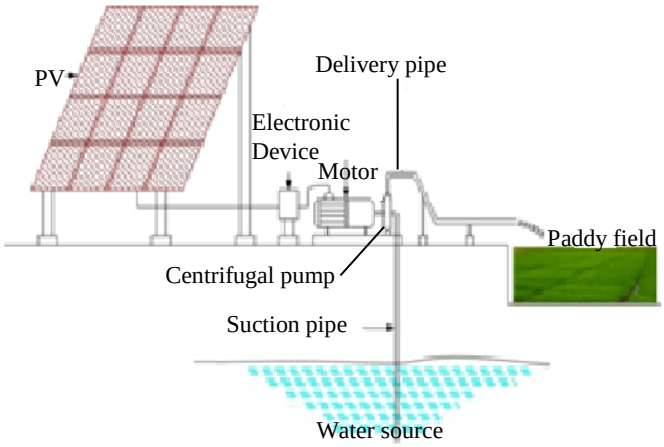

Fig.1. Layout Diagram of Solar Water Pumping System

2. METHODOLOGY OF THE SYSTEM

Solar Radiations

Solar radiation is transmitted from the sun through space to the earth by electromagnetic radiation. The earth moves about the sun in an elliptical orbit, completing one revolution per year. In addition, the earth rotates once per day about its polar axis. The polar axis is inclined at an angle of 23.45˚ from the normal to the plane of the earth's orbit. These rotations and the inclination between polar axis and ecliptic cause the day and night cycle and the seasons. As a result of the earth's axial rotation and its revolution around the sun, the sun is constantly changing

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its position in the sky. This motion of the sun determines the amount of solar energy incident upon a collector located on the earth's surface, since it depends on the distance travelled by the sun's rays first to the earth and then through the earth's atmosphere. The area of a solar collector exposed to the direct solar radiation depends upon the angle between the sun's rays and the collector. These and other factors must be considered when deciding on the solar energy available to a receiver [3].

Specification for Radiation

Design location	= Mandalay
North latitude, ϕ	= 21˚59′ N = 21.983˚N
East latitude, L_{loc}	= 96˚06′ E = 96.1˚E
Elevation above sea level	= 74.676 × 10^{-3} km
Solar constant, G_{sc}	= 1367 W/m2
Climate type	= Tropical

Clear sky model, Hottel (1976)

(1) Monthly mean daily extraterrestrial radiation on horizontal surface is calculated by

$$\overline{H_0} = G_{sc}\left[1+0.033\cos\left(\frac{360n}{365}\right)\right]\times Z \qquad (1)$$

(i) Solar declination (δ) is the angle formed by the line from the center of the earth to the center of the sun on a particular day and the plane containing the earth's equator [3].

$$\delta = 23.45\sin\left[\frac{360}{365}(284+n)\right]$$

n = Day of the year

(ii) Sunset hour angle (ω_s) occurred when the zenith angle reaches 90˚. It is given by,

$$\omega_s = \cos^{-1}(-\tan\lambda\tan\delta)$$

$$Z = \left[\cos\phi\cos\delta\sin\omega_s + \frac{\pi\omega_s}{180}(\sin\phi\sin\delta)\right]$$

(2) Monthly mean daily total radiation on horizontal surface is described by

$$\overline{H} = \overline{H_0}\left[a+b\left(\frac{\text{Average sunshine hour}}{\text{Monthly avg day length}}\right)\right] \qquad (2)$$

Regression constants (a, b) for monthly average global horizontal radiation are given by

$$a = 0.1+0.24\left(\frac{\text{Average sunshine hour}}{\text{Monthly avg day length}}\right)$$

$$b = 0.38+0.08\left(\frac{\text{Average sunshine hour}}{\text{Monthly avg day length}}\right)$$

Cleanliness index is

$$\overline{K_T} = \frac{\overline{H}}{\overline{H_0}}$$

$$B = \frac{360}{364}(n-81)$$

Equation-of-time correlation, e

$$e = 9.87\sin 2B - 7.53\cos B - 1.5\sin B$$

Local solar time of day measured from solar noon. Solar time coincides with real time only at certain time of the year which earth is at the perigee or apogee of its orbit. At other times, real and solar time may differ by as much as ± 15 minutes. The solar time is defined as following.

$$LSoT = ST + 4(L_{st} - L_{loc}) + e$$

L_{st} = Local standard time of meridian, (97˚30′ E)
L_{loc} = East longitude, (96˚06′ E)

Hour angle is angular displacement of the sun from noon. It is also measured in degree and can be expressed by

$$\omega = \frac{360}{24}\times LSoT$$

Ratio of hourly total to daily total diffuse radiation (r_d) is

$$r_d = \frac{\pi}{24}\times\frac{\cos\omega - \cos\omega_s}{\sin\omega_s - \omega_s\cos\omega_s}$$

ω = Hour angle, (degree)
ω_s = Sunset hour angle, (degree)

Ratio of hourly total to daily total global radiation (r_t) is described by

$$r_t = \frac{\pi}{24}(a+b\cos\omega)\frac{\cos\omega - \cos\omega_s}{\sin\omega - \omega_s\cos\omega_s}$$

(3) Monthly average diffuse radiation ($\overline{H_d}$) is calculated from monthly average daily global radiation.

$$\frac{\overline{H_d}}{\overline{H}} = 1.391 - 3.56\overline{K_t} + 4.189\overline{K_t}^2 - 2.137\overline{K_t}^3 \qquad (3)$$

(4) Hourly global horizontal radiation on the earth surface (H) is calculated from the following equation.

$$H = r_t \overline{H} \tag{4}$$

(5) Hourly diffuse radiation (H_d) is defined by

$$H_d = r_d \overline{H}_d \tag{5}$$

(6) Hourly beam radiation (H_b) is calculated as follows;

$$H_b = H - H_d \tag{6}$$

(7) Total radiation striking on PV plane(H_t) is described by

$$H_t = \left(H_b + H_d A_i\right) R_b + H\rho_g \left(\frac{1-\cos\beta}{2}\right) \tag{7}$$

β = Slope of PV surface in deg (20˚for summer, 60˚for winter)

(i) Ratio of beam to extraterrestrial radiation (A_i)

$$A_i = \frac{H_b}{\overline{H}_0}$$

(ii) Modulating factor(f)

$$f = \sqrt{\frac{H_b}{H}}$$

ρ_g = Ground albedo (0.2 for non-snow cover)

Calculation of PV Array Sizing

Table 1. Specification of PV

Serial No.	Description	Value	Unit
1.	Type	Poly-crystalline	-
2.	Model	2013 OPAI 300 W	-
3.	Module nominal vol;	17.5	V
4.	Module short circuit current, Isc	18.32	A
5.	Maximum series fuse rating	20	A
6.	Module length	1950	mm
7.	Module width	992	mm

The PV array model is dependent upon the module characteristics of the specific technology as well as the incoming solar radiation in the plane of the PV array [1]. The use of PV technology varies considerably, from PV cells in calculators and watches, to solar modules in telecommunications equipment and highway signs, to PV arrays for water pumping and generation of electricity in agricultural and rural areas. Water pumping using photovoltaic may be the most common use of complete PV systems in both developed and developing areas [1].

(8) The number of PV series module is calculated from the following equation [3].

$$N_s = \frac{V_{sys}}{V_{module}} \tag{8}$$

(9) The number of PV parallel module is calculated as

$$N_p = \frac{E_{demand}}{V_{sys} \times DSH \times I_{sc,module}} \tag{9}$$

$$N_{PV} = N_p \times N_s$$

V_{sys} = System nominal voltage(24volt)

V_{module} = Module nominal voltage (17.5 volt)

E_{demand} = Energy demand (1.1kW)

DSH = Daily peak sun hour[7hrs(9am-3pm)]

$I_{sc,\ module}$ = Module short circuit current (17.14 A)

(10) In this design, 16 numbers of PV modules are used to save the design.

$$P_{module} = H_t \times A_{PV} \times \eta_{PV} \times \eta_0 \tag{10}$$

H_t = Total radiation striking on PV plane

A_{PV} = Module area

η_{PV} = Overall efficiency of the PV panel

η_0 = Efficiency of the conversion devices (0.75)

(11) Power output of the PV array is shown by

$$P_{array} = N_{PV} \times P_{module} \tag{11}$$

The selected photovoltaic module for solar water pumping system is shown in Fig 2.

Fig.2. Polycrystalline Silicon PV Module

Centrifugal Pump

Centrifugal pump is driven by two horsepower motor. Totally enclosed impellers are designed with the blades between two support shrouds or plates. Impeller is the main part that provides the centrifugal acceleration to the fluid within the casing[8].

Flow rate, Q_s = 0.01427 m^3/s

Head, H = 5m

Pump speed, n = 1500 rpm

Gravitational acceleration, g = 9.81 m/s^2

Density of water, ρ = 1000 kg/m^3

Impeller Design

(1) Specific speed is defined as the speed in revolutions per minute at which an impeller operate if reduced proportionately in size so as to deliver one unit of capacity against one unit of total head[8]. It is mathematically expressed as;

$$n_s = \frac{n \times \sqrt{Q}}{H^{3/4}} \tag{12}$$

Q = Flow rate (0.8562m^3/min)

(2) Shaft input power is determined from the equation;

$$L = \rho Q_s g H / \eta \tag{13}$$

(3) Rated output power of an electric motor is decided from the equation;

$$L_r = (1 + f_a) L / \eta_{tr} \tag{14}$$

f_a = Allowance factor (0.1 ~ 0.4)

η_{tr} = Transmission efficiency (1 for direct coupling)

(4) Flow rate enough through an impeller is defined by;

$$Q_s = \frac{Q_s}{\eta_v} \tag{15}$$

η_v = Volumetric efficiency

(5) The diameter of end of the main shaft is calculated from the equation;

$$d_c = 0.365 \sqrt[3]{\left(\frac{L_r}{n}\right)/\tau_{al}} \tag{16}$$

τ_{al} = Permissible shear stress (24.5 MPa for S30C)

The shaft diameter at the hub section is selected so as to satisfy $d_{sh} > d_c$.

(6) Hub diameter at the impeller eye is;

$$D_h = (1.5 \sim 2) d_{sh} \tag{17}$$

(7) Hub length at the impeller eye is;

$$L_h = (1.0 \sim 2.0) d_{sh} \tag{18}$$

(8) Eye diameter of the impeller is;

$$D_0 = K_0 \sqrt[3]{\frac{Q_s}{n}} \tag{19}$$

Velocity at the eye section is given by;

$$V_{m0} = K_{m0} \sqrt{2gH}$$

Where

$$K_{m0} = (0.07 \sim 0.11) + 0.00023 n_s$$

(9) Impeller inlet diameter is;

$$D_1 = (1.1 \sim 1.15) \times K_0 \times \sqrt[3]{\frac{Q_s}{n}} \tag{20}$$

(10) Peripheral velocity at the impeller inlet;

$$U_1 = \frac{\pi D_1 n}{60} \tag{21}$$

Inlet flow velocity is calculated by;

$$V_{m1} = K_{m1} \sqrt{2gH}$$

The value of K_{m1} is chosen as 0.215.

The inlet blade angle in the impeller is;

$$\beta_{b1} = \tan^{-1}\left(\frac{V_{m1}}{U_1}\right)$$

(11) Peripheral velocity at outlet;

$$U_2 = K_U \sqrt[3]{2gH} \tag{22}$$

The value of K_U is chosen as 1.3.

Outlet flow velocity is;

$$V_{m2} = K_{m2} \sqrt{2gH}$$

The value K_{m2} is chosen as 0.165.

(12) Impeller outlet diameter is;

$$D_2 = \frac{60U_2}{\pi n} \quad (23)$$

(13) The number of blades is calculated as;

$$Z = 6.5\frac{D_2 + D_1}{D_2 - D_1}\sin\frac{(\beta_1 + \beta_2)}{2} \quad (24)$$

(14) The required parameter to draw the impeller blade is;

$$\rho_A = \frac{(R_A^2 - R_B^2)/2}{(R_A\cos\beta_{b2} - R_B\cos\beta_b)} \quad (25)$$

$$\rho_B = \frac{(R_B^2 - R_C^2)/2}{(R_B\cos\beta_B - R_C\cos\beta_C)} \quad (26)$$

$$\rho_C = \frac{(R_C^2 - R_D^2)/2}{(R_C\cos\beta_C - R_D\cos\beta_{b2})} \quad (27)$$

Volute Casing Design

Design of volute casing is calculated depend upon the impeller outlet dimensions. Volute casings are designed on the basis of constant average flow velocity in the volute casing. The volute casing increases proportionally in size from cut water to the discharge nozzle. In real velocities distribution across the volute section is not uniform.Volute casings are designed on the basis of constant average flow velocity in the volute casing. This is very important in designing the volute casings[8].

Flow rate, Q = 0.01427 m3/s

Pump head, H = 5m

Pump speed, n = 1500 rpm

Impeller diameter at outlet, D_2 = 164 mm

Impeller wadth at outlet, b_2 = 21 mm

Outlet angle of impeller, β_2 = 20˚

Specific speed, n_s = 415

Shroud thickness = 2.5 mm

(1) The average flow velocity is;

$$V_v = K_v\sqrt{2gH} \quad (28)$$

(2)Volute area at the throat is;

$$A_v = \frac{Q_s}{V_v} \quad (29)$$

(3) Other volute sections are;

$$A_{vi} = \frac{A_v \times i}{8} \quad (30)$$

i = 1 to 8 volute sections

(4) Volute width is;

$$b_v = b_2 + (2\times t_{sh}) + (2\times Cl_{im}) \quad (31)$$

b_2 = Outlet passage width

t_{sh} = Shroud thickness

Cl_{im} = Clearance on side of impeller

(5) Volute area with its radius;

$$\rho_{vi} = \sqrt{\frac{(A_{vi} + 0.604b_v^2)}{0.367}} \quad (32)$$

Radius of the volute tangent circle is;

$$r_{vi} = 0.206\rho_{vi}$$

Basic Governing Equation of the Model

This study uses SolidWorks software for three-dimensional flow. The software works using the finite volume (FV) solution method to solve the governing equations over the computational mesh[18].

(i) Mass conservation equation is;

$$\frac{\partial\rho}{\partial t} + \frac{\partial}{\partial x_i}(\rho u_i) = 0 \quad (33)$$

(i) Momentum conservation equation is described by;

$$\frac{\partial\rho u_i}{\partial t} + \frac{\partial}{\partial x_j}(\rho\rho_i u_j) + \frac{\partial\rho}{\partial x_i} = \frac{\partial}{\partial x_j}(\tau_{ij} + \tau_{ij}^R) + S_i \quad (34)$$

(i) Energy conservation equation is ;

$$\frac{\partial\rho H}{\partial t} + \frac{\partial\rho u_i H}{\partial x_i} = \frac{\partial}{\partial x_i}\left(u_j(\tau_{ij} + \tau_{ij}^R) + q_i\right) + \frac{\partial P}{\partial t} - \tau_{ij}^R\frac{\partial u_i}{\partial x_j} + \rho\varepsilon + S_i u_i + Q_H \quad (35)$$

3. RESULT DATA FOR THE SYSTEM

Table 2. Result Data for Radiation from Sun to PV

Months	$\overline{H_0}$	$\overline{H}$	H_d	H_b	$\overline{H_T}$
Jan	940	597	17.42	136.18	861
Feb	1085	718	21.92	163.81	885
March	1244	552	27.64	98.44	579
April	1374	667	28.86	102.8	661
May	1437	713	29.17	102.02	677
June	1452	576	29.27	77.92	542
July	1440	466	28.42	63.83	444
August	1392	486	28.37	69.43	474
Sept	1286	410	25.26	52.98	413
Oct	1128	593	22.66	82.2	653
Nov	972	499	19.76	69.79	602
Dec	896	583	15.11	104.57	863

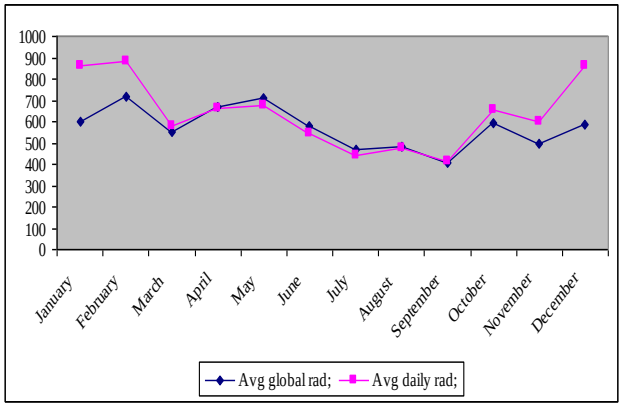

Fig.3. Monthly Average Global and Daily Horizontal Solar Radiation

Table 3. Result Data for Power Output from PV

Month	$\overline{H_t}$	T_C	η_{PV}	P_{Mod}	N_{PV}	P_{arr}
Jan	863	46.92	0.1003	128.71	16	2.06
Feb	885	47.64	0.1	128.33	16	2.05
Mar	579	38.09	0.1042	87.51	16	1.4
Apr	661	40.65	0.1031	98.86	16	1.58
May	677	41.16	0.1028	100.99	16	1.62
June	542	36.93	0.1047	82.31	16	1.32
July	444	33.89	0.106	68.36	16	1.1
Aug	474	34.8	0.1056	72.57	16	1.16
Sep	413	32.92	0.1065	63.87	16	1.02
Oct	653	40.41	0.1032	97.79	16	1.56
Nov	602	38.82	0.1039	90.76	16	1.45
Dec	863	46.98	0.1003	125.62	16	2.01

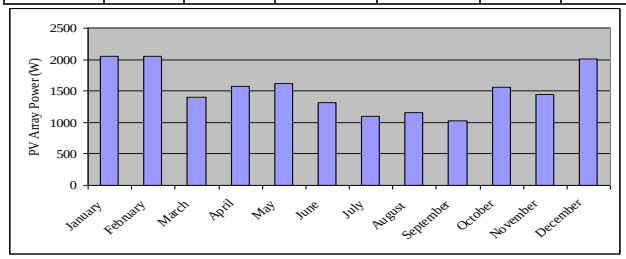

Fig.4. Monthly PV Array Power

Centrifugal pump

The result data for the centrifugal pump is described in table 2.

Table 4. Result Data for Centrifugal Pump

No.	Description	Value	Unit
1.	Shaft diameter, d_s	24	mm
2.	Hub diameter, D_h	40	mm
3.	Hub length, l_h	48	mm
4.	Impeller inlet diameter, D_1	93	mm
5.	Impeller outlet diameter, D_2	164	mm
6.	Impeller eye diameter, D_0	84	mm
7.	End main shaft diameter, d_c	12	mm
8.	Blade thickness	2	mm
9.	Shroud thickness	2.5	mm
10.	Inlet passage width, b_1	28	mm
11.	Outlet passage width, b_2	21	mm
12.	Inlet blade angle, β_{b1}	16	deg
13.	Outlet blade angle, β_{b2}	20	deg
14.	Number of blades, Z	8	-
15.	Volute throat area, A_v	4.65×10^{-3}	m^2
16.	Base circle diameter, D_3	188.6	mm
17.	Volute width, b_v	31	mm

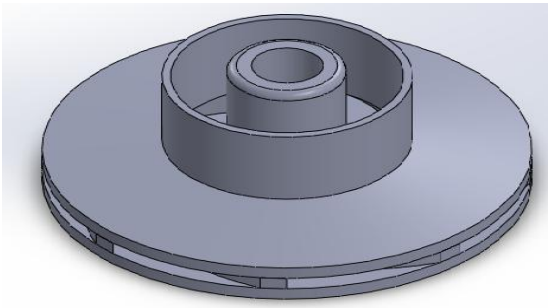

Fig.5. Isometric View of Centrifugal Pump's Impeller

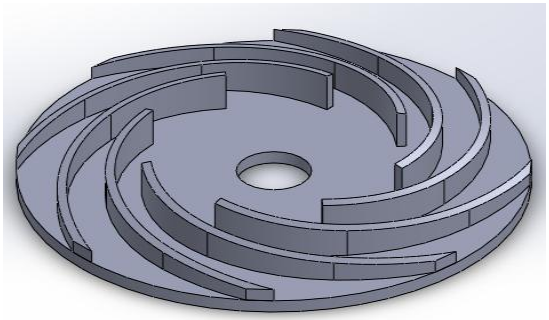

Fig.6. Isometric View of the Impeller Blades

Table 5. Calculation Data to Draw the Volute Casing

Section, i	$A_{vi}(m^2)$	ρ_{vi}	r_{vi}
1	5.81×10^{-4}	0.0563	0.0115
2	1.162×10^{-3}	0.0689	0.0141
3	1.743×10^{-3}	0.0795	0.0163
4	2.324×10^{-3}	0.0889	0.0183
5	2.905×10^{-3}	0.0974	0.02
6	3.486×10^{-3}	0.105	0.0216
7	4.067×10^{-3}	0.113	0.0232
8	4.648×10^{-3}	0.119	0.0245

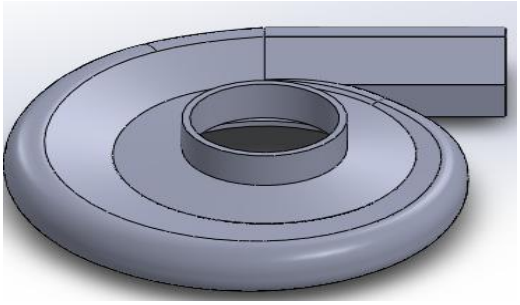

Fig.7. Isometric View of Centrifugal Pump's Casing

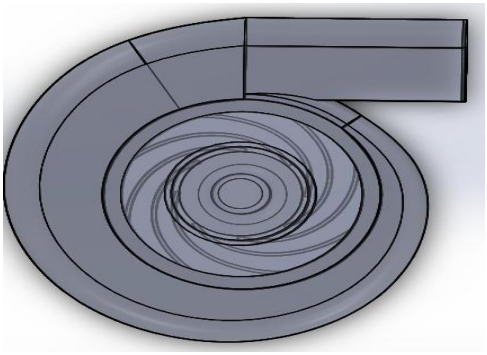

Fig.8. Isometric Model for Centrifugal Pump Assembly

Table 6. Equipment for Solar Water Pumping System

Equipment	Specification	Quantity
Water pump	2 HP Centrifugal	1 unit
PV module	Polycrystalline silicon(300W)	16 units
Controller	160A Solarcon	1 unit
Battery	2P1101Ah Lead acid battery	12 units

3. FLOW ANALYSIS OF CENTRIFUGAL PUMP

SolidWorks is a 3-D computer-aided-design (CAD) software suit currently developed by Dassault. It allows creation and manipulation of 3-D parts and assemblies using a parametric design approach. It is widely used in engineering fields for product design, testing and manufacture. SolidWorks flow simulation is a fluid dynamics and thermal simulation program that works through SolidWorks models and assemblies. It works using the finite volume (FV) solution method to solve the governing equation over the computational mesh. To complete the problem statement, let us specify the following inlet and outlet boundary conditions: inlet of 0.01427 m^3/s volume flow rate having uniform velocity profile with vectors parallel to the pump's axis; at the radial-directed outlet a static pressure of 1 atm is specified.

Table 7. Flow Analysis for Rotating Impeller

Goal Type	Flow Condition
Unit system	SI
Type of analysis	Internal
Feature	Rotation: Global rotating
Speed	1500 rev/min
Rotation	Angular velocity= 157 rad/s
Axis of coordinate system	Y
Fluid	Water
Wall condition	Adiabatic wall
Boundary condition	At inlet; Inlet volume flow(0.01427m^3/s) At outlet: Environmental pressure

Pressure Simulation

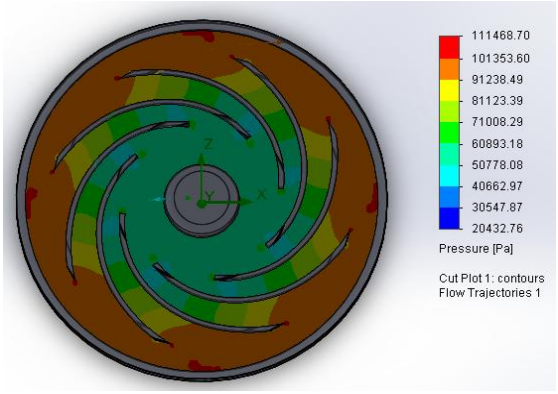

Fig.9. Pressure Distribution in the Centrifugal Pump

According to the simulation of pressure distribution diagram (Fig. 9), it can be observed as follows:

(1) Pressure distribution from inlet to outlet of the impeller is 40662 to 101353 Pa.
(2) With respect to the pressure distribution analysis, impeller eye pressure is less than the atmospheric pressure.
(3) At the impeller outlet, the pressure increases to 111468.7 Pa.

Velocity Simulation

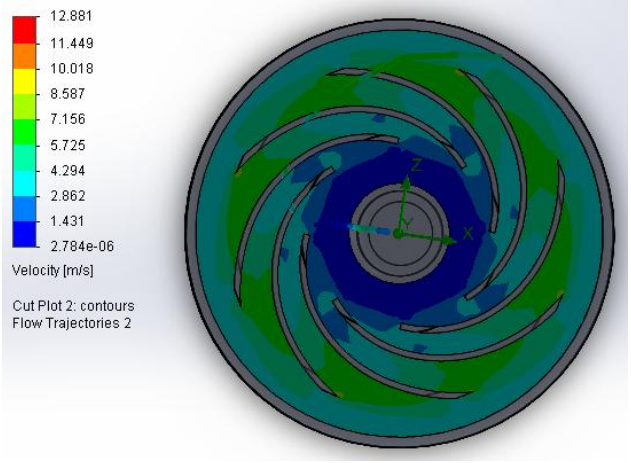

Fig.10. Velocity Distribution in the Centrifugal Pump

According to the simulation of velocity distribution diagram (Fig. 10), it can be observed as follows;

(1) Velocity distribution from inlet to outlet of impeller is from 2.882 to 8.587 m/s according to simulation result.
(2) Average flow velocity in the impeller is about 5.055 m/s .
(3) At the impeller outlet, the velocity decreases to 2.889 m/s.

4. CONCLUSION

In this research, single-suction centrifugal pump generated by solar energy is observed. A closed type impeller and volute type casing are used. The calculated results for the impeller and the volute casing are approximately equal to the actual design. According to the theoretical result, both of velocity and pressure are increased. By observing the simulation result, both of velocity and pressure are steadily increased so flow analysis is matched with theory. The type of module as polycrystalline PV is chosen because of its high efficiency and reliable for long life. The results showed that it was technically possible to supply water in the irrigation system using solar energy. From this research, better understanding and useful technical information are provided for constructing a solar water pumping system. In this system, the water pumped on sunny daytime can be stored for night and cloudy days use. Water pumping has long been the most reliable and economic application of solar-electric (photovoltaic) system.

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APPENDIX

Table A1. Recommended Average Days for Each Month

Month	Date	Day of year (n)	Average sunshine hour
January	17	17	8.63
February	16	47	9.02
March	16	75	6.67
April	15	105	7.69
May	15	135	7.89
June	11	162	6.01
July	17	198	4.59
August	16	228	5.09
September	15	258	4.5
October	15	288	8.44
November	14	318	6.79
December	10	344	8.85

Table A2. PV Module Characteristics

-	Mono	Poly	Amor	CdTe	CIS
η_r(%)	13	11	5	7	7.5
NOCT	45	45	50	46	47
β_P	0.4	0.4	0.11	0.24	0.46

Energy Potential of Biogas Production from Animal Manure in the Lao People's Democratic Republic

Dethanou Koumphonphakdi and Ratchaphon Suntivarakorn

Abstract— *This paper presented a study of biogas production potential from animal manure in the Lao People Democratic Republic (Lao PDR). The data from four kinds of animal such as cow, buffalo, pig and chicken were surveyed and calculated in order to know the potential of biogas production. The feasibility study of biogas production from pig farm in a case study was also done in order to know the investment cost as the net present value (NPV), the internal rate of return (IRR), the payback period (PB) and the benefit cost ratio (B/C). From a study, it was found that the Lao P.D.R had 31,747,297 of all animals and the potential for biogas production was 806.70 m^3/year, which can produce the electricity of 1,129.39 million kWh/year. The highest potential for biogas production are in Salavanh, Savannakhet and Chapasack provinces, which had the potential to produce 162.96, 123.51, and 70.72 million m^3/year of biogas, respectively. In addition, from the feasibility study in a case study with 520 pigs, it was revealed that biogas production from pig manure was a high feasible project, which can produce biogas of 175.3 m^3/day or 245 kWh/day of electricity. The project cost is amount 174.70 million kip of investment for biogas production system. From the economic analysis of this study, it was found that the NPV was 144.77 million kip, the IRR was 22.96%, PB was 4.1 years and the B/C was 1.82. This project is suitable for investment and it can be a data base for set up the policy to promote the biogas production in the Lao PDR.*

Keywords— Energy Potential, Biogas, Animal Manure, Feasibility study.

1. INTRODUCTION

The Lao People's Democratic Republic (Lao P.D.R) has total population of 6.5 million people in year 2010, and the most of population about 80 percent were agriculture, especially rice farmer and rancher. Since the Lao P.D.R opened the country in 1986, it made the Lao P.D.R economic continuously grows up to now, and caused of energy consumption increasing. Although the Lao P.D.R is a country that can produce the power electricity from several large dams and sell the electricity to neighbor countries, there is a lack of domestic electrical energy at some time. Besides, the Lao government has the policy to increase a proportion of the population having power electricity up to 90 percent by 2020 [1], and has the policy to promote the use of renewable energy. However, the Lao P.D.R has an insufficient information on the production of electricity from renewable energy sources, particularly the production of biogas from animal manure.

The objective of this work is to study an energy potential of biogas production from manure in the Lao People Democratic Republic (Lao P.D.R). The datum of four kinds of animals, consisting of cow, buffalo, pig and chicken were collected and investigated. Then, the biogas production potential will be calculated from animal manure. The case study of biogas production in pig farm will be studied to know the economic feasibility of biogas production project in Lao PDR.

Therefore, researchers are interested in study the potential of biogas production from animal manure to obtain the information and helpful guidelines for further alternative energy development in Lao P.D.R.

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2. RESEARCH METHOD

The research method was divided in to four main components, which are data collection, data analysis, economic analysis and data summary.

2.1 Data Collection

The data was collected from the Department of Livestock and Fisheries, Ministry of Agriculture and Forestry. The obtained information consists of

1) The number of animals and farm in nationwide, there are four kinds of animals consisting of cow, buffalo, pig and chicken.

2) The farm's location and name's farmer in the provinces.

In addition, the data for case study feasibility was also collected by interview with the staff working in the Animals Research Centre, the Pig and Poultry Breeding Station, Ministry of Agriculture and Forestry in Lao PDR.

2.2 Data Analysis

The data analysis was divided in two parts as follow:

1) In order to know the energy potential of biogas production. Four kind of animals manure such as cow, buffalo, pig and chicken were collected. The gathering of each manure has the ratio of 50%, 50%, 80% and 90%, respectively [2].

2) From the case study, the amount of pig was analyzed to find the feasibility of the biogas production project. Four financial analysis were used to study the project feasibility, there were the net present value (NPV), the internal rate of return (IRR), the payback period (PB) and the benefit cost ratio (B/C).

2.3 Economic Analysis

The economic analysis of this project was considered by the four economic parameters as follow [3].

1) Net Present Value: NPV

The NPV is the difference between the value of present income and expenses over the life of the project. NPV is an indicator of net benefit of the project as the equation below:

$$NPV = PVB - PVC \quad (1)$$

where the PVB is the present value of benefit and PVC is the present value of cost. If the NPV is more than 0 (Zero), the benefit of project is more than the project cost. The project is high feasible for investment.

2) Internal Rate of Return : IRR

The IRR is the return from the investment. IRR is a rate that makes the present value of revenue equal to the initial investment of the project. IRR can be calculated by:

$$\sum_{t=1}^{n} \frac{R_t}{(1+k)^t} = I \quad (2)$$

where the Rt is Bt - Ct, Bt and Ct are the benefit and cost in the time during the project, k is the return of the project (IRR) and I is the initial cost . If the IRR is more than the discount rate. It can be acceptable for the project. The project will be rejectable when the IRR is less than or equal to the discount rate.

3) Payback Period: PB

The payback period is the duration (number of years) when the return is equal to investment. The PB can be calculated by

$$PB = \text{Initial Cost} / \text{Net Revenue} \quad (3)$$

If the project can be returned by short time. It is acceptable for the project.

4) Benefit Cost ratio: B/C

The B/C is a comparison between the present value of the return and the current cost of the investment and expenses. B/C can be calculated by:

$$B/C = \left(\sum_{t=0}^{n} \frac{B_t}{(1+i)^t}\right) / \left(\sum_{t=0}^{n} \frac{C_t}{(1+i)^t}\right) \quad (4)$$

If the B/C is more than 1, that means the return of project will be worth. However, if the value is less than 1, that means the returns from the project is not worth for investment.

2.4 Data Summary

To obtain the information in order to use and set up the policy for alternative energy promotion in Lao PDR. The energy production potential was divided by provinces and types of animal. The data from feasibility study was also summarized in this part.

3. The Energy Potential of Biogas Production

From the data collection of animal farms, the Lao P.D.R has 17 provinces that having animal farms. The number of animal from four kinds of animals: cow, buffalo, pig and chicken were shown in Table 1.

Table 1. The amount of animals in Lao P.D.R. [4]

(1,000 unit)

Provinces	Cow	Buffalo	Pig	Chicken	Total
Phongsaly	23	37	170	554	785
Louang namtha	20	17	88	458	584
Oudomxay	49	44	140	1,476	1,703
Bokeo	54	24	62	402	542
Louang phabang	79	63	179	1,869	2,190
Huaphan	72	44	244	332	692
Xayabuly	117	48	133	2,205	2,504
Vientiane capital	118	18	137	1,319	1,593
Xieng khouang	167	51	66	604	889
Viengchanh	167	71	103	1,541	1,884
Boli khamxay	58	45	66	727	897
Khammoun	94	62	75	507	739
Savannakhet	398	290	281	2,882	3,852
Salavanh	149	133	794	5,329	6,405
Sekong	25	28	129	611	794
Champasak	140	133	180	4,736	5,189
Attapeu	18	42	31	413	505
Total	1,748	1,150	2,878	25,965	31,747

From the Table 1, it was found that the Lao PDR has the total number of 31.75 million animals. The most animal portion was chicken, 25.97 million animals or 81.7 % of the total numbers. The next lower portions were pig, cow and buffalo respectively.

Moreover, from the calculation of the energy potential for biogas production from animal manure, the ability of manure gathering was considered. The percentage of the manure gathering from the total manure of cow, buffalo, pig and chicken were 50%, 50%, 80% and 90%, respectively [3]. The energy potential of biogas production from animal manure was shown in Table 2.

Table 2. The energy potential of biogas production

List	Cow	Buffalo	Pig	Chicken	Total
Amount of animal (million)	1.75	1.12	2.88	25.97	31.75
Weight of manure (kg/animal)	5.44	8	1.47	0.03	
Weight of manure (million-kg/day)	9.5	9.2	4.2	0.76	23.6
Percentage can be gathered (%)	50	50	80	90	
Weight of animal manure production. (million-kg/day)	4.7	4.6	3.3	0.7	13.3
Volume of biogas can be produced (liter/kg)	90	90	340	310	
Volume of biogas production. (million-liter/day)	428	415	1,149	217	2,210
Volume of biogas production. (million-m^3/year)	156	152	419	79	807

From Table 2, it was found that the total of energy from biogas production in the Lao P.D.R was 807 million m^3/year. This was assumed to be able to produce electricity about 1,163 million kWh (1m^3 of biogas equivalent to 1.4 kWh). [3]

The potential of biogas production which was pig's manure has the highest 419 million m^3/year or 52% of the total energy potential. The next highest potential were the manure of cow, buffalo and chicken which had a portion of 19%, 19%, and 11%, respectively. The percentage of volume of biogas was shown in Figure 1.

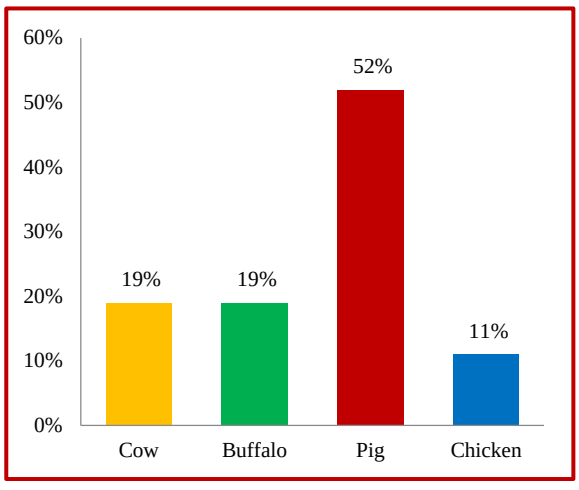

Figure 1. The percentage of volume of biogas production.

Furthermore, consider the energy potential of biogas production segmented by provinces, it was found that the potential area was divided in to 3 groups as shown in Figure 2.

Figure 2. Map of energy potential of Lao P.D.R

From Figure 2, three groups were the high potential provinces (Green), the middle potential provinces (Yellow), and low potential provinces (Blue), respectively. The high potential group has an energy potential of biogas production more than 70 million m^3/year. The provinces in this group were Savannakhet, Salavanh and Champhsack provinces. The middle potential group has an energy potential of biogas production between 37 to 70 million m^3/year. The low potential group has an energy potential of biogas production less than 37 million m^3/year. The average biogas product for each level was shown in Table 3.

Table 3. The average of energy potential in Lao P.D.R

Rank	Provinces	Amount of animal (10^3 unit)	Biogas production (m^3/year)	Average (m^3/year)
High potential	Savannakhet	3,852	123.51	119.06
	Salavanh	6,405	162.96	
	Champasak	5,189	70.72	
Middle potential	Huaphan	692	48.85	44.03
	Louang phabang	692	47.18	
	Xayabuly	2,504	44.20	
	Vientiane capital	1,593	42.92	
	Xieng khouang	889	37.00	
Low potential	Phongsaly	785	33.51	25.47
	Louang namtha	584	18.36	
	Oudomxay	1,703	34.17	
	Bokeo	542	18.28	
	Viengchanh	1,884	33.19	
	Boli khamxay	897	23.07	
	Khammoun	739	29.07	
	Sekong	794	26.70	
	Attapeu	505	12.95	

4. Case Study

A feasibility of biogas production project was studied by using economic analysis. The pig farm with 520 pigs were selected to use in this study. The basic data of the case study were shown below

1) The farm has the average of electrical consumption of 3,453 kWh/month or 2,689,822 kip/month (1 kWh equivalent to 799 kip)
2) The pig are 520 pigs, which consists of male pig, sow and piglet with the number of 20, 100 and 400, respectively.

4.1 Estimation of Potential Biogas in the Farm

The biogas production potential was calculated and shown in Table 4.

Table 4. The biogas production potential in the farm

List	Male pig	Sow	Piglet	Total
Amount of pig	20	100	400	31.75
Weight of manure (kg/animal/day)	1.83	1.40	1.17	
Weight of manure (kg/day)	36.60	140.00	468.00	644.60
Percentage can be gathered (%)	80	80	80	
Weight of animal manure production. (kg/day)	29.28	112	374.4	515.68
Volume of biogas can be produced (liter/kg)	340	340	340	
Volume of biogas production. (liter/day)	9,955	38,080	127,296	175,33

From table 4, it was found that there was 644.60 kg/day and the biogas potential can be produced 175.33 m^3/day. This can be able to produce electricity about 245 kWh/day.

4.2 Economic Analysis of the Project

The economic analysis was done and based on the following conditions;

i) Project period is 15 years.
ii) Discount rate is 10%.
iii) Operation days are 365 days.
iv) Technology of Biogas is MC-UASB (Medium Farm Channel Up flow Anaerobic Sludge Blanket) is used [5].
v) The size of biogas system is selected to be 200 m^3.

The project cost for construction of biogas system was shown in Table 5, and the operating cost and return from biogas system were shown in Table 6 and Table 7, respectively.

Table 5. The project cost of building biogas systems.

Investment cost	Amount (kip)
1. Biogas production system	56,348,750
2. Power house	10,355,000
3. Power generator (15 kW)	53,000,000
4. Consultant	53,000,000
5. Transportation	2,000,000
Total	174,703,750

Table 6. The operation and management cost of biogas production system (O&M).

O&M cost	Amount/year (kip)
1. Labour	7,512,000
2. Maintenance of generator	17,490,000
3. Electricity price	3,600,000
Total	28,602,000

Table 7. The returns from biogas system

Volume of biogas production. (m^3/day)	175.33
1m^3 of biogas equivalent to 1.4 kWh	1.4
Energy power (kWh/day)	245
Electricity price (kip/kWh)	779
Total of Amount/year (kip)	70,605,168

From table 5 to table 7, the total project cost for investment of biogas production system was 174,703,750 kip (Lao currency), the operation and management cost was 28,602,000 kip/year, and the returns from biogas system was 70,605,168 kip/year. Thus the net revenue of this project was calculated as below:

Net Revenue = Revenue - Payment (O&M)
= 70,605,168 - 28,602,000
Net Revenue = 42,003,173 kip/year.

4.3 Economic Calculation

The net present value (NPV) can be calculated from investment cost and the present value of benefit (PVB). The PVB means the conversion of all revenue of the project to the revenue in the present as the following the equation;

$$PVB = FV / (1+r)^n \quad (5)$$

$$= \frac{42{,}003{,}172}{(1+0.1)^1} + \ldots + \frac{42{,}003{,}172}{(1+0.1)^{15}}$$

PVB = 319,479,473 kip

From equation (1), NPV can be calculated by

NPV = PVB− PVC

NPV = 319,479,473 - 174,703,750

NPV = 144,775,723 kip

From the calculation, it was found that the NPV of the project during 15 years was 144,775,723 kip.

The internal rate of return (IRR) can be calculated from investment cost (I) and revenue of project (R) from equation (2) as follow:

$$\frac{42{,}003{,}172}{(1+k)^1} + \ldots + \frac{42{,}003{,}172}{(1+k)^{15}} = 174{,}703{,}750$$

k = 0.2296 or IRR = 22.96 %

From the calculation, it was found that the IRR of the project was 22.96%.

The payback period (PB) can be calculated from equation (3) as follow:

PB = Initial Cost / Net Revenue

PB = 174,703,750 / 42,003,172

PB = 4.16 years

The result shown that the PB of the project was 4.16 years.

The benefit cost ratio (B/C) can be calculated with comparison the present value of benefit (PVB) and investment cost from equation (4) as follow:

$$B/C = \frac{319{,}479{,}473}{174{,}703{,}750} = 1.82$$

The result shown that the B/C of the project was 1.82.

All results of financial analysis can be shown in Table 8.

Table 8. The result of economic analysis of the farm

NPV (kip)	IRR (%)	PB (year)	B/C (kip)
144,775,723	22.96	4.16	1.82

4. Conclusion

From the study, the results revealed that the Lao P.D.R has a potential of biogas production from animal manure of 807 million m^3/year or 1,163 million kWh. The result can give important data of biogas production potential to Lao P.D.R for encouraging and developing the alternative energy within the country.

Moreover, from the financial analysis of the case study, it was found that the net present value (NPV) at discount rate (10%) was 144,775,723, it has profit from the investment. The internal rate of return of the project (IRR) was 22.96%, which was more than the discount rate. The payback period was 4.1 years and the benefit cost ratio (BCR) was 1.82. The project of biogas production was acceptable and feasible to promote in Lao PDR.

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A Study of Electrical Energy Consumption and Electrical Energy Conservation in Luangprabang Province, Lao People's Democratic Republic

Ratchaphon Sutivarakorn, Wasakorn Treedet, and Thongpane Bounsanith

Abstract*—This research presents a study of electric energy consumption and electrical energy conservation in Luangprabang Province, Lao People's Democratic Republic. The electrical energy consumption of the province and the district of Luangprabang were collected by using the questionnaire and surveying in the households. Xieng Thong sub-district was selected to be a sample area for study the energy consumption and conservation. From the surveyed result, it was found that the energy consumption in Luangprabang Province was 83.32 million kWh/year, while the energy consumption in Luangprabang district was 58.90 million kWh/year. This was 70.80 % of the total energy consumption in Luangprabang Province. From the study of electrical consumption in Xieng Thong sub-district, it was found that Xieng Thong sub-district consumed 6.80 million kWh/year. The maximum energy consumption was mainly used in air condition system which was 789,246.53 kWh/year or 40.96 % of the total energy consumption. The next highest energy consumption was used in electrical appliance, cooking equipment and lighting system which consumed 775,092.30 kWh/year (40.23%), 210,514.69 kWh/year (10.93%) and 151,866.56 kWh/year (7.88%), respectively, The predicted energy consumption in 2015 was 11.91 million kWh/year, which was 5.11 million kWh/year or 42.91% higher than that of 2010. If the proposed projects are implemented, the energy consumption of 548,713.69 kWh/year will be decreased and the payback period will be 3.24 years.*

***Keywords*—Energy consumption, Electrical energy conservation, Energy policy**

1. INTRODUCTION

Currently, many countries were interested in a topic of energy conservation. A security of energy is an urgent problem in a presently day and it can be made trouble of energy crisis in the future. Energy conservation is one of the solution to solve this problem. It can reduce a risk of energy security and an affect of a global warming. Therefore, many reseachs were studied and conducted in order to increase an energy efficiency and reduce the energy consumption.

From a statistics of electrical energy consumption in Luangprabang province, Lao People's Democratic Republic (Lao P.D.R), it was found that an electrical energy consumption has been increased continuously in every year since 2006. The electrical energy consumption in 2010 was increasing about 84.20% compared with that of the year 2006. In additional, Luangprabang province did not have a policy of energy conservation. For this reason, this research was studied to understand an electrical energy consumption in Luangprabang province for finding the way to reduce the electrical energy consumption in Luangprabang province.

Xieng Thong sub-district of Luangprabang was selected to be a sample area for studying the electrical energy consumption and conservation because this area is a center of a town which has a high population density. Therefore, this paper was aimed to study the energy consumption and conservation in Xieng Thong sub-district. An electrical energy consumption was collected by using the questionnaire and surveying in the households. The electrical energy consumption will be predicted by using multiple regrssion analysis from 2010 to 2015. Then, the energy conservation measures will be proposed in order to reduce 10% of electrical energy consumption for Xieng Thong sub-district, Luangprabang province. The study of energy consumption and conservation in Luangprabang province will be an case study for Lao P.D.R in order to extend the result to other areas and determine an energy conservation policy in the future.

Fig. 1. Location of Luangprabang province.

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2. ELECTRICAL ENERGY CONSUMPTION

Electrical energy consumption in Luangprabang

A statistics of electrical energy consumption in Luangprabang province from 2006 - 2010 was shown in Fig. 2 [1-6]. It was found that an electrical energy consumption has been increased continuously in every year. From the surveyed results, it was found that the energy consumption in Luangprabang Province was 83.32 million kWh/year in 2010, which was increasing 84.20% compared with the energy consumption in 2006. The growth rate of energy consumption was averagely increased about 21% per year. Luangprabang province consists of 11 districts, and the highest energy consumption was in Luangprabang district which had the consumption of 58.90 million kWh/year. This was 70.80 % of the total energy consumption in Luangprabang Province.

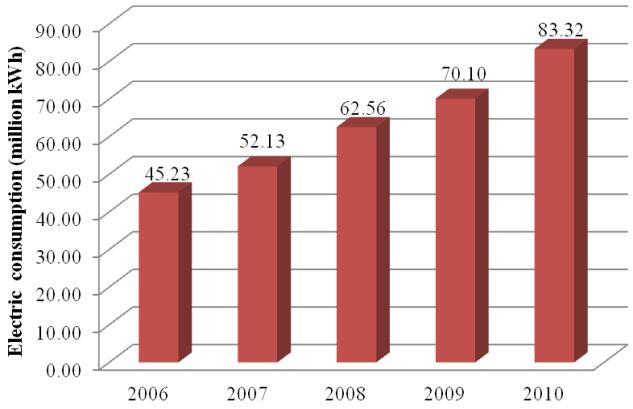

Fig. 2. Electrical energy consumption in Luangprabang province.

Luangprabang district consists of 14 sub-districts, and Xieng Thong sub-district was a center of a town, which has a high density of population. Therefore, Xieng Thong sub-district was selected to study the energy consumption and consrevation in this work. Xieng Thong sub-district has 8 villages, 499 houses and a populations of 2,852 people. The electrical energy consumption was 6.80 million kWh/year or 11.54% of total electrical energy consumption in Luangprabang district.

Electrical energy consumption by economics sector

To know the energy consumption segmented by economics sector in Luangprabang province, the electrical energy consumption was divided into 5 sectors consisting of household, industrial, commercial, government agency and other sectors. The energy consumptions segmented by economics sectors in 2010 was shown in Table 1. The result was shown that the household was the sector having the highest energy consumption. There was 42.93 and 29.86 million kWh for electrical energy consumption in Luangprabang province and Luangprabang district, respectively. The household sector showed the most proportion about a half of the total energy consumption both in the province and district. The next highest energy consumption sectors were commercial sector which had an energy consumption about 1/3 of the total energy consumption.

Table 1. Electrical energy consumption by economic sector.

Economics sector	Province		District	
	million kWh	%	million kWh	%
Household	42.93	51.52	29.86	50.70
Commercial	20.73	24.88	18.47	31.36
Government agency	7.06	8.47	6.13	10.41
Industrial	12.03	14.44	3.88	6.59
Other	0.58	0.69	0.57	0.94
Total	*83.33*	*100*	*58.9*	*100*

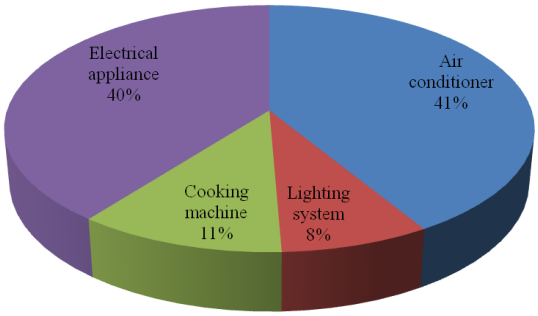

Fig. 3. Proportional of electric consumption in mainly electrical devices.

Electrical energy consumption by electrical devices

To understand the energy consumption behavior of the people in Xieng Thong sub-district, the survey was conducted by using questionnaires. 115 houses (or 23%) of the total houses were interviewed in order to know a number and type of electrical equipments ad devices used in the houses. From the survey and analysis, it was found that the maximum energy consumption was mainly used in an air conditioner system which has an energy consumption of 789,246.53 kWh/year or 41% of the total energy consumption. The next highest energy consumption of the electrical devices were used in electrical appliance, cooking device and lighting system which had an energy consumption of 775,092.30 kWh/year (40%), 210,514.69 kWh/year (11%) and 151,866.56 kWh/year (8%), respectively.

Electric power consumption by the hour

To know the energy consumption varied by a time of use, the electrical energy consumption in every hour was shown in Figure 4. It was revealed that the peak load was occurred at the time between 20:00 – 21:00, which had the maximum power consumption of 11.86 MW. Most of the people consumed the energy in the evening from 18:00-23:00. This period had a high energy consumption due to many activities related to commercial such as 1) using air conditioning system in the household and restuarant, 2) using lighting system in the night market and 3) using electric energy in a public street light. The period that had a low energy consumption was in the early morning from 2:00-6:00.

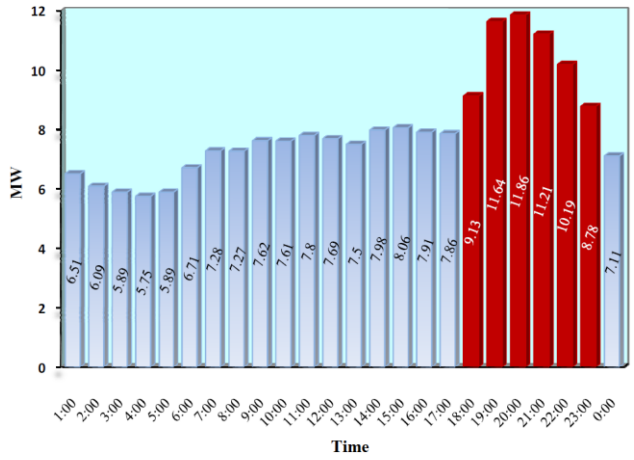

Fig. 4. Electrical Energy Consumption by the time.

3. PREDICTION OF ELECTRICAL ENERGY CONSUMPTION

In order to know the trend of energy consumption in the next 5 years, the prediction of electrical energy consumption of Xieng Thong sub-district was done by using the multiple linear regression method. There were 3 variables used in the regression model, which consisted of the electrical energy consumption (Y_1), the population (X_{11}) and the income (X_{12}). The equation of the regression model can be expressed by

$$Y_1 = a + bX_{11} + cX_{12} \quad (1)$$

Where *a*, *b* and *c* are the constant value. The data of energy consumption, population and income of Xieng Thong sub-district from 2006 – 2010 were shown in Table 2. The units of energy consumption, population and income were million kWh, thousand people and million Kip, respectively.

Table 2. The energy consumption, population and income of Xieng Thong sub-district from 2006 – 2010.

Variable	2006	2007	2008	2009	2010
Y_1	3.74	4.29	5.19	5.80	6.80
X_{11}	2.85	2.77	2.80	2.82	2.85
X_{12}	4.81	5.23	5.69	5.92	6.81

To determine the prediction of energy consumption, the the prediction of population and income will be previously done by using simple linear regression anlysis. The equation of the regression model can be expressed by

$$Y_2 = d + eX_2 \quad (2)$$

$$Y_3 = f + gX_3 \quad (3)$$

where *d*, *e*, *f* and *g* are the constant value. Y_2 is the population ($Y_2 = X_{11}$), and Y_3 is the income ($Y_3 = X_{12}$) The prediction algrorithm was expressed in Figure 5. From the regression analysis, the constant values were calculated and the regression equation can be expressed in equation (4) - (6), as follow

$$Y_1 = -5.37 + 0.56X_{11} + 1.58X_{12} \quad (4)$$

$$Y_2 = -613.04 + 0.31X_2 \quad (5)$$

$$Y_3 = -934.05 + 0.47X_3 \quad (6)$$

Using the regression model from the above equestion, the prediction of the electrical energy consumption, population and income for Xieng Thong sub district in the next 5 years were showed Table 3 and Figure 6.

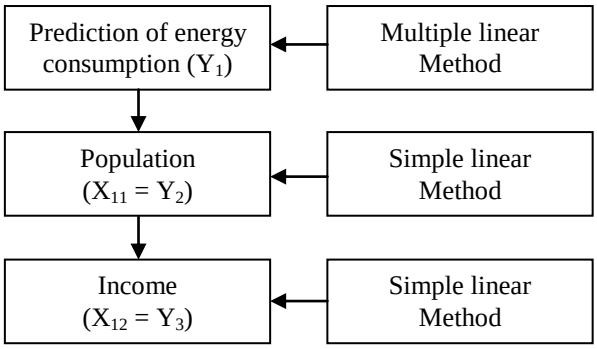

Fig. 5. Prediction algorithm.

Table 3 The Results of Prediction Model.

Year	Income (million Kip)	Population (thousand people)	Energy Consumption (million kWh)
2011	7.09	4.34	8.27
2012	7.56	4.64	9.18
2013	8.03	4.95	10.09
2014	8.50	5.26	11.00
2015	8.97	5.57	11.91

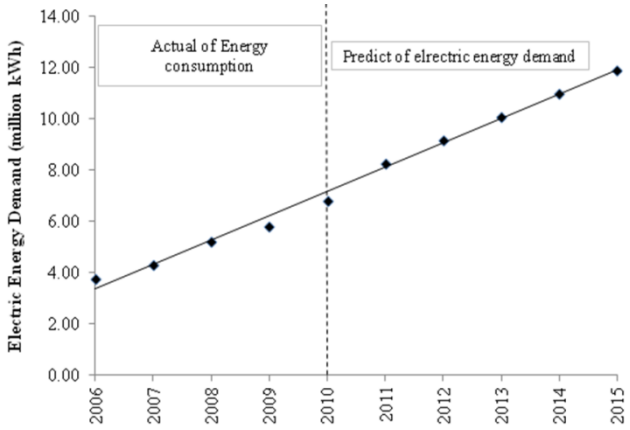

Fig. 6. Prediction results in Xieng Thong sub district.

From Table 3 and Figure 6, it was found that a predicted electrical energy consumption of Xieng Thong sub district in 2015 will be 11.91 million kWh/year, which was 42.90% higher than the energy consumption in 2006.

4. ENERGY CONSERVATION MEASURES

To reduce the energy consumption, the enery conservation measures were proposed. If the target of energy saving is decreasing 10% of the energy consumption in 2015, it means that the energy consumption should be reduced 1.19 million kWh from 11.91 to 10.72 million kWh as shown in Figure 7. To achieve the target, the statistics of the energy consumption and the results from surveying were used and analysed to

set the strategic enery plan. The strategic energy plan can be concluded in five strategies as shown below:

1) Energy research and knowledge developement
2) Revision of energy regulation
3) Public relation and awareness campaign
4) Energy consumption monotoring system
5) Energy conservation in household

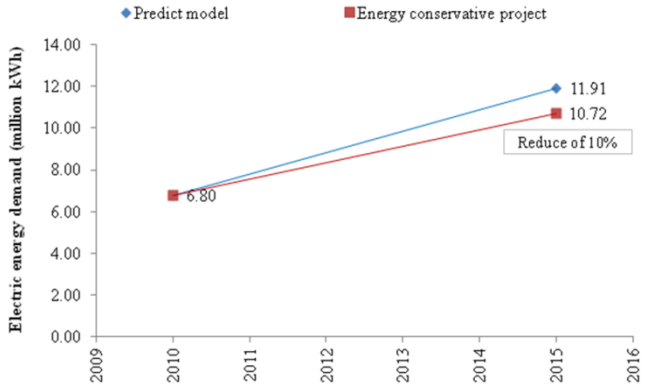

Figure 7 Comparison of electric energy consumption between predict model and energy conservative project.

In order to reduce the energy consumption according with the energy strategic plans, 10 pilot projects were proposed to implement in Xieng Thong sub district. Those pilot projects were considered about the project feasibility, and the energy saving and payback period were shown in Table 4. The pilot energy for energy conservation were proposed as following:

1. Using high efficiency of split type air conditioner.
2. Training an energy conservation measeure to people.
3. Turning off a computer when no active.
4. Reducing time to watch television one hour per day.
5. Using high effciency of water heater.
6. Changing to use a 550W iron.
7. Reducing time to use an electrical frying pan.
8. Changing to use a 600W of rice cooker.
9. Reducing time to use a washer.
10. Changing to use a high effciency of fluorescent lighting (T5).

Table 4 Total of Energy Saving by Ten Pilot Projects

Number of project	Energy Consumption (kWh/year)	Energy saving (kWh/year)	Payback period (year)
1	789,247	288,505	15
2	192,931	75,243	0.21
3	17,956	10,797	1.41
4	96,683	18,962	0.42
5	50,674	16,168	3.24
6	25,515	10,215	1.81
7	113,750	49,630	0.65
8	63,269	29,724	1.8
9	35,868	10,883	2.96
10	92,297	38,586	4.64
Total	*1,478,190*	*548,713*	*Average 3.24 year*

If the proposed projects are conducted, the electrical energy consumption of 548,713.69 kWh/year will be decreased and it is equivalent to 24.48% of the energy consumption in 2010. The energy consumption can be reduced 10% of the total energy consumption predicted in 2015.

From an analysis of ten pilot projects, it was found that the proposed energy conservation project has a payback period of 3.24 year with the energy saving of 548,713.69 kWh/year. However, it will be difficult to achieve the target, if there is no motivation incentive in the first year of the implement. The promotion or encourage from government is very important to make the project succes.

5. CONCLUSION

This paper was a study of energy consumption and conservation in Luangprabang Province, Lao People's Democratic Republic. Xieng Thong sub-district of Luangprabang was selected to be a case study in order to know the energy consumption behaviour and the suitable energy strategic plan.

From the collected energy data of Luangprabang province from 2006 – 2010, it was found that the energy consumption in Luangprabang Province was 83.32 million kWh/year in 2010, while the energy consumption of Xieng Thong sub-district was only 6.80 million kWh/year or 8.16% of total energy consumption in Luangprabang province. The economic sector that had the most of energy consumption was household sector, while the electrical devices that consumed te most proportion of energy consumption was an air conditioner.

The multiple linear regression model was used to predict the energy consumption of Xieng Thong sub-district in the nest 5 years. The results were revealed that the energy consumption will be 11.91 million kWh/year in 2015. To reduce 10% of the energy consumption, ten pilot energy projects were proposed. If ten proposed energy pilot projects are implemented, the energy saving will be 548,713.69 kWh/year and the payback will be 3.24 year, which is acceptable.

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Reliability Centered Maintenance (RCM) Implementation on PEA Power Distribution Systems: A Case Study of Bang-Pa-In Branch Office

Watchara Pobporn, Onurai Noohawm, and Dulpichet Rerkpreedapong

Abstract*— *This paper describes a Reliability Centered Maintenance (RCM) implementation on PEA power distribution systems. In order to achieve a cost-effective maintenance program, RCM is to prioritize the failure modes according to their effects, and then to select the effective maintenance activities for those failure modes. Preventive maintenance (PM) activities are mainly focused on the RCM program driven by the marginal benefit-to-cost ratio (B/C) between outage costs and maintenance costs. For a case study, Bang Pa In branch office located in Phra Nakhorn Si Ayutthaya Province, one of local power distribution utilities of Provincial Electricity Authority Central Area 1 (PEA C1) is selected for RCM implementation.

***Keywords*— Power distribution reliability, Maintenance planning, Cost-effective maintenance, Failure modes**.

1. INTRODUCTION

All industrial units require a reliable production process for sustainable survival in growing competition in today's economy. It is apparent that the continuity of power supply is essential to the function of industrial processes. Therefore, power distribution systems operated by electric utilities must provide even more reliable electrical power to serve such requirement. This has become the primary objective of electric utilities to maintain their power distribution infrastructure at peak reliability levels.

Reliability Centered Maintenance (RCM) is a method of maintenance optimization widely used in global industries. In this paper, RCM is modified to a simple version well suited for applications to PEA power distribution networks. The main concept of the modified RCM is to prioritize the failure modes according to their effects, and then to select the effective maintenance activities for those failure modes. Preventive maintenance (PM) activities are mainly focused on the RCM program taking into account the marginal benefit-to-cost ratio (B/C) between outage costs (OC) and maintenance costs.

In this paper, the modified RCM is applied to power distribution systems of a PEA local utility, Bang Pa In branch office in Phra Nakhorn Si Ayutthaya Province in Central Area 1 of Provincial Electricity Authority of Thailand (PEA C1). The method is illustrated in step by step procedure. The PM program resulted from the proposed RCM guarantees the cost effectiveness, and reduces the amount of corrective maintenance (CM) and outage costs of both PEA and their customers.

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2. Overview of RCM

Reliability centered maintenance is a qualitative method for determining applicable and effective preventive maintenance tasks to preserve the primary function of selected components or systems. RCM has been widely used in a number of industries since it increases cost effectiveness of maintenance programs, and provides a better understanding of criticality of failure modes that interrupt the system from functioning. The general RCM process [1]-[4] is summarized in the following steps.

1. List the critical components and define their functions
2. Identify the dominant failure modes for each chosen component, and then prioritize the failure mode criticality determined from their failure history and consequences.
3. Determine preventive maintenance tasks for those critical failure modes.
4. Formulate an RCM program.
5. Evaluate the worth of RCM Program including cost analysis.

3. Modified RCM and Case Study

The RCM procedure is modified to a simple version well suited for applications with PEA power distribution networks. It is presented in four steps as follows.

Step 1: Feeder Selection and Information Collection

Step 2: Definition of Feeder Boundary and Function

Step 3: Failure Modes and Effects Analysis

Step 4: Preventive Maintenance Task Selection

The above steps are illustrated through an application to a case study, which is Bang Pa In branch office. It is one of twenty branch offices in PEA C1, supplying electricity to 35,155 customers. The Bang Pa In branch office is responsible for 8 substations with 441 circuit-km of 22-kV power distribution system. In the case study, the

proposed RCM method is applied to 3 critical substations including 26 feeders that supply electrical power to large industrial and commercial customers.

Step 1 Feeder Selection and Information Collection.

The first step of RCM is the selection of power distribution feeders. To do this task, PEA maintenance data must be collected such as technical documents, interruption records, historical maintenance tasks data and maintenance expenses. The interruption records from year 2010 to September 2013 are shown in Table 1. Those interruptions were caused by unknown causes, equipment failures such as fuses, insulators and cable spacers, animals, and lightning strikes.

Table 1. Number of Interruptions by Failure Causes

Failure causes	Substation		
	BKS	BNL	BNM
Equipment failures	10	4	3
Unknown	26	22	6
Birds	1	1	0
Snakes	2	0	0
Lightning strikes	0	0	1

In this step, the interruption records are considered to select a few significant distribution feeders for RCM implementation. They are selected from the outage cost ranking of all feeders of Bang Pa In branch office. Each feeder outage cost is a sum of PEA and customer outage costs as described in equations (1) to (4). As a result, feeders BKS06, BNL01, BNL03 and BKS04 are selected because their outage costs as given in Table 2. are higher than the others as shown in Fig. 1. Then, the single-line diagrams of those feeders are prepared, interruption statistic of selected feeder in the next step.

$$FOC^{i} = \sum_{k} FOC_{k}^{i} = \sum_{k} (OC_{k}^{i,PEA} + OC_{k}^{i,Cust}) \quad (1)$$

$$OC_{k}^{i,PEA} = ICA_{PEA} \times \lambda^{i} \quad (2)$$

$$OC_{k}^{i,Cust} = ICPE_{Cust.} \times \lambda^{i} \quad (3)$$

$$ICA_{PEA} = CM + LossLoad \quad (4)$$

where

FOC^{i} Total outage cost of feeder i (Baht)

$OC_{k}^{i,PEA}$ PEA outage cost of feeder i (Baht)

$OC_{k}^{i,Cust}$ Customer outage cost of feeder i (Baht)

λ^{i} Failure rate of feeder i (events/yr)

ICA_{PEA} Average PEA interruption cost per event (Baht/event)

$ICPE_{Cust}$ Customer interruption cost per event (Baht/event) [9]

CM Average corrective maintenance cost per event (Baht/event)

LossLoad Average revenue losses due to interruptions per event (Baht/event)

k Interruption cause k

Then, the benefits resulted from mitigating an interruption cause by associated PM is determined from (5).

$$B_{k}^{i} = \eta_{k} \times FOC_{k}^{i} \quad (5)$$

where

B_{k}^{i} Benefits from mitigating interruption cause k by associated PM of feeder i (Baht)

FOC_{k}^{i} Feeder outage cost due to interruption cause k of feeder i (Baht)

η_{k} Effectiveness ratio of PM mitigating interruption cause k

Table 2. FOC of Selected Feeders

Feeder	Total FOC(Baht)
BKS06	66,094,209.66
BNL01	52,875,367.72
BNL03	46,265,946.76
BKS04	39,656,525.79

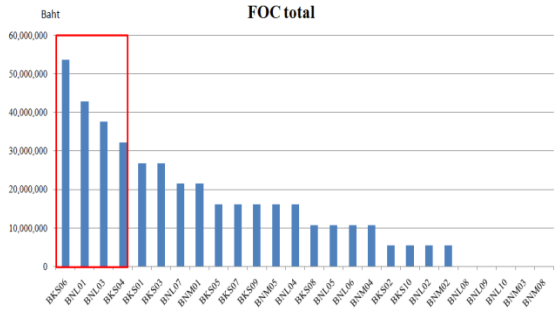

Fig.1. FOC in all feeders

Step 2 Definition of Feeder Boundary and Function.

In this step, the boundary of all selected feeders is first defined to frame the scope of analysis. It will also help the RCM team members to focus on the targeted areas. In this work, single-line diagrams of the feeders together with geographic maps of service areas of Bang Pa In branch office are used to define the boundaries as shown in Fig. 2 to 4. For each feeder, the boundary covers all medium-voltage equipment. Then, the primary function of each feeder that RCM wishes to preserve is delivering electrical power from the substation to all distribution transformers continuously.

Fig.2. geographic maps of service areas of Bang Pa In branch office

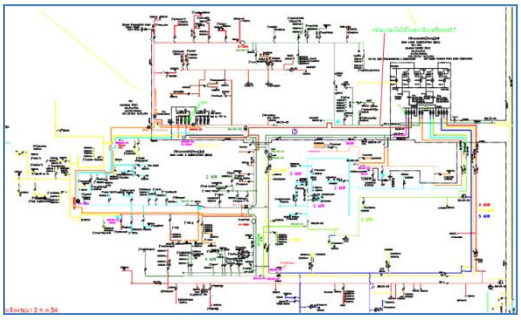

Fig.3. Single line diagram of BNL & BNM substations

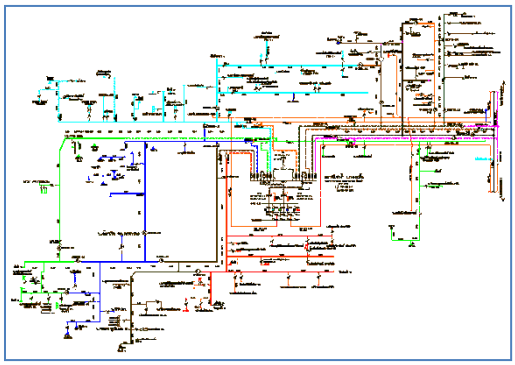

Fig.4. Single line diagram of BKS substations

Step 3 Failure modes and Effects Analysis.

After the primary function of the systems has been specified in the previous step, all dominant failure modes which interrupt the function must be determined. In this paper, the failure mode is defined as the dominant causes that interrupt power delivery. Thus, all failure modes and their effects in terms of FOC are given in Table 2.

Table 2. Feeder failure modes and effects analysis

Feeder	Failure modes	FOC(Baht)
BKS06	Unknown	66,094,210
BNL01	Unknown	39,656,526
	Equipment Failure	13,218,842
BNL03	Unknown	33,047,105
	Equipment Failure	13,218,842
BKS04	Unknown	19,828,263
	Snake	13,218,842
	Bird	6,609,421

Step 4 Preventive Maintenance Task Selection.

The objective of this step is to select the optimal PM tasks that achieve the highest reliability worth as presented in terms of a reduction of FOC. In other words, the methodology is designed to find the most cost-effective maintenance tasks. Here, the cost is all expenses of maintenance tasks including hardware costs, labor costs, etc. PM tasks selected for this case study including replacement of bare conductors with spaced aerial cables (SAC), cable spacer maintenance, bird guards or snake guards installation and tree trimming are shown in Table 3. The marginal benefit-to-cost ratio (B/C) between outage costs and maintenance costs is considered to achieve effective PM task selection in equation (5) The costs of maintenance activities are presented in Table 4.

Table 3. Failure modes and associated PM tasks

Failure modes	PM tasks
Unknown	Replacement of bare conductor with SAC
	Cable spacer maintenance
	Bird guard installation
	Snake guard installation
	Tree trimming
Equipment Failures	Replacement of bare conductor with SAC
	Bird guard installation
	Snake guard installation
	Cable spacer maintenance
Snake	Snake guard installation
	Replacement of bare conductor with SAC
Bird	Bird guard installation
	Replacement of bare conductor with SAC

Table 4. Average costs of maintenance activities

Maintenance Task	Average Costs	Unit
Tree trimming	1,083	Baht/km
Snake Guard installation	110	Baht/set
Bird Guard installation	1,000	Baht/set
Replacement of bare conductor with SAC	1,000,000	Baht/cct-km
Cable spacer maintenance	61,700	Baht/km

For example, all PM tasks ranked by marginal benefit-to-cost ratio for BNL01 are shown in Table 5.

Table 5. Ranking of PM tasks for BNL01

Failure modes	PM tasks	B/C
Unknown	Tree trimming	183.16
Unknown	Snake Guard Installation	72.10
Unknown	Bird Guard Installation	38.33
Equipment Failures	Snake Guard Installation	33.65
Equipment Failures	Bird Guard Installation	17.89
Unknown	Cable Spacer maintenance	3.21
Equipment Failures	Cable Spacer maintenance	1.50
Unknown	Replacement of bare conductor with SAC	0.20
Equipment Failures	Replacement of bare conductor with SAC	0.09

For feeder BNL01, the optimal PM tasks which attain the highest marginal B/C ratio are tree trimming, bird guards and snake guards installation and cable spacer maintenance. The marginal benefit-to-cost ratio (B/C) between outage costs and maintenance costs is considered for the effective PM task selection(all dots above red line) for all feeders as shown in Fig. 5 to 8.

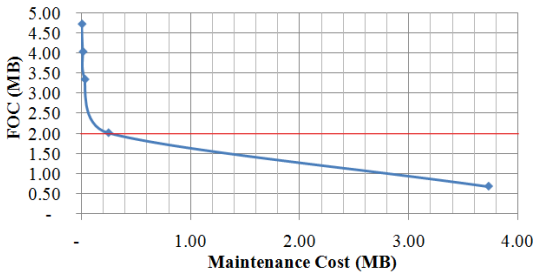

Fig.5. The Maintenance cost and FOC of BNL01

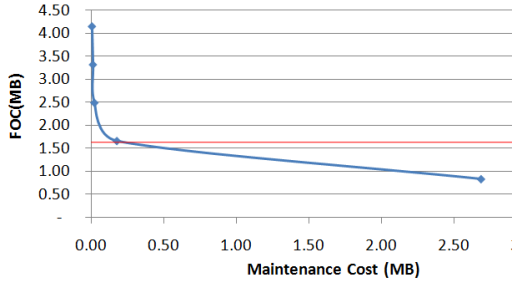

Fig.6. The Maintenance cost and FOC of BKS06

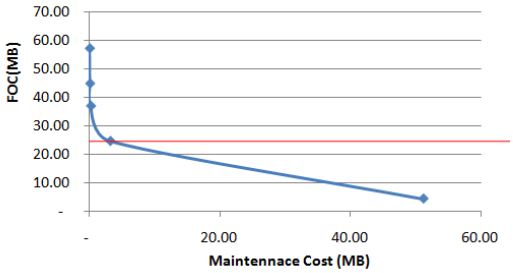

Fig.7. The Maintenance cost and FOC of BNL03

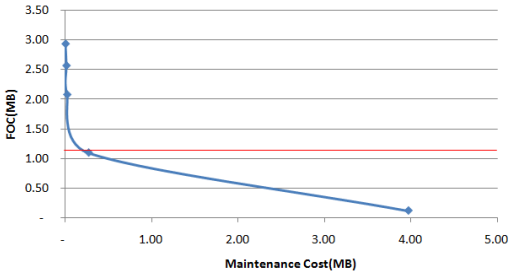

Fig.8. The Maintenance cost and FOC of BKS04

The total cost of selected PM tasks versus a reduction of feeder outage costs are shown in Table 6. for each feeder.

Table 6. Total cost of PM tasks versus a reduction of FOC

Selected Feeder	Maintenance Cost (Baht)	FOC reduction (Baht)
BKS06	175,774.94	2,488,446.99
BNL01	246,053.28	2,714,092.63
BNL03	3,166,873.10	32,690,592.66
BKS04	270,645.44	1,834,114.32
Total	**3,859,346.76**	**39,727,247**

4. CONCLUSION

In this paper, Reliability Centered Maintenance (RCM) is implemented on PEA power distribution systems. In order to achieve a cost-effective maintenance program, RCM is to prioritize the failure modes according to their effects, and then to select the effective maintenance activities for those failure modes. Preventive maintenance (PM) activities are mainly focused on the RCM program driven by the marginal benefit-to-cost ratio (B/C) between outage costs and maintenance costs. The PM program resulted from the proposed RCM guarantees the cost effectiveness, and reduces the amount of corrective maintenance (CM) and outage costs of both PEA and their customers.

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The Effect of Contact Resistance on PEA Power Transmission Systems

Yuttana Yimprasert, Onurai Noohawm, Dulpichet Rerkpreedapong, and Winai Plueksawan

Abstract *— This paper presents hotspots inspection practices for overhead power transmission systems of Provincial Electricity Authority of Thailand (PEA). The selected inspection techniques using infrared thermography and contact resistance measurement can be performed while transmission lines are energized so that system reliability is not worsened. The Navanakorn industrial real estate located in Pathumtanee province of Thailand is selected as a case study to illustrate the inspection practices. After the detected hot spots are mitigated by appropriate corrective maintenance, the payoff is evaluated by a decrease in transmission losses resulted from hot spot correction.*

Keywords **— Contact resistance, transmission connectors, infrared inspection, hotline maintenance technique**

1. INTRODUCTION

At present, it is known that electricity power plays an important role in economic development of the country due to the all industrial sectors need electricity power as raw material adding to cost of production both directly or indirectly. Generating electricity power consists of major steps: generation, transmission and distribution. The difficult problem which always occurs in overhead power transmission systems is the equipment damage caused by the external factors such as storm, broken pole from vehicle accident, small animals and the internal factors such as equipment failure, electrical treeing, overloading, etc. The efficient inspection and maintenance is necessary in order to maintain the power transmission stability and reliability. Normally, the major equipments such as conductor, insulator and transformer should be inspected in routine maintenance. Besides, the minor equipments such as connectors, pad terminal, clamp terminal, cable lug, etc. Are also important equipments and should be inspected.

Mostly, the major causes of the transmission line hotspots are from the cause of overheating. It is the mathematical product of contact resistance inside equipments and the loading of electric current flowing through its contact. The overheating always occurs in the case of the transmission line which designed for to carry the transferred loading from another system for a while. In the case of short circuit, the increased loading electricity flows could create hotspots several times more than during the normal usage. So, the appropriate inspection method and frequency is necessary for the continuity of transmission of the electricity flow int~~o~~ the power transmission systems.

In this paper, The hotspots inspection of the 115 kV power transmission line from Bang Pa-In 2 substation is selected as a case study. The PEA electric energy are supplied for the industrial customers in Navanakorn industrial zone in Pathumthani province, The aim of the study was to investigate the effect of the contact resistance on the power transmission systems by using infrared thermography and hotline maintenance technique.

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2. TRANSMISSION LINE HOTSPOTS INSPECTION

The preliminary condition monitoring of transmission line during normal operation is by visual inspection. Currently, PEA used tools for inspection improvement by which 2 techniques are used: the infrared inspection technique and the hotline maintenance technique.

The infrared inspection technique uses infrared camera to capture heat or quantity of electromagnetic energy and measure its temperature in order to assess the abnormal of resistance on the hotspots surface. The hotline maintenance technique will assess the condition of the resistance on the hotspots surface from the voltage and electric current through the surface of hotspots.

The infrared inspection technique

Normally, all objects with a temperature above absolute zero Kelvin or -273.15 degree Celsius will emit electromagnetic energy. The amount of energy is related to its temperature. The higher the temperature of the hotspots, the more electromagnetic energy the hotspots emit~~s~~. The electromagnetic spectrum contains various forms of radiated energy including x-ray, ultraviolet, infrared, and radio. Infrared energy covers the spectrum of 0.7 - 100 micron which is light functions outside the dynamic range of the human eyes. Infrared images was developed to detect and measure this heat. These data are transformed into digital data and processed into video images that are called infrared image. Each pixel of an infrared image has a temperature value. And the image's contrast is derived from the differences in surface temperature. An infrared inspection is a nondestructive technique for detecting thermal differences that indicate inception of problems with equipments. Infrared surveys are being conducted to find hotspots while the transmission is in operation, so availability of the system need not be interrupted [1].

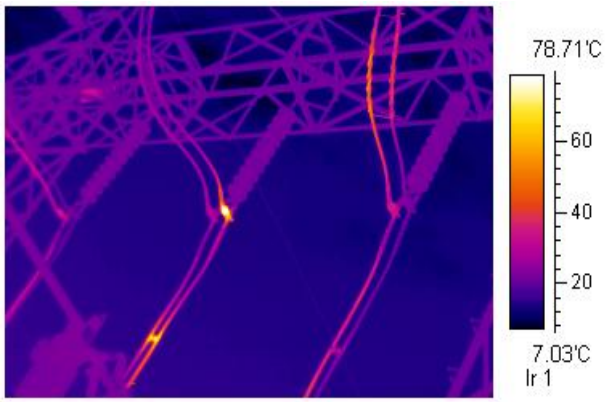

Fig.1. Infrared image of transmission hotspots

Fig.2. Contact measuring with live line micro ohmmeter

In the practical procedure of infrared thermography, the factors such as the emissivity of object, the reflected temperature, the distance between the object and the thermal viewer, and the relative humidity should be controlled and adjusted. This method is still measure the increasing heat from the abnormal resistance of hotspots in which not the actual resistance factors of desired connectors. The high current through transmission line hotspots has significant impacts to receive higher temperature. Besides that, contact resistance of hotspots is still based on the heating ventilation rate of the material according to the qualification of heating rate such as the convection, the radiation and the conduction. The convection and the radiation are the major qualification to use as the range factor or capacity of conductivity and other equipments of electricity system. The heat which ventilated from material according to qualification of the convection is up to the shape and size of transmission hotspots. The wind speed will also decrease the temperature as well as equipment ventilation. Moreover, the qualification of radiation always decrease the temperature by moving as straight line and perpendicular line with the material surface. And the qualification of the conduction is based on the qualification of each material which is part of making equipment [2].

Therefore, the heating from measurement will vary by the multiplication of the current through the resistance of the equipments. If the current on the power transmission line increase continually or suddenly, the power losses of transmission hotspots will more increased immediately. It could say that the condition monitoring preventive maintenance on the infrared inspection technique is not the best efficiency for the power transmission system.

The hotline maintenance technique

This technique could measure the contact resistance directly by using the live line micro-ohmmeter to measure the electric current and voltage drop on the hotspots by using the operation of 115 kV bare hand hotline team in the normal online condition.

The principle of 115 kV bare hand hotline work is a simple one that can be best appreciated by watching a bird approaching and perch on an energized conductor. Since a bird does not from a part through which line current may flow, it can remain on the energized conductor safely, even though its body has become electrically charged to the potential of the transmission line. The bare hand hotline teams have skill and capability to work on the power transmission system such as branching line connecting or disconnecting, performing rods installation or split compression sleeve for conductor repair during which it is not difficult for them to measure contact resistance of the transmission connectors by not disturbing the electrical power of the transmission line system. However, this method incurs higher expenses and higher operating time than the infrared inspection technique.

Contact Resistance of Transmission Hotspots

The good contact surface of connector should be smooth, polished and clean without oxide or any contamination. Normally, contact resistance will be affected by two major factors: overall pressure to the surface and total surface area. Although the surface is smooth, glitter in visual inspection but this surface is not smooth when a power microscope inspection is used. The rough surface is consisted of swell, invented scattering all around which can be clearly seen. It was only one swells area occurred from the actual contact, and the pressure at the swell area is bigger than other areas in which impacted to that contacted area was damaged from the former. This caused inappropriate contact surface when compared with the total surface. If the total pressure on the surface during operation is stable at all the time but the area of the surface is changing, the contact resistance in general will remain stable. In order that the appropriate total pressure should not be higher than the elastic limit or the stress limit of equipment holding the connectors. The total pressure can be controlled by controlling the force on the connectors such as bolts, nuts, etc and keep them in the correct position and appropriate position according to the specification of each holder size and type. The total pressure on the surface will vary according to the temperature changing and the coefficient of connector expansion which could be controlled by installing a qualified and appropriate disc spring washers [2]. Therefore, controlling the pressure on the surface will affect the connectors to have good contacts all the time.

3. OPERATION

Currently, the PEA transmission line hotspots inspection deploys the infrared inspection technique once a year. PEA used the infrared thermography video type which is attached to a moving car at the average speed of 10 - 20 km per hour and the average distance to be covered is around 40 km per day. From the survey in the central region of Thailand, it is found that the total length of the power transmission line is more than 1,800 km-circuit. The major usages are factory or industrial customers where the average of daily peak load may occur for 2 - 4 hours. According to the operations, there are the operation cost which include the staff expenses such as allowance, overtime wage, on-site accommodation and the equipment expenses such as transportation charge with average cost of 72.43 baht per km and its standard deviation which may vary depending on the distance to the operation site is about 29.84 baht per km [3]. The average operating cost is about 5,183 baht per day and its standard deviation which may vary depending on the distance to the operation site is about 196 baht per day [3].

The hotline maintenance technique can be deployed during the daytime or at the low humidity, fogless and dry weather. The average usage time can be mostly dedicated to the preparation and readiness of the team and equipments which is about 30 minutes prior to detecting the transmission line hotspots which is transmitting the power. Then, the usage time in hotspots detection and correction is approximately 10 minutes for each phase. The mean time to repair (MTTR) is about 90 minutes per pillar or 80 minutes per transmission line which containing a set of 6 hotspots per pillar (2 hotspots per phase). The inspection always takes place with the hotspot correction, for example in the case of bolts and nuts replacement, interface cleaning also performed. This technique can lead to the transmission hotspots inspection and maintenance at once for average 4 pillars or 6 hotspots.

4. CASE STUDY

The power transmission line no.4 from Bang Pa-In 2 substation is a sample of the transmission line which is verified by the hotline maintenance technique. During the year of 2008, the transmission line was supplied for the electric energy around 140 MW to electronic plant and all industrial customers in Navanakorn industrial zone, Pathumthani province and the electric energy would increase about 95.158 MW during the transfer loading from Bang Pa-In 1 substation and during the transfer loading from Banmai substation in the contingency operation.

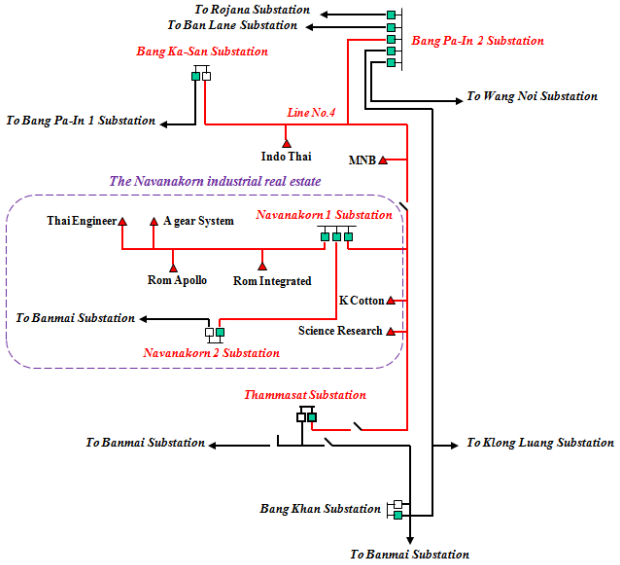

Fig.3. Transmission line no.4 from Bang Pa-In 2 Substation

The cost of transmission line hotspots inspection for 234 points on 25 km distance is about 1,630 baht for the infrared technique. Meanwhile, the hotline maintenance technique takes time for the hotspots correction to keeps in good condition during 10 days. This payment of this method would be 23,100 baht higher than the infrared technique by 36.67 times.

Table 1. Total maintenance cost

Maintenance	Infrared Technique Cost (Baht)	Hotline Technique Cost (Baht)
Staff Expenses	630	18,900
Transportation Charge	1,000	4,200
Total	**1,630**	**23,100**

For all hotspots correction, we have found that the first thing to be done is to correct the total force on the connector's bolt and nuts which have the contact resistance less than 300 μΩ (around 230 points), while increasing the bolts and disc spring washers of the connectors results in the contact resistance being more than 300 μΩ (4 points).

Table 2. Total contact resistance after maintenance

Resistance (μΩ)	Inspect (point)	Decrease (point)	Not decrease (point)
> 500	1	1	-
400 - 500	1	1	-
300 - 400	2	2	-
200 - 300	7	7	-
100 - 200	22	14	8
0 - 100	201	65	136
Total	234	90	144

Table 3. Contact resistance decreasing

Resistance (μΩ)	Decrease (point)	Decrease (μΩ)	Decrease (%)
> 500	1	522	93.05
400 - 500	1	377	88.50
300 - 400	2	279, 285	83.88
200 - 300	7	46 - 118	32.91
100 - 200	14	3 - 88	17.73
0 - 100	65	1 - 62	12.44
Total	90	2,960	32.09

All corrected hotspots resulted in decreasing of the contact resistance about 32.09 % from 9,225 μΩ down to 6,265 μΩ. This decreased contact resistance will save the electric power loss by a factor of 2,960 μΩ which is used in calculation from the equation (1) using the current of 41,495.40 A, the loss will decrease about 5.097 MW or 44.650 MW-hours per year.

$$E_{Line\ Loss} = \left(\sum_{i=1}^{N_c} i^2 \times \left(\sum_{i=1}^{N_c} CR_{Before} - \sum_{i=1}^{N_c} CR_{After} \right) \right) \times T \qquad (1)$$

Where

$E_{Line\ Loss}$ = Power loss on transmission line (Watt - hour)
i = Electric current flow through the connectors (Amp)
CR_{Before} = Contact resistance before maintenance (Ohm)
CR_{After} = Contact resistance after maintenance (Ohm)
N_C = Number of connectors on transmission line
T = Time (Hour)

The payback period of hotspots inspection and correction on the power transmission line no.4 from Bang Pa-In 2 substation is 0.2496 year or 3 months which is obtained from equation (2) by using the hotline maintenance cost and the electric power loss with the 115 kV power purchase rate 2.0726 baths per kW-hour.

$$PB = \frac{HC}{CEL} \qquad (2)$$

Where

PB = Payback period on maintence investment
HC = Hotspots correction cost per year
CEL = Cost of loss on transmission line per year

After using hotline maintenance technique in PEA operation from the beginning till today, the outage caused by damaged arc of the transmission system from Bang Pa-In 2 is never happened again. And this technique was applied to another system such as the transmission line from Banmai substation in Pathumthani province, the power transmission line from Saraburi 4 substation which supplied the electrical energy to The Siam Industrial Land (SIL) located in Saraburi province, Thailand.

5. CONCLUSIONS

Within the 12-month period of inspection by the infrared inspection technique, this method would not be practical to prevent the transmission line no.4 from Bang Pa-In 2 substation from the overheating problem because of connector arc damaged by the electrical power increased up to more than 200 MW when the power generation changes. The hotline maintenance technique can help under the circumstance. The latter can detect and handle efficiently the problematic hotspots which have high contact resistance value. Therefore, this technique should be considered to be integrated in the inspection methodology of the power transmission system.

ACKNOWLEDGEMENTS

The authors would like to express thanks to the hotline team of Provincial Electricity Authority Central Area 1 for providing valuable technical data and information. Finally, this paper is dedicated to the memory of our beloved teacher, Associate Professor Jamnarn Hokierti.

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Design Biogas Production from Mixed Napier Pak Chong I/Food Waste at Thermophilic Temperature by Anaerobic Digestion in Cow Dung and Chicken Dung

Lertluck Saitawee, Kanokorn Hussaro, Sombat Teekasap, and Noppadon Cheamsawat

***Abstract*—** Anaerobic digestion (AD) is a beneficial and efficient technique for the treatment of agricultural wastes, food wastes and wasteswater to produce renewable energy. Solid agricultural are potential renewable energy resoures. Biogas production by co-digestion of mixed napier pak chong I and food waste at thermophilic temperature using anaerobic digestion in cow dung and chicken dung as the seed inoculums were investigated. The total reactor volume of the co-digester reactor was 7.94 m^3, which was equipped with pump, and it was operated continuously for the 20 days as a pilot scale at 50 °C. The napier pak chong I was cut into 2 mm sections, and the initial volatile solids (VS) was 30%. The initial volatile solids (VS) of food waste was 70%. Two pilot-scale digesters filled with napier pak chong I and food waste, which both digesters contained 476 kg of napier pak chong I mixed 305 L of food waste, and 1,305 L of water. There were carried out to investigate the optimum carbon to nitrogen (C/N) ratio for effective biogas production. The slurry raw materials provided sufficient buffering capacity to maintain appropriate pH values (between 7.0 and 8.0). Digester I was designed for 1.98 m^3 of cow dung as the seed inoculum while digester II was designed to establish 1.98 m^3 of chicken dung as the seed inoculum. Analysis gas production is performed by gas detector. The experimental results indicate that total biogas production was 2.19 m^3/day in digester I and 1.86 m^3/day from digester II, resulting in specific methane yields of 1.26 and 1.07 m^3 CH_4/kgVS added, respectively. Biogas production in digester I was directly correlated with temperature.

***Keywords*— Biogas production, napier pakchong I, food wastes, cow dung, chicken dung, inoculum.**

1. INTRODUCTION

Problem of energy clan misses has become a big problem in the world. One way to solve this problem is by biogas production from agricultural and animal manure source. Thailand is a major agricultural country in the world because the terrain is filled with rich natural resources suitable for agriculture and amount of land under cultivation is increasing energy every year. Due to the expansion of agriculture, especially livestock, the raw material for producing biogas can be different like cow dung and chicken dung. There is a high availability indeed, and they are also low-cost sources of gas. Raw materials for biogas production cover a wide range of feedstock including animal wastes, household wastes, crop residues, sewage sludge, food waste, and wastewater [1].

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Anaerobic digestion (AD) of organic matter in livestock manures is a natural mineralization process completed by microbial consortia composed of hydrolytic and fermentative bacteria as well as acetogens and methanogens. Manure component (carbohydrates, proteins, and lipids) carbon is ultimately transformed into methane (CH_4) and carbon dioxide (CO_2) [2]. Biogas contains 50-70% methane and 30-50% carbon dioxide, depending on the substrate as well as small amounts of other gases including hydrogen sulphide. Methane is the component chiefly responsible for a typical caloric value of 21-24 MJ/m^3 or around 6 kWh/m^3. Biogas is often used for cooking, heating, lighting or electricity generation [3]. AD, which can be divided into 6 parallel or series reactions completed by a variety of bacterial species, as followed [2]: (I) hydrolysis of solid organic particles and high molecular weight compounds such as polymers which are too large to permeate the cell membrane into soluble and metabolizable molecules small enough to diffuse across the membrane. Bacteria is catalyzed by extracellular enzymes released by fermentative and/or acid forming on hydrolysis process, (II) the sugars, lipids, and amino acids resulting from carbohydrate and protein hydrolysis are transformed into volatile fatty acids (VFA), hydrogen (H_2), and carbon dioxide (CO_2) by fermentative bacteria, (III) hydrogen (H_2) producing acetogens oxidize VFA with more than two carbon, and long with methanogens which consume the H_2 produced during oxidation, (IV) homoacetogenic bacteria transform CO_2 and H_2 into actic acid, (V) acetoclastic methanogens degrade acetic acid into CH_4 and CO_2, and (VI) H_2 utilizing hydrogenotrophs (methanogens) reduce CO_2 to CH_4. The latter population plays an important role in AD

as they regulate the process by maintaining a low concentration of dissolved H_2 making degradation of organic matter thermodynamically feasible.

A number of factors can affect the reaction process leading to the ultimate formation of methane and carbon dioxide. The particulate nature, lignin, cellulose and hemicelluloses content of biomass may affect the overall reaction kinetics leading to biogas formation. Other factors that may affect the biogas yield include, low pH due to accumulation of by-products formed during biodegradation, carbon to nitrogen ratio (C/N ratio), temperature, hydraulic retention time, and loading rate [4]. AD can be completed at psychrophilic (10-25 °C), mesophilic (30-40°C), and thermophilic (50-60 °C) temperatures, and can occur under hydraulic flow regimes being batch reactor (BR), sequencing batch reactor (SBR) or continuous flow reactors (CFR). Continuous flow bioreactors are operated as a plug flow reactor (PER) or as completely stirred tank reactor (CSTR). Both CFR types are operated at constant volume, which means that as substrate is fed into the bioreactor an equivalent volume of bioreactor content is removed at the same flow rate. Continuous flow operation requires more sophisticated equipment and is more prone to biomass washout and bioreactor failure than sequencing batch reactors [2]. In anaerobic biological processes, proper carbon to nitrogen (C/N) ratio is important for efficient digestion. The optimal C/N ratio for the microbes is 15 to 30 according to Haug [5], who claims that a decreased ratio is no problem for the composting process but leads to losses of excess nitrogen via ammonia volatilization. Others claim the optimal range for bacterial decomposition to be C/N ratio 20 to 40. A balance nutrient availability for the microorganisms is important for a high decomposition rate. Literature review reported that the proper C/N ratio for anaerobic digestion was 25 to 30 from lignocellulosic materials (C/N ratio 35 to 118) mixed with waste with high nitrogen carbon combined with lignocellulosic material with carbon content can provide a versatile mixture for anaerobic processes that could be optimized for each organic waste source to maximize the desired product. As other research reported biohydrogen production could be enhanced by co-digestion of food waste and sewage sludge due to the balanced C/N ratio [6]. However, the desired C/N ratio for efficient hydrogen fornmation by co-digestion of napier pak chong I and animal dung has not been reported in literature.

Co-digestion is the simultaneous digestion of more than one type of waste in the same digester. Advantage includes better digestibility, enhanced biogas production/methane yield arising from availability of additional nutrients, as well as a more efficient utilization of equipment and cost sharing [7]. Every year in Thailand, several million tons of agricultural wastes are being disposed through different ways such as incineration, land applications and land filling. These wastes have a high potential as a bio renewable energy resources and can be turned into high-value by-products. Napier pak chong I, beside the biogas produced from the anaerobic digestion, which is beneficial to be used as digested residues, as soil amendments, as the availability of nitrogen and phosphorus increases. The high carbon content, high solid content and the low nitrogen content of napier pak chong I require the use of other sources of nitrogen and water. Nitrogen can be added in inorganic form (ammonia) or in organic form (urea, animal manure of food wastes).

Based on these requirements, there were proposed a simple and cost effective biogas fermentation process without pretreatment of substrate and inoculum, namely napier pak chong I, food waste, and inoculum (cow dung and chicken dung), as used in this study. The aim of this study was to investigate the desired of biogas production from napier pak chong I/food waste using inoculum cow dung and chicken dung) in anaerobic thermophilic digestion conditions, in order to (1) investigate the possibility of biogas production from napier pak chong I/food waste using different inoculum directly, and (2) compare the effects of different inoculum to amount of biogas and methane.

2. MATERIALS AND METHODS

Materials: Cow dung and chicken dung (inoculum) were collected from a dairy farm near Nakhonratchasima Provice, Thailand during June 2013. The samples were transported immediately to the LC Technologies Limited Partnership, Pakkred, Nonthaburi, Thailand and stored in a refrigerator at approximately 5°C. Food waste was colleted, during June 2013, from household Bangtalad, Pakkred, Nonthaburi, Thailand and provided by a LC Technologies Limited Partnership processing 305 L of food waste, by screening and grinding, as feedstock for a municipal anaerobic digester. Napier pak chong I was collected, during June 2013, from Pakchong, Nakhonratchasima Provice, Thailand. The samples were scraped off the feed lanes and collected in 5 tons buckets. The samples were transported immediately to the LC Technologies Limited Partnership, Pakkred, Nonthaburi, Thailand. To determine the effect of different type inoculum on biogas production, raw materials was diluted with tap water and screened with a 2-mm screen. The characteristices of the substrates testes in this study, including inoculum (cow dung and chicken dung), food waste, and napier pak chong I, are shown in Table 1.

Methods: Schematic diagram of pilot experimental reactor is shown in Fig.1. The essay was carried out in batch digestion on cylinder stainless steel reactor with an internal diameter of 1.9 m and a total height of 2.8 m. The total volume capacity was 7.94 m^3. The system was operated in thermophilic temperature (50°C) for 20 days. A set of two batch reactors were used as digesters. Digester I cosisted of 476 kg of napier pak chong I, 305 L of food waste, 1,305 L of water, and 1.98 m^3 of cow dung as inoculum. Digester II consisted of 476 kg of napier pak chong I, 305 L of food waste, 1,305 L of water, and 1.98 m^3 of chicken dung as inoculum. Temperature of reactor was recorded. Biogas and leachate were sampled every days.

Anlytical methods: The initial volatile solids (VS) of raw materials were measured in triolicate according to standard methods [8]. The elements analyses were performed by CHNS/O analyser (Perkin Elmer PE 2400 Series II, which haseous products freed by pyrolysis in high-purity oxygen and were chromatographically seperated by frontal analysis with quantitatively detected by thermal conductivity detector. The total biogas production and methan content from digester was recorded every day, the daily biogas yield was calculated according tot he volume of water in water receiver, and this method exists error which can be minimized by

adding equivalent water volume in biogas storage and reducing the times of changing reactor; gas production of anaerobic digestion was directly measured by gas flow meter. The gas composition (CH_4, CO_2, and N_2) was determined using a Gas Chromatograph equipped with a thermal conductivity detector (TCD).

Table 1. Characteristics of Substrate

Parameters	Substrates		Inoculum	
	Napier pak chong I	Food waste	Cow dung	Chicken dung
pH	4.5	4.27	7.5	7.1
TKN(mg/L)	420	1,185	285	256
NH_3(mg/L)	38.49	42.7	30.1	30.5
Total solids (mg/L)	629,293	176,728	588,366	566,764
Volatile solids (mg/L)	68,400	158,231	11,400	10,050
Volatile Suspended solids (mg/L)	69,300	109,210	7,600	6,900
Total phosphorus (mg/L)	88.040	546	299.33	250.12
Suspended solids (mg/L)	467,693	111,240	533,116	600,006

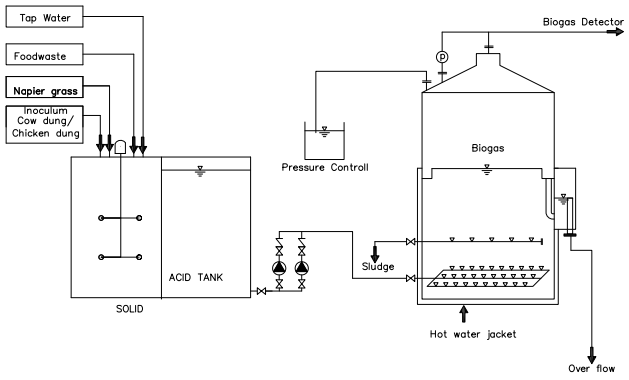

Fig.1. Schematic Diagram of Pilot Experimental Set-up.

3. RESULTS AND DISCUSSION

Temperature plays a critical role in the anaerobic co-digestion. The temperature for anaerobic co-digestion of napier pak chonk I, food waste, and inoculum (cow dung and chicken dung is average 50°C (thermophilic temperature). Along with temperature, the appropriate balance of nutrients is very important fort he anaerobic digestion of napier pak chong I and food waste. The advagetage of co-digestion with animal dung is that optimum C/N ratios are established without adding chemical and higher methane yield and biogas production are the result. Napier pak chong I has a low content of nitrogen which results in relatively high C/N ratios, and typical C/N ratios values of substrate are shown in Table 1. The napier pak chong I and food waste used in both digesters had a C/N ratio of 35 and 16, respectively. Therefore, the nutrient balance in the digesters is dependent upon the addition of an inoculum (cow dung and chicken dung), which relatively high content of nitrogen. The cow dung and chicken dung used in the digesters had a C/N ratio of 24 and 12, respectively. The initial mixtures napier pak chong I, food waste, and cow dung resulted in an overall C/N ratio of 25 in digester I. The initial mixtures in digester II (napier pak chong I, food waste, and chicken dung) resulted in an overall C/N ratio of 21. This resulted indicates that the C/N ratios for digester I is near the optinum range (25-30)[6].

Table 2. Typical Carbon to Nitrogen Ratios (C/N) for Inoculum (Cow Dung and Chicken Dung), Napier Pak Chong I, and Food Waste.

Substrate	Carbon to Nitrogen Ratio (C/N)
Napier pak chong I	35
Food waste	16
Cow dung	24
Chicken dung	12
Digester I (Napier pak chong I, food waste, and cow dung)	25
Digester I (Napier pak chong I, food waste, and chicken dung)	21

Biogas production of digester I and digester II are shown in Fig. 2. The digester I had the highest biogas production, compare with digester II. After 13 days of digestion, biogas production was 2.19 m^3/day and 1.86 m^3/day for digester I and digester II, respectively.

The methane yield in different inoculum is presented in Fig. 3. The digester I had the higest biogas yield, compare with the digester II. The methane yield reached its peak value of 1.26 m^3 CH_4 /kgVS added and 1.07 m^3 CH_4 /kgVS added on 17th day for digester I and digester II, respectively. Mainly, beacuse digester I had C/N ratio close to optimum comdition about 25 and the better contact between microorganisms and cow dung was achieved in anaerobic digester and the utilization of

inoculum was improved, so it is very importent to fully use differnt inoculum to improve biogas production efficeincy.

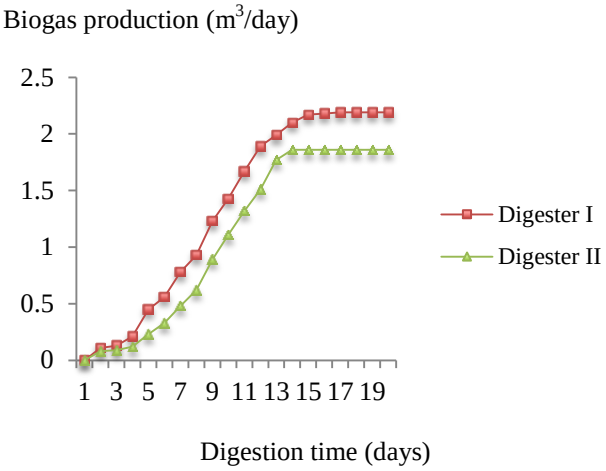

Fig. 2. Biogas production from digester I and digester II.

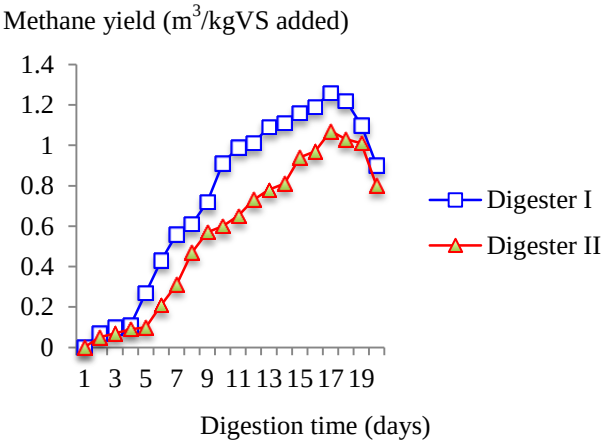

Fig.3. Methane yields of digester I and digester II.

Methane content in biogas is presented in Fig.4. Both digesters (digester I and digester II) had reduced of methane content, which the accumulation of intermediates during the initial period of digester (first 9 days) as indicated by higher methane content. The proportions of methane was remained constant and with value between of 50% and 68% (after 10 days) for different inoculum (digester I and digester II) Maximum methane content of 68% and 65% at thermophilic temperature (50°C) for digester I and digester II, respectively. Since, the changes of methane content were corresponding to the biological biogas-producing phase. Therefore, the biogas-producing phase can be divided into two main process, the first is hydrolysis and acetogenesis processes, CO_2, hydrogen and mainly acetic acid produced in this process, and the second phase the methanoges utilize mainly H_2/CO_2 and acetic acid to form methane and carbon dioxide [9]. This resulted, it was found that, its needs much C/N ratio for napier pak chong I, food waste, and cow dung to attain higher methane content.

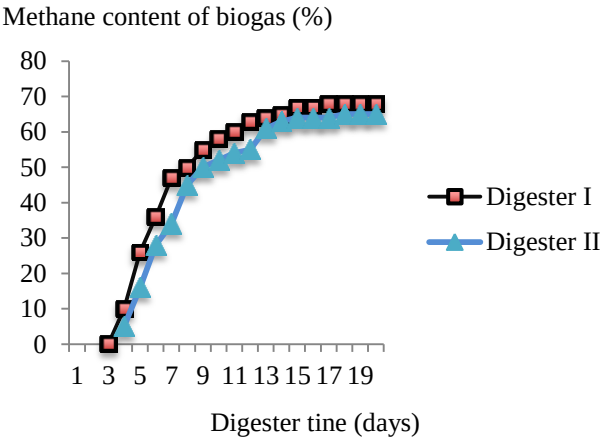

Fig.4. Methane content of biogas for digester I and digester II.

4. CONCLUSION

Currently, anaerobic digestion technology not only applied for various pollution control, such as waste water, industrial wastes and municipal solid waste (MSW), but also fort he production of renewable energy, such as biogas. The design pilot scale digester is quite innovative for ist dimensions and for ist easy transportability in a farm and industrial, giving the possibility to conduct the test directly in situ. The anaerobic co-digester is relived tob e an extreaely useful instrument for better calculation of biogas productivity besides it being versatile and reliable. The co-digestion of substrates comprising napier pak chong I, food waste, and inoculum (cow dung and chicken dung) is feasible at thermophilic temperature for 20 days. The addition of inoculum to fixed amount of napier pak chong I and food waste was observed to improve biogas production. However, the biogas production, the methane yield, and the methane content was observed to highest in digester I, which there were 2.19 m^3/day, 1.26 CH_4/kg VS, and 68%, respectively. While, the biogas production, the methane yield, and the methane content for digester II were 1.86 m^3/day, 1.07 CH_4/kg VS, and 65%, respectively. In addition, the C/N ratio was employed in digester I for given value of 25, which it is optimum region to biogas production. Moreover, inoculum is necessary for improving the biogas production of system.

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General Smart Grids Concepts and Future Power Supply Systems

Gumpanart Bumroonggit, Worpong Sinsukthavorn, Sakul Pochanart

Abstract *- Distributed generation (DG) technologies such as wind systems, photovoltaic, fuel cells and micro turbines are integrating and becoming an alternative energy supply to assist the conventional power plants. The increased grid integration of these DG leads to control changes and significant structural in power supply systems. The efficient strategy and management are definitely required. This led to the idea of a "smart grid" which is an intelligent concept to handle the changing in future power supply systems. However, the existing conventional power systems could not be completely changed as they are enormous. Any new integration system should follow and base on the concepts of conventional power systems (i.e. hierarchy automation control, grid code, communication and etc.). In the paper, examples of conventional and distributed power plants in EGCO group are presented for understanding description and technical background of the reality operating plants. Finally, the general definition and concepts of smart grid are discussed.*

Keywords **- Conventional power system, distributed generation, inverter, smart grid**

1. INTRODUCTION

Since significant growth of electrical energy supply is a main key to develop the economical and social standards of living, new establishing conventional power plants will lead to many certain problems such as protest, pollution emission, source depletion and etc. Policy of the Thailand government has a positive aim to promote electricity generation from renewable energy and sustainable energy. Renewable energy which has high potential to be used in place of fossil energy (i.e. coal, fuel and gas), includes, for example, hydropower, biogas and biomass energy, solar energy and geothermal energy. Therefore, modern technology energy supplies have been developed and integrated into the existing power grids to support the future energy requirements. However, the increased grid integration of these modern supplies leads to significant structural changes for grid automation. New flexible concepts and reliable management for control, security and economic issues are required, which is recently a hot topic for the power system field, so called "smart grid" [1].

As the key responsibility of power supply system is to control and maintain frequency and voltage, this is currently done using synchronous generators in conventional power system [1-4]. This synchronous generator is functioned as an interfacing unit to the grid. Therefore, any new modern energy supply or distributed power system will also require interfacing units to provide the necessary crossing point to the grid which are power electronics technologies "inverters" [1-2]. The inverter is fundamentally multifunctional and can provide not only their principle interfacing role but also various utility functions as well. This will be the core point for the grid integration of the future smart grids.

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In Thailand, Electricity Generating Public Company Limited (EGCO) is the first independent power producer (IPP) to becoming the first public company. EGCO group has planned to invest in power plants with a wide variety of sources [5]. In this paper, two power plant projects in EGCO group are demonstrated including project description, technical background and generating process of the power plants. First, BLCP Power Limited, a coal-fired power plant is presented. This project is represented as a conventional power supply system. Second, Natural Energy Development Company Limited (NED) is proudly presented. The major interfacing units in the solar power plant that used for generating electricity are inverters. This project can be represented as a distributed power supply system. Afterward, smart grid description and concepts are introduced. Finally, conclusion is given.

2. BLCP

Project Description

BLCP Power Limited is a coal-fired power plant located in Map Ta Phut Industrial Estate Phase 2, Rayong province, Thailand. BLCP Power Station generates 1,434 MW of power using about 3.64 million tons of good quality of bituminuos coal per year and installed with Flue Gas Desulfurization (FGD), Electrostatic Precipitator (ESP), Low NO_x Burner, waste water treatment system and environment management equipment. The BLCP plant site is shown in Fig. 1. BLCP is a joint venture of Thailand's Electricity Generating Public Company Limited (EGCO) and BANPU. Each holds equally 50% stake. The project description is shown as in Table 1.

Fig. 1. BLCP's plant overview [6].

Table 1. BLCP Project Description

Plant Location	Map Ta Phut, Rayong Province
Installed Capacity	2 × 717 MW
Energy Source	Bituminous coal from Australia and Indonesia
Technology	Conventional two unit of coal fired, steam-electric generation
Boiler	Subcritical pressure, single reheat, single drum, single furnace, balanced draft, forced circulation
Steam Turbine	Triple pressure, single reheat, condensing, tandem compound
Environmental Control Equipment	- NO_x: Low NO_x burner, S-OFA - SO_2: Seawater flue gas desulphurisation plant - Particulate: Electrostatic precipitator
Contract	25 years PPA with EGAT
Grid Connection	500-kv transmission line
COD	- Unit 1: October 2006 - Unit 2: February 2007

Coal-Fired Power Generation Process

The coal-fired power generation process for BLCP power plant is shown as a diagram in Fig. 2. The process begins at the bottom right-hand corner. The bituminous coal is transported from ships to the coal yard. Then the coal is transported via conveyors to bunkers and pulverizers where it is ground to suitable size for inputting into boiler furnace in suspension in transport air. At the boiler, boiling water and steam are separated by the boiler drum. The water is heated again in the furnace, whereas the steam enters superheat coil where the temperature is increased and the pressure be properly adjusted before entering a steam turbine. The steam transfers energy to the steam turbine and turn the generator. The magnetic field crossing the coils within the generator results in electrical power. Later on, the power output boosted up to 500 kV by the transformer and feeding later to the grid. The steam passing through the steam turbine will be condensed in the condenser which is later returned to the boiler again to produce steam.

Moreover, while heavy ash called 'bottom ahs' settle at the bottom of the boiler furnace, fly ash will be carried with the flue gas through the boiler and at the outlet will be trapped by electrostatic precipitator. Since the coal has sulfur as an impurity, combustion leads to a reaction which produces SO_2. Therefore, a seawater flue gas desulfurization system is provided to trap SO_2 before it is emitted into the air. NO_x will also be minimized by use of low NO_x burners of advanced design. More detail of generation process, environmental care procedure and project description can be seen in [6].

3. NED SOLAR POWER PLANTS (LSP/WSP)

Project Description

Natural Energy Development Company Limited (NED) is a solar power company located in Lopburi province, Thailand with its aim to develop clean renewable project. NED is represented as an innovative project which is a new beginning of history of the renewable energy and energy businesses in Thailand. The operation is to generate and distribute electricity along with the educating knowledge to communities. NED is a joint venture of Thailand's Electricity Generating Public Company Limited (EGCO), Hong Kong-based China Light & Power Company Limited (CLP) and Diamond Generating Asia Company Limited (DGA) of Japan. Each holds a 33.33% stake of NED, which currently operates 73 DC/55 AC MW Lopburi Solar Power Plant (LSP) and 11 DC/8 AC MW Wang Ploeng Solar Power Plant (WSP). The LSP and WSP sites are shown in Fig. 3. and Fig. 4. respectively.

Fig. 3. LSP's plant overview [7].

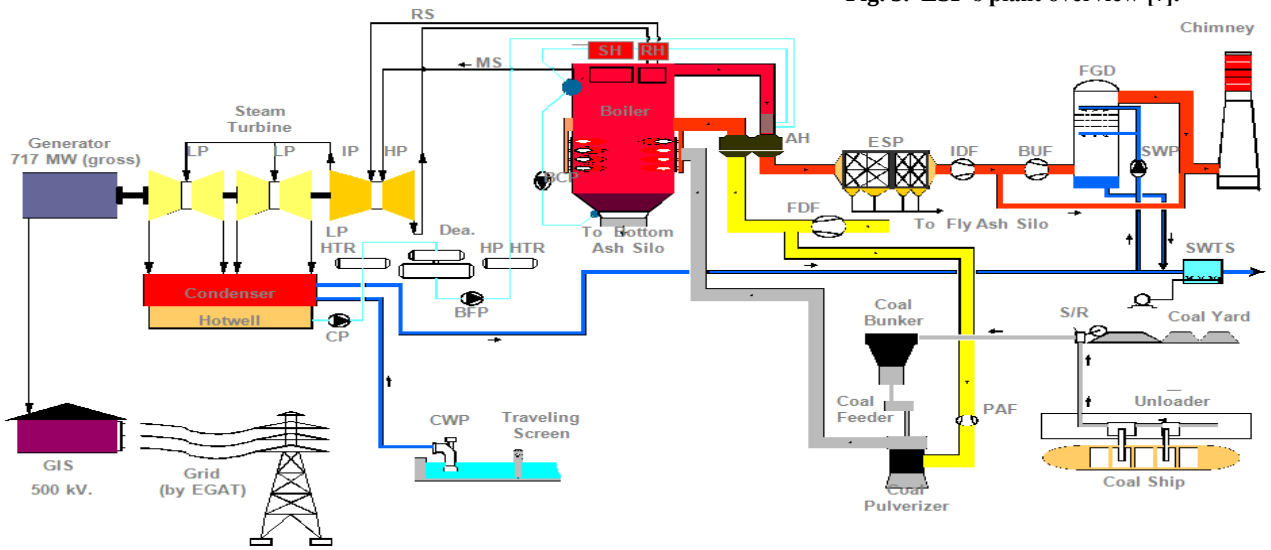

Fig. 2. BLCP's power generation process diagram [6].

Fig. 4. WSP's plant overview [7].

The project description is shown as in Table 2. These solar power plants can supply clean energy to 300,000 - 400,000 people. It is not only help the country reduce carbon dioxide CO_2 emissions by over 1.3 million tonnes throughout the 25-year project period but also cut fuel imports by over 35,000 tonnes/year. Moreover, with new innovation of frameless glass-on-glass thin-film, it provides less dust accumulation and requires less frequent cleaning and maintenance [8].

Table 2. LSP and WSP Project Description

Plant Location	Lopburi Province
Installed Capacity	-73 DC/55 AC MW to EGAT (LSP) -11 DC/8 AC MW to PEA (WSP)
Energy Source	Solar (~ 5 kwh/sq.m./day)
Technology	Frameless thin-film solar cell
PV Panel	-560,000 panels (LSP) - 63,000 panels (WSP)
Contract	-SPP (Non-Firm), (LSP) -VSPP (Non-Firm), (WSP)
Adder	8 Baht/kwh for 10 years
Grid Connection	-115-kV transmission line (LSP) -22-kV distribution line (WSP)
Area	Approx. 1,400 rai
COD	-December 2011 -May 2013

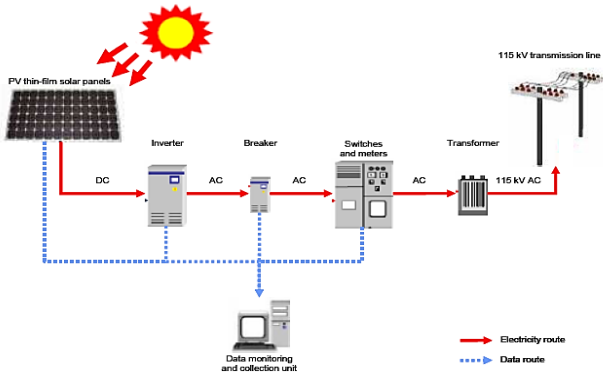

Fig. 5. Photovoltaic power generation process diagram [7].

Photovoltaic Power Generation Process

The photovoltaic (PV) technology is selected for generating electricity in the plants. This method is an electrical power generation by converting solar radiation into direct current electricity. The general generation process of both LSP and WSP plants are shown in Fig. 5.

There are main seven parts required to generate electricity which are PV solar panel, inverter, circuit breaker, switches and meters, transformer and control unit. The PV panels receive solar radiation and convert to DC power and feed to inverter. Inverter main role is to convert DC current to AC current alone with keeping constant of state variables (frequency and voltage) in an acceptable range. The AC output from inverter flows through the circuit breaker which is responsible for protecting electronic devices from any damage caused by overload and short circuit. Later on, AC current flows through switch and meter unit to control and meter amount of electricity flow. Finally, the AC output is boosted up to 155 kV at step up transformer and feed to substation and dispatching in transmission networks. Moreover, there is the control unit which is responsible for monitoring, data collecting and information recording from PV panels, inverter, circuit breaker, switch and meter unit. Moreover, the generated output is monitored and detected the error by SCADA system which monitors the AC side and DC side of PV system. SCADA are provided to controls the main equipment in substation system.

4. SMART GRIDS

Nowadays, the limitation of power grid is an ongoing problem, since power demand is still extremely continuously increasing along with the new DG technologies and power system innovation. The integration of new power plants and new segments for transmission and distribution networks is getting very difficult to control and manage. New high voltage transmission networks can be established only related to permission and activities of citizens' initiatives, as well as environmental concerns. It requires government support, future oriented power system knowledge, highest efforts, extremely long planning and realization periods. As well new distribution networks must be carefully managed and planned as they will be a large number of it to be implemented to the existing networks.

New strategies and concepts are required to better utilize the existing power system elements. This led to the idea of a "smart grid" which is presently very common term for a future vision of power systems with advanced automation concepts, smart and intelligence. Although the term is commonly used, there is still no agreement on an exactly accepted definition. A very general definition of a smart grid is an intelligent system, auto-balancing and self-monitoring power grid that accepts any kind of sources and transforms it into an electricity consumer's end use along with the environmental concerns. The smart grid must have the ability to sense and proper response when any section of its system is overloaded, tripped and reroute power to reduce that overload and prevent a potential outage situation. A grid that enables real-time communication between the consumer and utility allowing for optimizing a consumer's energy usage based on environmental and/or price preferences [3].

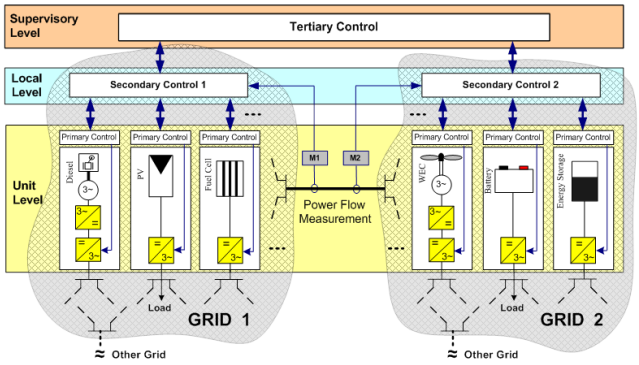

Fig. 6. Overview automation control in a smart grid [2].

To be summarized in the majority of descriptions and definitions, smart grid can generally consist of three main applications which are automation control, information and communication technology (ICT) and system management. These three cores must be clearly clarify, understood, merging and developed before going forward to get bright and reliable future power supply systems.

Automation Control

The automation control is a major part for smart grid which must be seriously taken into consideration. In the future, due to the various operating functions and architectures used by power systems (mainly DG in form of grids), an automation control strategy to link these systems to operate in parallel with compatibility with the existing power systems, is needed. As the main task is to control and maintain frequency and voltage of the power system to nominal values, this is currently operated in the conventional way by using synchronous generators as an interface. The automation control strategy of conventional power systems can be adapted to distributed power systems (smart grids) through their interface unit (inverter) to the grid [9].

An overview of the automation control strategy can be seen in Fig. 6. The main target is to link supply systems to interact and operate in parallel to form a large smart grid. In each supply system, there are a primary control at unit level and secondary control at local level to regulate and maintain the voltage and frequency. The secondary control at local level manages power sharing between the sources along with user settings and rated power. Each link contains measurement units to observe power flow, while communicating with tertiary control at supervisory level. The tertiary control uses information such as meteorological forecasting and also data from local levels to optimize and control power dispatching and load sharing for the entire power system.

An obvious advantage of the automation control is that the systems can support each other and automatically balance in case of failure and allow economical dispatching. Supply security and protection are also improved through the parallel connections of subsystems.

Information and Communication Technology

Information and Communication Technology (ICT) is one of the major parts in modern power supply systems and becoming one of the corner pillars. Assuming further decentralization of modern power sources, automation control and communication technology will play a central role within the restructuring of future power supply systems. Nevertheless, it must be understood as a tool, enabling the implementation of, however centralized or decentralized functionalities that are required for safe and reliable control and management of the power system.

Beside the basic physical automation control in power system control, additional supervision functions are required for system optimization, as well as for visualization and security tasks. All supervision and operational management tasks of power plants and grids are organized by grid control systems, already today built with a very high ratio of ICT. In conventional power supply, this is normally a centralized operational control with high efforts for automation related to the equipment and the automation algorithms. The grid control systems are hierarchically assigned to the different voltage levels. Under-laid to these grid control systems, grid control stations (control rooms) are responsible for the general communication of data [10].

An important role of communication techniques are modern communication networks. While in the past most often point-to-point communication was applied, which was either connected fixed or established by certain routing, networks on basis of e.g. Ethernet offer more flexibility. Data transfer between transmitter and receiver in turn is mainly realized by vendor specific and standardized protocols [11].

Limitations in ICT may have direct impact on the control of the power system [12-13]. Nevertheless, the enabling of the power system control and automation, to fulfill future power system demands, will be the main responsibility of sufficient strategies and philosophies for grid control, based on the physical behavior of the power system. ICT related limitations or potential risks for power system control should of course be taken into account.

System Management

Future smart grid required advanced power system management to manage both automation control and ICT application in an efficient way. The system service of system management should include all tasks performed by the system operator as part of coordinated power station commitment (e.g. for frequency stability) and network management, and of national/international interconnected operation by control centers with competence for their own areas. System management also includes all measures for the creation and maintenance of the requisite preconditions for metering and charging of all services performed [14].

Any control architecture to be developed, should create the physical control basis as a fundamental platform for higher level management functionalities. The SC architecture should empower the power system for smart grid, virtual power plant and other applications.

5. CONCLUSION

The actual power supply system is changing from a conventional power system, based on large power plants, towards distributed power system with a large number of distributed generation, renewable energy systems and small energy systems to form smart grids. However, a completely decentralized and proprietary control is also not possible, since all sources, loads, and losses in the higher voltage levels, must be assigned to any controller to avoid steady state errors in the control of the state

variables. Therefore, before going further implementing any new power supply system, the existing conventional power system must be clearly understood. The challenge of smart grid has to be carefully defined, clarified and managed in order to ensure high performance, sustainability, flexibility and reliability. The general definition is that the smart grid concepts should compose of power system management in combination with high performance automation control and modern information and communication technology. The smart grid should also be flexible to any latest adaptation of the new technologies and technical regulations.

ACKNOWLEDGMENT

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Bilateral Contract for Electricity Retailer using the Risk Adjusted Capital Asset Pricing Model: A Case of Thailand

Pasapong Gamonwet

Abstract *-- Under the competitive market structure, the retailers have to purchase the electricity power from the spot market at the Market Clearing Price (MCP) or consider through bilateral contract at agreed price, while most customers pay for their electricity bill to the retailers at the fixed price. According to these different methods of purchasing and selling, there is a hardly avoidable risk associated with financial return for the retailers. This paper will use the methodology to offer a range of bilateral quantity and participatory price for retailer to guarantee their risk-limited payoff. The paper will provide two scenarios which are single retailer in the market provide electricity to the specific customers and two competitive retailers provide power to those royal customers and switched customers. The retail price will be defined by using financial quantitative method. Capital Asset Pricing Model (CAPM) will be used for financial analysis. Apart from that, the risk factor will be considered by using Risk Adjustment Recovery on Capital (RAROC). Additionally, Provincial Electricity Authority, plan to install Smart Grid technology to the system. Under the Smart Grid technology, customers enable to manage their load via AMI. Hence, the paper will also define and compare the bilateral quantity and price for retailer under two scenarios - with and without installation of AMI.*

***Keywords*— AMI, Bilateral Contract, CAPM, and RAROC**

1. INTRODUCTION

Over the decades, Electricity Markets are broadening and liberalized in many countries throughout the world. The major concept for Liberalizing and broadening is that the wholesale electricity prices will be no longer fixed or regulated by the government or a regulatory committee, but defined by the law of supply and demand instead. Liberalized in electricity market structure is not only driven more competitive level to the generation and transmission sector but also retail sector. Opening access in electricity retail sector will provide the chance for customers, especially for those who categorized in residential sector, to select favor and affordable electricity price which provided by different retailers, furthermore the efficiency of electricity demand will be more promoted. Although, many countries in ASEAN, such as, Thailand, Indonesia, Malaysia, and Cambodia, still have the low level of competitive in their electricity structure, the trend of competitive level is believed to be increased due to many agreements and master plans under the process of the new institutional arrangements as being conducted under the heads of ASEAN Power Utilities and Authorities (HAPUA) or the ASEAN Center for ENERGY (ACE). The primary objective is to improve the reliability, quality and available of electricity throughout ASEAN and, especially, the authorities have to response for subordinate objectives for example, major transmission and interconnection cooperation and coordination, the development, set down by policy maker, in relation to transmission access, connection and pricing, system operation, and physical contract trading, etc. Thus, according to the objectives of HAPUA, in the next few years, the structure of electricity market, formal access, connection and pricing regimes, and coordinated planning to encourage commercial investment, for those ASEAN countries, will be changed.

The structure of electricity market in Thailand is still monopolistic. Generation and Transmission sector are both under controlled by Electricity Generation Authority of Thailand (EGAT) who is considered as the single buyer (monopsony) and seller (monopoly). As for Distribution and Retail sector, two utilities are majorly managed, which are Provincial Electricity Authority (PEA) and Metropolitan Electricity Authority (MEA), manage for the rural and metropolitan area of the countries, respectively. Nonetheless, under this less competitive electricity market, an inefficient in electricity demand is in serious concern. Hence, the efficient retail price is essentially needed to ensure that the electricity will be used in the most optimal state and both producer and consumer will gain the maximized of their benefit. Thus, following with the HAPUA objective, which states the establishment of regulatory that in relation with pricing and contract trading could be extremely challenging and complicated tasks.

In this paper, the offer of bilateral quantity and participatory price for retailer to guarantee their risk-limited payoff will be calculated by two financial methods. Capital Asset Pricing Model (CAPM) will define the proper price which will generate the favor revenues for the retailer company (RETCO), in the meanwhile, Risk Adjustment Recovery on Capital (RAROC) will considered the price and quantity of bilateral contract, that RETCO will purchase from Generation company (GENCO), which mean that RETCO will decide by using this financial method for selecting which price, with given quantity, has the most risk and should be avoided for offering the bilateral contract or which price that has the lowest risk that retailer should opt. The practice of this paper is carries out for two scenarios, namely, without competitor or single retailer in the market, and competing retailer which will cause the customer decides to change their electricity supplier due to which retailer will offer the lower price. Moreover, the paper will also define and compare the bilateral quantity and price for two more scenarios - with and without installation of AMI. The rest of paper is arranged as follows: Section 2 gives the overview of electricity structure that is used as the model to generate the result in this paper. The briefing of fundamental of CAPM and RAROC are given in section 3. In section 4, it shows the sample calculation of market clearing price (MCP). As for section 5, the result for no-competition case with and without AMI installed are given.

Whilst, as for competition case with and without AMI deployment, it will present in the section 6. The main conclusions are summarize in section 7.

2. OVERVIEW OF THE ELCTRCITY STRUCTURE

Fig.1 presented single retailer, without the competitor case, where under this electricity structure, Retailer purchases the power from GENCO at the spot price which determined every hour by Transmission System Operator (TSO) or Independent System Operator (ISO). In the meanwhile, it sells the power to the customers at the fixed price. Hence, the spot price or considered as market clearing price (MCP) is very volatile. The risk payoff for retailer is characterized by this unstable MCP. For hedging this risk, the concept of bilateral contract has to be taken into account. The bilateral contract can be fixed for decision period, for instance, a few days or monthly or hourly basis. Therefore, after the bilateral contract has been settle and agreed, the retailer cannot avoid and has to carry on the deal.

As for Fig 2, it is presenting when there are more than one retailer in the market, namely the competition level has been increased. The electricity loads are classified into loyal and switching load. It is assume that, when the competitor price is more attracting than the incumbent retailer, those who not the loyal customers will intend to change the supplier, that is where the switching load will be occurred and incumbent retailer has to considers the risk of this switching incident. However, for the study of this paper, the rest of the load is set up to be loyal to each individual retailer. The fixed tariff for loyal load for each retailer clients can be settle by the individual retailers themselves or by the regulator, following with the electricity structure model, for a longer period of months or years, in the meanwhile, the switching tariff will be defined for a shorter fixed period such as days or weeks, hence, the revising of contract can be reconsidered after the switching contract has been expired. The model in Fig 3 will be considering used as the methodology for evaluating the range of bilateral price and quantity for both with and without competitive retailer in the system, furthermore, the case will be also associated with the installation of AMI.

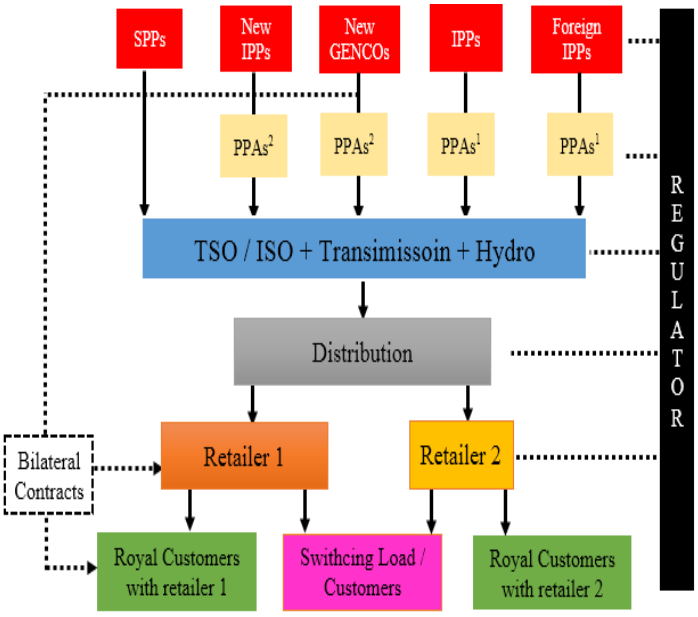

Fig. 1. Model for electricity retailing without competition

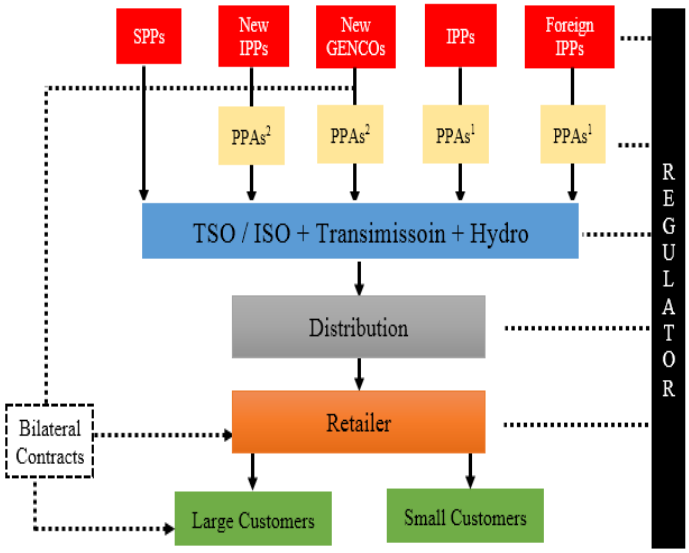

Fig. 2. Model for electricity retailing with competition

3. FUNDAMENTAL OF CAPM AND RAROC

3.1 A Capital Asset Pricing Model (CAPM)

The CAPM is one of the investment modelings which can define the reasonable price for the asset. The investor (in this case can be considered as retailer) can get profit depending on the variation in the asset price. In model, risk will be considered as variance and for any capital the total variance of return must be minimized.

Under the CAPM model, the expected return $E\{r_i\}$ of any asset i satisfies (1). The $(E\{ r_i - r_f \})$ is called the Expected Excess Rate of Return of asset i. It indicates the amount by which the rate of return exceeds the risk-free rate. The $(E\{r_m\} - r_f)$ is called the Expected Excess Rate of Return of the market portfolio.

$$E\{r_i\} = \beta_i(E\{r_m\} - r_f) + r_f \quad (1)$$

Where,

$\beta_i = \sigma_{i\,m} / \sigma^2_m$

β_i is normalized covariance between i^{th} asset and total portfolio returns.

r_i is return of any asset i

r_m is rate of market return

r_f is risk free rate of return

In case that β_i is almost zero, then the asset is completely uncorrelated with the market. Accordingly, in this case, the expected return is the risk free rate. If $E\{r_i\} < r_f$, the asset may face the high risk. Under this circumstance, retailer companies will accept the lower expected value by concern some forms of insurance. For conclusion, RETCOs can quantify their business risk by applying CAPM model for the different electricity tariff.

3.2 Risk Adjustment Recovery on Capital (RAROC)

Risk Adjusted Recovery on Capital (RAROC) is specified as the ratio of expected return and Economic

Capital (EC), which is known as the number of money that needed to secure the investor's existing and it also captures all type of risks including calculated with Value at Risk (VaR). VaR is an α-quantile of the gain and loss distribution. As for RAROC, it compares the expected return and economic capital, thus, if it is higher than zero, which will mean that the return that expected can cover the economic capital. Consequently, if retailer decides to base their bilateral quantity and price on the RAROC method, then its return are considered with risk constrained. Moreover, RAROC has varied terms to express which are shown as below:

$$\text{RAROC} = \text{Expected Return} / \text{Economic Capital} = E(\text{Payoff}) / (E(\text{Payoff}) + (\text{VaR})) \quad (2)$$

$$\text{RAROC} = \text{Mean(Payoff)} / [\text{Mean(Payoff)} + (\alpha \text{ Quantile of Payoff Distribution})] \quad (3)$$

$$\text{RAROC} = \text{Mean(Payoff)} / [\text{Mean(Payoff)} - 1.65(\text{Standard Deviation of Payoff})] \quad (4)$$

If the investor is a risk-averter, thus, the maximum of RAROC will be most preferred due to the risk of the business is minimised under this result of RAROC. Meanwhile, if the RAROC is just greater than one, it will be inferred that high risk is coverage and payoff-risk is constrained however, it will draw the attention from those who categorized as the risk-lover because this condition of RAROC will also refer to the high profit. Nonetheless, if RAROC is resulted less than one and negative, the average payoff will also be negative which means loss.

Therefore, if considering with many energy trading company or retailer, who is playing as the middle man in the electricity market, who purchase the power from GENCOs at the very volatile spot price and distribute to those end-users at the fixed-price, thus, in case that the bilateral contract conceptual is genuinely need for diversified the several kind of risks which retailer has to bear. Accordingly, it can be inferred that RAROC is an appropriate risk measure for the retailer to define risk before taking any decision on bilateral contract agreement.

4. THE CALCULATON OF MARKET CLEARING PRICE (MCP)

The price mechanism in this study will be considered with an auction approach where every generator is instructed to bid only at their short-run marginal cost (SRMC) – fuel cost and fixed and Variable operating and maintenance cost (FOM & VOM). This paper will used electricity structure as shown in Fig.3 as the model to calculate the spot price and retail price which both result will be used as the input for evaluating the bilateral contract in both with and without competition.

For generating the spot price, the supply and demand curves have to be generated. After gathering the SRMC of available generators from EGAT, Independent Power Producer (IPPs), Small Power Producer (SPPs), and also including with Very Small Power Producer (VSPP), the merit order has been taken into account to create a discrete stair-step supply function as shown in fig.3

According to demand and supply approch, the equlibrium of price or namely as MCP will be generate where the supply and demand curve are both intersected. Thus, to the define the demand curve, the load has been collected by using the combination of PEA and MEA load profile of January 2011, which consisted of 744 hours. The load will be vary from hour to hour as shown below:

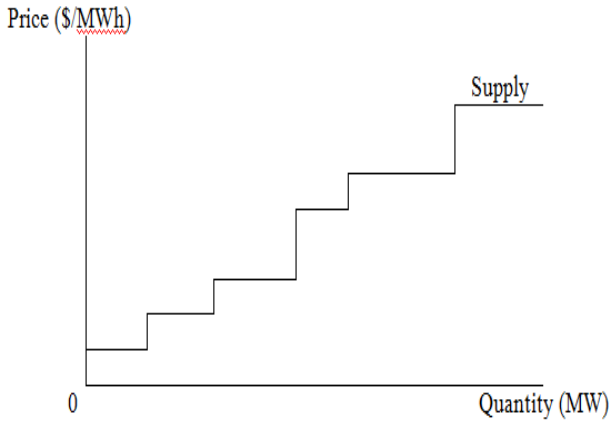

Fig. 3. A Discrete Stair-Step Supply Function

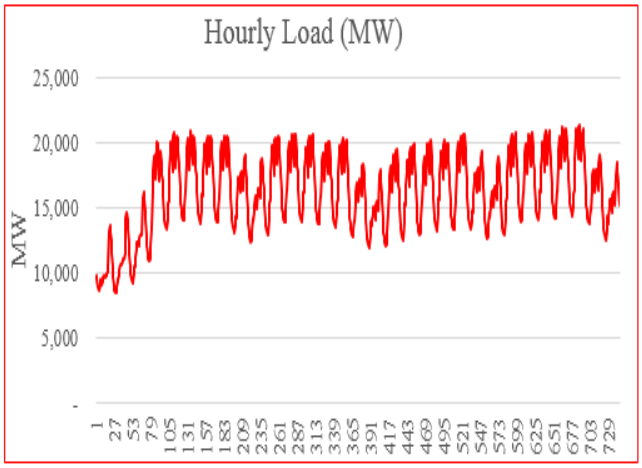

Fig. 4. Hourly load MEA and PEA of January 2011.

As shown in fig.4, the load for this practice is varying hour to hour. The total average load is 16,328.25 MW, the maximum is 21,318.19 MW, and the minimum is 8,440.13 MW.

After all the demand and supply curve are generated, the market clearing price (MCP) is determined when demand curve is equal to supply curve for each hour. By using the approach of demand and supply, the result of MCP for each hour are generated. The maximum MCP is 23.62 $/MWh, while the average and minimum are 23.15 $/MWh and 22.76 $/MWh, respectively. The data are shown in fig.5 as follow:

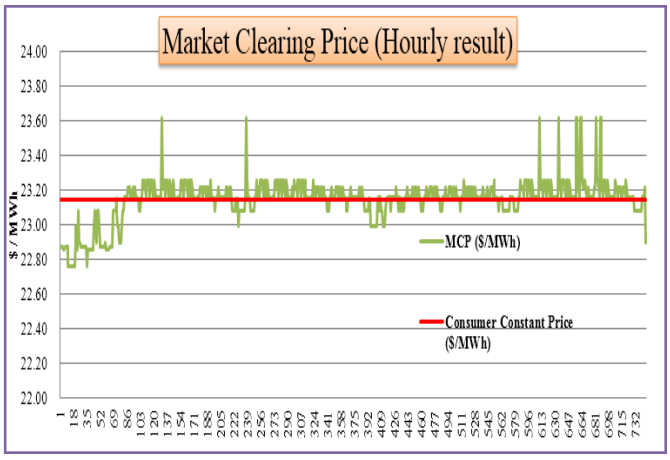

Fig. 5. Variation of MCP compared to average MCP of 23.15 $/MWh

5. BILATERAL CONTRACT FOR NO-COMPETTION CASE WITH AND WITHOUT AMI INSTALLATION

Under the formulated problem, which is to evaluate the bilateral quantity and participated price considered with risk-constrained, RAROC will be using as the quantified method to see how the risk level in payoff. The prerequisited data such as MCP, Fixed retail price which is generated by using the CAPM method are needed. In the case of no competion, there is no swithcing load, thus all of the demand load, which will affect the result of MCP and Fixed tariff, will all fully come form incumbant retailer's customers only. The problem shown in this study is based on the historical data of price and load of 744 hours. The formulation to estimate the range of bilateral contract is presented based on the risk-constrained payoff by using the RAROC.

5.1 CALCULATION OF RAROC

The essentials of RAROC are shown in section 3. Thus, as known that the RAROC is considered as the method to quantify the risk of retailer in an elerctricity market. For variation value of bilateral price, RAROC is estimated and plotted at the different spot. The result of RAROC will give the risk-constrained data for retailer to decide which amount of bilateral and also the price should be opt. The maxsimised RAROC give retailer risk-constrained for the payoff, while the positive and just greater than unity result of RAROC, it will ensure the maximum payoff. On the other hand, if the negative and less than one has come as the result, as the result, the loss will be considered in the payoff. Furthermore, if the result just negative, it will be meant that α-quantile of payoff is more tham mean payoff, for instance, economic capital is negative, thus ignorance should be considered. This section will calculate the variation of RAROC as a function of bilateral price, with the variation of fixed-price that has been calculated under CAPM, and also considered with the variable bilateral quantity.

According from the data of load and MCP which are shown in section 4, the total average load is 16,328.25 MW, the maximum load is 21,318.19 MW, the minimum load is 8,440.13 MW, the maximum MCP is 23.62 $/MWh, while the average and minimum are 23.15 $/MWh and 22.76 $/MWh, respectively. Furthermore, after calculate by using CAPM and RAROC, the proper range of consumer's fixed price is in the range of 23 – 24.5 $/MWh.

For generating the variation of RAROC functionalized with differed price, let assign consumer's fixed price is P, while Pd_h, Pg_h and MCP_h are the load, total generation, and MCP, respectively. As for bilateral generation and price at hour h are given by BG_h and BP_h, serially. According to (4), the Mean(payoff) and Standard Deviation of Payoff are given by

$$\begin{aligned}\text{Mean[Payoff]} &= [p(\text{Mean}(P_{gh}) - \text{Mean}[(MCP_h)(P_{gh})] \\ &\quad - [\text{Mean}(MCP^h)\text{Mean}(BG^h))] \\ &\quad - \text{Mean}[(BG^h)(BP^h)] \qquad (5)\end{aligned}$$

$$\begin{aligned}\text{Std(Payoff)} = [P^2\text{var(load))} &+ \text{var}((\text{load} - BG_h) \times MCP) \\ &+ \text{var}(BG_h \times BP_h)] \\ &- 2\text{pcov}[(\text{load}),((\text{load} - BG_h) \times MCP) \\ &- 2\text{pcov}(\text{load}, (BG_h \times BP_h) \\ &+ 2\text{cov}((\text{load}-BG_h) \times MCP), (BGh, \times BPh)]^{0.5} \qquad (6)\end{aligned}$$

Let, the fixed tariff equaled to 23.7 $/MWh, which is still be in the range of proper calculated retail price, and the given bilateral quantity for 35% for each hourly load. For historical data of MCP and load that shown in Fig 4 and 5 will be used as the input data to calculate the bilateral quantity at the given differed price of bilateral contract.

Table 1 Variation of RAROC at vary bilateral price

BPh	Mean Payoff	STD	RAROC
23.1	9,332.544	3,412.682	2.5212
23.11	9,275.466	3,617.854	2.8056
23.12	9,218.387	3,812.027	3.1478
23.13	9,161.308	3,996.804	3.5695
23.14	9,104.229	4,173.435	4.1046
23.15	9,047.150	4,342.913	4.8089
23.16	8,990.071	4,506.044	5.7810
23.17	8,932.992	4,663.496	7.2144
23.18	8,875.913	4,815.826	9.5460
23.19	8,818.834	4,963.504	14.0192
23.2	8,761.756	5,106.935	26.1300
23.25	8,476.361	5,771.141	- 8.1034
23.3	8,190.967	6,366.848	- 3.5392
23.35	7,905.572	6,911.790	- 2.2595
23.4	7,620.178	7,417.164	- 1.6501
23.45	7,334.783	7,890.577	- 1.2903
23.5	7,049.389	8,337.475	- 1.0510
MAX	**9,332.544**	**8,337.475**	**26.1300**
MIN	**7,049.389**	**3,412.682**	**- 8.1034**

With reference to table 1, retailer may go for bilateral price of 35% of total demand for the range of price of 23.1 – 23.2 $/MWh to ensure the payoff will not be considered as the loss. However, at level of 23.2$/MWh should regard as the highest return but also considered as the highest risk, thus, the risk-averter may not be preferred this level of bilateral price. Moreover, the graph which detailed the variation of RAROC compared to difference price is shown as follow:

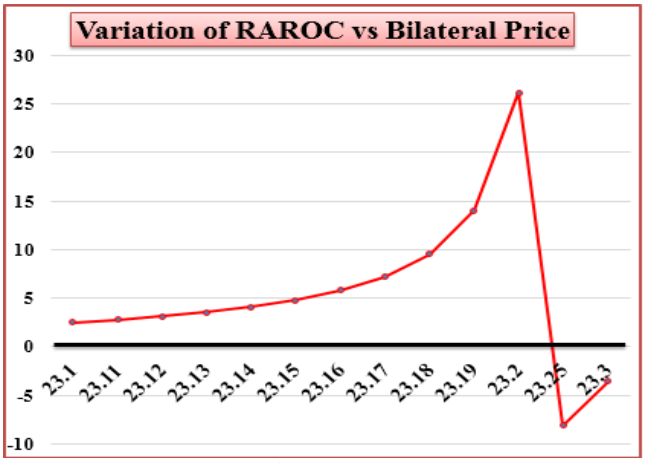

Fig.6. Variation of RAROC vs. bilateral price

However, Retailer may has different point of view to decide, not only relied on the positive value of RAROC, but also considered other result such as the maximize payoff value, where bilateral price is at 23.5 $/MWh, due to the value of RAROC is not low too much. Moreover, from the result in table 1, it can be inferred that the minimum level of standard deviation does not mean that the RAROC and payoff are maximized.

After change the fixed tariff from 23.7 $/MWh to 24$/MWh for different result, the plot of bilateral price at different given quantity, which has been set at 35%, 40%

and 50%, are shown in Fig.7. The main concept for selecting the bilateral price at given quantity is to see at the price that is as low as possible. As the result of varied

Table 2 Bilateral price and quantity for the tariff of $24

@24 $/MWh	RAROC	STD	AVG Payoff ($)	Bilateral price ($)	%
Minimum RAROC	-17.08668	7,981.90	12,441.97	23.4	40%
Maximun RAROC	108.8571	7,587.21	12,634.97	23.4	35%
Maximum Payoff	1.758817	3,791.99	14,502.23	23.1	50%
Minimum STD	1.758899	3,765.22	14,398.96	23.1	40%

RAROC which is shown in Fig. 7. As it can be seen in fig.7, at the fixed tariff 24$ as the referenced price, the range the considered with the risk-constrained is between 23.1$/MWh – 23.4$/MWh. At the level of bilateral quantity at 50% the preferred price has dropped from 23.4$/MWh to 23.3 $/MWh which can be inferred that the more level of bilateral quantity, the less level of bilateral price that retailer has to be consider. Moreover, table 2 also shows the details such as the value of RAROC, STD and average payoff at different bilateral price at different percentage of bilateral quantity.

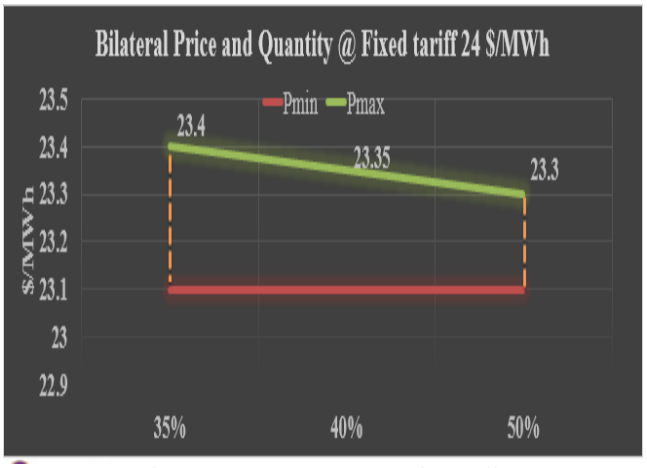

Fig.7. Plot of bilateral price and quantity for tariff 24&/MWh

According to, electricity utility in Thailand, especially PEA, plans to install Smart Grid technology to the system. Under the Smart Grid technology, customers enable to manage their load via AMI. Hence, with reference to the research data, it is found that, if the installation of AMI come as plan at 75%, the peak load assume to be reduced by 2%, whilst, the off-peak load will be reduce by 1.67% (Rodchuea, 2012). Hence, after recalculated the MCP with reference to the changing of peak and off-off load which is affected from the installtion of AMI, the result of RAROC under the given fixed price at 24$/MWh are shown in the fig.8. as follow:

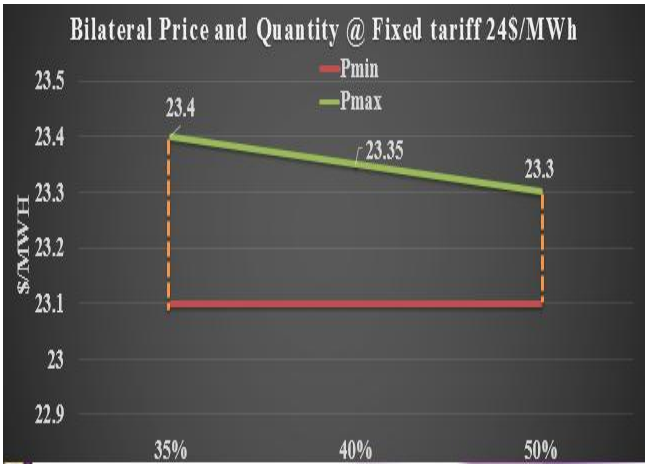

Fig.8. Plot of bilateral price and quantity with AMI installed

From the fig.8., unfortunately, there is no diffent of the range of bilateral contract compare between both with and without AMI installation. The next section will present the case of competiton in the retailing market.

6. BILATERAL CONTRACT FOR COMPETITION CASE WITH AND WITHOUT AMI INSTALLATION

Under the condition of competition which is introduced to the calculation of the range of bilateral contract price at the different given quantity by using the risk-adjusted method such a RAROC, a retailer has to submits the bid of fixed price to complete with other retailer company. Thus, the one that propose the lower price to those who tended to change the supplier if the proposed price is lower, will get more demand load, on the other hand, those who propose higher price to the customer, except the loyal load, they will lose the portion of the original load. The procedure used to get the solution of bilateral contract price under this situation is as follows;

- Load and MCP data for 744 hours is required.
- Defined the highest and lowest range of bilateral contract quantity and price with reference to minimum and maximum price and load values, thus, let, give the demonstrated fixed price at 24.3$/MWh.
- Defined the level of switching load, while as for this study, the level of switching load will be 2% of every 744 hours.

Table 2 Variation of RAROC at vary bilateral price under competitive

BPh	Mean Payoff	STD	RAROC
23.1	10,099.20	3,460.38	2.30
23.11	10,041.86	3,663.47	2.51
23.12	9,984.53	3,855.91	2.76
23.13	9,927.19	4,039.21	3.04
23.14	9,869.85	4,214.58	3.38
23.15	9,812.52	4,382.96	3.80
23.16	9,755.18	4,545.13	4.32
23.17	9,697.85	4,701.73	5.00
23.18	9,640.51	4,853.30	5.91
23.19	9,583.18	5,000.31	7.19
23.2	9,525.84	5,143.13	9.16
23.25	9,468.50	5,282.12	12.57
23.3	9,411.17	5,417.56	19.93
23.35	9,353.83	5,549.71	47.53
23.4	9,296.50	5,678.81	- 126.42
23.45	9,239.16	5,805.06	- 27.24
23.5	9,181.82	5,928.63	- 15.29
MAX	10,099.20	5,928.63	47.53
MIN	9,181.82	3,460.38	- 126.42

Under the condition that there are moer than one retailer who will bid for switching load, in case the incumbant retailer has to lose the bid due to the higher retailer price is offer compared to another retailer, thus the requirement of bilateral contract consideration is necessary. Let the fixed tariff is at 24.3$/MWH which is higher than prior demonstrated data at 24$/MWh only, which can be meant that the higher of the retail price will gain the higher opportunity to lose the bid the those retialer who bid lower.

Furthermore, the switching load is defined as 2% of totally load at every historical hour load which is used as the input data under the case of no competition.

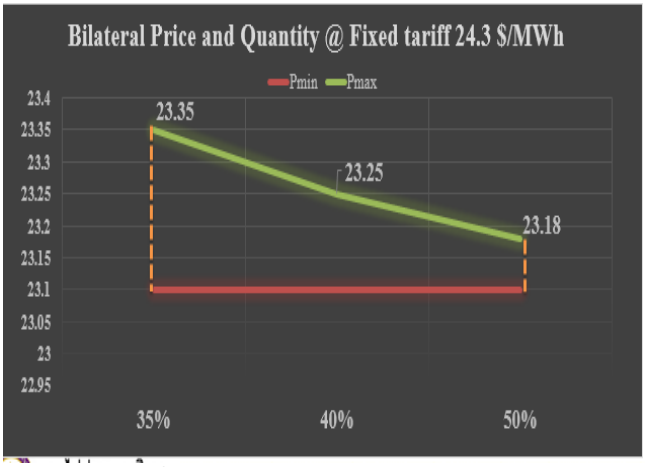

Fig.9. Plot of bilateral price and quantity under competitive

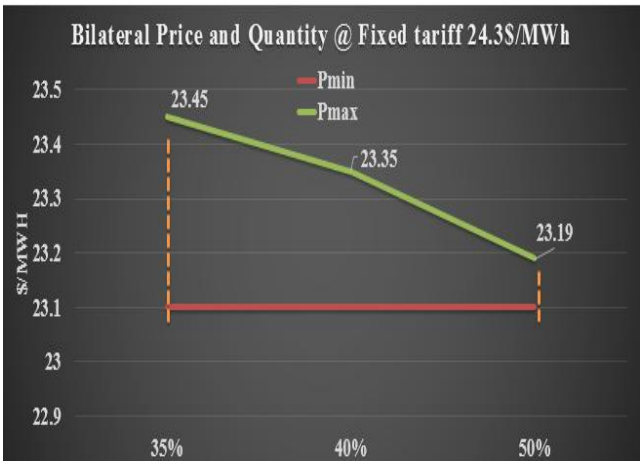

Fig.10. Plot of bilateral price and quantity under competitive and with AMI Deploymented

As can be inferred from the fig 9 and 10, under the situation of switching load at 2%, the plotting area of bilateral price and quantity have slightly change compared to the case of no-competition. When, the competitive has been more pushing into the market, the result from fig, 9 shows that at the level of bilateral of 35% has slightly different of optimal price compared to no-competitive case, however, when the amount of quantity come up to 40% and 50% the range of bilateral price are both higher decreased which mean the availability for retailer to decide to do the bilateral contract at the higher price with lower risk is decreased or mean that less choice for retailer to decide.

With consideration with 75% of AMI deployment, the result of the range of bilateral contract price and quantity are shown in fig.10, which show the surprised result compared to the case of no-competitive. The availability for retailer to negotiated with the GENCOs when do the bilateral contract at 35% of the total load is higher due to the optimal or highest allowing bilateral price is increased from 23.4$/MWh in no-competition case to 23.45 $/MWh. However, at the level of bilateral quantity at 40%, the highest limit does not differ from previous case. Nonetheless, the result still show that if the level of bilateral quantity increased to 50%, the range of price will drastically collapsed to 23.19$/MWh. Consequently, to prevent this kind of fluctuated trend of bilateral price retailer should wisely consider by using more financial method to define the proper fixed tariff price which will be preferred to those who does not considered as royal customers.

7. CONCLUSIONS

These financial methods – CAPM and RAROC, including with the developed methodology can empower a retailer to measuring and estimating the range of both quantity and price of bilateral contract. Due to the risk-constrained that cannot be avoid for every economic capital or any investment, the Risk Adjusted Recovery on Capital, can play as the essential tools to quantify those risk-constrained. Moreover, many investors, who considered more on risk, unfortunately, an improper tool has been used as a risk indicator, thus, this concept of risk measure – RAROC, would give more diversification of risk-quantifying tool to those who concern with the risk. The practice shows a range of bilateral quantity and participated price for four cases which are no-competition considered with or without AMI deployment, and the cases have competition discussed with or without AMI deployment. The risk-lover, who desires to challenge with the higher risk will considered if the RAROC is just greater than one, however, this practice will assume that the retailer is a risk-averter who seek to find the higher value in RAROC result. Consequently, this methodology will give the availability for retailer to make a choice about bilateral transaction for insuring a risk-constrained payoff.

NOMENCLATURE

CAPM	Capital Asset Pricing Model
EGAT	Electricity Generation Authority of Thailand
ESI	Electricity Supply Industry
FOM	Fixed Operating and Maintenance Cost
GENCO	Generation Company
ISO	Independent System Operator
MC	Marginal Cost
MCP	Market Clearing Price
MEA	Metropolitan Electricity Authority
PEA	Provincial Electricity Authority
RAROC	Risk Adjustment Recovery on Capital
RETCO	Retail Company
SRMC	Short-Run Marginal Cost
TSO	Transmission System Operator
VOM	Variable Operating and Maintenance Cost

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A Comparative Study of Two Control Algorithms for Balancing a Single-phase Powered Three-phase Induction Motor

Yaw-Juen Wang, Ruey-Long Sheu, En-Ching Lian and Ding-Sian Cai

Abstract*—Two algorithms are proposed in this paper for controlling a pair of static var compensators (SVCs) to balance a three-phase induction motor that is supplied from a single-phase source. By controlling the firing angles of the two SVCs, the motor is able to operate under balanced conditions. The first algorithm is the speed-feedback method that directly computes the required values of the firing angles according to the motor speed. This method is straightforward and quick, but the motor parameters must be known and kept invariant. The second algorithm is the two-dimensional perturbation and observation method that searches the appropriate firing angles and balances the supply voltage of the motor. Simulation of the operation of the motor controlled by the two algorithms has been carried out using the ATP/ATPDraw. The both proposed algorithms are able to control the motor with satisfactory results.*

***Keywords*—Induction motor, Steinmetz connection, static var compensator, voltage unbalance.**

1. INTRODUCTION

Electrification in remote coastal and hilly areas is usually started with single-phase power networks because of their lower initial cost and shorter construction time. The mechanical power needed for water pumping, irrigation, ventilation, material blending or agricultural conveying in these areas can be provided by single-phase induction motors (IMs). However, with lower cost, lighter weight and higher efficiency than a single-phase IM of the same rating and voltage class, a three-phase IM driven by single-phase voltage is often an economical alternative. Residential customers in the city, who are usually serviced only with single-phase electricity, may face a similar scenario when they need to run a three-phase IM.

The standard method for supplying a three-phase IM from a single-phase source involves using a static AC/DC/AC converter, but commercially available converters for this purpose are limited to fractional horsepower motors [1-2]. A very old and simple way for single-to-three-phase conversion is the Steinmetz connection where two terminals of a motor are connected to the source and the third terminal is connected to either of the two terminals through a capacitor.

Studies on Steinmetz connection can be traced back to as early as 1959 when Brown and Jha [3] analyzed the starting and run-up characteristics of an IM with Steinmetz connection. This type of phase conversion inspired several interesting works. For example, Murthy *et al.* [4] conducted transient simulation of a three-phase IM supplied from single-phase supply. An analysis conducted by Mohamadein *et al.* [5] showed how the capacitance value of a Steinmetz-connected IM would influence its torque, efficiency and power factor. Pillay and Brzezinski [6] invented a vector diagram method to study three configurations of single- to three-phase conversion for a three-phase IM: Steinmetz connection, autotransformer-capacitor converter and variable inductor - variable capacitor converter.

Since a Steinmetz-connected IM is supplied with unbalanced three-phase voltage, several strategies have been proposed to mitigate or solve this problem. Tindall and Monteith [7] proposed a modified scheme in which two reactive elements were used to achieve balanced operation in the steady state. The modified scheme was further developed by Holmes [8] who demonstrated a two-element phase converter that was able to supply an IM with balanced three-phase voltage from start to full speed. In Holmes' work, the two reactive elements were controlled as functions of the motor slip. The firs reactive element was a capacitor controlled by a 400-Hz chopper while the other was a thyristor-controlled reactor (TCR) in parallel with a capacitor. Tozune [9] proposed another way of balanced operation using asymmetrical stator windings.

Not only do the aforementioned phase conversion methods apply to IMs, they have also been used to drive three-phase permanent magnetic motors, reluctance motors and synchronous motors. For example, Chaudhari and Fernandes [10-11] used the Steinmetz connection to supply a three-phase permanent magnetic motor. Alolah [12-13] applied the two-element scheme proposed by Tindall and Monteith [7] to drive a three-phase reluctance motor and a synchronous motor from a single-phase supply.

The two-element scheme used in [7, 8, 12, 13] was also adopted to balance an IM in Wang and Zhou's work [14] where two static var compensators (SVC) were employed as the two reactive elements, the values of which were controlled by thyristors as functions of the motor slip. Basically, Ref. [14] applied the speed feedback (SF) algorithm to balance the IM. The motor slip was

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monitored and inputted into a polynomial function and a rational function to generate appropriate firing angles for two thyristors. While the SF algorithm is fast and straightforward, it relies heavily on the correctness and stability of the motor parameters. When the motor parameters vary because of temperature rise or aging, the thyristor firing angles become inaccurate and the motor voltage cannot be balanced as desired. This paper continues the research theme of [14] by developing a new algorithm that does not rely on the motor parameters. The perturbation and observation algorithms, which have been widely used in photovoltaic generation systems for maximum power tracking, inspired the authors to develop a two-dimensional perturbation and observation (2DP&O) algorithm that searches the two firing angles that allow the motor to be balanced. This paper compares the SF algorithm with the 2D P&O algorithm for their performance and accuracy using the Alternative Transients Program (ATP).

2. MODELING AND FORMULATION

A brief analysis of the two-element circuit would help quickly familiarize the reader with the basic principle based on which a single-phase-supplied three-phase IM is balanced.

Equivalent Circuit Analysis

The following relations of the voltages and currents in the equivalent circuit of a Δ-connected IM shown in Fig. 1 can be written as per the KVL and KCL:

$$V_{L1}+V_{L2}+V_{L3}=0 \tag{1}$$

$$V=V_{L1} \tag{2}$$

$$I_1=V_{L3}\,Y_1 \tag{3}$$

$$I_2=V_{L2}\,Y_2 \tag{4}$$

$$I_{L2}+I_2-I_{L3}-I_1=0 \tag{5}$$

where V_{L1}, V_{L2} and V_{L3} are the stator line voltages, I_{L1}, I_{L2} and I_{L3} the winding currents, V the voltage of the single-phase source, and I_1 and I_2 the currents flowing in the two reactive elements Y_1 and Y_2. The method of symmetrical components allows the three-phase line voltages and winding currents to be expressed in terms of their sequence components as

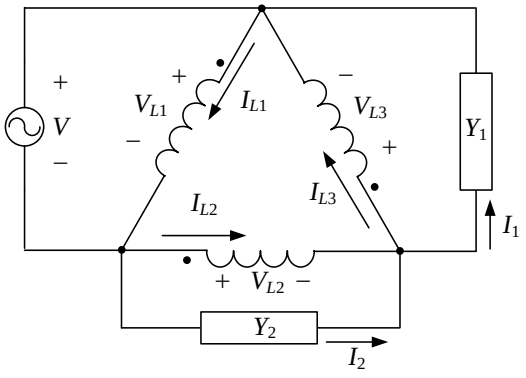

Fig.1. A Three-phase IM Balanced by Two Reactive Elements Y_1 and Y_2.

$$\begin{bmatrix}V_{L1}\\V_{L2}\\V_{L3}\end{bmatrix}=\begin{bmatrix}1&1&1\\1&a^2&a\\1&a&a^2\end{bmatrix}\cdot\begin{bmatrix}V_0\\V_p\\V_n\end{bmatrix}=\boldsymbol{A}\begin{bmatrix}V_0\\V_p\\V_n\end{bmatrix} \tag{6}$$

where subscripts 0, p and n refers to the zero-, positive- and negative-sequence components, respectively, and matrix $\boldsymbol{A}$ is given by

$$\boldsymbol{A}=\begin{bmatrix}1&1&1\\1&a^2&a\\1&a&a^2\end{bmatrix} \tag{7}$$

with phasor operator a= $1\angle 120°$. The three-phase winding currents can then be expressed as

$$\begin{bmatrix}I_{L1}\\I_{L2}\\I_{L3}\end{bmatrix}=\begin{bmatrix}1&1&1\\1&a^2&a\\1&a&a^2\end{bmatrix}\cdot\begin{bmatrix}I_0\\I_p\\I_n\end{bmatrix}=\boldsymbol{A}\begin{bmatrix}Y_0&0&0\\0&Y_p&0\\0&0&Y_n\end{bmatrix}\begin{bmatrix}V_0\\V_p\\V_n\end{bmatrix} \tag{8}$$

where Y_0, Y_p and Y_n are the zero-, positive- and negative-sequence admittances of the motor. The zero-sequence admittance of a Δ-connected motor is zero. The positive- and negative-sequence admittances are illustrated by the sequence equivalent circuits shown in Fig. 2 in which R_s and X_s are the stator resistance and reactance, R_r and X_r the rotor resistance and reactance, X_m the magnetizing reactance, and s the slip. Substitution of (6) and (8) into eqs. (1)-(5), substitution of (3) and (4) into (5), and rearrangement gives the following equation

$$\begin{bmatrix}0\\V\\0\end{bmatrix}=\begin{bmatrix}3&(1+a^2+a)Y_p&(1+a+a^2)Y_n\\1&1&1\\Y_2-Y_1&-aY_1+a^2Y_2+(a^2-a)Y_p&-a^2Y_1+aY_2+(a-a^2)Y_n\end{bmatrix}\cdot\begin{bmatrix}V_0\\V_p\\V_n\end{bmatrix} \tag{9}$$

The positive- and negative-sequence voltages can be solved using Cramer's rule and are given by

$$V_p=\frac{V}{D_\Delta}\cdot\left(Y_n+\frac{1}{\sqrt{3}}Y_1\angle -30°+\frac{1}{\sqrt{3}}Y_2\angle 30°\right) \tag{10}$$

$$V_n=\frac{V}{D_\Delta}\cdot\left(Y_p+\frac{1}{\sqrt{3}}Y_1\angle 30°+\frac{1}{\sqrt{3}}Y_2\angle -30°\right) \tag{11}$$

with $D_\Delta=Y_1+Y_2+Y_P+Y_n$.

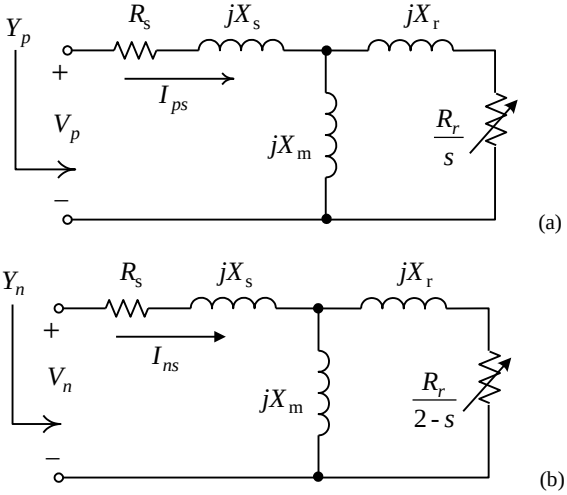

Fig.2. Sequence circuits of the motor. (a) positive sequence; (b) negative sequence.

Values of the Two Reactive Elements

For balanced operation of the motor, its negative-sequence voltage must be zero. We assume that Y_1 and Y_2 are pure susceptances jB_1 and jB_2. Substituting jB_1 and jB_2 into (11) for Y_1 and Y_2, respectively, yields

$$\left(G_p - \frac{\sqrt{3}}{6}(B_1 - B_2)\right) + j\left(B_p + \frac{B_1 + B_2}{2}\right) = 0 \qquad (12)$$

where G_p and B_p are real and imaginary parts of Y_p and are functions of the motor slip s. Since both real and imaginary parts of (12) must be zero, the values of B_1 and B_2 are given by

$$B_1 = \sqrt{3}G_p - B_p \qquad (13)$$

$$B_2 = -\left(\sqrt{3}G_p + B_p\right) \qquad (14)$$

The inductive nature of a motor implies that G_p must be positive and B_p negative, which concludes from (13) that B_1 is positive for any value of the slip s. On the other hand, (14) reveals that B_2 is positive if $|B_p| > \sqrt{3}G_p$, so B_2 can be positive or negative depending on slip s. In conclusion, for balanced operation of the motor, Y_1 is always capacitive for whatever speed of the motor, but Y_2 can be inductive or capacitive for different motor speeds.

Thyristor-Controlled Reactors

In this paper, the two reactive elements are to be realized by two static var compensators (SVC), a parallel combination of a thyristor-controlled reactor (TCR) and a capacitor, as shown in Fig. 3. The current flowing through the TCR is controlled by the firing angle α that is measured by the interval from the voltage zero-crossing until the thyristor starts to conduct. The current and voltage waveforms in Fig. 4 illustrate how a TCR works.

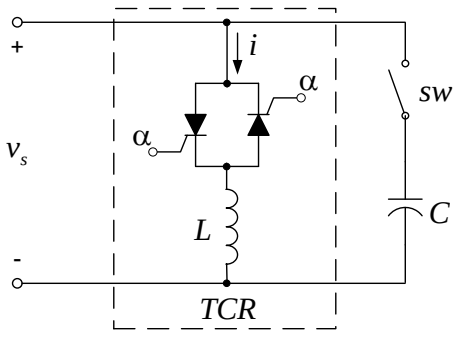

Fig.3. Parallel combination of a TCR and a capacitor to make an SVC

The firing angle α of a TCR ranges from π/2 to π, and the TCR is controlled from fully conducting to totally cut-off. As a result, a TCR can be reckoned as a variable inductance that varies from its uncontrolled value L when α=90°, to infinity when α =180°. The effective inductance of a TCR can be given as a function of α by [15]

$$L_{TCR}(\alpha) = \frac{\pi L}{2(\pi - \alpha) + \sin 2\alpha} = g(\alpha) \cdot L, \quad \frac{\pi}{2} < \alpha < \pi \qquad (15)$$

where $g(\alpha)$ is the amplification function ranging from one to infinity. Fig. 5 shows the curve of the amplification that extends to infinity when α approaches 180°.

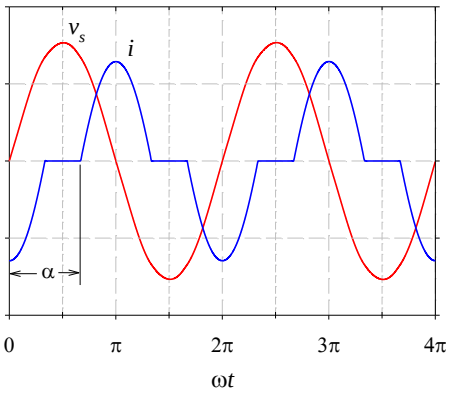

Fig.4. Voltage and current waveforms of a TCR with firing angle α.

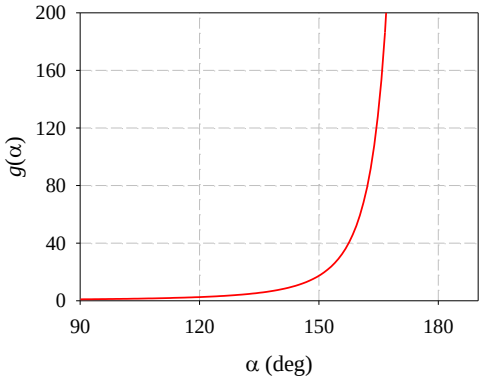

Fig.5. Amplification function

3. NUMERICAL EXAMPLE AND DESIGN

A 220-V, 60 Hz, 1/2 hp, three-phase laboratory induction motor is taken as an example to design a two-element balancer. The motor parameters have been obtained from the DC, no-load, and blocked-rotor tests, and are listed in Table 1.

Table 1. Parameters of the Three-phase IM

Parameter	Value (Ω)
R_s	20.75
X_s	21.30
X_m	297.3
R_r	13.91
X_r	21.30

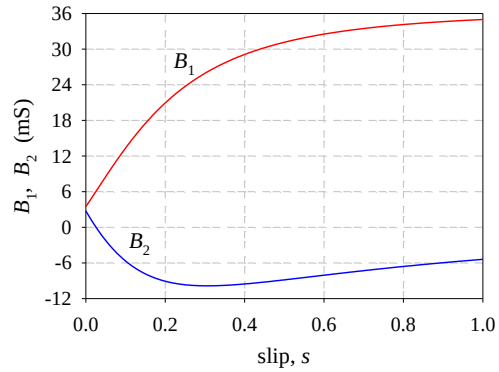

Fig.6. Curves of B_1 and B_2 against the slip s.

These motor parameters and Fig. 2(a) enable us to find the positive-sequence admittance Y_p that again allows the values of the two reactive elements B_1 and B_2 at a given slip to be calculated by (13) and (14). Fig. 6 traces the curves of B_1 and B_2 against the slip s, and shows that B_1 is

always positive and is a monotonically increasing function while B_2 has positive and negative values.

Basic Design

The two reactive elements Y_1 and Y_2 shwon in Fig. 1 can be realized by two SVCs as shown in Fig. 7 in which the thyristors have been replaced by two bidirectional triode tyristors (triacs), and the values of the four reactive elements L_1, C_1, L_2 and C_2 can be determined by the maximum and minimum values of B_1 and B_2.

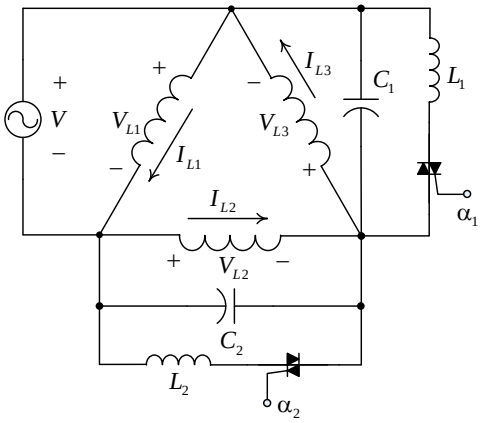

Fig. 7. Basic two-element scheme using two SVCs.

The curves in Fig. 6 give B_{1max}=35 mS, B_{1min}=3.478 mS, B_{2max}=2.772 mS, B_{2min}=–9.853 mS. Capacitance C_1 satisfies the condition

$$C_1 > B_{1\max}/\omega. \tag{16}$$

C_1 must be larger than 93 μF, so we take 95 μF for it. Inductance L_1 needs to be able to cancel out the susceptance of C_1, which gives the condition

$$L_1 < \frac{1}{\omega(\omega C_1 - B_{1\min})}. \tag{17}$$

We get L_1<82 mH, so L_1=70 mH is taken as the designed value. The same procedure applies to L_2 and C_2. Relation $C_2 > B_{2max}/\omega$ implies that C_2 must be larger than 7.35 μF. We then take C_2= 10 μF. Condition $L_2<[\omega(\omega C_2 - B_{2min})]^{-1}$ reveals that L_2 has to be smaller than 195 mH. We then take L_2=150 mH. The designed values of reactive elements are summaried in Table 2.

Table 2. Designed Values of Reactive Elements

Parameter	Value
L_1	70 mH
C_1	95 μF
L_2	150 mH
C_2	10 μF

After L_1, C_1, L_2 and C_2 are determined, firing angles α_1 and α_2 as functions of the slip s can be obtained by solving the following equations

$$\omega C_1 - \frac{1}{g(\alpha_1)\cdot\omega L_1} = B_1(s) \tag{18}$$

$$\omega C_2 - \frac{1}{g(\alpha_2)\cdot\omega L_2} = B_2(s) \tag{19}$$

Fig. 8 shows two curves of α_1 and α_2 as functions of s obtained by solving (18) and (19) using the Newton-Raphson method. To accelerate the speed of calculation when performing the control, a polynomial function and a rational function have been employed to approximate the two curves:

$$\alpha_1(s) = a_0 + a_1 s + a_2 s^2 + a_3 s^3 \tag{20}$$

$$\alpha_2(s) = \frac{b_0 + b_1 s + b_2 s^2}{1 + b_3 s + b_4 s^2} \tag{21}$$

The coefficients of the approximation functions are listed in Table 3. The results calculated by (20) and (21) are depicted by scattered square and circle symbols in Fig. 8.

Table 3. Coefficients of approximation functions

a_0	96.1982	b_0	147.7501
a_1	141.9117	b_1	527.7938
a_2	-129.7675	b_2	1521.0476
a_3	50.4787	b_3	8.2989
–	–	b_4	10.1296

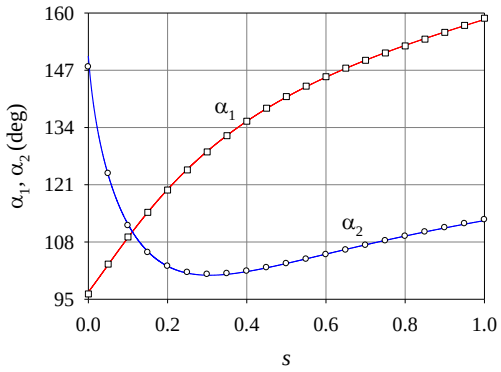

Fig. 8. Firing angles α_1 and α_2 as functions of the slip s for the basic scheme.

Improved Design

Inductance L_1 in the basic design shown in Fig. 7 is 70 mH. Its current rating needs to be greater than 8.3 A for a 220-V source. A better design would be to use a higher inductance so that the current rating, volume and cost can be reduced, and the circuit implementation can be further simplified if L_1 and L_2 are of the same value. For these reasons, an improved design that takes 150 mH for both L_1 and L_2 is presented in Fig. 9.

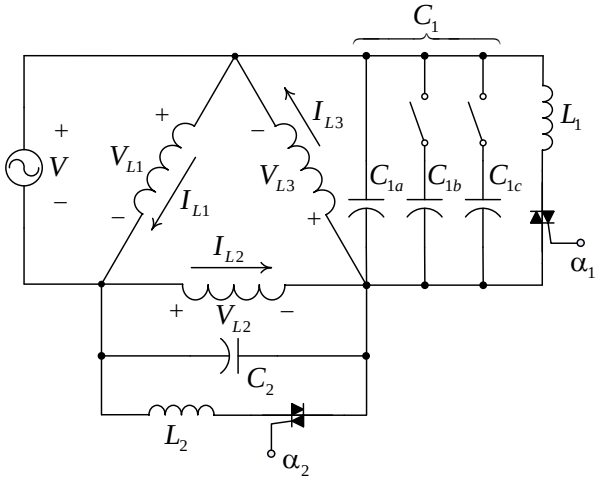

Fig. 9. Improved design using two inductors of the same value.

The design shown in Fig. 9 differs from that in Fig. 7 in the realization of susceptance B_1, which is composed of a TCR in parallel with a fixed capacitor C_{1a} and two

switchable capacitors C_{1b} and C_{1c}. The values of the reactive elements in Fig. 9 are listed in Table 4. In this improved design a higher inductance L_1 is used, making the adjustment range of the TCR smaller, so the capacitance C_1 needs to be changed according to the slip value. The value of C_1 as a piecewise defined function of s is given by

$$C_1 = \begin{cases} C_{1a}, & 0 \le s < 0.09 \\ C_{1a} + C_{1b}, & 0.09 \le s < 0.3 \\ C_{1a} + C_{1b} + C_{1c}, & 0.3 \le s < 1 \end{cases} . \quad (22)$$

The relation between firing angle α_2 and s remains unchanged since L_2 and C_2 did not change. The firing angle α_1 at a given slip s can be obtained by solving simultaneous equations (18) and (22). Fig. 10 shows α_1 and α_2 as functions of s. Because the curve of α_1 has two discontinuous drops at s=0.09 and s=0.3, and the slip s happens to be defined over the interval [0, 1] that is the same as probability interval, the curves in Fig. 10 have been depicted with the horizontal axis in probability scale to more clearly present the part of the curve of α_1 for s less than 0.5.

Table 4. Values of reactive elements in the improved design

Parameter	Value
L_1	150 mH
C_{1a}	35 μF
C_{1b}	35 μF
C_{1c}	25 μF
L_2	150 mH
C_2	10 μF

The function $\alpha_1(s)$ can also be approximated to accelerate the calculation. Since C_1 is piecewise defined, $\alpha_1(s)$ is also approximated in three ranges using different functions:

$$\alpha_1(s) = \begin{cases} \dfrac{c_0 + c_1 s + c_2 s^2}{1 + c_3 s + c_4 s^3}, & 0 \le s < 0.09 \\ \dfrac{d_0 + d_1 s + d_2 s^2}{1 + d_3 s + d_4 s^3}, & 0.09 \le s < 0.3 \\ q_0 + q_1 s + q_2 s^2 + q_3 s^3, & 0.3 \le s < 1.0 \end{cases} \quad (23)$$

where the coefficient values are listed in Table 5.

Table 5. Coefficients of approximation function

c_0	109.4466	d_0	72.9592	q_0	63.4162
c_1	-1104.8681	d_1	141.7308	q_1	198.7024
c_2	543.0935	d_2	-995.2706	q_2	-174.6820
c_3	-12.7601	d_3	-1.9933	q_3	64.2672
c_4	30.0281	d_4	-2.6277	–	–

4. CONTROL ALGORITHMS

The SF and the 2DP&O algorithms are proposed in this paper to control the circuit scheme shown in Fig. 9. The SF method continuously monitors the motor speed and transforms it to the slip s, which is then inputted to the functions described by (23) and (21) to generate firing signals α_1 and α_2, respectively. Hence, the firing signals control the values of B_1 and B_2 according to the monitored motor speed. The SF algorithm is straightforward and fast since the required calculation time for (21) and (23) is brief and the TCRs respond much faster than the motor.

Another proposed control method is the 2DP&O algorithm that does not rely on the predetermined firing angles-slip relations such as (21) and (23) but on a trial and error procedure to gradually approach the correct solution. The 2DP&O algorithm is inherently slower than the SF method since it needs more time to grope for the solution. The advantage of the 2DP&O algorithm lies is that it is not affected by variations of the motor parameters caused by temperature rise or ageing. Fig. 11 is the flowchart of the 2DP&O algorithm.

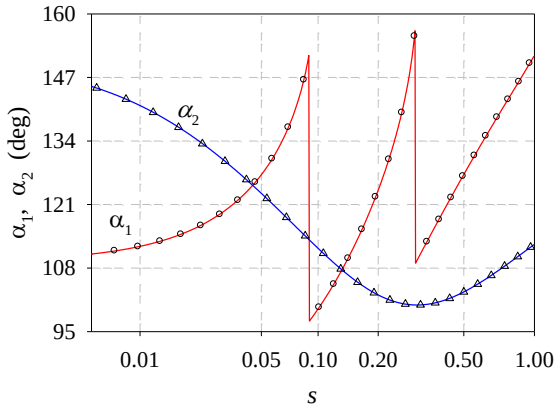

Fig. 10. Firing angles α_1 and α_2 as functions of s with the horizontal axis in probability scale.

The basic philosophy of the algorithm is to correct the firing angles α_1 and α_2 according to the resulting voltage unbalance factor of the three-phase voltage across the motor. The voltage unbalance factor (VUF) is defined as the ratio of the negative- to positive-sequence voltage, which is obtained by motoring the voltages V_{ab}, V_{bc} and V_{ca} across the motor terminals. The VUF measured after perturbing α_1 is denoted by τ_1, and after perturbing α_2 denoted by τ_2 .The algorithm starts with a brief increase in α_1 while keeping α_2 unchanged and then checks if τ_1 decreases. If yes, it means the direction of movement of α_1 is correct (set k_1=+1), otherwise the direction has to be reversed (k_1=–1). The same procedure applies to α_2 to correct the sign variable k_2. Though not shown in the flowchart, the correction steps $\Delta\alpha_1$ and $\Delta\alpha_2$ are variable as per the value of VUF. When the VUF is large, larger correction steps are used to accelerate the search; when the VUF reduces, the correction steps also reduce so that the oscillation of α_1 and α_2 can be smaller. As the controller continues to correct α_1 and α_2, the resulting VUF gradually decreases to a value lower than the upper limit. When the motor's mechanical load changes, new values of α_1 and α_2 need to be searched again to balance the motor.

5. NUMERICAL SIMULATION

The circuit scheme shown in Fig. 9 has been implemented in a simulation tool called the Alternative Transients Program (ATP) through the tool's graphical preprocessor ATPDraw. The laboratory IM model, the parameters of which have been shown in Table 1, is also included in the simulation using ATP's Universal Machine (UM) module. Two simulation cases that employ the SF and the 2DP&O algorithms, respectively, have been carried out.

Simulation Experiment Applying the SF Algorithm

The circuit diagram implemented in the ATPDraw for the SF control algorithm is depicted in Fig. 12 where the two TCRs, capacitors and IM model are demonstrated. The control functions in the ATP are simulated using MODELS [16] that allows the user to describe the desired control behavior using the MODELS programming language. ATP also supports TACS blocks such as comparator and rms meter for simpler control functions.

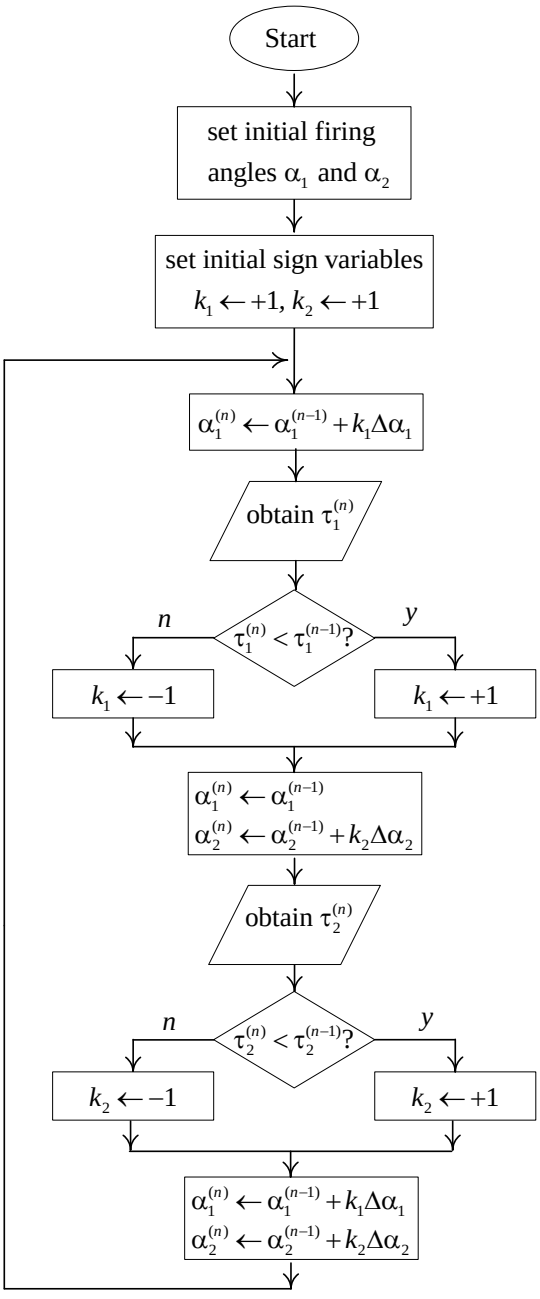

Fig. 11. Flowchart of the 2DP&O algorithm.

Fig. 12 also shows how the VUF value is measured. Three-phase instantaneous line voltages v_{ab}, v_{bc}, and v_{ca} are converted into their respective rms values V_{ab}, V_{bc}, and V_{ca} via rms meters. These rms voltage signals are then inputted into a MODELS control block in which formulae calculating the VUF have been written in MODELS language, to send out the VUF signal. The SF controller requires only the motor slip as the input and calculates the values of firing angles using (21) and (23) to control the TCRs.

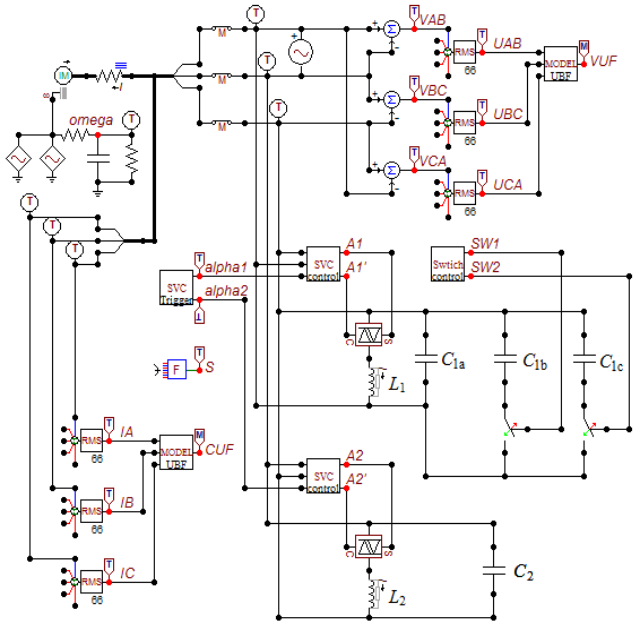

Fig. 12. ATP simulation of the balancer scheme applying the SF algorithm.

The simulation results are shown in Figs. 13-15. For the simulation, we start the motor and apply a mechanical load at t=4 s, then reduce the load at t=7 s. The variation of the slip s from motor start to 10 s is shown in Fig. 13 in which variations of firing angles α_1 and α_2 are also depicted. It merits to note that α_1 goes through two sudden changes at around t=1 s since the capacitors C_{1b} and C_{1c} are switched on sequentially, which alters the required inductive susceptance contributed by L_1. Fig. 14 plots the motor torque and angular speed against time. The torque is negative because the UM module of the ATP reckons all the electric machines as generators. The torque is hence negative for a motor. The torque curve exhibits some degree of oscillation. This is because the motor is not perfectly balanced. However, the pulsating torque is not significant.

The performance of the balancer can be evaluated by the three-phase voltages across the motor terminals. The variations of the rms values of three-phase line voltages are plotted in Fig. 15. The voltages fluctuate around 220-V with the torque. The resulting VUF is also depicted in the figure and its value is around 1% at no-load and lower than 1% when loaded. The heavier the load, the lower the VUF value. It is noted that for a three-phase IM the VUF of 2% is generally acceptable.

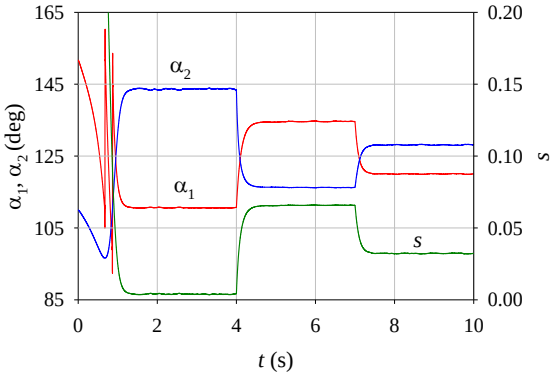

Fig. 13. Variations of firing angles α_1 and α_2, and slip s from motor start to 10 s.

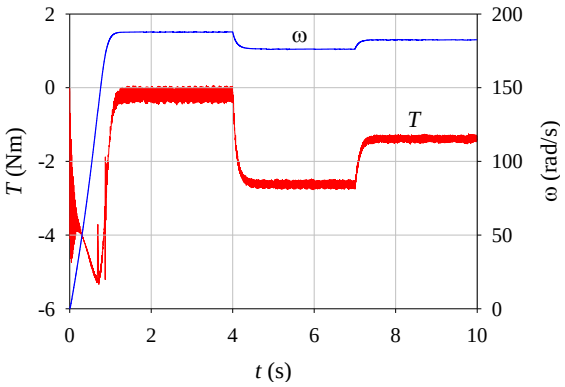

Fig. 14. Variations of the torque *T* and angular speed ω.

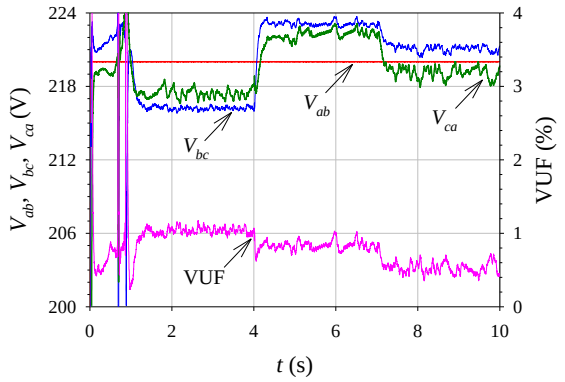

Fig. 15. Variations of three-phase voltages and the VUF.

Simulation Experiment of the 2DP&O Algorithm

The two-element scheme controlled by the 2DP&O algorithm is modeled using ATP and is shown in Fig. 16. It is noted that the switchable capacitors C_{1b} and C_{1c} are not employed in this experiment because the 2DP&O algorithm cannot respond as fast as the SF algorithm. Since in this control regime the motor slip is not monitored, the controller has no reference signal to determine when to switch on the capacitors. The 2DP&O algorithm monitors only the VUF signal to decide increasing or decreasing the firing angles.

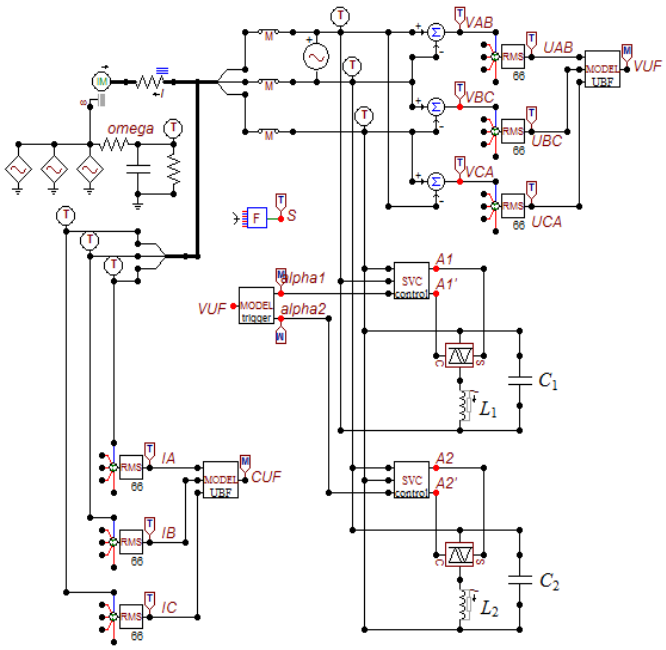

Fig. 16. Simulation of the balancer applying the 2DP&O algorithm in ATP

The initial values of α_1 and α_2 are set to 160º and 130º, respectively. The controller does not regulate the firing angles until *t*=4s at which the motor has been started and running. Fig. 17 shows how the controller regulates firing angles α_1 and α_2 with changes of the motor's load. At *t*=4s, α_1 and α_2 begin to change and take about 2 s to reach their new values and then stabilize. We can see the corresponding torque curve depicted in Fig. 18 in which the torque oscillates significantly over the interval 2s<*t*<4s because of no regulation of the firing angles. The pulsating torque starts to reduce at *t*=4s and stabilize at *t*=6s. We have programmed to increase the mechanical load at *t*=10s, 20s and 30s and see how the 2DP&O algorithm responds to these increase of load. We observe in Fig. 18 that the torque takes 2 to 5 seconds to stabilize, which is much longer than the SF algorithm.

The variations of three-phase rms voltages are demonstrated in Fig. 19. We can see that V_{ab} remains constant with time because it is the single-phase voltage source while V_{bc} and V_{ca} fluctuate around 220-V. The resulting VUF is also traced in Fig. 19. We observe that after load changes, the VUF goes up higher than 10% and drops, because of regulation of firing angles, to less than 1%.

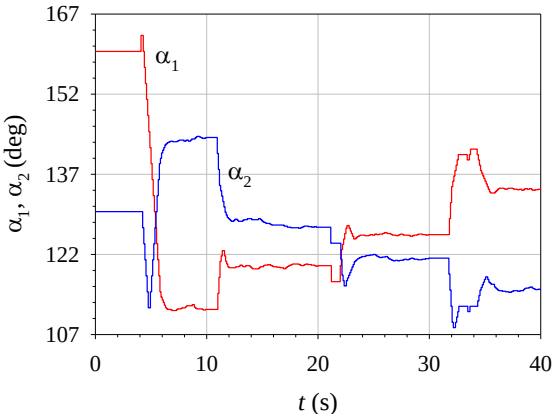

Fig. 17. Regulation of the firing angles by the 2DP&O algorithm

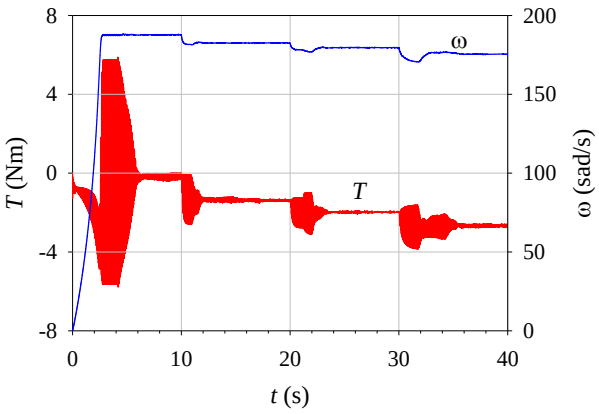

Fig. 18. Evolution of the torque and angular speed with time.

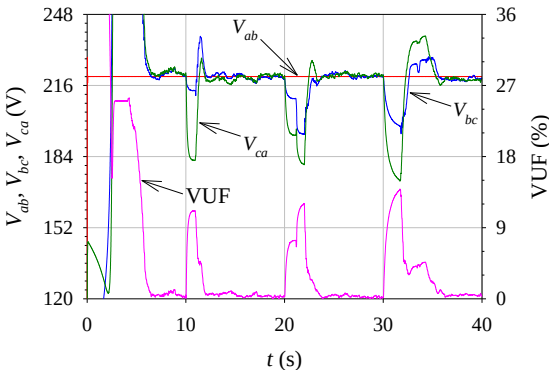

Fig. 19. Variations of three-phase voltages and the VUF

6. CONCLUSIONS

A two-element scheme that employs two reactive elements for supplying a three-phase IM from a single-phase source has been studied and presented. In this paper, SVCs have been proposed to carry out the function of variable susceptances for balancing the motor.

Two control algorithms have been proposed to control the SVCs. For the SF algorithm, a basic design was first introduced to explain how it worked and how to use polynomial and rational functions to approximate the nonlinear firing angles-slip relations so that the controller can respond faster. To reduce the current rating of one of the inductors, an improved design associated with switchable capacitors was also introduced, followed by developing a new firing angle-slip approximate function. For the 2DP&O algorithm, the basic principle of perturbing two firing angles to reach the solution for balancing the motor has been explained in detailed.

Digital simulation in the ATP of the two proposed algorithm has been conducted for comparing the performance of the two algorithms. The SF algorithm can quickly respond to change in load. Basically, it can balance the motor from start to full speed, and it keeps the motor balanced even when load changes. The disadvantage of the SF algorithm lies in the possibility that the firing angles may be inaccurate when the motor parameters change because of temperature rise or aging. On the other hand, the 2DP&O algorithm, which does not rely on the motor parameters nor on the feedback of the motor speed, is not influenced by drift of motor parameters. The response time of the 2DP&O algorithm is much longer than that of the SF algorithm, but both algorithms are able to balance the motor with the VUF lower than 1%.

NOMENCLATURE

Acronyms

2DP&O	two-dimensional perturbation and observation
ATP	Alternative Transients Program
IM	induction motor
SF	speed feedback
SVC	static var compensator
TCR	thyristor-controlled reactor
UM	universal machine
VUF	voltage unbalance factor

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Monte Carlo Simulation of Partial Shading of Photovoltaic Arrays

Yaw-Juen Wang, Ming-Jeng Huang, and Wen-Chin Zeng

Abstract*—Partial shading often happens to photovoltaic (PV) arrays because of fallen tree leaves, snow, or bird dung that covers a part of PV modules. Partial shading of a PV array reduces its energy conversion efficiency and may cause hot spots that damage PV cells. While the performance of a shaded PV module can be analyzed using a simulation program, it is not that easy when the number and the location of shaded PV modules exhibit some degree of uncertainty. In this paper, Monte Carlo method is used to study the performance of a PV array with a random location of shaded modules. The influence of module connection configurations on the array performance when random partial shading occurs, is also studied.*

***Keywords*—Connection configurations, Monte Carlo simulation, photovoltaic modules, random shading.**

1. INTRODUCTION

Partial shading is an often encountered phenomenon in solar energy conversion using photovoltaic (PV) cells. A part of PV modules covered by undesired shadows not only reduce solar energy received by the modules but also create hot spots that may damage the PV cells under the shadows. Designers of PV arrays always do their best to avoid shadowing of PV modules. However, fallen tree leaves, bird dung, unmelted snow, and shadows from branches and leaves of newly growing trees sometimes unexpectedly shade PV modules.

Methods of Analysis

Evaluation of the performance of a PV array with partial shading can be achieved by solving the array circuit equations or by a circuit simulation program as long as the condition of shading is given. For instance, the works of Quaschning and Hanitsch [1], Kawamura *et al*. [2], Alonso-Garcia *et al*. [3], and Wang and Hsu [4] all involved solving equations of PV networks using the Newton-Raphson method. On the other hand, PV array networks were also modeled using circuit simulation programs that included PV-specific programs (*e.g*., PVSIM [5] and PVSYST [6]) and general-purpose programs (*e.g.*, Matlab [7], Pspice [8-10], PSIM [11] and ATP [12-14], *etc*.). Basically, the former group of works resorted to an equation-based method while the later group to a circuit-based method. Regardless of which method was used for analyzing partial shading, this phenomenon always exhibits some degree of uncertainty. To take into account the uncertainty, studies into partial shading usually enumerated a few typical cases with shaded modules of different numbers, locations and shading percentages to compare the influences of different shading patterns. Indeed, the number of shading patterns of a PV array can be infinite. Analysis of a few cases of partial shading only provides the PV array performance at the conditions of those cases, and does not allow the uncertainty to be fully mastered.

Conncection Configurations

Another factor that influences the performance of a partially shaded PV array is how its modules are connected. In this regard, the following literatures are worth mentioning. Gautam *et al*. [15-18] compared performance of three connection configurations of PV cells in a module: series-parallel (SP), total-cross-tied (TCT), and bridge-linked (BL), and concluded that TCT and BL configurations performed better to partial shading than SP. Wang and Hsu [19] proposed a new scheme called the honey-comb (HC) connection, and compared performance of five schemes: simple-series (SS), SP, TCT, BL and HC. These five schemes plus a parallel-linked (PL) scheme were also compared in a study conducted by Ramaprabha and Mathur [20] to determine the configuration of a PV array less susceptible to partial shading.

Probabilistic Modeling

It is interesting to review how the uncertainty of partial shading was dealt with in these studies. Gautam *et al.* assumed three [16], two [17] and six [18] shading patterns in their studies. One randomly generated shading pattern was tested in Wang and Hsu's investigation [19]. Ramaprabha and Mathur [20] applied 15 random patterns to arrays of 10 different sizes. Although [19] and [20] have introduced the idea of randomization, and [20] considered a comprehensive number of shading patterns to handle the uncertainty of partial shading, further efforts are still needed to extend the study of partial shading from a deterministic model towards a probabilistic model.

In this paper, the uncertainty of partial shading is to be tackled using the Monte Carlo method with which random sampling of shading patterns is carried out. A problem arising from the Monte Carlo method is the time of computation. Solving a PV array network at a given shading pattern is already a time-consuming job, let alone repeating the job for thousands of shading patterns. To limit the calculation time to a reasonable range, a few

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simplifying assumptions have been made in this study. First, a module has only two states: normal or shaded. Second, a fixed number of four modules are shaded in an array but their locations are randomly selected. Third, the four shaded modules form one of four shading patterns: row, column, square, and diagonal shading with an equal probability.

Monte Carlo Simulation

As mentioned earlier, the PV networks can be solved using an equation-based method or a circuit-based method. The Monte Carlo simulation can also be carried out in the two ways. The first involves solving a PV network for repeated random selection of shading patterns using the equation-based method, which we will call the conventional Monte Carlo (CMC) method. The second is to simulate a PV network in the time domain using a circuit simulation program. In this paper the Alternative Transients Program (ATP) is used for this purpose. The shading pattern of the PV array is changed periodically in time by controlling the pre-arranged switches in the circuit. We will name it the time domain Monte Carlo (TDMC) method. Six connection configurations: SS, PL, SP, TCT, BL, and HC, will be tested using both the CMC and TDMC methods.

2. ANALYTICAL MODEL OF A PV MODULE

A PV module is usually composed of 36 or more identical PV cells connected in series, and a PV array comprises several modules that are wired to supply appropriate levels of voltage and current.

Cell Model

PV cell is well represented by the one-diode circuit model as shown in Fig. 1(a) where I and V are the output current and voltage, R_s and R_p the series and parallel resistances, V_d and I_d the voltage and current of the equivalent diode, and I_L the light-generated current that is given by

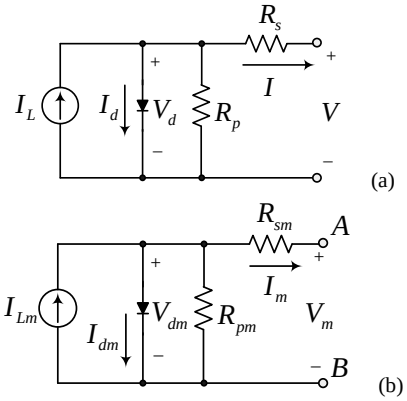

Fig.1. Equivalent circuit of (a) PV cell; (b) PV module

$$I_L(G) = (G/G_0)\cdot I_{g0} + \alpha(T_c - T_{ref}) \tag{1}$$

where G is the irradiance, G_0 the reference irradiance usually taking the value of 1 kW/m^2, I_{G0} the light-generated current at G_0, α the temperature coefficient of I_L, T_c and T_{ref} the cell and the reference absolute temperatures. The diode current I_d is given by the Schockley equation by

$$I_d(V_d) = I_0\left(\exp\left(\frac{qV_d}{nkT_c}\right) - 1\right) \tag{2}$$

where I_0 is the reverse saturation current, q the electron charge ($=1.6\times10^{-19}\ C$), n the ideality factor ($1<n<2$), k the Boltzmann constant ($=1.38\times10^{-23}\ J/K$). The reverse saturation current I_0 is sensitive to temperature. Detailed calculation of I_0 can be found in [4]. The cell temperature is closely related to the irradiance. It can be estimated by the empirical formula

$$T_c = T_a + \left(\frac{\mathrm{NOCT} - 20}{0.8}\right)\cdot G \tag{3}$$

where T_a refers to the ambient temperature, NOCT to the nominal operating cell temperature in ^oC, and G is in kW/m^2. As per the Kirchoff's current law, the cell current I can be given by

$$I = I_L(G) - I_d(V + IR_s) - \frac{V + IR_s}{R_p} \tag{4}$$

where $V+IR_s$ is the diode voltage V_d. Since the current I appears on both sides of (4) and cannot be expressed as an explicit function of V, the I-V relation is expressed in an implicit function as

$$f(I,V,G) = I - \left[I_L(G) - I_d(V + IR_s) - \frac{V + IR_s}{R_p}\right] = 0 \tag{5}$$

where I_L and I_d have been expressed as functions of G.

Module Model

The one-diode model is also applicable to a PV module. The cell model has five parameters: I_L, I_0, n, R_s and R_p. The same parameters apply to the module model with an additional subsctipt m to refer to module as shown in Fig. 1(b). For a module composed of m identical PV cells connected in series, its five parameters can be obtained from the cell's parameters as follows [4]

$$I_{Lm} = I_L,\ I_{0m} = I_0,\ n_m = mn,\ R_{sm} = mR_s,\ R_{pm} = mR_p. \tag{6}$$

and the following relation holds

$$f_m(I_m, V_m, G) = I_m - \left[I_{Lm}(G) - I_{dm}(V_{dm}) - \frac{V_{dm}}{R_{pm}}\right] = 0 \tag{7}$$

where $V_{dm}=V_m+I_mR_{sm}$ is the voltage of the equivalent diode and I_{dm} the current of the equivalent diode given by

$$I_{dm}(V_{dm}) = I_{0m}\cdot\left(\exp\left(\frac{qV_{dm}}{n_m kT}\right) - 1\right) \tag{8}$$

Bypass Diode

A PV module is shunt with a bypass diode to provide a current path when the module is showed. Fig. 2 shows a piecewise linear model of the I-V relation of bypass diode. The equivalent circuit is composed of an ideal diode, a barrier voltage V_{D0} and a resistance r_D connected in series. The electrical behavior of the diode can be modeled by a voltage-controlled resistance by

$$R_{by}(V_D)=\begin{cases} r_R & \text{if } V_D \le V_{D0} \\ r_F & \text{if } V_D > V_{D0} \end{cases} \quad (9)$$

In this study, V_{D0} takes the value of 0.7 V, R_F 0.2 Ω and R_R 10 MΩ.

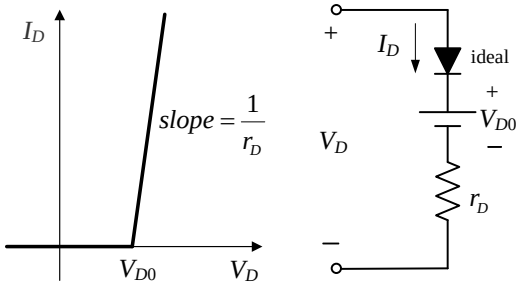

Fig. 2. Piecewise linear model and equivalent circuit of a bypass diode

3. MODELS OF PV ARRAYS

A PV array is composed of several PV modules that can be connected in SS, PL, SP, TCT, BL or HC configuration. In this paper, we consider an array containing 36 identical modules. Each module is shunted with a bypass diode. Fig. 3 shows arrays wired with these configurations.

Simple Series Configuration

PV modules in Fig. 3 (a) are wired with the SS configuration. The *I-V* relation of the k-th module is given by

$$f_m(I_k, V_k, G_k) = 0,\ k = 1,\ 2,\ 3, \cdots, 36 \quad (10)$$

where f_m is the implicit function described by (7), I_k, V_k, and G_k are the current, voltage and irradiance level of the k-th module. The array voltage V_a is the sum of all the module voltages

$$V_a = \sum_{k=1}^{36} V_k \quad (11)$$

The array current I_a is given by

$$I_a = I_k + \frac{-V_k - 0.7}{R_{by}(-V_k)},\ k = 1, 2, 3, \ldots, 36 \quad (12)$$

For a known array voltage V_a, there are 36 module currents, 36 module voltages, and an array current I_a, summing up to 73 unknowns in total. Eqs. (10)-(12) actually represent 73 equations that allow these unknown to be solved.

Parallel-linked Configuration

In the PL scheme, all the 36 modules are shunted as shown in Fig. 3(b). We can write the equations as follows:

$$f_m(I_k, V_a, G_k) = 0,\ k = 1,\ 2,\ 3, \cdots, 36 \quad (13)$$

$$I_a = \sum_{k=1}^{36} I_k + \frac{-V_k - 0.7}{R_{by}(-V_k)} \quad (14)$$

The unknowns are 36 module currents and an array current. Eqs. (13) and (14) provide 37 equations, which meets the number of equations required for solving 37 unknowns.

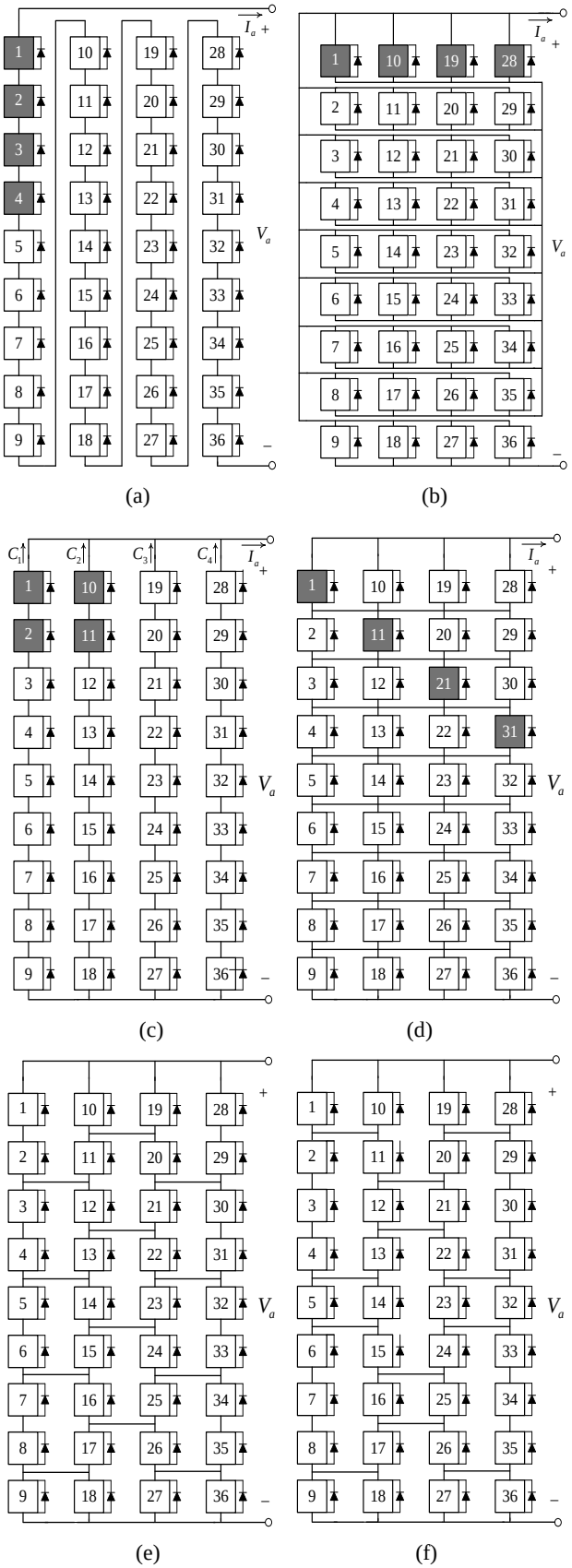

Fig. 3. PV array containing 36 modules connected in (a) SS, (b) PL, (c) SP, (d) TCT, (e) BL and (f) HC configurations

Series-parallel Configuration

The modules in the SP configuration (Fig. 3 (c)) are composed of four parallel strings, each of which contains nine series modules. The string currents are denoted as C_1, C_2, C_3 and C_4. The following equations can be written

$$f_m\left(I_k, V_k, G_k\right)=0,\ k=1,\ 2,\ 3,\cdots,\ 36 \tag{15}$$

$$C_1+C_2+C_3+C_4=I_a \tag{16}$$

$$\sum_{k=1}^{9}V_k=\sum_{k=10}^{18}V_k=\sum_{k=19}^{27}V_k=\sum_{k=28}^{36}V_k=V_a \tag{17}$$

$$C_n-\left(I_k+\frac{-V_k-0.7}{R_{by}(-V_k)}\right)=0,\ k=1,2,...,36 \tag{18}$$

where k refers to the module number and the string number n is related to k by

$$n=\begin{cases}1,\ \text{for}\ 1\le k\le 9\\ 2,\ \text{for}\ 10\le k\le 18\\ 3,\ \text{for}\ 19\le k\le 27\\ 4,\ \text{for}\ 28\le k\le 36\end{cases} \tag{19}$$

The SP configuration has 77 unknowns: 36 module currents, 36 module voltages, four string currents and an array current. Eqs. (15)-(18) make a total of 77 equations that meet the number of equations required.

Total-cross-tied Configuration

The TCT configuration shown in Fig. 3(d) has 36 equations for the *I-V* relation of 36 modules

$$f_m\left(I_k, V_n, G_k\right)=0,\ k=1,\ 2,\ 3,\cdots,\ 36 \tag{20}$$

where k refers to the module number and the voltage subscript n relates to k by

$$n=\begin{cases}k\ ,\ \text{for}\ 1\le k\le 9\\ k-9\ ,\ \text{for}\ 10\le k\le 18\\ k-18,\ \text{for}\ 19\le k\le 27\\ k-27,\ \text{for}\ 28\le k\le 36\end{cases} \tag{21}$$

The voltage V_n refers to the voltage of the four parallel modules at the nth row. The array voltage V_a equals the sum of nine row voltages

$$\sum_{n=1}^{9}V_n=V_a \tag{22}$$

The array current I_a can be given by the sum of the currents of any four modules at the same row. We can take the four upper-most modules and write

$$I_a=\sum_{k=1,10,19,28}I_k+\frac{-V_1-0.7}{R_{by}(-V_1)} \tag{23}$$

Finally, we write the KCL equations for the eight nodes, each of which is connected to eight modules and eight diodes.

$$\sum_{i=0}^{3}\left(I_{9\times i+k}+\frac{-V_k-0.7}{R_{by}(-V_k)}\right)-\left(I_{9\times i+(k-1)}+\frac{-V_{k-1}-0.7}{R_{by}(-V_{k-1})}\right)=0 \tag{24}$$

k=2, 3, 4,…, 9

This scheme has 36 module currents, an array current and nine row voltages, summing up to 46 unknown variables. We check that (20) gives 36 *I-V* equations, (22) one KVL equation, (23) one KCL equations, and (24) eight KCL equations, making up to a total of 46 equations.

Bridge-linked Configuration

Fig. 3(e) shows the network of a BL array. The *I-V* relations of the 36 modules are given by

$$f_m\left(I_k, V_k, G_k\right)=0,\ k=1,\ 2,\ 3,\cdots,\ 36 \tag{25}$$

There are 12 nodes to which four modules connect. We can write the KCL equations for these nodes

$$\sum_{i=0}^{1}\left\{\left(I_{9\times i+k}+\frac{-V_{(9\times i+k)}-0.7}{R_{by}(-V_{(9\times i+k)})}\right)-\left(I_{9\times i+(k-1)}+\frac{-V_{(9\times i+(k-1))}-0.7}{R_{by}(-V_{(9\times i+(k-1))})}\right)\right\}=0 \tag{26}$$

where k=3, 5, 7, 9, 11, 13, 15, 17, 21, 23, 25, and 27 are module numbers located to the lower-left of the nodes. For the eight nodes connecting to only two modules, the KCL equations are given by

$$I_k+\frac{-V_k-0.7}{R_{by}(-V_k)}=I_{k+1}+\frac{-V_{(k+1)}-0.7}{R_{by}(-V_{(k+1)})} \tag{27}$$

where k=1, 3, 5, 7, 28, 30, 32 and 34. The array current I_a can be written as

$$I_a=\sum_{k=1,10,19,28}I_k+\frac{-V_1-0.7}{R_{by}(-V_1)} \tag{28}$$

which is the same as (23). We now write KVL equations for three loops containing two modules

$$V_k-V_{k+9}=0 \tag{29}$$

with k = 9, 10 and 27, and for 12 loops containing four modules

$$\sum_{i=k}^{k+1}\left(V_i-V_{i+9}\right)=0 \tag{30}$$

with k= 1, 3, 5, 7, 11, 13, 15, 17, 19, 21, 23 and 25. Finally, the array voltage V_a can be given by

$$\sum_{k=1}^{9}V_k=V_a \tag{31}$$

The BL configuration has 36 module voltages, 36 module currents and an array current, making up to 73 unknowns. Eqs. (25)-(31) provides 73 equations which are checked for correct number of equations.

Honey Comb Configuration

The HC scheme is as complicated as the BL. The same method is used for writing the equations. The *I-V* relations of the 36 modules are given by

$$f_m\left(I_k, V_k, G_k\right)=0,\ k=1,\ 2,\ 3,\cdots,\ 36 \tag{32}$$

There are 12 nodes connecting to four modules. The corresponding KCL equations are

$$\sum_{i=0}^{1}\left\{\left(I_{9\times i+k}+\frac{-V_{(9\times i+k)}-0.7}{R_{by}(-V_{(9\times i+k)})}\right)-\left(I_{9\times i+(k-1)}+\frac{-V_{(9\times i+(k-1))}-0.7}{R_{by}(-V_{(9\times i+(k-1))})}\right)\right\}=0 \tag{33}$$

where k=2, 5, 6, 9, 12, 13, 16, 17, 20, 23, 24, and 27 are module numbers located to the lower-left of the nodes. For the eight nodes connecting to only two modules, the

KCL equations are given by

$$I_k + \frac{-V_k - 0.7}{R_{by}(-V_k)} = I_{k+1} + \frac{-V_{(k+1)} - 0.7}{R_{by}(-V_{(k+1)})} \tag{34}$$

with k=2, 3, 6, 7, 29, 30, 33 and 34. The array current I_a can be written as

$$I_a = \sum_{k=1,10,19,28} I_k + \frac{-V_1 - 0.7}{R_{by}(-V_1)} \tag{35}$$

The KVL equations for loops containing two modules are

$$V_k - V_{k+9} = 0 \tag{36}$$

with k=1, 5, 9, 12, 16, 19, 23 and 27. The KVL equations for loops with four modules are

$$\sum_{i=k}^{k+1} (V_i - V_{i+9}) = 0,\ k = 10,\ 17 \tag{37}$$

The KVL equations for loops with six modules are

$$\sum_{i=k}^{k+2} (V_i - V_{i+9}) = 0,\ k = 2,\ 6,\ 13,\ 20,\ 24 \tag{38}$$

Finally, the array voltage V_a can be given by

$$\sum_{k=1}^{9} V_k = V_a \tag{39}$$

The HC scheme also has 73 variables. Eqs. (32)-(39) provide a total of 73 equations, agreeing with the number of equations required.

4. ATP MODEL OF PV CELL AND MODULE

In addition to the analytical models mentioned in the earlier two paragraphs, PV cells and modules can also be analyzed with a circuit simulation program. The ATP, which was once called EMTP (Electromagnetic Transients Program) and is power system simulation software widely used in universities and power industries, is adopted as the simulation tool in this paper. The ATP PV cell/module model a few years earlier proposed by Wang and Hsu [14, 21] involves using an equivalent circuit composed of parallel linear piecewise branches (PLPB) to assimilate the nonlinear I-V relation of a diode. While the PLPB model provides an effective and accurate solution for simulating PV systems in ATP, its implementation is a bit complicated. The newly released version of ATPDraw, a graphical preprocessor of ATP, supports the Shockley diode model. This model automatically generates equally spaced voltage points between zero and a maximum voltage, and applies the Shockley diode equation (*i.e.*, (2) or (8)) to find the corresponding current values. The number of points and the maximum voltage are provided by the user.

Basic Model of PV Module

With the Shockley diode model, the equivalent circuits shown in Fig. 1 (a) and (b) can be built in ATPDraw as shown in Fig 4 (a) that refers to a grounded PV module. For an ungrounded PV module as shown in Fig. 4 (b), the current source representing light-generated current is replaced by two current sources of the same value but opposite directions: one enters and the other leaves the module. The voltage source connected to the module output terminals *A* and *B* serves to carry out voltage sweeping to obtain an *I-V* curve.

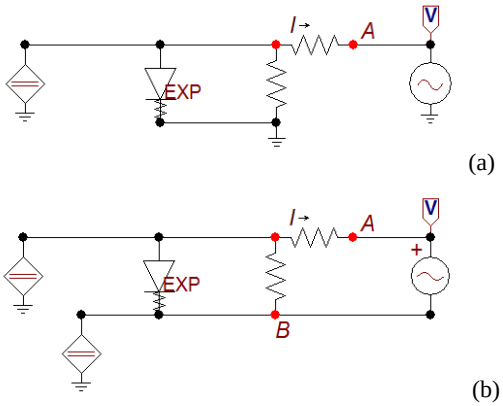

Fig. 4. ATP model of: (a) a grounded module, (b) a floating module.

Shading of Module

Shading of a PV module changes the module's temperature and the irradiance it receives. In this paper, a module is modeled in ATP to have only two states: normal and shaded. To simulate a module in either of the two states, the ATP circuit model for each state is built and then connected together as shown in Fig. 5 where the normal and shaded modules are controlled by MODELS via switches (S1 and S2). MODELS [22] is a built-in control system simulation tool in ATP that generates desired control signals according to programs designed by the user. The module's temperature is 69 ºC and struck by irradiance of 1 kW/m^2 for normal state, and 33.2 ºC and 250 W/m^2 for shaded state. Fig. 6 shows how the idea shown in Fig. 5 is implemented in ATP using the floating equivalent circuit of Fig. 4. In Fig. 6, the circuit looking into terminals *A* and *B* is controlled by four switches to behave as either a normal or a shaded module. The actions of the four switches are programmed in MODELS so that the module's state can be changed with time. The branch connecting terminals *A* and *B* is the piecewise linear model of the bypass diode.

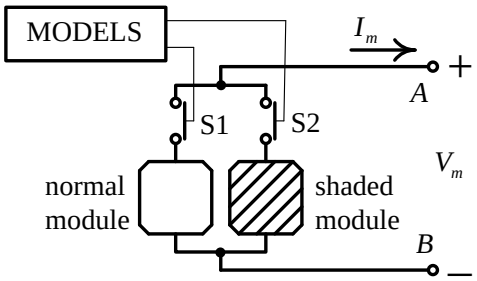

Fig. 5. ATP model for normal and shaded states of a module

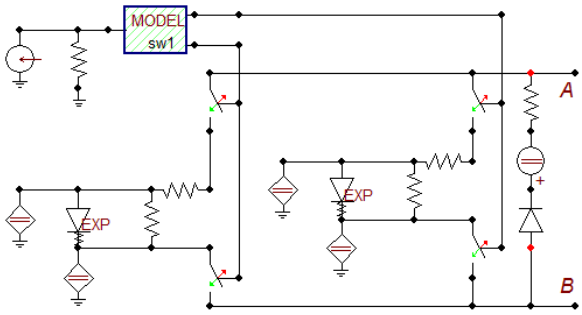

Fig. 6. Implementation of a module in ATP

5. MONTE CARLO SIMULATION

The analytical models presented in paragraph 3 allow a PV array to be solved for a given shading condition. The ATP module model given in paragraph 4 also enables one to simulate a shaded PV array. However, the shading condition of an array always has some uncertainty. To handle this uncertainty, Monte Carlo method can be used to provide a more insightful evaluation of the array performance. There are indeed an infinite number of possible patterns of shading. Simplification and classification of the shading patterns are hence necessary to make Monte Carlo simulation possible and practical.

Patterns of Shading

In this paper, a PV module is simplified to have only two states: normal or shaded. A fixed number of four modules in the array is shaded and forms one of the four patterns: column shading, row shading, square shading and diagonal shading. The four shading patterns are illustrated in Fig. 3 (a), (b), (c) and (d), respectively with grey shaded blocks. In the Monte Carlo simulation, the location of the shaded modules is random, but they must form in one of the four patterns with an equal probability. That is, the program randomly selects a shading pattern, and then determines the location that is also random.

CMC Algorithm

The CMC algorithm is based on the analytical models of arrays presented in paragraph 3 to perform Monte Carlo simulation. The simulation run begins with random selection of a shading pattern and its location that provides all the circuit parameters of the array. The array circuit is then solved using the Newton-Raphson method for an array voltage varying from zero to the open-circuit voltage of the array, which allows the *I-V* curve at this shading pattern to be traced. With this *I-V* curve, the maximum power, fill-factor, short-circuit current and efficiency can be found and recorded. This finishes a simulation cycle. The simulation repeats for as many times as needed.

The CMC simulation was carried out using the Mathcad software. The computation time depends on the number of simulation cycles and on the connection configuration of an array. For simple networks such as PL and SS schemes, the computation time is shorter because they have less numbers of equations. On the other hand, simulation of more complicated configurations like BL and HC schemes solves more equations and the computation time is much longer. In general, the CMC algorithm is straightforward and easy to implement in Mathcad, but the calculation speed is slow.

TDMC Algorithm

The TDMC algorithm is a newly developed procedure that carries out Monte Carlo simulation in the time domain. In this paper, we use ATP to simulate a PV array circuit. Each module of the array is modeled as the circuit shown by Figs 5 and 6. and is controlled by the MODELS program to behave as either a normal or a shaded module. The MODELS program also controls the pattern of shading according to the probability assigned to each pattern. In this work, the four shading patterns have an equal probability of happening. The output terminals of the array are connected with a low-frequency AC voltage with DC offset to conduct voltage sweeping over a range from slightly negative to a bit higher than the peak of the open-circuit voltage of the array. The switches that control the shading states of modules are synchronized with the sweeping voltage. The MODELS program randomly changes the shading states of the modules at the end of each cycle.

Fig. 7 illustrates how the TDMC algorithm works. Fig. 7(a) shows the waveforms of the sweeping voltage v_a and array current i_a for $0<t<0.10$ s, being 5 cycles, of a PV array connected in BL scheme. The voltage v_a has a period of 20 ms and sweeps from -0.18 V to 181 V. For the TDMC, each cycle of voltage sweeping generates a random sampling of *I-V* curve. The careful reader can find changes of the waveform of i_a over different cycles. The waveforms of v_a and i_a shown in Fig. 7(a) can be drawn in the *V-I* plane to provide *I-V* curves corresponding to different shading patterns as shown in Fig. 7(b) where *I-V* curves for a simulation duration of 0.3 s are depicted.

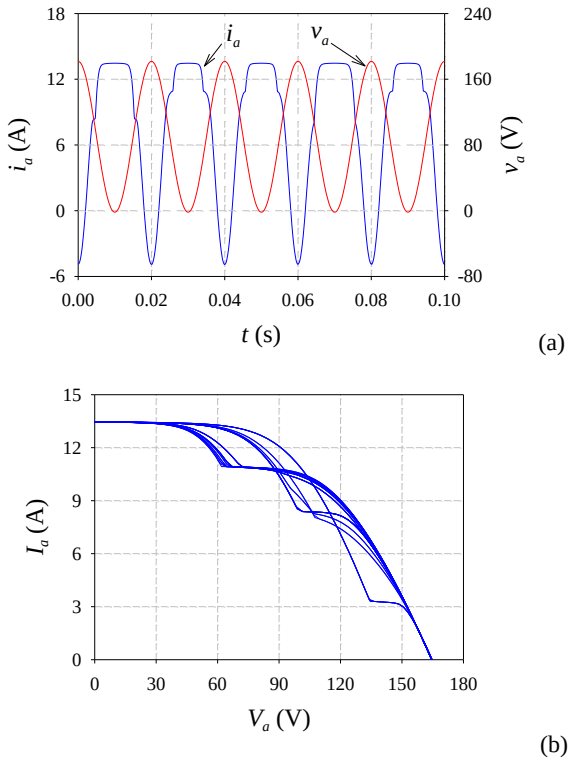

Fig. 7. (a) Waveforms of the sweeping voltage and array current, (b) *I-V* curves obtained from voltage sweeping.

6. NUMERICAL APPLICATIONS

A practical 50-W PV module is taken as example to study the effects of partial shading and array connection configurations using the proposed CMC and TDMC algorithms. PV module SM50, a product of Shihlin Electric, Taiwan, is composed of 36 PV cells in series. Its electrical characteristics at 25 $^{\circ}C$ and solar irradiance of 1.0 kW/m^2 are listed in Table 1. Table 2 lists the parameters of the cells used in SM50 module that are obtained from experiments in our lab.

Table 1. SM50 PV Module Electrical Specification

Specification	Quantity
Rated power	50 W
Current at maximum power point	2.7 A
Voltage at maximum power point	18 V
Average short-circuit current	3.3 A
Average open-circuit voltage	22 V

Table 2. Parameters of Cells of SM50 PV Module

Parameter	Quantity
Reverse saturation current at T_{ref} (I_0)	2×10^{-7} A
Ideality factor (n)	1.4
Series resistance (R_s)	0.031 Ω
Parallel resistance (R_p)	15 Ω
Light-generated current at reference irradiance (I_{L0})	3.3 A
Reference value of irradiance (G_0)	1 kW/m^2
Reference temperature (T_{ref})	25$^o C$

I-V Characteristics for Specified Shading Patterns

A deterministic study is fist conducted to find the *I-V* characteristics of PV arrays connected in six different configurations for given patterns of shading. Both the analytical models and ATP model are used to solve the array networks. The numbers of shaded modules are specified and listed in Table The shaded modules are also shown in Fig. 3 (a), (b), (c) and (d) by grey shaded blocks. The *I-V* curves obtained by the analytical models (solid lines) and ATP model (dots) are depicted in Fig. 8 in which dotted lines are reference curves when no modules are shaded. For SS and PL configurations, the four different shading patterns bring the same *I-V* curves because for SS and PL, only the number but not the location of shaded modules, affects the *I-V* characteristics. On the other hand, shading pattern does influence *I-V* curves of the four other configurations. It is noted that the results of the analytical models and ATP model agree well.

Table 3. Shaded Modules for Four Shading Patterns

Shading Pattern	Numbers of Shaded Modules
column shading	1, 2, 3, 4
row shading	1, 10, 19, 28
diagonal shading	1, 2, 10, 11
square shading	1, 11, 21, 31

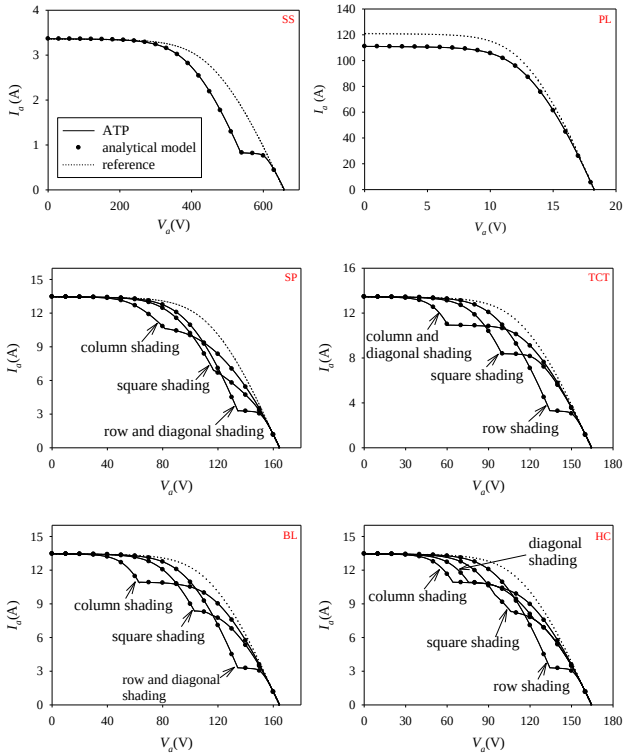

Fig. 8. *I-V* curves for arrays in six connection configurations and for four shading patterns, obtained by ATP and analytical models

Probabilistic Analysis of Different Array Configurations

Monte Carlo simulation using the CMC and TDMC algorithms have been conducted to compare the performance of six different array connection configurations subject to random partial shading. The shading patterns include row, column, diagonal and square shading of four modules. The patterns and their locations are randomly selected with an equal probability. At every simulation run, the Monte Carlo simulation generates an *I-V* curve corresponding to a randomly selected shading pattern and location. The *I-V* curve allows a sample of the maximum power P_a to be found. Fig. 9 shows the results of performing 10,000 simulation runs. In the figure, the probability mass functions (pmf) and the cumulative distribution functions (CDF) of P_a for six array connection configurations are traced. The pmfs and CDFs brought by the CMC (dashed line) and TDMC (solid line) algorithms are compared and found to agree very well for all the six configurations. The calculation times of the CMC and TDMC for different configurations for 1,000 simulation runs are listed in Table 4.

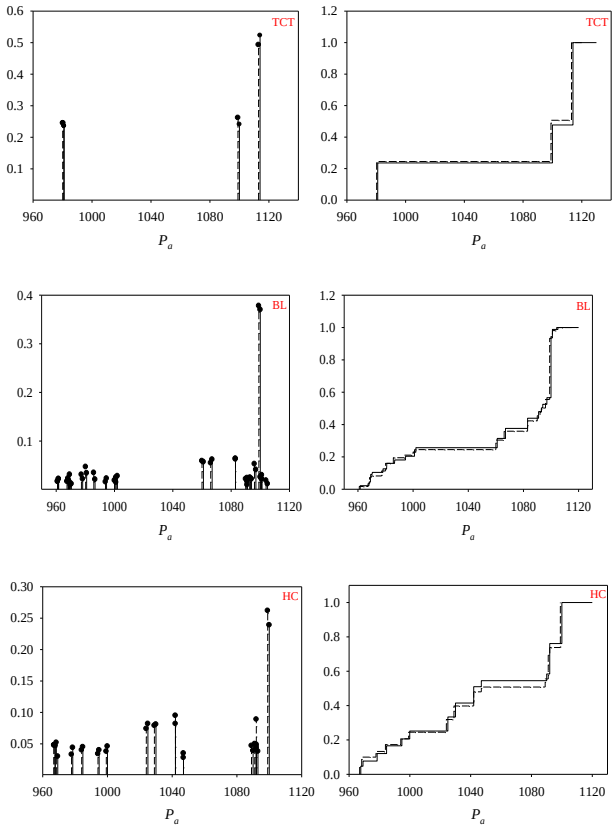

Fig. 9. pmfs (left) and CDFs (right) of P_a for PV arrays connected in six different configurations

It is noted that the calculation time of the CMC algorithm varies from 1 hour for PL scheme to about 10 hours for BL scheme. On the contrary, the calculation time of the TDMC algorithm is nearly independent of the connection configuration. This distinct difference arises from the fact that the speed of the CMC is closely related to the complexity of the array network. The more complicated is the network, the more equations need to be solved. On the other hand, the calculation speed of the TDMC is chiefly determined by the number of nodes (or buses in power system terms) of an object circuit to be simulated. All the six connection configurations studies in this paper have indeed the same number of nodes, which

explains why the calculation times for the six schemes using the TDMC method only differ slightly. In general, the TDMC runs two to 20 times faster than the CMC depending on the complexity of the network.

The expected values, standard deviations and coefficients of variation of the maximum power of PV arrays connected in the six schemes are listed in Table 5. Results brought by the two algorithms are very close. The SS has the highest mean value followed by the TCT and then the SP. However, both the SS and PL are not practical because they offer either too high a voltage or too large a current. The TCT, SP and BL perform nicely under the simulation conditions we have assumed.

Table 4. Times Needed (Hrs) for Performing 1,000 Monte Carlo Simulation Runs for Different Configurations

Algorithm	Connection Configuration					
	SS	PL	SP	TCT	BL	HC
CMC	4.24	1.04	5.64	4.57	9.86	6.97
TDMC	0.421	0.425	0.425	0.423	0.425	0.423

Table 5. Comparison of Maximum Power Statistics Obtained by CMC and TDMC

Statistics	algorithm	SS	PL	TCT	SP	BL	HC
expected value (W)	CMC	1099.42	1150.73	1077.11	1066.62	1064.31	1051.03
	TDMC	1100.21	1151.49	1079.37	1067.93	1063.58	1049.69
standard deviation (W)	CMC	0	0	55.506	32.932	49.766	48.412
	TDMC	0	0	55.002	32.919	50.264	47.279
coefficient of variation	CMC	0	0	0.0515	0.0309	0.0467	0.0461
	TDMC	0	0	0.0509	0.0308	0.0472	0.0451

7. CONCLUSION

The effects of random shading on the performance of a PV array composed of 36 modules have been studied using the Monte Carlo simulation method in this paper that proposes two algorithms for carrying out the simulation: the CMC and the TDMC. The former is based on analytical models while the later on a circuit transient simulation program using the ATP. Both the CMC and TDMC algorithms bring satisfactory results but the TDMC runs two to 20 times as fast as the CMC. The performance of six array connection configurations, SS, PL, TCT, SP, BL and HC is compared and found that the TCT practically performs superior to other configurations under the shading conditions we assumed.

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A Study on Measures Towards Green Building Case Study of the AIT Energy Building

Supan Thonprom

Abstract— *Building sector had shared 15 percent of final energy consumption in a year. This study proposes the preliminary assessment of GreenBuilding Standard for an existing building. This can reduce materials, resources and energy utilizations in building sector. However, it can keep thermal comfort and environmental friendly. For Green Building Standard, This study used Leadership in Energy and Environmental Design (LEED) Version 2009.*

The LEED rating system was established by U.S. Green Building Council (USGBC). There provides building owners and operatorsand option and measures for identifying and implementing practical and measurable green building design, construction, operations and maintenance solutions. It has a 5 rating system. The study selectedGreen Building Operation Existing Building: Operation & Maintenance (EB: O&M) Rating System. The system is assessed in 5 groups.

Preliminary assessment, Energy Building earned 24 points and there did not passed all prerequisites. The major prerequisites were on Sustainable Sites and Water Efficiency. The study had conducted a review for improving and achieving higher points. There are 45 points, 57 points, 70 points and 89 points for certified, silver, gold and platinum respectively. For platinum level, the total investment cost was $ 316,640. The major groups are Facility Alterations and Additions, space condition system, photovoltaic system and building management system. This level could give the total annual income was $ 46,711/year. These are by energy saving, revenue of photovoltaicand water bill reduction. By this, the payback period was 6.78 years..

Keywords— **Green Building, Specific Energy Consumption, U.S. Green Building Council, Leadership in Energy and Environmental Design (LEED) Rating System.**

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Optimal Allocation of Maintenance Resources and Reliability Benchmarking of Electric Power Utilities

N. Teera-achariyakul, and D. Rerkpreedapong

Abstract*— *This paper develops a practical procedure to optimally allocate the maintenance resources for all 12 regions of Provincial Electricity Authority (PEA) of Thailand. In this research, supplementary maintenance activities are selected by the modified reliability centered maintenance analysis (RCM) to increase the reliability level of each region. Then, the reliability improvement opportunity (RIO) of power distribution systems can be assessed for each PEA region. The regional RIO curves are used for allocation of maintenance resources in order to minimize the customer-minute of interruptions (CMI) of the whole PEA system. The most cost-effective maintenance activities allocated by the proposed method can be further used to set a reliability benchmark for all PEA regions.

***Keywords*— RCM, Reliability benchmark, Reliability improvement opportunity, Reliability index**

1. INTRODUCTION

In a competitive environment today, power system reliability plays a significant role for electric power industry. It can be assessed by using the system average interruption frequency index (SAIFI) and the system average duration index (SAIDI), which are the KPI most widely used around the world for electric utilities. While the power system reliability depends on maintenance activities applied to the system, achieving an appropriate balance between maintenance resources and the system reliability is a primary objective of power distribution utilities. This becomes the motivation of this research to develop a practical procedure for optimally allocating the maintenance resources based on a reliability improvement opportunity (RIO) evaluated by skillful personnel responsible for the power distribution systems.

The proposed method is applied to Provincial Electricity Authority of Thailand (PEA) for optimally allocating the maintenance resources to twelve service regions. Those regions supply electricity to 15 million customers all over the country as shown in Fig.1. The objective of this allocation problem is to minimize the total customer-minute of interruptions (*CMI*) of the PEA subject to a given maintenance budget. Once the solutions are reached, the SAIFI and SAIDI of each region can be found, and also the SAIFI and SAIDI of the whole system are calculated by (1) and (2) respectively.

$$SAIFI_P = \frac{\sum_{R=N1}^{S3} \left(SAIFI_R \times N_R \right)}{N_P} \quad (1)$$

$$SAIDI_P = \frac{\sum_{R=N1}^{S3} \left(SAIDI_R \times N_R \right)}{N_P} \quad (2)$$

Where

$SAIFI_P$, $SAIDI_P$ Reliability indices of PEA
$SAIFI_R$, $SAIDI_R$ Reliability indices of each region
N_R Number of customers in each PEA region
N_P Total number of customers of PEA

Region	No. Customers
N1	1,535,950
N2	1,308,824
N3	1,039,460
NE1	1,825,657
NE2	1,960,569
NE3	1,663,092
C1	1,169,883
C2	1,207,710
C3	982,262
S1	815,622
S2	1,292,164
S3	1,080,875
PEA	**15,882,068**

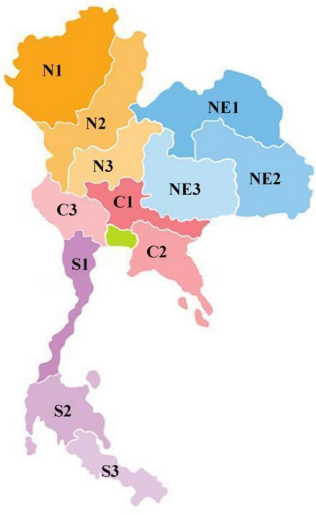

Fig.1. Number of PEA' Customers in 12 Regions (N_R)

In section 2, the overview of the proposed procedure is illustrated. It explains sequential steps to determine the optimal allocation of maintenance resources for each region. In section 3, the essential data required by the proposed procedure including interruption records, costs and reliability effect of each maintenance activity are collected.

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The list of selected maintenance activities resulted from the modified Reliability Centered Maintenance analysis (RCM) is addressed. In this analysis, the essential data are required such as cost of each maintenance activity, and the reliability effect of each maintenance activity assessed by experienced PEA operators. Next, a decrease in *CMI* caused by each maintenance activity in the list is determined. To develop the Reliability Improvement Opportunity (RIO) curve, each change in CMI due to a maintenance activity is accumulated and plotted against the cost accumulation of those maintenance activities, in such a way that the slope of the curve (regardless of "-" sign) is continuously decreased. As a result, the RIO curves are attained for all 12 regions in section 4. Then, the optimally allocated resources of maintenance are achieved by solving the optimization problem addressed in section 5. The results from section 5 can be used to set the reliability benchmarks as described in section 6. Finally, conclusions are given in section 7.

2. OVERVIEW OF PROPOSED PROCEDURE

The sequential steps to carry out the optimal maintenance resource allocation, which minimizes the total *CMI* of the PEA, and later used to set the reliability benchmarks of $SAIFI_R$ and $SAIDI_R$ for each region, are illustrated as a flowchart in Fig. 2.

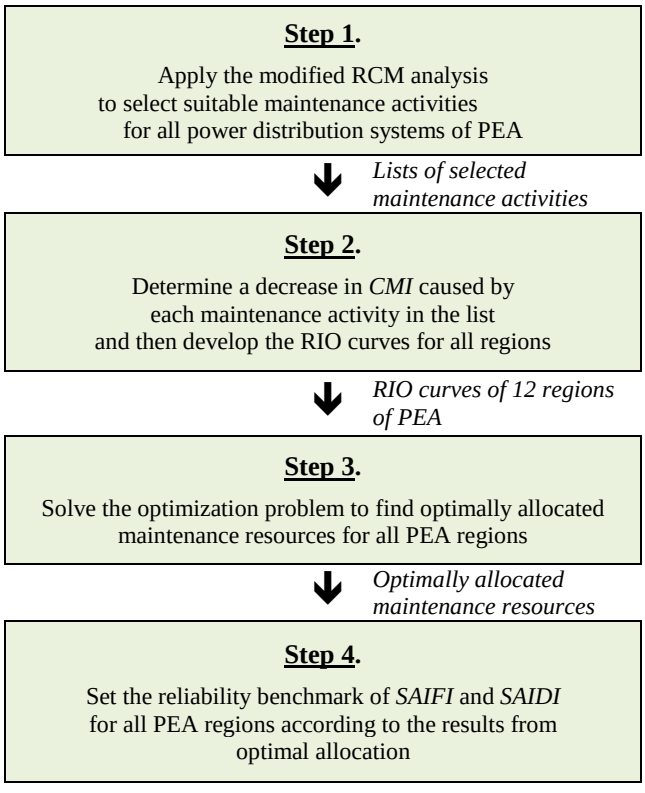

Fig. 2. A Flowchart of the Proposed Procedure

3. MODIFIED RELIABILITY CENTERED MAINTENANCE ANALYSIS

To choose the most cost effective maintenance activities for PEA power distribution systems, the modified RCM analysis is employed. The process of modified RCM analysis with the required data and the supporting information is illustrated in Fig. 3.

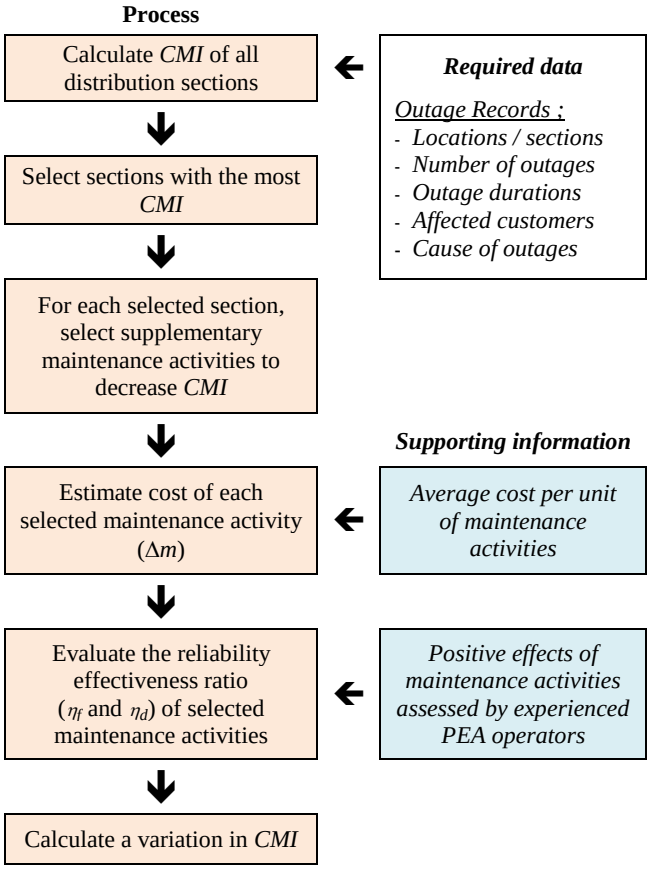

Fig. 3. Modified RCM Analysis Process

The *CMI* of each section in a distribution system, as mentioned in Fig. 3, can be calculated by using (3).

$$cmi_S = N_S \times n \times d \tag{3}$$

Where

cmi_S The *CMI* of section in a distribution system

N_S Number of customers affected when the upstream protection device of section operates

n Number of outage events caused by a fault in section

d Average outage duration of all events caused by a fault in section

Supporting information in the modified RCM analysis includes the average cost per unit of maintenance activities and reliability effectiveness ratio of each maintenance activity. The effectiveness ratios (η_f and η_d) are obtained from the survey that more than a hundred of experienced engineers, technicians, and skilled operators answered the questionnaires based on their maintenance records and experiences. According to the number of outages of a distribution section in the year before a selected maintenance activity is performed, the expected number of outages after performing the selected maintenance activity can be determined by (4).

$$n^{After} = \left(1-\eta_f\right) \times n^{Before} \tag{4}$$

Where

n^{Before} The number of outages of a distribution section in the year before a selected maintenance activity is performed

n^{After} The expected number of outages after performing the selected maintenance activity

η_f Reliability effectiveness ratio in outage frequency of a selected maintenance activity

Similarly, the expected average outage duration after performing the selected maintenance activity can be determined by (5).

$$d^{After} = (1-\eta_d) \times d^{Before} \quad (5)$$

Where

d^{Before} Average outage duration of a distribution section in the year before a selected maintenance activity is performed

d^{After} Expected average outage duration after performing the selected maintenance activity

η_d Reliability effectiveness ratio in outage duration of a selected maintenance activity

Table 1 shows the reliability effectiveness ratio in outage frequency of the selected maintenance activities in the best and worst cases. The reliability effectiveness ratio in outage duration of the selected maintenance activities in the best and worst cases are tabulated in Table 2.

Table 1. Reliability Effectiveness Ratio in Outage Frequency of the Selected Preventive Maintenance Activities.

Preventable Cause of Outages	Selected Preventive Maintenance Activity	Reliability Effectiveness Ratio η_f	
		Best case	Worst case
Tree Contact	Tree trimming	0.7	0.2
Animal Contact	Installation of snake guards	0.4	0.1
	Installation of bird guards	0.3	0.0
Equipment Failures	Patrol and preventive actions	0.5	0.1
	Increase frequency of condition-based maintenance	0.7	0.3
Pollution	Insulator cleaning	0.8	0.5

Table 2. Reliability Effectiveness Ratio in Outage Duration of the Selected Activities.

Activity	Reliability Effectiveness ratio η_d	
	Best case	Worst case
Purchase new tools to reduce repair time	0.1	0.0
Educate the dispatch crews in order to reduce repair time	0.1	0.0
Decrease time to dispatch crews to the fault location	0.1	0.0
Improve spare parts management	0.3	0.2

After a selected maintenance activity is implemented, a change in *CMI*, *SAIFI*, and *SAIDI* caused by that activity can be calculated by using (6)-(8) respectively.

$$\Delta cmi = N_S \times (\Delta n \Delta d + d\Delta n + n\Delta d) \quad (6)$$

$$\Delta saifi_R = N_S \Delta n / N_R \quad (7)$$

$$\Delta saidi_R = \Delta cmi / N_R \quad (8)$$

Where

Δn Change in number of outages $= n^{After} - n^{Before}$

Δd Change in average duration of outages $= d^{After} - d^{Before}$

Δcmi Change in *CMI*

$\Delta saifi_R$ Change in *SAIFI* on a PEA region base

$\Delta saidi_R$ Change in *SAIDI* on a PEA region base

For example, Fig. 4 shows two overhead power distribution feeders with five laterals which are a portion of an area in the region S2. Their outage records which give the top-5 *CMI* of the area is shown in the left columns of Table 3. The modified RCM analysis is used to develop the list of supplementary maintenance activities. The required parameters: η_f and η_d, and also the calculation results of Δn, Δd, $\Delta saifi_R$, and Δcmi of each activity are shown in the middle columns.

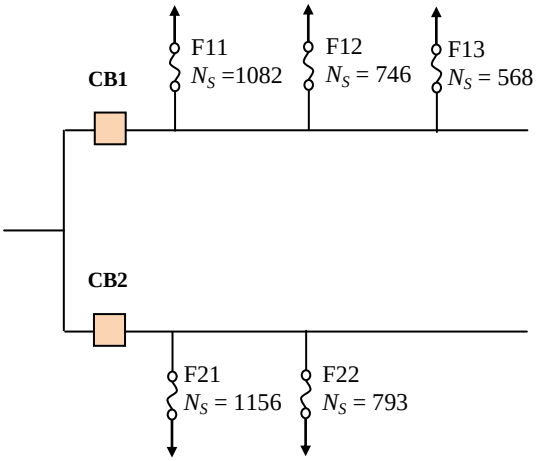

Fig. 4. A Portion of Power Distribution Feeders in Region S2

Table 3. Example of Top-5 *CMI* Sections and List of Maintenance Acitivities Resulted from Modified RCM Analysis

Outage Records of system in fig.4.						Modified RCM Analysis							RIO index	
Section	N_S	Cause of outage	N	d	*Top-5 CMI*	Maintenance activity / Remark	η_f	η_d	Δn	Δd	$\Delta saifi_R$	Δcmi	Δm	*CE*	Rank
CB2	1949	Equipment failure	2	30	116,940	Implement condition-based maintenance more than twice a year	0.7	-	-1.4	-	-0.0021	-81,858	5,000	16.37	2
F11	1082	Car accident	1	180	194,760	No suitable activity to prevent this kind of events	-	-	-	-	-	-	-	-	-
F22	793	Animal contact (snake)	9	57	406,809	- Install 90 snake guards, 120 Baht /piece. - Reduce time to dispatch crews to the fault location	0.4 -	- 0.1	-3.6 -	- -5.7	-0.0022 -0.0000	-187,132	10,800	17.33	1
F21	1156	Unknown	5	50	289,000	Purchase new tools to decrease repair time	-	0.1	0.0	-5.0	-0.0000	-28,900	8,000	3.61	4
F21	1156	Animal contact (snake)	3	45	156,060	- Install 100 snake guards, 120 Baht /piece. - Reduce time to dispatch crews to the fault location	0.4 -	- 0.1	-1.2 -	- -4.5	-0.0011 -0.0000	-71,788	12,000	5.98	3

4. RELIABILITY IMPROVEMENT OPPORTUNITY (RIO)

A change in *CMI* due to a maintenance activity and its associated cost, resulted from the modified RCM analysis, are used to determine the cost-effectiveness index as expressed by (9).

$$CE = \frac{|\Delta cmi|}{\Delta m} \tag{9}$$

Where

CE	Cost-effectiveness index of each maintenance activity
Δcmi	Change in *CMI*
Δm	Associated cost of maintenance activity

The rank of the maintenance activities as shown in the last column of Table 3 is obtained by sorting their cost-effectiveness indices from maximum to minimum.

The RIO curve is developed to describe the relationship between the cumulative value of Δcmi, as ΔCMI, and the cumulative value of Δm, as ΔM, as given in (10) and (11) respectively.

$$\Delta CMI = \sum_{Rank=1} \Delta cmi \tag{10}$$

$$\Delta M = \sum_{Rank=1} \Delta m \tag{11}$$

The cumulative values of the ranked maintenance activities in Table 3 are shown in Table 4. Later, the values of ΔCMI are plotted versus those of ΔM to present the RIO curve of an area in the region S2 as shown in Fig. 5.

Table 4. Cumulative Values of Ranked Maintenance Activities

Rank	Customer-minute of interruption		Maintenance cost (Baht)		Reliability index	
	Δcmi	ΔCMI	Δm	ΔM	$\Delta saifi$	$\Delta SAIFI$
1	-187,132	-187,132	10,800	10,800	-0.0022	-0.0022
2	-81,858	-268,990	5,000	15,800	-0.0021	-0.0043
3	-71,788	-340,778	12,000	27,800	-0.0011	-0.0054
4	-28,900	-369,678	8,000	35,800	-0.0000	-0.0054

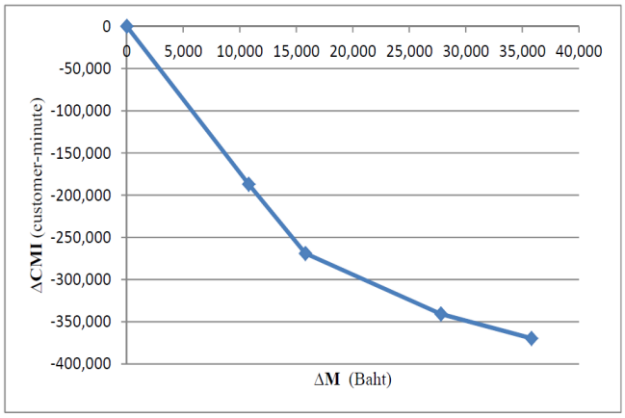

Fig. 5. RIO Curve of a Sub-region in Region S2

To acquire a regional RIO curve, the maintenance activities of all areas within the region must be considered altogether. Afterward, Table 3 and 4 as described above must be reproduced to obtain the values of ΔCMI_R against ΔM_R for each region. Fig. 6 shows the RIO curves of 12 PEA regions.

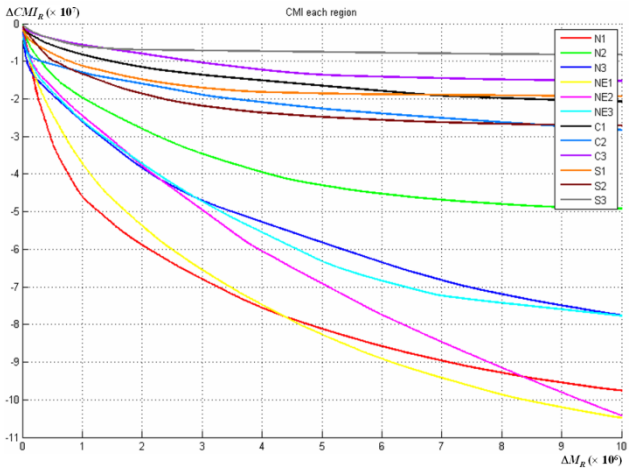

Fig. 6. RIO curves of 12 PEA regions

5. OPTIMAL RESOURCE ALLOCATION

The optimal allocation of maintenance resources for each region can be attained, when the RIO curves of 12 regions as described in Fig. 6 become available. Then, the objective function as given in (12) is proposed to minimize the total CMI of the whole PEA system subject to a limited maintenance resource (ΔM_P), i.e., an extra amount of money that PEA wants to expend in additional maintenance activities to achieve a better level of reliability, unlike annual maintenance budget.

$$\begin{aligned} \text{minimize} &: \Delta CMI_P = \sum_{R=N1}^{S3} \Delta CMI_R \\ \text{subject to} &: \sum_{R=N1}^{S3} \Delta M_R \le \Delta M_P \\ \text{where} &: 0 \le \Delta M_R \le \Delta M_P \end{aligned} \tag{12}$$

Where

ΔCMI_P	Cumulative value of Δcmi of PEA (Total reduction of customer-minute of interuptions)
ΔCMI_R	Cumulative value of Δcmi of each region
ΔM_P	Limited maintenance resource (Total supplementary maintenance budget)
ΔM_R	Cumulative value of Δm of each region (Allocated maintenance budget for each region)

Finally, after the optimization problem is solved, it will result in the optimal allocation of maintence budget (ΔM_R) for all regions that reduce the total customer-minute of interruptions (ΔCMI_P) the most.

Table 5 shows the optimization results when ΔM_P is set to 30 millions baht in this case study. These optimal results are compared with the results when ΔM_P is equally divided into 2.5 million baht per region that shown in the right columns of Table 5.

The ΔCMI_P and $\Delta SAIFI_P$ obtained from the proposed procedure are shown in the last row of Table 5, which are better than the ΔCMI_P and $\Delta SAIFI_P$ when ΔM_P is equally divided approximately 19% and 13% respectively.

Table 5. Optimally Allocated Maintenance Resources vs. Equally Divided Maintenance Resources of Each Region

Region	Optimal Allocation			Equal Division		
	ΔM_R ($\times 10^6$)	ΔCMI_R ($\times 10^6$)	$\Delta SAIFI_R$	ΔM_R ($\times 10^6$)	ΔCMI_R ($\times 10^6$)	$\Delta SAIFI_R$
N1	3.03	-55.96	-0.89	2.50	-44.12	-0.66
N2	2.28	-32.21	-0.71	2.50	-32.65	-0.69
N3	3.98	-42.33	-1.15	2.50	-25.59	-0.70
NE1	4.15	-48.91	-0.59	2.50	-29.46	-0.30
NE2	5.44	-50.22	-0.54	2.50	-23.08	-0.19
NE3	2.98	-35.55	-0.79	2.50	-29.82	-0.48
C1	1.83	-8.99	-0.48	2.50	-12.28	-0.52
C2	1.28	-7.11	-0.61	2.50	-13.89	-0.98
C3	1.41	-3.37	-0.42	2.50	-5.98	-0.52
S1	1.27	-12.65	-0.44	2.50	-24.90	-0.54
S2	1.36	-3.39	-0.38	2.50	-6.23	-0.43
S3	0.99	-2.68	-0.16	2.50	-5.74	-0.21
PEA	**30.00**	**-303.37**	**-0.61**	**30.00**	**-253.74**	**-0.54**

6. RELIABILITY BENCHMARK SETTING

The ΔCMI_R and $\Delta SAIFI_R$ obtained from the optimal allocation of maintenance resources in Table 5 can be used to set the regional reliability benchmarks (i.e. $SAIFI_R^{BM}$ and $SAIDI_R^{BM}$) using (13) and (14) respectively.

$$SAIFI_R^{BM} = SAIFI_R^{IN} + \Delta SAIFI_R \quad (13)$$

Where

$SAIFI_R^{BM}$ Benchmark of *SAIFI* of each region

$SAIFI_R^{IN}$ Initial value of *SAIFI* of each region

$$SAIDI_R^{BM} = SAIDI_R^{IN} + \Delta SAIDI_R \quad (14)$$

Where

$SAIDI_R^{BM}$ Benchmark of *SAIDI* of each region

$SAIDI_R^{IN}$ Initial value of *SAIDI* of each region

The logarithmic trend curves are used to fit the last 4-year values (excluding an outlier) of $SAIFI_R$ and $SAIDI_R$ in order to find the $SAIFI_R^{IN}$ and $SAIDI_R^{IN}$ which are used as the base values for reliability benchmark next year. The logarithmic functions used to fit the data can be described as (15) and (16) respectively. In this work, an assumption is made that the reliability indices cannot be reduced below those of previous years without implementation of any extra maintenance activities.

$$SAIFI_R^{IN} = A \ln(t) + B \quad (15)$$

$$SAIDI_R^{IN} = A \ln(t) + B \quad (16)$$

Where

A , B Constant parameters resulted from curve fitting

t Year t starting from 1 to 4 where $SAIFI_R^{IN}$ and $SAIDI_R^{IN}$ are obtained at $t = 4$

For example, the actual *SAIDI* of region N3 during years 2009-2012 are 256.39, 260.38, 227.72 and 205.05 minutes respectively. Fig. 7 shows the logarithmic trend curve used to fit these data. To improve the accuracy, the outlier (256.39) is excluded before fitting again. The new curve is presented in Fig. 8. Thus, the $SAIDI_{N3}^{IN}$ to be used as the base value of year 2013 is -79.87ln(4)+315.66 = 204.93 minutes.

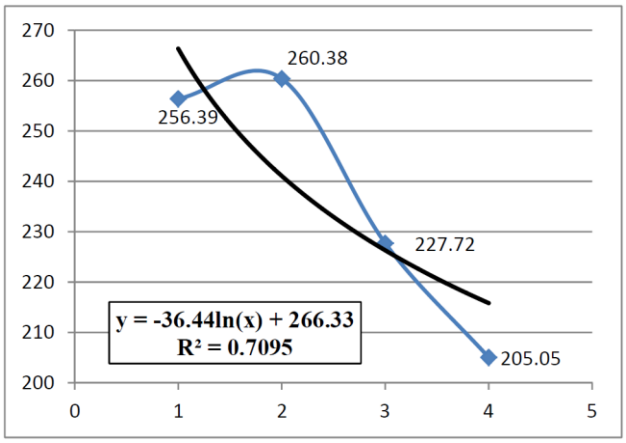

Fig.7 Logarithmic Trend Curve of SAIDI of Region N3

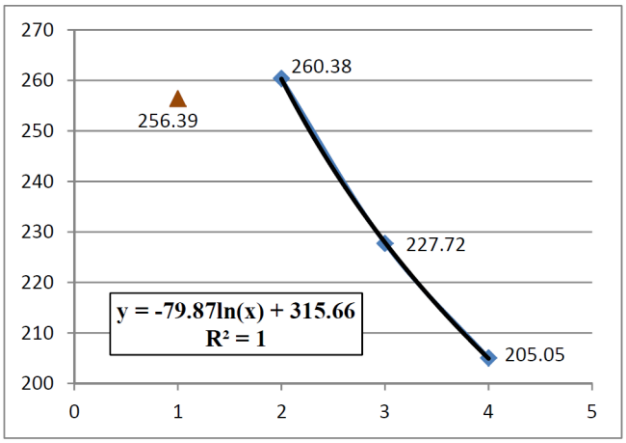

Fig.8 Logarithmic Trend Curve of SAIDI of Region N3 Without an Outlier

After the base value of *SAIFI* and *SAIDI* are found, the benchmarks of *SAIFI* and *SAIDI* for all PEA regions can be calculated by using (13) and (14). For example, $\Delta SAIDI_{N3}$ = -42.33×10^6/1,039,460 = -40.72. Therefore, $SAIDI_{N3}^{BM}$ = 204.93-40.72 = 164.21 minutes.

Table 6 shows the benchmarks of *SAIFI* and *SAIDI* for the year 2013 compared with the actual *SAIFI* and *SAIDI* of the year 2012.

Table 6. Benchmarks of *SAIFI* and *SAIDI* for 12 PEA Regions

Region	Actual *SAIFI* (2012)	$SAIFI^{BM}$ (2013)	Actual *SAIDI* (2012)	$SAIDI^{BM}$ (2013)
N1	7.58	7.27	234.53	222.65
N2	6.75	6.56	235.99	225.14
N3	7.30	7.06	205.05	164.21
NE1	8.50	8.18	313.05	280.37
NE2	7.58	7.32	313.54	281.67
NE3	7.27	7.04	286.27	261.49
C1	5.98	5.91	176.23	170.01
C2	6.63	6.52	195.11	183.38
C3	6.00	5.92	162.15	157.72
S1	7.71	7.44	296.77	280.02
S2	13.43	12.79	552.24	496.11
S3	8.56	8.31	369.40	345.56
PEA	**7.81**	**7.57**	**281.19**	**259.70**

7. CONCLUSIONS

This paper presents a practical procedure of maintenance resource allocation based on the reliability improvement opportunity of power distribution systems. In this research, supplementary maintenance activities are selected by the modified RCM analysis to raise the reliability level of each PEA region. The optimization problem is formulated in order to optimally allocate maintenance resources to all regions with the obective of minimizing the total *CMI* of the whole PEA system. The optimal resource allocation resulted from the proposed procedure offers the most cost-effective maintenance programs, and can be further used to set the reliability benchmarks of power distribution systems.

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An Assessment method of Reliability Improvement on Power Distribution Systems in Large Cities

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Abstract*—This paper presents an assessment method of reliability improvement on power distribution systems in large cities. First, appropriate activities are selected for reliability improvement such as converting overhead distribution lines to underground cables, replacing bare conductors (BC) and partial-insulated cables (PIC) with spaced aerial cables (SAC), installing load break switches with a Fault Detection Isolation and Restoration (FDIR) system. Then, the method of reliability assessment, which will be employed after the systems are improved, is proposed. For underground sections, the reliability is evaluated from the failure rate of installed compact type unit substations. For those remaining overhead power distribution systems (OPDS), the reliability indices can be evaluated by using interruption records classified by type of protective devices. Finally, the numerical results are obtained through the given procedure in terms of improved reliability indices, SAIFI and SAIDI, of the selected feeders in large cities of Thailand.*

***Keywords*— Reliability, Large city, SAIFI, SAIDI, Power Distribution System, Underground**

NOMENCLATURE

N_i Number of interrupted customers whenthe protective device type i operates

$N_{i,city}$ Number of interrupted customers in large city when the protective device type i operates

N_{feeder} Total number of customers in feeder

n_P Number of protective device types on feeder which are unit substation, breaker, recloser and fuse

$n_{p,i}$ Number of the protective device type i on feeder

λ_i Failure rate of the protection zone of the protective device type i

λ_{us} Failure rate of the unit substation

$O_{i,k}$ Number of interruptions of the protective device k type i

$DT_{i,k}$ An outage time of the protective device k type i in considered year

y Number of considered year

r_{us} Repair time of the unit substation

$r'_{s,ug}$ Repair time of the underground section

$r'_{s,oh,i}$ Repair time of a section in the protection zone of the protective device type i on OPDS after improvement

$\%_{cc,oh,i}$ Percent of controllable causes in the protection zone of the protective device type i on OPDS

$\lambda_{cc,oh,i}$ Failure rate of controllable causes in the protection zone of the protective device type i on OPDS

$\lambda_{uc,oh,i}$ Failure rate of uncontrollable causes in the protection zone of the protective device type i on OPDS

$\lambda'_{s,oh,i}$ Failure rate of a section in the protection zone of the protective device type i on OPDS in large city

k_{cc} Estimated percent of the controllable causes decreasing on OPDS

Number of sections in the protective zone of the protective device type i on main feeder before improvement in large city

$n'_{s,i}$ Number of sections in the protective zone of the protective device type i on main feeder which should be improved in large city

$n'_{s,oh,i}$ Number of OPDS sections in the protective zone of the protective device type i on main feeder in large city after improvement

P_s Average load in each section

P_{feeder} Rated of power load on feeder

1. INTRODUCTION

Large cities are the crowded areas which are the centre of economics. A power interruption can result in losses of economics both directly and indirectly. Direct losses of economics can be described by the customer outage costs. On the other hand, indirect losses can yield a lack of investors' confidence. Most interruptions in large cities are caused by animals, tree contacts, foreign materials and accidents [1], [2]. Moreover, most power distribution systems in the large cities still rely on manual fault isolation. When an interruption occurs, it takes a long time to isolate a faulted section before the remaining sections can be energized again. Therefore, the Provincial Electricity Authority of Thailand (PEA) is developing a reliability improvement project to enhance power distribution systems in the large cities of Thailand so as to eliminate these troubles. This paper presents appropriate activities for the above purpose as follows.

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1. Convert overhead distribution lines to underground cables for vital areas. This activity will eliminate those faults caused by tree and animal contacts, lightning, foreign materials, pollutions, car accidents, etc. Also, it provides more safety and improves urban scenery of the cities.
2. Replace bare conductors (BA) and partial insulated cables (PIC) with spaced aerial cables (SAC) over the rest of the cities. This option requires less investment than the above activity. It is recommended when the budget is limited.
3. Install a recloser before the border of the city to prevent urban customers from interruptions caused by faults outside the city.
4. Install animal guards to cover all live parts. This is to assure that all overhead sections will not be harmed by any animals.
5. Install overhead ground wires (OHGW) for the overhead systems. This activity will reduce risk of lightning strikes on the power lines.
6. Install load break switches with Fault Detection Isolation and Restoration (FDIR) system [3]. This will significantly reduce outage duration of the system, and only faulted section will experience a sustained interruption.

To quantify the reliability benefits from the selected activities, a practical method of reliability assessment is introduced. For underground sections, the reliability is evaluated from the failure rate of installed compact type unit substations. For those remaining overhead, the reliability indices can be evaluated by using interruption records classified by type of protective devices. This approach is much more convenient than those requiring failure rates of all equipment installed on the feeders.

To illustrate the details of this research, this paper is organized as follows. The proposed method of reliability assessment is introduced and explained in Section 2.Parameters and numerical results of assessment of the selected feeders in large cities are presented in Section 3. Finally, conclusions of this work are given in Section 4.

2. METHOD OF RELIABILITY ASSESSMENT

SAIFI and SAIDI are the reliability indices commonly used in worldwide. They are also used in this work to measure effectiveness of the reliability improvement project. The SAIFI and SAIDI indices of a feeder in large cities prior to reliability improvement can be determined by equations (1) and (2), respectively. [4]

$$SAIFI_{Old} = \frac{\sum_{i=1}^{np} \lambda_i \mathrm{N}_{i,city}}{N_{city}} \quad (1)$$

$$SAIDI_{Old} = \frac{\sum_{i=1}^{np} \lambda_i r_i \mathrm{N}_{i,city}}{N_{city}} \quad (2)$$

$$\text{Where,} \lambda_i = \lambda_{i,cc} + \lambda_{i,uc} = \frac{525{,}600}{MTTF_i} \quad (3)$$

$MTTF_i$ is an average of time intervals (minutes) while those sections within protection zone of protective device type i are continuously supplied. $\lambda_{i,cc}$ and $\lambda_{i,uc}$ are the average interruption frequency due to controllable causes and uncontrollable causes respectively, associated with sections within a protection zone of protective device type i.

To determine $MTTF_i$as mentioned above, PEA interruption records for the last 3 years are used in equation (5). In addition [4], the average repair time (r_i) or average down time in other words, of those sections within protection zone of protective device type i can be calculated by equation (6).

$$MTTF_i = \frac{\sum_{j=1}^{y}(525{,}600 \times n_{p,i} - \sum_{k=1}^{n_{p,i}} DT_{i,k})_j}{\sum_{j=1}^{y}\left(\sum_{k=1}^{n_{p,i}} O_{i,k}\right)_j} \quad (5)$$

$$r_i = \frac{\sum_{j=1}^{y}\left(\sum_{k=1}^{n_{p,i}} DT_{i,k}\right)_j}{\sum_{j=1}^{y}\left(\sum_{k=1}^{n_{p,i}} O_{i,k}\right)_j} \quad (6)$$

In this paper, each power distribution feeder supplying the city areas is divided into 2 zones as shown in Figure 1. Zone 1 covers sections within the protection zone of protective devices responsible for only urban area. As a result, this zone covers only urban customers. Zone 2 includes the other sections protected by the recloser so it may cover some customers in urban and suburb areas.

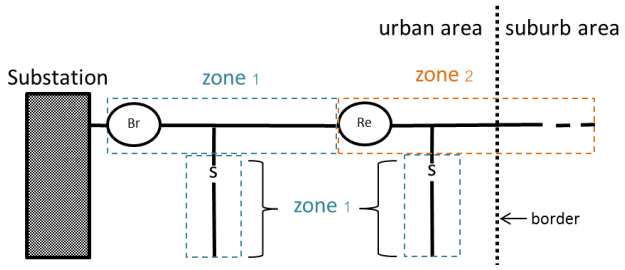

Fig.1. Zones 1 and 2 of a feeder supplying the city areas

This paper will present steps of reliability assessment associated with the reliability improvement activities. First, load break switches installed with FDIR system [3] are placed on each feeder in every P_s MW of load to reduce the outage duration of unfaulted sections when a permanent fault occurs. Therefore, the number of sections only in the urban area within the protection zone of protective device type i can be found by equation (7).

$$n'_{s,i} = roundup\left(\frac{N_{i,city}}{N_{feeder}} \times \frac{P_{feeder}}{P_s}\right) \quad (7)$$

Secondly, a key portion of overhead power distribution lines is converted to underground cables. After this conversion, the corresponding customers will be supplied electricity by unit substations. As a result, the reliability of underground systems depends on the failure rate of unit substations (US). In this paper, an assumption is made that only the first section of each feeder is converted to underground systems because of a limitation of budget. In addition, the rating of all pad-mounted transformers used in underground systems is selected at 500 kVA, with utilization factor ($U.F.$) of 0.55 along with power factor ($P.F.$) of 0.90. Then, the number of unit substations can be determined by equation (8).

$$n_{us} = \frac{MVA_{TR} \times U.F. \times P.F.}{P_s} \quad (8)$$

Third, a recloser is installed on each feeder at or before the border of urban area to prevent the customers in urban

areas from interruptions caused by faults in suburb areas. Then, the failure rate of each overhead section in urban areas is determined from equation (9) [2], [4].

$$\lambda'_{s,oh,i} = \begin{cases} \left[\lambda_{uc,oh,i}\right] & \text{;for zone 1} \\ \left[\frac{N_{i,city}}{N_i} \times \frac{(k_{cc}\lambda_{cc,oh,i}+\lambda_{uc,oh,i})}{\overline{n_{s,i}}}\right] & \text{; for zone 2} \end{cases} \quad (9)$$

Where, $\lambda_{cc,oh,i} = \%_{cc,oh,i} \times \lambda_i$,

$\lambda_{uc,oh,i} = (1 - \%_{cc,oh,i}) \times \lambda_i$ and

$$\overline{n_{s,i}} = \begin{cases} \max(n_{s,i}, n'_{s,i}); & \text{where i is breaker or recloser} \\ 1 & \text{;where i is fuse by lumping all sections protected by fuses as one section} \end{cases}$$

Thus, the number of overhead sections in the urban area is resulted from equation (10).

$$n'_{s,oh,br} = \overline{n_{s,br}} - \overline{n_{s,re}} - 1 \quad (10)$$

Due to most electricity users in large cities are residential customers uniformly distributed along feeders, the number of customers of each section can be approximated by equation (11).

$$N_s = \frac{N_{br,city}}{(\overline{n_{s,br}})} \quad (11)$$

Finally, the remaining activites for reliability improvement on overhead distribution systems are listed below:

1. Replace bare conductors (BC) and partial-insulated cables (PIC) with spaced aerial cables (SAC) in order to eliminate the outage causes due to animals, trees, foreign materials and accidents.
2. Install overhead ground wires to reduce power interruptions caused by lightning strikes.
3. Install animal guards to cover all live parts at transformer bushings and drop-out fuses to eliminate those interruptions caused by birds, squirrels, snakes, etc.

All interruption causes which can be eliminated by the above activities are summarized in Table1. [2]

Evaluation of reliability indices after improvement is divided into two cases. For underground systems, all customers are fed by a loop distribution system with a number of unit substations. They will be interrupted only when their own unit substation fails. As a result, the failure rate and repair time of unit substations are the key parameters used for reliability evaluation in this case. For overhead systems, when a breaker, recloser or fuse interrupts the fault current, only the faulted section will experience a sustained interruption for r_i minutes, while the other sections can be restored within a shorter time, i.e., the switching time (r'_{sw}). To clarify the given idea, an example feeder resulting from the proposed improvement is shown in Figure 2. Its reliability indices, SAIFI and SAIDI, are expressed as equations (12) and (13) respectively.

Table 1. Interruption causes versus corresponding activities

Improvement activities	Interruption causes			
	Trees	Foreign objects, human accidents	Lightning	Animals
Replace BC, PIC with SAC	✓	✓		✓
Install animal guards				✓
Install OHGW			✓	

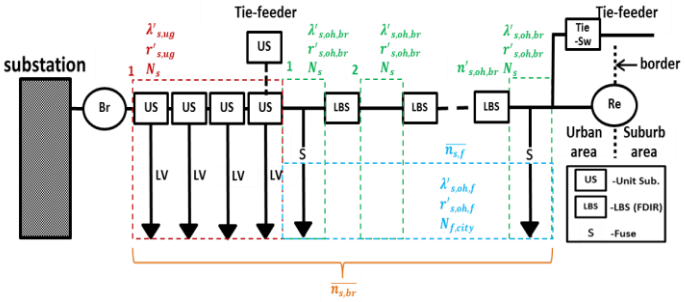

Fig.2. An example feeder resulting from proposed improvement

$$SAIFI_{new} = \frac{\lambda'_{s,ug}N_s + \lambda'_{s,oh,br}N_s n'_{s,oh,br}(\overline{n_{s,br}}-1) + \lambda'_{s,oh,re}N_s\overline{n_{s,re}}^2 + \lambda'_{s,oh,f}N_{f,city}\overline{n_{s,f}}}{N_{br,city}} \quad (12)$$

$$SAIDI_{new} = \frac{\lambda'_{s,ug}r'_{s,ug}N_s + \lambda'_{s,oh,br}r'_{s,oh,br}N_s n'_{s,oh,br} + \lambda'_{s,oh,br}r'_{sw}N_s(\overline{n_{s,br}}-2)n'_{s,oh,br} + \lambda'_{s,oh,re}r'_{s,oh,re}N_s\overline{n_{s,re}} + \lambda'_{s,oh,re}r'_{sw}N_s(\overline{n_{s,re}}-1)\overline{n_{s,re}} + \lambda'_{s,oh,f}r'_{s,oh,f}N_{f,city}\overline{n_{s,f}}}{N_{br,city}} \quad (13)$$

Where, $\lambda'_{s,ug} = \lambda_{us}$ and $r'_{s,ug} = r_{us}$; $N_s = \sum_{i=1}^{n_{p,us}} N_i$

3. PARAMETERS and NUMERICAL RESULTS

In this section, the numerical results of reliability assessment are presented. Two feeders supplying large cities of Thailand are selected for case studies. All parameters required for the reliability assessment are given in Table 2 [1], [2], [4], [6].

Table 2. Parameters required for reliability assessment

Parameter	Value	Unit	Parameter	Value	Unit
k_{cc}	50	%	r'_{sw}	3	min
$\lambda'_{s,ug}$	0.01	failure/ year	P_s	1	MW
$r'_{s,oh,i}$	r_i	min	P_{feeder}	6	MW
$r'_{s,ug}$	390	min			
Probability of equipment operating success				100	%

The first feeder (N_ID06) located in the northern part of Thailand includes 3 types of protective devices, which are one breaker, one recloser and fuses. Its service area covers

both zone 1 and zone 2. An additional recloser is placed at the border of urban area to comply with the reliablity requirement. On the other hand, the second feeder (S_ID05) located in the southern part of Thailand includes only one breaker and fuses, but its service area covers both zone 1 and zone 2. As a result, one recloser is placed at the border of the urban area to enhance its reliability. Table 3 shows interruption records categorized by type of protective devices during years 2010-2012 of these feeders. Results of reliability improvement on these feeders are expressed in terms of SAIFI and SAIDI before and after in Table 4.

Table 3. Interruption records categorized by type of protective devices during years 2010-2012

Feeder	**N_ID06**			**S_ID05**	
Protective device	**Breaker**	**Recloser**	**Fuse**	**Breaker**	**Fuse**
$n_{p,i}$	3	3	6	3	30
$O_{i,k}$ (time)	1	3	6	3	18
$\sum_{k=1}^{n_{p,i}} DT_{i,k}$ (min)	34	21	375	29	861
$\%_{cc,oh,i}$ (%)	100.00	83.33	75.00	33.33	86.11
$n_{s,i}$ (section)	1	4	1	3	1
$N_{i,city}$ (customer)	5,117	4,917	657	4,199	1,628
N_{feeder} (customer)	5,225			5,959	

Table 4. Reliability indices before and after improvement of feeders N_ID06 and S_ID05

Feeder	**N_ID06**		**S_ID05**	
Index	**Before**	**After**	**Before**	**After**
SAIFI (interruption/customer/ year)	1.41	0.55	1.22	0.51
SAIDI (minute/customer/year)	25.10	5.70	18.45	6.90

4. CONCLUSION

In this paper, appropriate activities for reliability improvement are presented for power distribution systems in large cities. The method of reliability assessment is illustrated through actual feeders supplying the large cities. For the sections converted to underground, the reliability is evaluated from the failure rate of installed compact type unit substations. For those remaining overhead, the reliability indices can be evaluated by using interruption records classified by type of protective devices. This approach is much more convenient than the conventional method requiring failure rates of all equipment installed on the feeders. The numerical results are presented in terms of SAIFI and SAIDI before and after improvement of the selected feeders. They show effectiveness of the proposed activities. Also, practicality and simplicity of the assessment method have been verified.

ACKNOWLEDGMENT

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Investment Risk Management to Enhance Feasible of LED Project in Chemical Industry

Suthisak Temkasemsuk, Pornrapeepat Bhasaputra, Woraratana Pattaraprakorn and Kitti Tirawannavit

Abstract— *This paper studies risk management of the lighting replacement with LED in chemical industry. The comparison of existing fluorescent lamp, highbay mercury and metal halide with LED lamp luminaries was investigated and verified the best lighting system for office building and production area in the chemical industry. The investment cost, and financial analysis of different cases were evaluated to clarify the opportunities for investment. However the unit cost of LED is still higher than that of the existing lamps; the replacement plan with the appropriate time schedule and portion is concerned. Longer operating time per day is the first priority. The results from this study show that LED can be applied for energy saving which can reduce 45-65% of energy depending on the type and service hour of the existing lighting. In addition, chemicals industry in Thailand has used the existing lamps 5,000 – 15,000 lamps depending on the size of industry. Moreover, some parts of the existing lighting in chemical industry are necessary to protect the explosion from flammable chemicals. The unexpected accident of explosion is protected by setting up the standard of lighting explosion proof IEC and NEC standards. .*

***Keywords*— LED lighting, Energy conservation, Investment risk management.**

1. INTRODUCTION

The energy management in Thai chemical industry can significantly benefit its business performance through energy savings with ultimately goal to reduce production costs. Reducing energy consumption can be mainly accomplished by having the most efficient use. This means water, steam, natural gas, fuel or electricity required for production must be used as efficiently as possible. Among of the energy has used in the chemical industry, electricity is most consumed. The majority of electricity is used for production, air conditioning, and illumination. This paper studies electricity consumption for the lighting in selected fertilizer industry.

The selected modern fertilizer industry uses the existing lighting Lamps of 7,651 bulbs and electricity consumption is 1,735,000 kWh per year. When comparing to the medium size industries in Thailand, the electricity consumption for lighting system in a selected fertilizer industrial is almost average total electricity consumption of the medium ones. Therefore, energy conservation in the modern fertilizer industry is interesting topic to study the optimal energy management of the lighting system. Finally, more than 90% of the existing lamps are fluorescent lamp, with mercury which is a hazard substance. The amount of mercury reported is up to 30-115 mg for linear fluorescent tubes [1-2]. Mercury content per lamp is developed by reducing mercury amount, but the demand of fluorescent lamps is still increased. In case of end-of-use fluorescent lamp, mercury-containing waste products can be disposed by the incineration or in landfills. However, the practical of waste management in Thailand is required to deal with a large quantity of fluorescent lamps. In addition, the broken fluorescent lamp contains mercury vapor and also contributes the human health risks [3]. In contrast, light emitting diode (LED) lamps provide zero-mercury content and high energy efficiency. The utilization of LED can be options for sustainable energy policy and development which concerns both energy security and environment aspects.

The revolution of lighting technology especially for energy saving is in global concerns. LED lamp become more important for general lighting because of its high energy efficiency and environmental friendliness. LED lamp is not only available for orientation and architectural lighting but more for general illumination applications [4-5]. A technology of LED is basically a small chip being sealed in the epoxy resin inside. Based on the priciple of diode, the working voltage of general LED lights is 2-3.6 V and current is 0.02-0.03 A, which means the power consumption is approximately 0.1 W and LED life time is over 50,000 hours.

Figuer1. LED lamp

The modernized fertilizer industry has the complicated process which needs a few kinds of the energies to supply high technology automation machines. In the Fig.2, the

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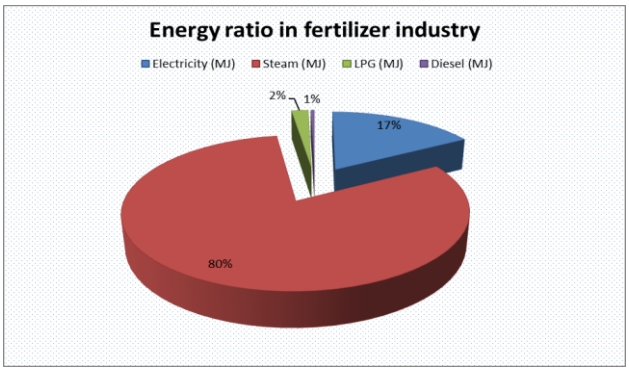
energy consumption has used in fertilizer industry is mainly from steam about 80% and from electricity about 17%. Electricity cost in fertilizer industry is divided to 3 parts. First of all, electricity cost for production process is the largest portion. The second and third portions are electricity has used for air conditioning and lighting system.



Figuer2. Energy consumption in the fertilizer industry

Electricity consumption is interesting issue by starting from the lighting system due to easily manage and not affect to the production. Moreover, some parts of the existing lighting are necessary to protect the explosion from flammable chemicals. The unexpected accident of explosion is protected by setting up the standard of lighting explosion proof IEC and NEC standards [6]. This paper presents the optimal energy management of the lighting system for a selected fertilizer industry. The existing lighting system in a selected fertilizer industry consists of street light (Metal halide lamps 250 W), Highbay mercury 400W, fluorescent T8 36 W for office building, and T8 36 W for lighting explosion proof. In addition, risk management of investment cost, replacement plan with the appropriate time and energy consumption are also discussed in term of acceptable economic evaluation with the long life cycle of LED. The simulation results show that LED can replace to the existing lamps with the accepted luminance standard of energy saving maximum more than 65% and life cycle of LED is more than 3-4 times of the existing lamps.

2. Electricity management for lighting in fertilizer industry

Table1 shows summaries of the lighting system in fertilizer industry. The existing lighting has divided by service hour per day is 8, 12 and 24 hour. In addition, the existing lighting has difference of lamp quantity, lamp type and ballast as shows in table1. Therefore, after replacing the existing lamp with LED lamp; the electricity cost can save up to 3.3 million Baht per year.

Table1. Lighting and electricity consumption in fertilizer industry

	Existing		LED System		Enegy consumption					
					Watt		Existing Lamp Baht/Year	New LED Lamp Baht/Year	Energy saving Baht/Year	Energy saving (%)
Item	Lamp type	Quantity	New LED Lamp	Service hour	Existing Lamp	LED Lamp				
1	FL 13W + Iron	45	LED Tube 11W	8	23	8	10,578	3,679	6,899	65.2
2	FL 18W + Iron	4	LED Tube 11W	8	28	10	1,145	409	736	64.3
3	FL 36W + Iron	2,822	LED Tube 20W	8	46	20	1,326,679	576,817	749,862	56.5
4	Highbay Mecury 400w	26	Highbay LED	8	440	175	116,917	46,501	70,416	60.2
5	FL 36W + EL	1,745	LED Tube 20W	12	37	20	989,781	535,017	454,764	45.9
6	FL 40W + EL	1,254	LED Tube 20W	12	41	20	788,177	384,476	403,700	51.2
7	FL 36W + Iron	114	LED Tube 20W	12	46	20	80,391	34,952	45,438	56.5
8	Metal halide 250w	141	Street light LED	12	275	110	594,421	237,768	356,652	60.0
9	FL 36W + EL	200	LED Tube 20W	24	37	20	226,884	122,640	104,244	45.9
10	FL18w + Iron	96	LED Tube 10W	24	28	10	82,414	29,434	52,980	64.3
11	FL36w + Iron	1,191	LED Tube 20W	24	46	20	1,679,739	730,321	949,418	56.5
12	Highbay Mecury 400w	13	Highbay LED	24	440	175	175,375	69,752	105,624	60.2
		7,651					6,072,499	2,771,766	3,300,733	

3. Feasibility of LED investment project

Investment risk management to replace the existing lamp with LED is the most important issue to enhance the feasibility of the LED project. Most of the existing lighting system in Thai chemical industry is fluorescent bulb while LED lamp becomes more attractive with longer life time and lower electricity consumption. However, the unit cost of LED is still higher than that of fluorescent lamp more than 10 times. Therefore, investment risk management of LED project have to studies in term of internal rate of return (IRR) and Net Present Value (NPV) have to considered in term of electricity cost and service hour per day has changing. In addition, internal rate of return (IRR) is a formula used to calculate the investment's profitability. Basically, it is the rate of return at which NPV is zero. Net Present Value (NPV) is a tool used to determine whether a project is worth the investments made.

Figure3 shows IRR through the LED life cycle, electricity cost is from 2.9 to 4.8 Baht per unit and service hour is from 8 to 24 hour per day. In addition, IRR will increase while electricity cost and service hour per day has increasing. IRR of LED project at electricity cost 2.9 Baht per unit and service hour 8 hour per day is 21.9 percent. The maximum IRR of this project is electricity cost 4.8 Baht per unit and service hour per day 24 hours IRR up to 99.1 percent.

Figure 3 shows IRR through the LED lift cycle is 21.9 to 99.1 percent. In addition, figure 4 shows NPV through life cycle of LED is 1,985 to 4,458 Baht. Therefore, this LED project is worth the investment.

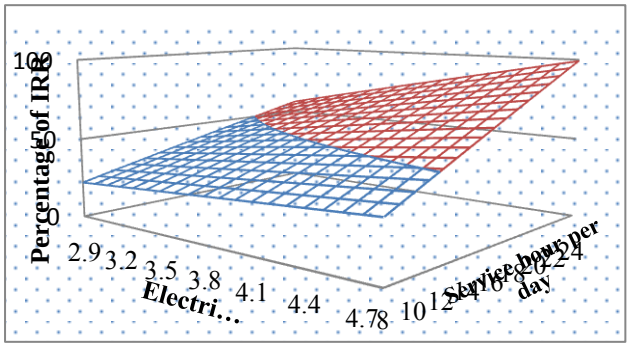


Figure3. IRR of LED investment.

Figure4 shows NPV through the LED life cycle. NPV of this project is more than zero in every electricity cost and service hour per day. In addition, the electricity cost and service hour per day increase, NPV also increases. The minimum and maximum of NPV are 1,985 and 4,458 Baht; therefore, the figure4 and 5 has shown that this project is worth to investment.

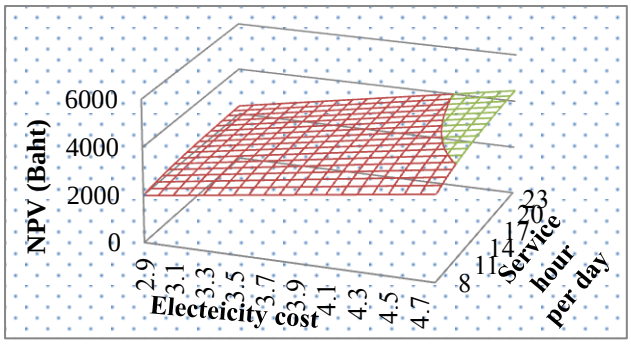


Figure4. NPV of LED investment

4. Investment risk management of LED project

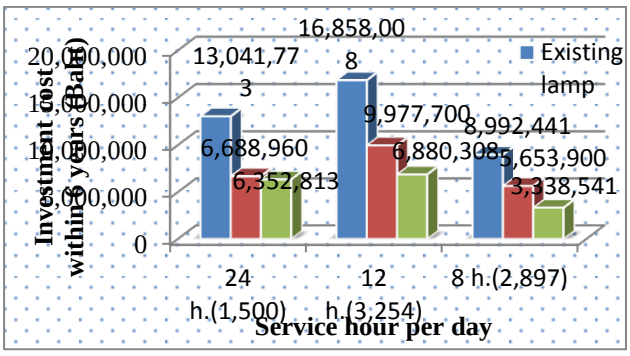


Figure5. Investment cost of LED & Existing lighting

Figure5 shows operation cost and maintenance cost of the existing lamp compared with investment cost and operation cost of LED with difference service hour and number of lamp. In addition, electricity cost saving of LED which service hour 24, 12, and 8 hour are 6.35, 6.88 and 3.34 MB respectively.

The LED ordering in large volume can make LED price decrease as showed in table2. In addition, when LED price has decreasing affect to payback period faster. Therefore, the fertilizer industry has used the existing fluorescent lamp 7,471 lamps which can replaced to LED tube with LED price is 1,100 Baht; payback period is 1.4 years. Moreover, the fertilizer industry has used the existing Metal halide and Highbay Mecury are 141 and 39 lamps which can replaced to LED with payback period are 3.2 and 2.2 years respectively.

Table2. Quantity of LED ordering

Number of order	1-100	101-1,000	1,001-3,000	3,001-5,000	5,001-10,000	10,001-15,000	15,001-20,000
LED Tube	1,600	1,500	1,400	1,250	1,100	1,000	900
LED MH.	18,000	16,000	14,000	14,000	14,000	14,000	14,000
LED HB.	18,000	16,000	14,000	14,000	14,000	14,000	14,000
LED tube (PB.)	2.0	1.9	1.8	1.6	1.4	1.3	1.1
LED MH. (PB.)	3.6	3.2	2.8	2.8	2.8	2.8	2.8
LED HB. (PB.)	2.2	2.0	1.7	1.7	1.7	1.7	1.7

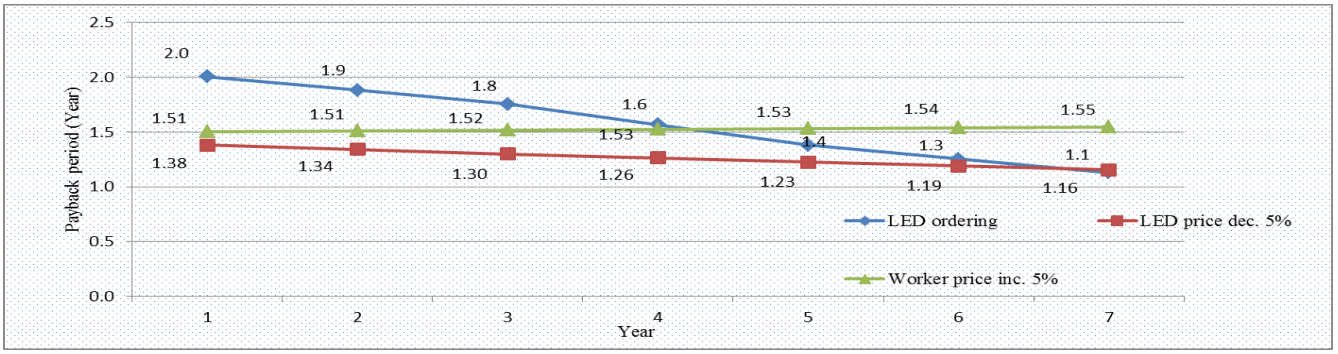


Figure 6 Payback period comparing in difference case

Figure 6 shows payback period of LED project in case of LED ordering, LED price decreasing rate per year and worker price changing rate per year. Thus, in figure 6 shows that LED price decreasing rate 5% per year and worker price increasing rate 5% per year are a little bit effect to the payback period of LED project changing. On the other hand, large volume of LED ordering has much effect to the LED investment. Therefore, cheaper LED price is much effect to the payback period shorter.

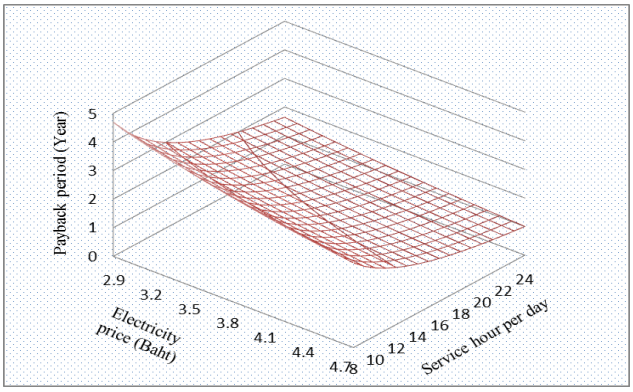


Figure7. Payback period of LED with difference service hour per day

Figure7 shows payback period of LED with difference service hour per day. In fertilizer industry has divided the existing lighting by service hour per day is 8, 12 and 24 hour. In addition, electricity price has increasing in every year. In figure 7 has shown electricity price 2.9 to 4.8 Baht per unit and service hour per day is 8, 12 and 24 hour respectively. Therefore, higher electricity price and longer service hour per day are effect to payback period shorter.

On the condition that industry has considered to replace the existing fluorescent lamp in some portion. The payback period of the LED replacement to the existing lighting system with different service hours has calculated and shown in Figure 7. The payback period is shorter when the service hour is longer. Therefore, the existing lighting which 24 service hours is the first priority.

5. LIFE CYCLE COST ANALYSIS

The life cycle cost (LCC) is a method that combine in economic and engineering knowledge to consider total cost that occurs during the period of use as the capital cost (investment cost), labor and installation costs, electricity cost, maintenance and repairing costs included with disposal cost that can be described in the form of equation (1)

$$LCC = C_{inv} + \sum_{n=1}^{N} \left[\frac{C_n}{(1+i)^n} \right] \quad (1)$$

Where

LCC	is life cycle cost
C_{inv}	is initial investment cost
C_n	is operation cost and maintenance installation cost all of year n
N	is life time of equipment
i	is discount rate (MLR)

This paper considers the LCC of whole lighting system in a selected fertilizer industry which divided by the service hour are 8, 12 and 24 hours, respectively.

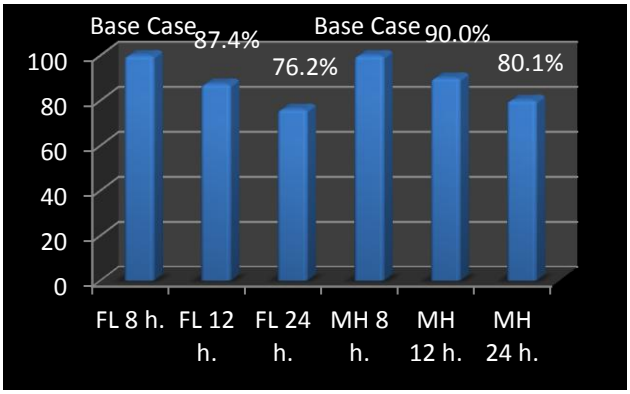


Figure 8 LCC of lighting bulbs with different service hour

Figure 8 shows that the percentage of LCC (both existing fluorescent and metal halide lamps), the base case is 8 service hours both the existing fluorescent and metal halide. Therefore, the percentage of LCC which is 24 service hours will be less than service hour 12 and 8 hours, respectively.

6. Conclusion

According to various types and service hours of lighting system in a selected fertilizer industry, the appropriate redesign for lighting system is needed to enhance the energy management ability. The simulation results show that LED lamp can reduce the energy consumption up to 65%. Therefore, energy cost saving of the lighting system in fertilizer industry has directly affected to the operating cost saving and can enhance profit for fertilizer product. Finally, the additional benefit of LED lamp is environmental friendly in term of mercury reduction.

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Failure Rate Analysis of Power Circuit Breaker in High Voltage Substation

Thanapong Suwanasri, May Thandar Hlaing and Cattareeya Suwanasri

Abstract— *This paper proposes the failure rates of power circuit breakers at the system voltage level of 115kV for control and protective system in power substation. Firstly, the recorded failure data of the existing power circuit breakers in the high voltage substations are analyzed. Secondly, the data analyzes are performed such as the classification of different failure types by separating three main groups such as live parts and insulation, control parts, and operating mechanism parts during the failure event year period from 1989 to 2011 including the total number of failed 607 power circuit breakers. Finally, failure rates and mean time between failures (MTBF) for all components in each main part can be estimated by using Weibull distribution technique is discussed for improving the reliability of the high voltage substations such as correct maintenance schedule or renovation tasks of equipment. The proposed method can also used with other high voltage equipment in the power system.*

Keywords— ***Age, failed types, failure rate, failure statistic, power circuit breaker.***

1. INTRODUCTION

Power circuit breaker is one of the most important protection and control apparatus in the power system. It's functions are used to sense a fault current for the control relay to operate the trip opening mechanism and then interrupt the electric circuit for preventing the power supply interruption in the power system. The power circuit breakers with high failure statistic should be analyzed intensively for preventing unpredictable failure in order to determine the reliability of circuit breakers components and system reliability. Various numbers and technologies of power circuit breakers were installed in the power system. The deterioration of power circuit breakers depends on equipment quality, operation such as load stress, maintenance, surrounding environment such as temperature, moisture, pollution, and etc.

In this paper, power circuit breakers at the system voltage level of 115kV including the total number of failed 607 breakers during the period from 1989 to 2011 have been analyzed. The objective of this paper is to describe a method for estimating the key reliability parameters such as failure rate and mean time between failure (MTBF) from recorded failure data of the Electricity Generating Authority of Thailand (EGAT) by using Weibull distribution technique for improving the reliability evaluation purpose. Then, the correct maintenance schedule or renovation tasks of equipment with the minimum cost can be applied.

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2. CLASSIFICATION OF FAILURE TYPES FOR RELIABILITY ANALYSIS

As the normal opening and closing motion of the power circuit breakers depends on their components working capability, control, and operating mechanisms are very important for the performance and reliability of power circuit breakers [1]. In this paper, the components of circuit breaker are divided into three main parts such as live parts and insulation, control parts, and operating mechanism parts. Firstly, the live parts and insulation are separated into two sub-components that consist of (1)main insulation to earth and (2)making and breaking units. Secondly, control parts include (1)auxiliary switches and associated drives, (2)contractors, relays, heaters, thermostats, fuses, (3)gas density supervision, and (4)triping and closing units. Lastly, operating mechanism parts take account of (1)actuator, (2)compressors, motors, pump, pipe union, (3)control elements, (4)counter, (5)damping device, (6)energy storage, (7)mechanical transmission, and (8)no return device, respectively.

The numbers of failed breakers for each main part are 91units, 153units, and 363units respectively and totally 607 breakers are observed. According to the recorded failed data, the most failure percentages are 52% at making and breaking units for live parts and insulation, 30% at contractors, relays, heaters, thermostats, fuses for control parts, and 23% at counter for operating mechanism parts. The second are the main insulation to earth 48%, gas density supervision 27% and mechanical transmission 14% for each main part respectively as shown in the Figure-1 to Figure-3.

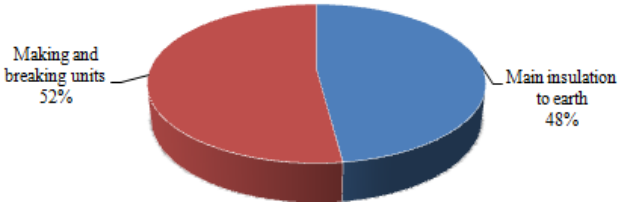

Fig.1. Failure Percentage for Live Parts and Insulation

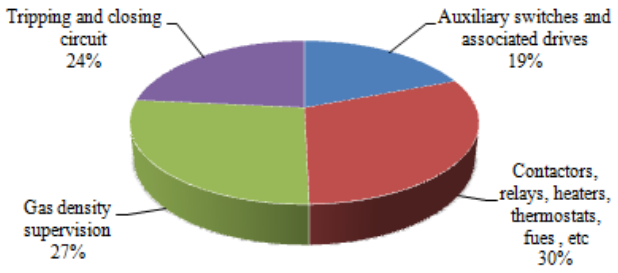

Fig.2. Failure Percentage for Control Parts

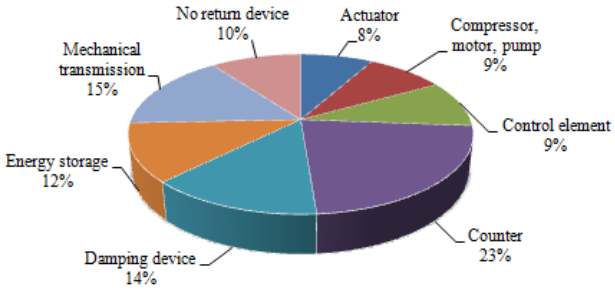

Fig.3. Failure Percentage for Operating Mechanism Parts

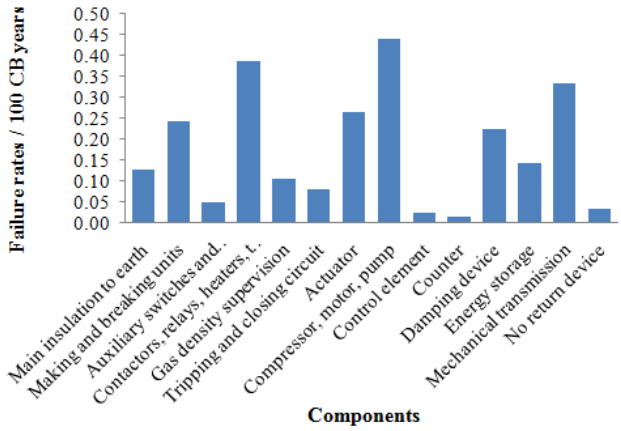

Fig.4. Failure Rates for All Components of Circuit Breaker

Table 1. All Components and Their Number of Failures

Type of Components	No. of failures	CB years	No of failures/ 100CB years
Main insulation to earth	31	24472	0.127
Making and breaking units	60	24472	0.245
Auxiliary switches and associate drives	12	24472	0.049
Contractors, relays, heaters, etc	95	24472	0.388
Gas density supervision	26	24472	0.106
Tripping and closing circuits	20	24472	0.082
Acuator	65	24472	0.266
Compressors, motors, pumps, pipe union	108	24472	0.441
Control elements	6	24472	0.025
Counter	4	24472	0.016
Damping device	55	24472	0.225
Energy storage	35	24472	0.143
Mechanical tranismission	82	24472	0.335
No return device	8	24472	0.033
Total	607		

Table 1 represents the number of failures by 100CB years for all components in each main part [2]. Their results are shown in Figure-4. It can be seen that the most failures rate is 0.441 at compressor, motors, pumps, pipe union of operating mechanism part. The second is 0.388 at contractors, relays, heaters, thermostats, fuses of the controls parts, and the third failure rate is 0.335 at mechanical transmission of operating mechanism parts respectively.

3. METHOD FOR ESTIMATING RELIABILITY PARAMETERS

Weibull distribution technique is one of the most widely used for accurate failure analysis, failure forecast, aging and reliability [3]. Firstly, the recorded failure data of the existing power circuit breakers in the high voltage substations are analyzed. Then an order of failure events is ranked. Finally, median rank F(t) or probability of failure is calculated by Equation (1).

$$\text{Median Rank} = \frac{i-0.3}{N+0.4} \tag{1}$$

where "i" is the adjusted rank and "N" is the number of failures observed.

Weibull parameters can be determined by using straight line formula as follows.

$$y = mx + c \tag{2}$$

$$\text{where, } y = \ln \ln \left[\frac{1}{1-F(t)}\right] \tag{3}$$

$$m = \beta = \frac{\sum_{i=1}^{N} x_i y_i - \frac{\sum_{i=1}^{N} x_i \sum_{i=1}^{N} y_i}{N}}{\sum_{i=1}^{N} x_i^2 - \frac{\left[\sum_{i=1}^{N} x_i\right]^2}{N}} \tag{4}$$

$$x = \ln (t) \tag{5}$$

$$c = \frac{\sum_{i=1}^{N} y_i}{N} - m\frac{\sum_{i=1}^{N} x_i}{N} \tag{6}$$

$$\eta = e^{-\left[\frac{c}{m}\right]} \tag{7}$$

The Weibull probability distribution function (PDF) represents the probability of failure at specific time (t), as written by Equation (8).

$$f(t) = \left(\frac{\beta}{\eta}\right)\left(\frac{t}{\eta}\right)^{\beta-1} e^{-\left[\frac{t}{\eta}\right]^{\beta}} \tag{8}$$

The Weibull cumulative distribution function (CDF) represents the probability of failure at specific time (t), as written by Equation (9) while the reliability and failure rate by Equations (10)-(11).

$$F(t) = 1 - e^{-\left(\frac{t}{\eta}\right)^{\beta}} \tag{9}$$

$$R(t) = 1 - F(t) = e^{-\left(\frac{t}{\eta}\right)^{\beta}} \quad (10)$$

$$\lambda(t) = \frac{f(t)}{R(t)} = \left(\frac{\beta}{\eta}\right)\left(\frac{t}{\eta}\right)^{\beta-1} \quad (11)$$

where β is the shape parameter and η is the life or scale parameter.

Mean time between failures (MTBF) is calculated by using Equation (12).

$$MTBF = \eta\,\Gamma\left[1+\frac{1}{\beta}\right] \quad (12)$$

where, $\Gamma\left[1+\frac{1}{\beta}\right]$ is the gamma function evaluated at the value of (1+ 1/β).

The Weibull cumulative distribution function F(t) for three main parts are as shown in Figure-5 to Figure-7[3]. The horizontal axis shows the values of (x) and the vertical axis is the values of (y) by using Equations (5) and Equation (3) [4].

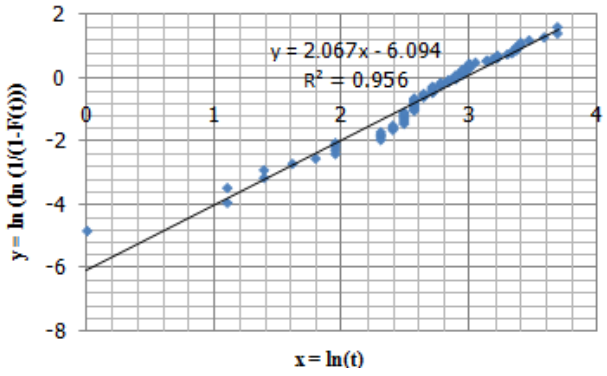

Fig.5. Straight Line of F(t) for Live Parts and Insulation

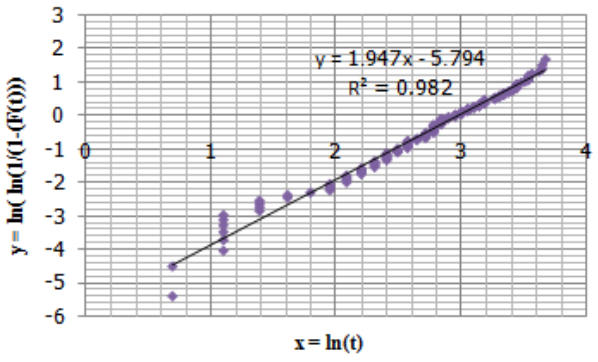

Fig.6. Straight Line of F(t) for Control Parts

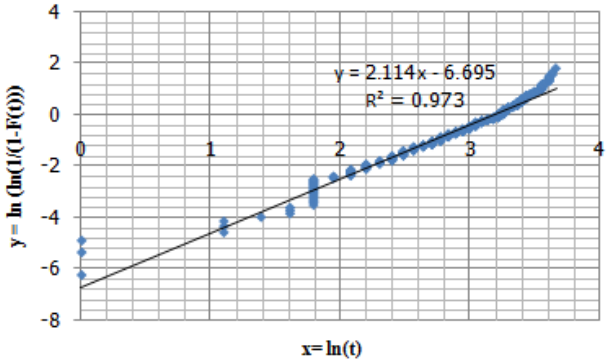

Fig.7. Straight Line of F(t) for Operating Mechanism Parts

4. STATICAL FAILURE ANALYSIS OF POWER CIRCUIT BREAKER

Calculating procedure of Weibull analysis involves data acquisition, data ranking, data plotting and outcome interpreting. After ranking by using Equation (1), the number of failure events are known [3]. Table-1 shows the Weibull reliability parameters, MTBF, and failure rate (λ) of power circuit breakers at the level of voltage 115kV are summarized from historical record from 1989 to 2011 which are scattering and paper-based in nature, are systematically recorded in the central database. Benefits of Weibull analysis are that it provides rationally accurate failure analysis [3]-[6].

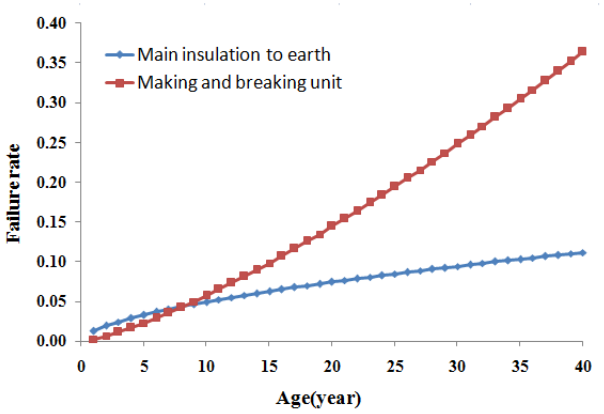

Fig.8. Failure Rates for Live Parts and Insulation

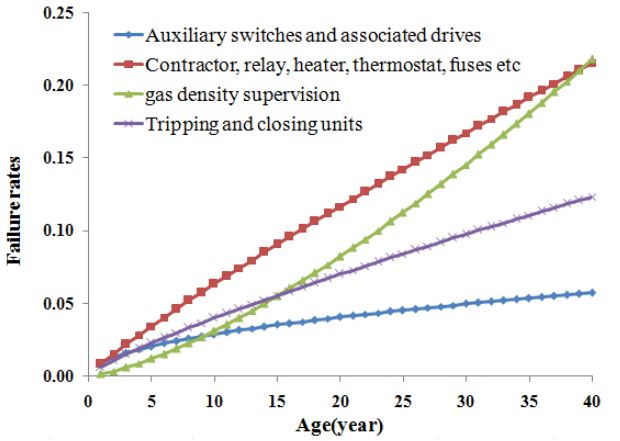

Fig.9. Failure Rates for Control Parts

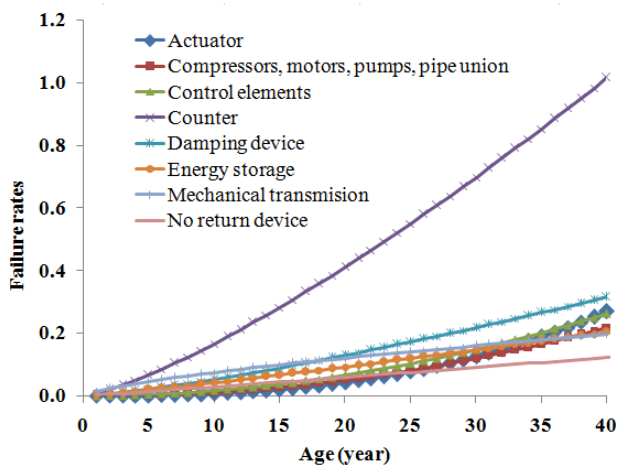

Fig.10. Failure Rates for Operating Mechanism Parts

The most failure rate occurs at making and breaking unit for live parts and insulation as shown in Figure-8. For the control parts, contractors, relays, heater, thermostats, fuses is the most failure occurred and the second failure rate is at gas density supervision as shown in Figure-9. According to Figure-10, the most failure rate is at counter and the second is at damping device for operating mechanism parts.

Table-2 represents the reliability parameters, MTBFs and failure rates for each component. It can be seen that the most failure rates are 0.1664(freq/year) at counter, 0.107(freq/year) at making and breaking units, and 0.1052(freq/year) at damping devices .The second failure rates are 0.0957(freq/year) at contractors, relays, heaters, thermostats, fuses etc. and 0.0946(freq/year) at mechanical transmission. The least failure rates are 0.0469(freq/year) at auxiliary switches and associated drives respectively [3].

Table 2. Reliability Parameters, MTBF, and Failure Rate for Each Component

Type of Components	Weibull Parameters		MTBF (year)	Failure Rate (λ) (freq/yr)
	β	η		
Main insulation to earth	1.5895	20.8894	18.8005	0.0697
Making and breaking units	2.3355	18.2773	16.4496	0.1070
Auxiliary switches and associated drives	1.4972	30.1995	27.1795	0.0469
Contractors, relays, heaters, thermostats, fuses	1.8873	17.8765	16.0889	0.0957
Gas density supervision	2.4086	23.4442	21.0998	0.0880
Tripping and closing circuits	1.8178	23.1004	20.7904	0.0699
Actuator	3.6509	29.7327	26.7594	0.0860
Compressors, motors, pumps, pipe union	3.1011	28.5908	25.7317	0.0818
Control elements	2.9999	26.3143	23.6829	0.0871
Counter	2.3048	11.5177	10.3660	0.1664
Damping device	2.2862	18.9271	17.0344	0.1052
Energy storage	2.1336	21.3189	19.1870	0.0878
Mechanical transmission	1.6907	16.1716	14.5544	0.0946
Non-return device	2.0399	25.9740	23.3766	0.0692

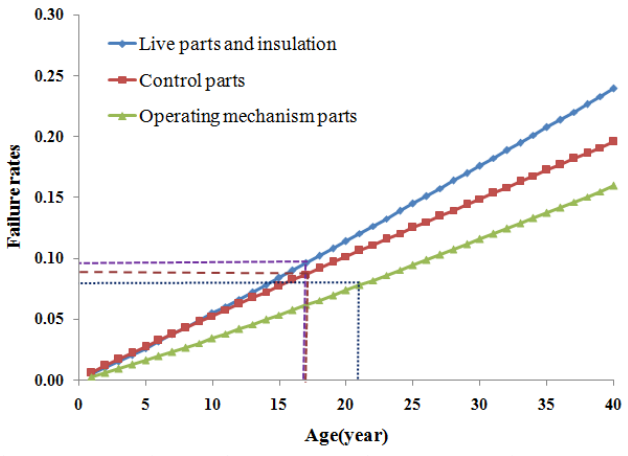

Fig.11. Failure Rates and MTBFs for Each Main Part

Figure-11 shows the failure rates and the MTBF for each part of the circuit breaker. The most failure rate is at live parts and insulation, the second is at control parts and the least failure rate is at operating mechanism parts.

Table 3. Reliability Parameters, MTBF, and Failure Rate for Each Main Part

Type of Components	Weibull Parameters		MTBF (year)	Failure Rate (λ) (freq/yr)
	β	η		
Live parts and insulation	2.0676	19.0644	17.1580	0.0960
Control parts	1.9474	19.5946	17.6351	0.0869
Operating mechanism parts	2.1140	23.7381	21.3643	0.0777

Table-3 shows the reliability parameters, MTBFs, and failure rates for each main parts. It can be seen that the life time of breaker (MTBFs) are nearly the same amount of 17(year) at liveparts and insulation and control parts. For operating mechanism parts is 21(year). The most failure rate is 0.0960(freq/year) at live parts and insulation. The second is 0.0869(freq/year) at control parts and the last failure rate is 0.0777(freq/year) at operating mechanism parts.

4. COMPARISON OF FAILURE RATES FOR ALL COMPONENT

Figure-12 shows the Weibull cumulative distribution function F(t) for all components[3]. Similarly, Fig.13 shows the failure rate and MTBF of all components in the breaker at associated voltage level. In addition, Table-4 shows the values of Weibull parameters, MTBF, and the failure rate of combined all components in the circuit breaker at 115kV voltage level. Each value are 2.0695, 21.8984, 19.7096, and 0.0812 respetively.

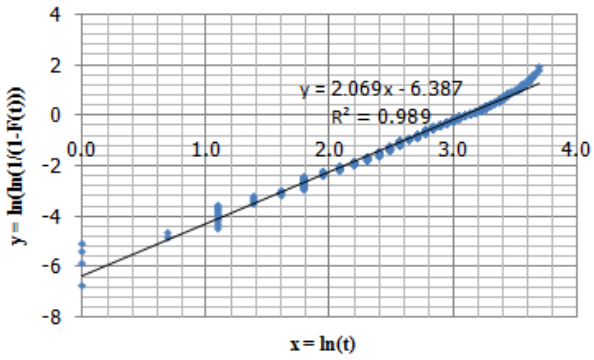

Fig.12. Straight Line of F(t) for Combined All Components

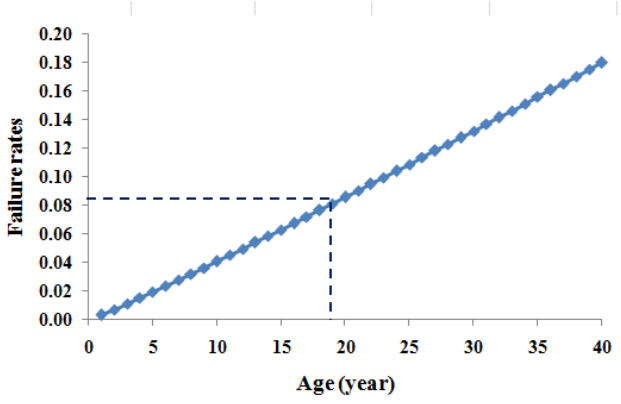

Fig.13. Failure Rate and MTBF for All Components

Table 4. Reliability Parameters, MTBF, and Failure Rate for All Components

Type of Components	Weibull Parameters		MTBF (year)	Failure Rate (λ) (freq/yr)
	β	η		
All components	2.0695	21.8984	19.7086	0.0812

5. CONCLUSIONS

In this paper, the total number of failed 607 breakers are considered during the event year 1989 to 2011 which are originated from separating three main parts such as live parts and insulation, control parts, and operating mechanism parts at the system voltage 115kV. After that, all components failure data are combined and compared the results.The life times of breakers and the failure rates can be calculated from the recorded failure data of EGAT by using Weibull statistic distribution technique.

The value of shape parameter (β) can describe the failure mode of the devices, power circuit breakers in this paper. According to the results, the values of (β) for three main parts are greater than 1. It means that the failure rates are very low at the beginning and significantly higher with increasing time. This can be seen that the failure rates of the components depend on the aging. The life or scale parameter (η) represents the time for which the failure percentage is 63.2%. The MTBF represents the life time of device, in this paper power circuit breaker. The MTBFs are nearly the same amount of 17 year at live parts and insulation and control parts, 21 year at operating mechanism parts and all components is 19 year respectively. The failure rates are nearly the same amount of 0.09 for live parts and insulation and control parts, 0.08 for operating mechanism parts and all components.

Each component has its own failure rate, but the performance of circuit breaker as a whole part depends on the state of all components. For reliability point of view, the breaker components are connected in series, so failure of a single component prevents proper fault interruption and causes breaker failure. If reliability of the components decreases, the system reliability can also be decreased. So, the correct maintenance schedule or renovation tasks of equipment are required for reliability evaluation.

According to the results, the proposed method is approximated life time of the equipment for strategy planning on reliability evaluation. Finally, the study results can be carried out and estimated failure rate, and the life time (MTBF) of other high voltage equipment in the power system.

ACKNOWLEDGEMENT

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The Integrated Energy and Environmental Management for The Expressway Authority of Thailand

Vivat Chutiprapat, Chokechai Sansilah, Pornrapeepat Bhasaputra and Woraratana Pattaraprakorn

Abstract*— *This paper proposes the integrated energy and environmental management by considering high efficiency equipment, which is light-emitting diode (LED) lamp, inverter and evaporative condensing air conditioner for The Expressway Authority of Thailand (EXAT). The EXAT spends two thirds of energy cost in electricity consumption, mainly from lighting and air conditioner. The comparison of the existing equipment with new proposed equipment is evaluated in term of energy consumption, environmental comfort and financial index. Lower energy consumption can be converted to the reduction of carbon dioxide equivalent. The result of this research will be a prototype of suitable solution for energy and environmental management.

***Keywords*— The Expressway Authority of Thailand (EXAT), Light-emitting diode (LED), Energy consumption, Carbon dioxide**

1. INTRODUCTION

According to the BBC report, Bangkok is the worst traffic jam city in the world, which comes from the population and number of vehicles are still increased year by year with significant, especially a policy to refund tax for first-time car buyers in year 2012 [1]. The government and local government have been planned the mega-project of infrastructure, such as sky train to connect the Bangkok Metropolitan Region. However, the single solution to manage the situation cannot be found under the present technology and know-how, but the multidisciplinary is needed to maintain the problem. Expressway Authority of Thailand (EXAT) is the proposed organization to manage the traffic congestion by reduction both of the distance and time for a trip that will be leaded to manage the energy consumption and environmental effect from the vehicles.

More than 7,000,000 automobiles registered in Bangkok metropolitan which affects to the average speed during rush hour in between 19.4 – 23.4 kilometer per hour. However, the average speed in expressway is 60 kilometer per hour which is around 3 times higher than typical road. Based on the cooperated research of EXAT and NECTEC [2], the time reduction can be evaluated in economic term about 59 Baht per trip or 22,656 MB per year. Consequently, economic value of time reduction trip is difficult to convert in actual value that is a social benefit. In addition, the reduction of fuel consumption can be directly evaluated in economic value, according to the cooperated research, 19 Baht per trip can be saved which is 47.5% of toll fee (The average toll fee of express way in Thailand is 40 Baht.) or 6,144 MB per year. From the customer point of view, the toll fee is only 52.5% of payment. The total traffic volume in each expressway is summarized in Table 1.

Table.1 The Total Traffic Volume in Each Expressway

Expressway	Traffic Volume (Avg No./ Day)
Chalome Maha Nakhon	370,214
Si Rat	664,702
Sector AB	321,751
Sector C	178,767
Sector D	164,184
Chalong Rat	181,520
Burapha Withi	137,266
Udon Ratthaya	68,904
Bang Phli - Suk Sawat	202,655
Net	**1,625,260**

As a result of Thailand Energy Statistics 2012 [3], Thailand's final energy consumption in 2012 was 73,316 ktoe or 1,798 billion Baht which is the transportation sector of 26,240 ktoe or 36% of all sectors. While industrial sector is the first rank of final energy consumption at 26,910 ktoe that is less than 1 % of difference with transportation sector. Moreover, the environmental impact from the energy sector is shown in Figure 1. The power generation is the highest portion of CO_2 emission at 40% while the transport is the second rank at 26%. From the cooperated research, not only economic term is considered, but the environmental

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aspect is also enhanced by the express way. According to CO_2 reduction by using express way, CO_2 can reduce 172,000 ton per year, which is equal to 18,700 trees.

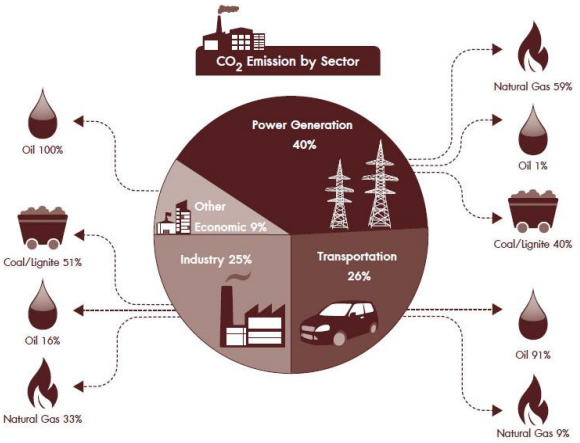

Fig.1. CO_2 Emission by Energy Sector [4]

However, the social benefit in term of time reduction, fuel consumption reduction and CO_2 reduction from express way cannot perform without resources. The EXAT needed the resources to operate and maintenance the expressway for security and convenience reasons that are human resources, energy resources and others. In 2013, the expected facility cost of EXAT are mainly electricity (62% of total facility cost) and fuel cost (30% of total facility cost) to offices and expressway (as presented in Fig.2.), which show the mechanism of optimal operation between reduction of energy consumption and environmental effect from the vehicles and incremental of energy consumption and emission from EXAT.

In this paper, the proposed integrated energy and environmental management by considering high efficiency equipment, which is light-emitting diode (LED) lamp, inverter and water cooled evaporative condenser types for air conditioner in the head office are introduced to EXAT, in addition the financial and economic evaluation will be presented by considering the risk management for both lighting system and air conditioning system project.

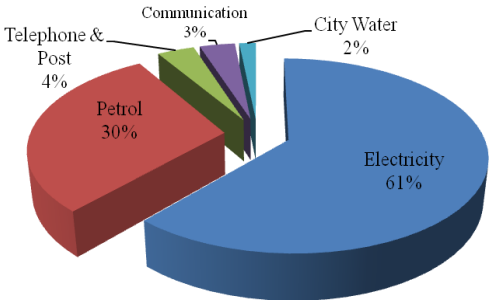

Fig.2. The EXAT's Facility Cost in 2012

2. THE EXISTING ENERGY AND ENVIRONMENTAL MANAGEMENT

In 2012, the electricity consumption of EXAT head office is higher than 2,000,000 kWh/Yr as shown in Figure 3. Electricity consumption of air conditioner is the highest portion at 76% while that of lighting system is the second portion at 12%. There are more 200 air conditioners in the head office (Fig.4) and the most of lighting system is fluorescence lamp of T8 (Fig.5.). As a result, the energy and environmental manage in the air condition and lighting system is focused.

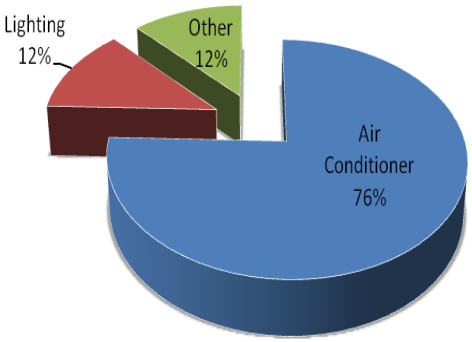

Fig.3. Electricity Consumption of EXAT Head Office in 2012

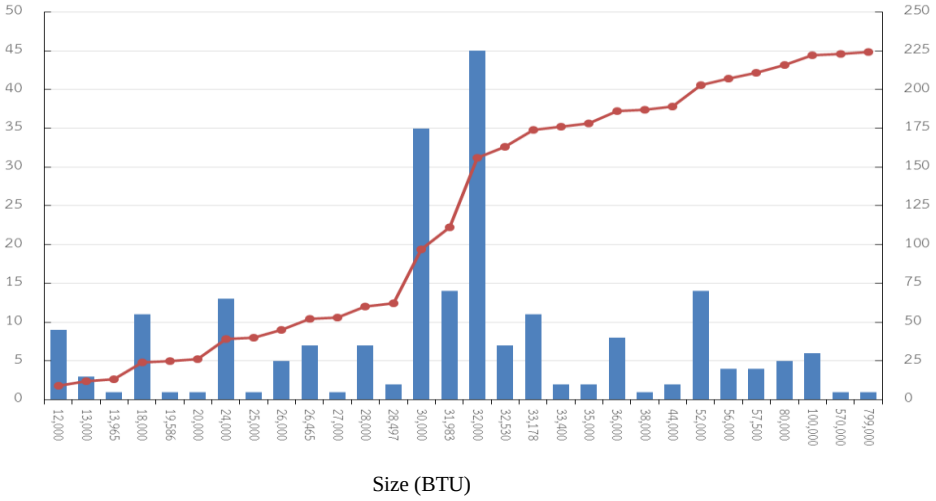

Fig.4. Amount and Accumulated Amount of Air Conditioning System with Various Sizes

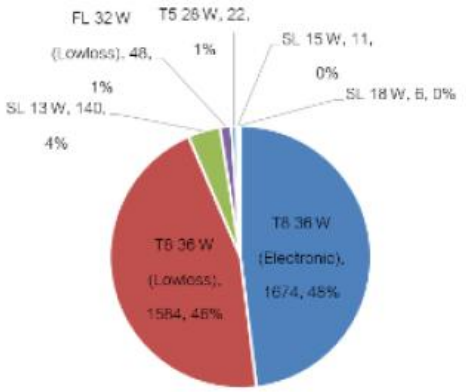

Fig.5. The Portion of Existing Lighting System

Specific energy consumption (SEC) of EXAT head office each month in 2012 is represented in Figure 6. Total SEC of office building is between 12.6 – 16.3 kWh/m^2 while SEC of air conditioners is between 9.9 - 12.3 kWh/m^2 whereas SEC of lighting system is slightly different in each month at average of 1.8 kWh/m^2. SEC is lowest in April due to long holidays such as Chakri memorial day, Thai's new year or Sonkran's day. The SEC in the unit of kWh/m^2/yr of the head office, air conditioner and lighting is 175.56, 131.76 and 21.77 kWh/m^2, respectively.

Table.2 Specific Energy Consumption of EXAT Head Office in 2012 in the Unit of kWh/m^2/yr

SEC (kWh/m^2/yr)		
Total	Air Conditioning	Lighting
175.56	131.76	21.77

3. THE MODERN TECHNOLOGY OF ENERGY AND ENVIRONMENTAL MANAGEMENT

Existing air conditioning system is replaced with the proposed air conditioning system. High efficient air conditioner (AC No.5), air conditioner with inverter (AC Inverter) and air conditioner with evaporative condensing (AC Evaporative) are proposed. An inverter in an air conditioner is used to control the speed of the compressor motor to drive variable refrigerant flow in an air conditioning system to regulate the conditioned-space temperature. Water is sprayed to cool down the condenser accompanied with air flowing, which increase the efficiency of air conditioning that is an evaporative condensing air conditioner.

The revolution of lighting system is the continuous increasing of luminous efficiency (Fig.7.). In the first stage, incandescent lamp was widely used, however, that it is lower efficiency and shorter life time. The higher efficiency lamps are replaced such as fluorescent, metal halide, high pressure sodium, LED, etc. In present, the lighting system with longer life time, higher efficiency and lower energy consumption is required thus LED is the attractive lamp that is still rapidly developed.

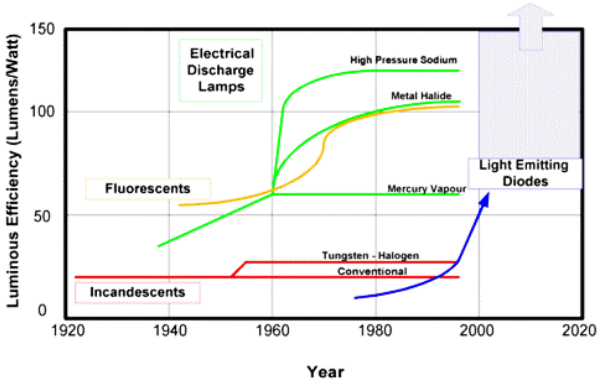

Fig.7. The Revolution of Lighting System with Luminous Efficiency

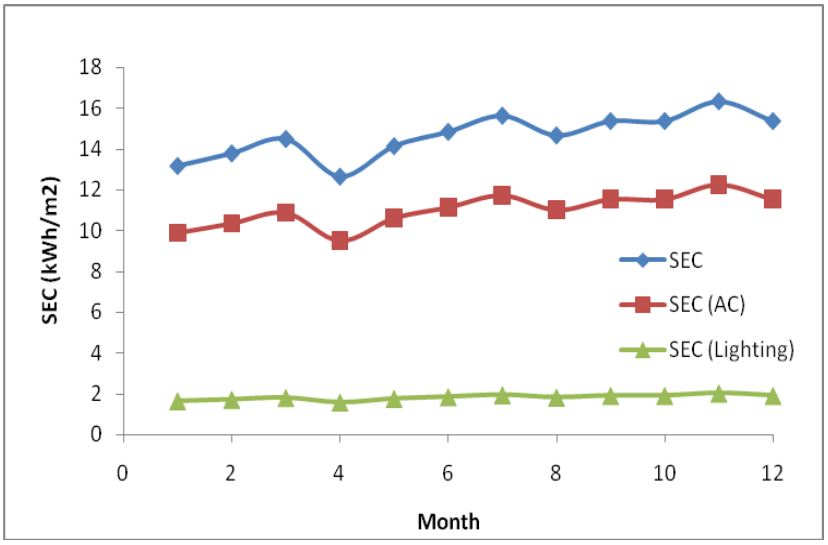

Fig.6. Specific Energy Consumption of Lighting, Air Conditioning and EXAT Head Office in 2012

The existing of air conditioning and lighting system is compared with proposed technologies in the point of electricity consumption, saving and financial index of the projects.

4. SIMULATION RESULTS

According to higher investment cost, the replacement of air conditioning in this simulation is only 30% of total amount of air conditioning while all of fluorescent lamps are changed. Specific energy consumption of EXAT head office with implemented high efficient equipment such as air conditioner no.5, air conditioner with inverter and evaporative condensing air conditioner for air conditioning system; and LED lamp for lighting system is summarized in Table.3. As a result in Table.3, the SEC of the head office is the lowest value about 13% reduction when the replacements with evaporative condensing air conditioner and LED are simulated. However, the financial analysis has to be considered.

Table.3 Specific Energy Consumption of EXAT Head Office with implemented High Efficient Equipment

Replacement Items	SEC ($kWh/m^2/yr$)		
	Total	Air Conditioning	Lighting
Air No.5+LED	156.47	124.23	10.15
Air Inverter + LED	153.21	120.97	10.15
Air Evaporative + LED	152.12	119.88	10.15

Table.4 Financial Analysis of the Replacement with High Efficient Equipment

Replacement Item	Investment Cost (Baht)	Saving (Baht/Year)	Payback Period (Yr)
Air No.5	2,215,600	352,722.20	6.28
Air Inverter	2,880,280	506,660.09	5.68
Air Evap.	2,991,060	557,972.63	5.36
LED	3,485,000	548,466.00	6.35

Table.5 Carbon Dioxide Reduction due to Lower Energy Consumption

Replacement Item	CO_2 Reduction ($kgCO_2/Yr$)
Air No.5	32,801.46
Air Inverter	47,116.94
Air Evap.	51,888.76
LED	51,004.69

Financial analysis of the replacement items in Table.4 shows that investment cost of LED is the highest cost almost 3.5 million Baht with the electricity saving cost of 548,500 Baht and payback period of this project of 6.35. In case of the replacement in air conditioning system, though high efficient air conditioners (No.5) are the lowest investment cost, the electricity saving cost is low. Thus the payback period of the replacement with air condition no.5 is longer than those of other cases. The evaporative condensing air conditioner is the most attractive project with the shortest payback period and the highest electricity saving. However, payback periods of the replacement in lighting system and air conditioning system are quite long due to the operation period of office building around 10 hours which affect to electricity saving cost. Therefore longer operation period per day is shorter payback period. Not only energy consumption reduction is performed, but environmental impact due to carbon dioxide reduction is also executed. When the replacement in air conditioning system with evaporative condensing air conditioner and the replacement in lighting system with LED are implemented, carbon dioxide can be reduced 102,893.45 $kgCO_2$ per year.

5. CONCLUSIONS

The replacements with high efficient equipment especially in air conditioning system and lighting system at office building of EXAT are worth. Nevertheless, the longer operation time is the shorter payback period and the more attractive project. In addition, the electricity usage of EXAT is also from expressway area and tool station and building that some areas operate 24 hours. As a result, the further study will be considered the energy and environmental management of EXAT in the additional areas.

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Maximum Installed Capacity of Solar Power Plant in Thailand By Considering Actual Hourly Load Profile

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Abstract*—This paper proposes an approach to determine the maximum installed capacity of solar power plants in Thailand by considering actual hourly load profiles and the various generated profiles of solar power. Load flow analysis has been applied to analyze the abnormality of the power system due to incremental uncertain generators. The capacity of solar power is limited by voltage stability and frequency response, depending on a characteristic of each power system. In this study, various generated profile and different capacities of solar power were integrated on difference location of the IEEE 30 bus test system under conditions of Thailand's load profiles. The results shown that in the case of spinning reserve of the system is 25 percent, the maximum installed capacity of solar power that can be integrated on each local bus are 20 percent of peaked load. While minimum voltage was observed at 0.92 p.u. on the weakest bus. However, the installed capacity of solar can be increased by increasing the spinning reserve of the system to maintain system reliability. Using this approach, the system operator can be utilized the results to make the protection and planning in order to integrate uncertain renewable source to the electric power system.*

***Keywords*— Maximum installed capacity, Solar power plant, Reliability of power system, Thailand's renewable energy.**

1. INTRODUCTION

Thailand is facing new challenge for both protection and planning in order to maintain reliability and security of the country electric power system. In near futures, large solar power plants are being integrated on the grid due to Thailand has been established the roadmap as the strategy to promote renewable energy though "The renewable and alternative energy development plan for 25 percent in 10 years (AEDP: 2012-2021)". According to the plan, the government has set the target capacity of solar power in 2021 at 2,000 MW while a present total generating capacity is only 75.48 MW [1]. Although solar power is well known as clean energy that does not release pollutants into the environment, but the nature of the resource produced power at most during the daytime with sunlight and generated uncertainty power that depending on the weather which is sometimes a considerable change on a short time scale of minutes [2]-[3].Figure 1 shows representative of various power outputs of a selected solar power plant. The probability of electrical generation at a moment present in different points and colors. The biggest different between the worst efficiency and the best efficiency is around 0.8 at the same time of day. The average generated power of each days are different that the standard deviation is more than 30%, almost in the same week.

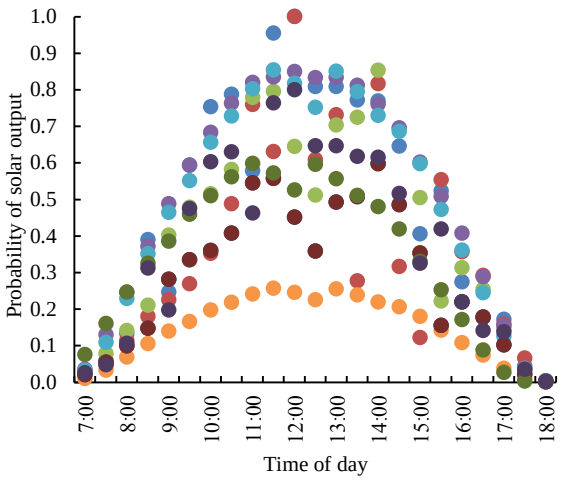

Fig 1. Various generated solar power of selected plant

Another uncertainty factor is electricity loads or electricity demand, which is always changes depending on the time and others complicated factors such as location, weather condition, local culture, government policy, user behaviors, etc. In this study; system loads will assume to follow the hourly load profiles of Thailand as show in figure 2. Due to cause of uncertainty, considerable change and rapid change of the solar resource as well as variability of loads, which are significantly affected to frequency responses and voltage stability of the power system [4]-[6]. Therefore, it is necessary to determine the maximum installed capacity of solar power that can be

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integrated on the power system.

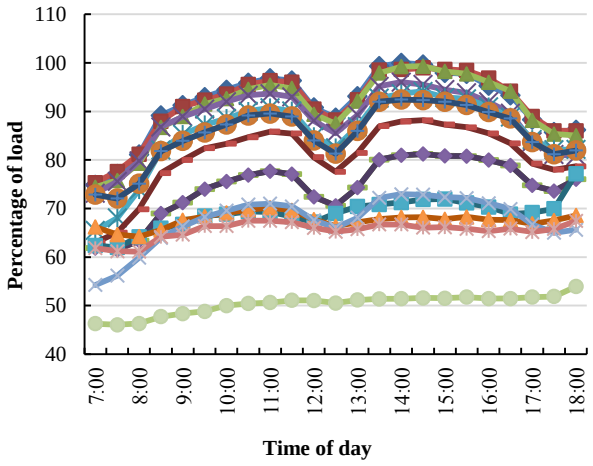

Fig.2 Thailand's hourly load profiles (15 pattern)

2. METHODOLOGY

In this study, the maximum installed capacity of solar power plants on each bus defined as the percentage of maximum capacity of solar power plant that can be connected with the bus without causing of abnormality in the system based on the totally peaked load.

In order to evaluate the maximum installed capacity of the solar power plants in IEEE 30 bus test system (figure 3). Solar capacity 10-50 percent of peaked load was integrated in the different voltage controlled buses (PV buses) and solar output generation randomly generate from 10 pattern of selected plant as show in figure 1. While 15 patterns of Thailand load profiles are used in this simulation. The spinning reserves of system are assuming from 0-30 percent of peaked load. The Newton Raphson method use to analyze load flow of each bus and each line in the system and the algorithm of programming shows in figure 4. The simulation integrated various power and different capacity of a solar power plant on a different local bus until found an abnormality which constrained by frequency response and voltage stability. At this point, the maximum capacity of integration solar power has been found.

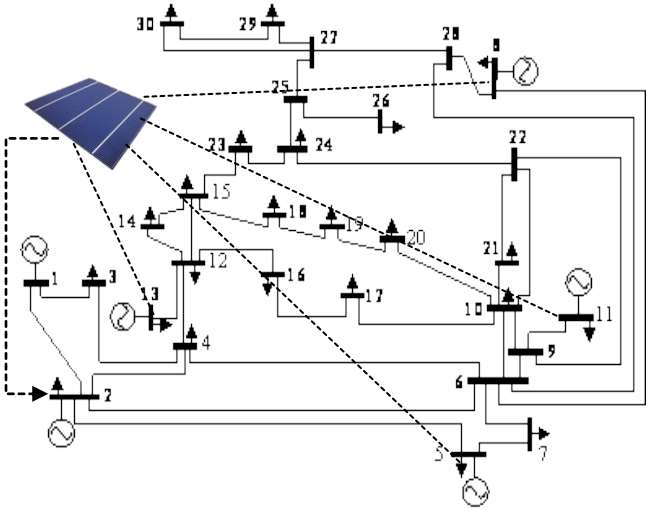

Fig.3 Integration of solar power plant on the modified IEEE 30 Bus test system.

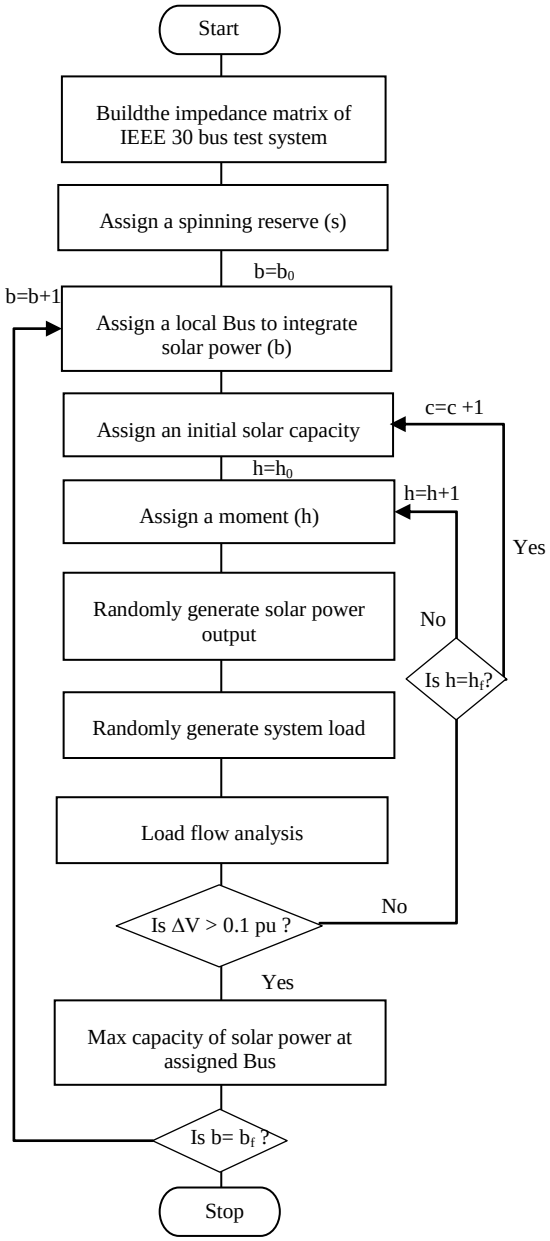

Fig.4 Procedure of the simulation

3. RESULT AND DISCUSSION

3.1Voltage stability

The IEEE power quality standard for voltage variation is allowed under voltage and overvoltage between 0.90-1.10 p.u. for more than 1 minute. Figure 5 shown voltage profile of each bus position in various load condition. Voltage magnitudes of each bus vary between 0.92-1.08 p.u. which in the standard depending on characteristic of each bus. Only at bus no. 9, 26 and 30can be observed the voltage magnitude lower than 0.95 especially when high load condition. The lowest voltage magnitude was observed around 0.92 p.u. at bus no.30 at the peaked load which occurred at 14.00 PM. In fact, voltage variation mostly depending on the load variation. While the intergraded solar power was generated active power which have not directly affected to voltage variation.

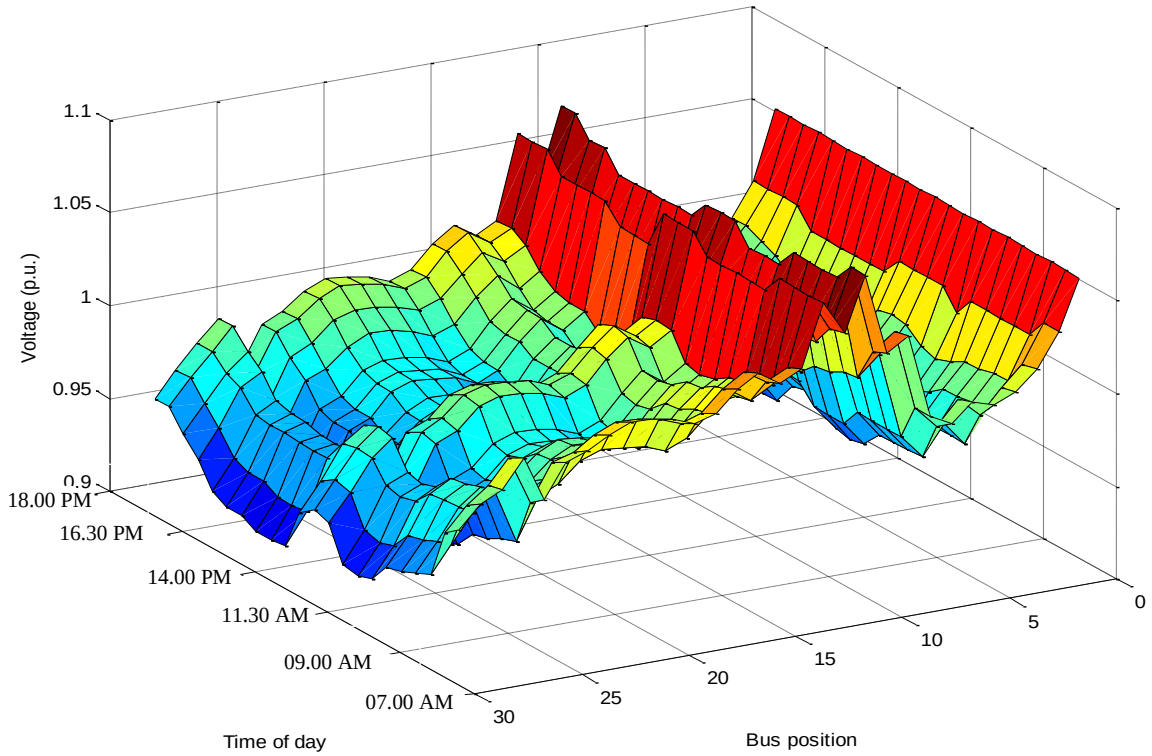

Fig. 5 Voltage profiles of IEEE 30 bus

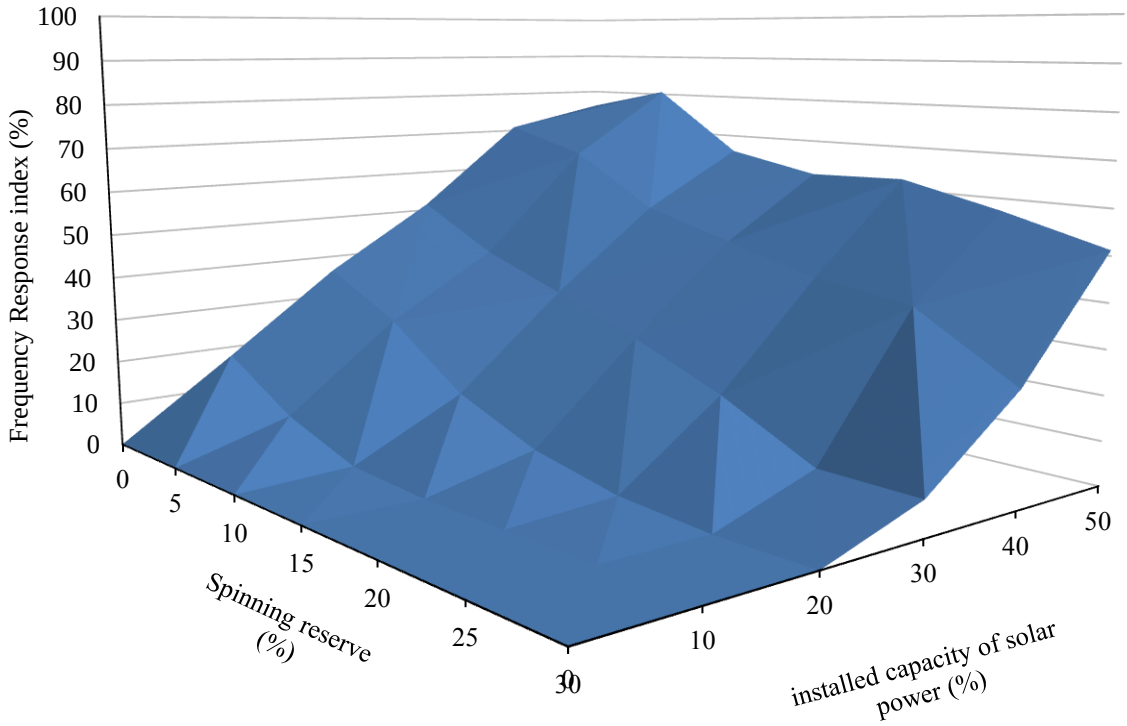

Fig.6 Frequency response index at various spinning reserve and installed capacity of solar power

3.2 Frequency response

The frequency response index defined as the percentage of system failure that may occur due to the biggest generator cannot supply reserve power to the system caused by load increases and solar generation drop. The considered time scale is every a haft hour and consider one year period. Actually, a time of system failure is not accepted for power systems thus the frequency response index should be zero percent. Figure 6 show frequency response index resulted by spinning reserve of the system and installed capacity of solar system. The result show that the maximum installed capacity of solar depended on the spinning reserve of the system. In a case of spinning reserve of the system was 10 percent and the installed capacity of solar power plant was 10 percent, the frequency response index was 1.2 percent. The other meaning is110 times of system failure per one year. In the case of Thailand's power system, the standard spinning reserve is 25 percent so the maximum installed capacity of solar power plant is 20 percent of peaked loads. The installed capacity of solar can be increased by increasing the spinning reserve of the system to maintain system reliability.

4. CONCLUSION

In this paper, a load flow analysis approach use to find the maximum installed capacity of solar power plant. This method would be very useful for power planners to prevent power quality problems which may cause by integration of uncertainty renewable power such as solar power plant. As a study case, the IEEE 30 Bus system with six generating units was simulated. The results shown that in the case of Thailand' power system with 25 percent of spinning reserve, the maximum installed capacity of solar power that can be integrated on each local bus are 20 percent of peaked loads. While minimum voltage was observed at 0.92 p.u. on bus no. 30. However, the installed capacity of solar can be increased by increasing the spinning reserve of the system to maintain system reliability. The proposed method is useful for makes the protection and planning in order to integrate uncertain renewable source to the electric power system.

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Development of Power Quality Controller for Renewable Energy Electric Hybrid Generation

Warunee Srisongkram, Wanida Pusorn, Kittiwat Chiangchin, and Krischonme Bhumkittipich

Abstract*—This paper presents the development of STATCOM for power quality controller of electric hybrid generation in renewable energy system. This voltage compensator compensates the STATCOM current signal with wind turbine generated voltage signal to constantly voltage supply to load that is less than 400 watts. In addition, the power electronic device so called SSCB is applied to be protective device in order to protect load from system fault that is detected by microcontroller. The result shows that the voltage supplying to load is smoothly sinusoidal waveform. The system is fast in maintaining system voltage with instantaneous action.*

***Keywords*— Renewable energy, electric hybrid generation, compensator, power electronic device, SSCB.**

1. INTRODUCTION

This research develops the power quality controller of electric generation in renewable energy system such as wind energy as a major energy resource in order to constantly voltage supply to load as shown in Fig. 1 This power quality controller is developed by using the basic concept of static synchronous compensator (STATCOM) that is supplied energy by the minor renewable energy resource as PV solar storage. This is so called electric hybrid generation in renewable energy system.

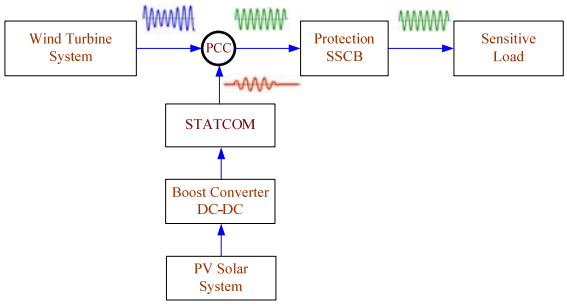

Fig.1. Power Quality Controller for Renewable Energy Hybrid Electric Generation

Additionally, the power electronic protective device so called solid state circuit breaker (SSCB) is used to protect load from fault occurring in the system. The fault detection is designed by using microcontroller. This power quality controller via STATCOM applies the DC voltage output from the PV as the minor energy resource to DC bus of STATCOM to control power quality from the major energy resource as wind turbine by using digital signal processing control process. The STATCOM can also supply reactive power to solve the problem on unstable voltage magnitude from wind turbine. Consequently, the energy in form of active power is finally supplied to load.

2. STATCOM: DESIGN AND CONSTRUCTION

STATCOM consists of three-phase voltage source inverter (VSI). Its components include a DC capacitor (C_{bus}), interface inductors on the ac-side and a fixed-point DSP. Moreover, a three-phase low pass filter which consists of capacitors C_f, inductors L_f and damping resistors R_f are added to the ac-side of VSC to eliminate the switching frequency. The reactive power output of the STATCOM from each phase, which could be inductive or capacitive, can be independently controlled by the controller of the STATCOM for real-time load compensation. For the fast real-time compensation, the STATCOM needs to very quickly detect the line-to-line voltage data in order to calculate the needed compensation current. So the dq detection method with recursive discrete fourier transform (RDFT) [1]-[2] is applied. By this way, any undesired signals such as harmonics are reduced. Moreover, this method can be implemented very easily by a high performance DSP-based system shown in Fig. 2

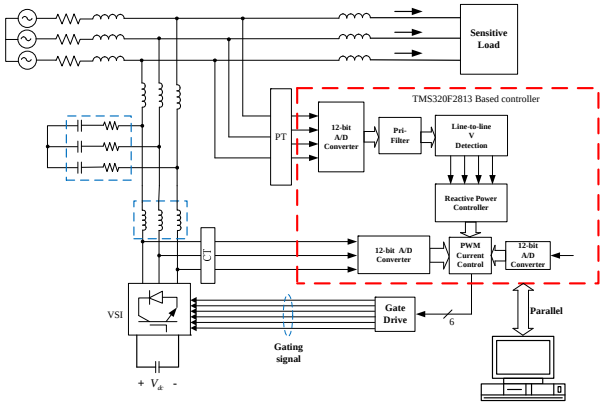

Fig.2. Parallel Power Quality Controller Diagram

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The circuit parameters of the STATCOM in Fig. 2 are C_f =10 μF, R_f = 23.5 ohm, L_f = 4mH and C_{bus} = 5,000 μF. An intelligent power module (IPM) is employed for the power stage of the STATCOM. The switching frequency of the inverter is 10 kHz.

After DSP received the system voltage signal, they will be transformed to dq-component [3] and filtered by RDFT. Next, the d-component of the voltage is controlled by the current on q-axis which will be injected into the system in order to control the reactive power flow via PI control. For active power control, the active current is controlled by the injected current on d-axis in order to flow the active power from PV unit to the system. By combining the above two currents, the needed d and q current command signals is generated for the STATCOM. Finally, the d-current and q-current signals are converted to voltage signals on d-axis and q-axis via decoupling control which is shown in equation (1) and (2) in order to control VSI acting as a CSI. At this state, the actual current on dq-axis is also required. Current in dq-axis can be calculated as given in equation (3) and (4). Fig. 3 shows block diagram of equations (3)-(4).

$$L_f \frac{d}{dt} i_d - L_f \omega \cdot i_q + R_f \cdot i_d + V_g d = V_{in} v_d \qquad (1)$$

$$L_f \frac{d}{dt} i_q + L_f \omega \cdot i_d + R_f \cdot i_q + V_g q = V_{in} v_q \qquad (2)$$

where:

$$id = \frac{1}{L_f \cdot s}\left[V_{in} v_d - V_g d + L_f \omega \cdot i_q - R_f \cdot i_d\right] \qquad (3)$$

$$iq = \frac{1}{L_f \cdot s}\left[V_{in} v_q - V_g q + L_f \omega \cdot i_d - R_f \cdot i_q\right] \qquad (4)$$

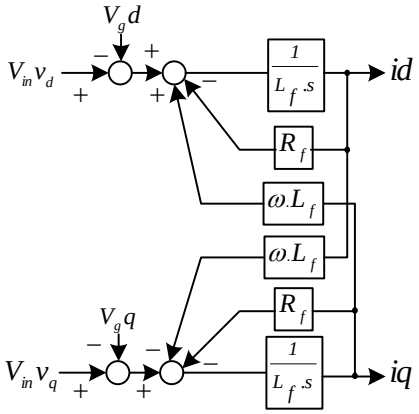


Fig.3. Mathematical Model of STATCOM

The objective is to produce a sinusoidal ac output whose magnitude and frequency can be controlled. The decoupling control has been implemented in the synchronous reference frame because the synchronous frame controller can eliminate steady state error and has fast transient response cross-coupling on d- component and q-component are shown in Fig. 4 [4]. The feed-forward component in Fig. 4 is the scheme that is used to eliminate the initiate sample value. The PI regulators, namely Kp and Ki [4], are designed to keep the stability margin of the entire system by getting the eigen values on the left hand side of the S-plane. The DC-Link voltage must be controlled to keep the constant DC voltage that used for generating the desired voltage component of shunt compensator. The implemented hardware is shown as Fig. 5.

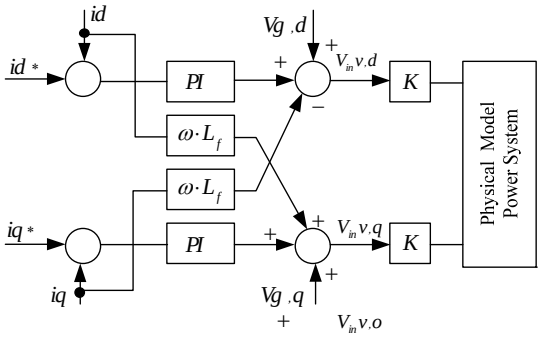


Fig.4. Mathematical Model of Decoupling Control

Fig.5. Hardware Prototype of the Proposed STATCOM

3. PROTECTION SYSTEM

The proposed controller is developed to solve the problem of voltage generated from wind turbine. This fault protection system applied to protect the fault in the renewable energy hybrid electric generation with rated not exceed 5-20 A, 110/380 V The microcontroller is introduced for processing and controlling. The design of the system protection with power electronic devices can detect abnormalities of the waveform.

The principal of fault protection equipment consists with power electronic device's principal by applying current conduction and non-conduction condition of power electronic devices to built protection devices. The operating method is same as a circuit breaker to connect or disconnect a circuit when fault occurs by using microcontroller for processing and detecting the characteristic of the current and voltage waveform that might cause any damage to the generator in case that the energy could not be produced and protecting all devices in case of voltage sag, over voltage, short circuit and over load. When fault occurred, microcontroller will stop the flow immediately and show one of conditions why the circuit is opened. The design is divided into 2 sections. The first section is the system fault detection via the processing of microcontroller and transfer a signal to the

second section that is the power electronic devices to connect or disconnect the circuit.

Table 1. Operating Condition of Fault Protection

Operating condition	Connect-disconnect circuit condition	Remark
1. Normal voltage	Connecting the system circuit	Normal system voltage
2. Voltage sag and over voltage (In case that the voltage is over or below the standard IEEE 1159-1995.)	- Disconnect the circuit when it detects that the voltage is lower or higher than 10% of the standard voltage (continuously for 1 minute.	Connect the circuit when the voltage in the system back to normal, with a delay to wait the voltage within the normal level longer than 1 minute before connecting the circuit.

4. RESULT AND DISCUSSION

In this paper, power quality controller for renewable energy electric hybrid generation consists of wind turbine and solar cell. The model of standalone hybrid generation is presented in Fig. 6 The wind turbine can control its speed equal to actual wind speed. This SSCB acts as switching device in order to "turn-on/turn-off" the circuit in standalone system. The system parameters are shown in Table 2.

Fig.6. Power Quality Controller and Compensate of Wind Turbine Generation

Table 2. System Parameters for Experiment

System Quantities	Values
System Voltage Level	110 V
Load	400 W at 110V
Line impedance	9 mH
DC-bus Voltage	416 V

4.1 STATCOM testing

Fig. 6 shows the experimental set up for STATCOM testing. To observe the STATCOM performance on voltage compensation, the rated system voltage is set as equal to 110 Vac,rms. Therefore, wind generator should generate voltage up to such level. In addition, the system load is as of 400 Watts per phase. The program is set to compensate the generated voltage from wind generator at 110 Vac,rms. The compensation testing is performed by decreasing or increasing the system voltage to be lower or higher than the rated voltage. The compensation then is investigated. Table 3 shows the performance of STATCOM under overvoltage and undervoltage situations produced by wind generator when the normal rated single phase voltage is 110 V

Table 3. Experimental Results of 110V Regulation for Undervoltage and Over voltage

Operation condition	Voltage (V)			Current (A)	
	V_{Source}	V_{Load}	$V_{DC\ Bus}$	$I_{sourrce}$	I_{Load}
Under voltage	95	107	416	3.78	0.803
	96	108	416	3.77	0.803
	97	109	416	3.77	0.803
	98	110	415	3.73	0.803
	99	110	416	3.53	0.803
Normal Voltage	110	110	416	0.873	0.803
Over Voltage	121	110	415	2.77	0.803
	122	110	415	2.95	0.803
	123	110	416	3.22	0.803
	124	111	416	3.34	0.803
	125	111	416	3.45	0.803

A. Undervoltage Compensation

The 1st experiment is undervoltage compensation testing performed at 95-99 V by adjusting the compensated voltage at 110 V_{rms}. As given in Table 2. the results signal are given in Fig. 7 The compensated voltage and current are around 110 V_{rms} and 3.53-3.78 A respectively. Leading power factor is caused from STATCIM acting as capacitive load in order to supply reactive power to load in normal situation.

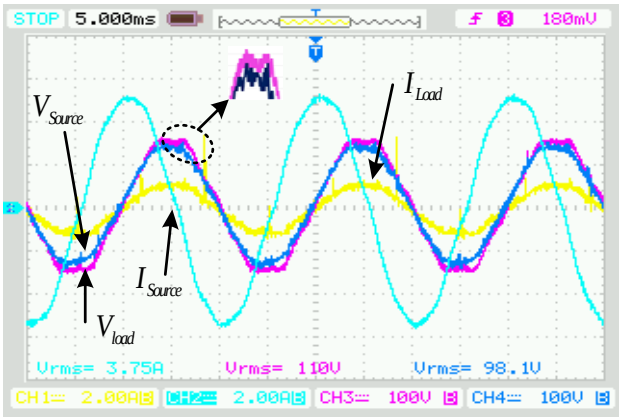


Fig.7. Compensated Undervoltage at 98 V

B. Overvoltage Compensation

The 2nd experiment is overvoltage compensation testing performed at 121-125 V by adjust the compensated voltage at 110 V_{rms}. The results are given in Fig. 8 The compensated voltage and current were around 110 V_{rms} and 2.77-3.45 A respectively. Lagging power factor is caused from STATCIM acting as inductive load in order to supply reactive power to load in normal situation.

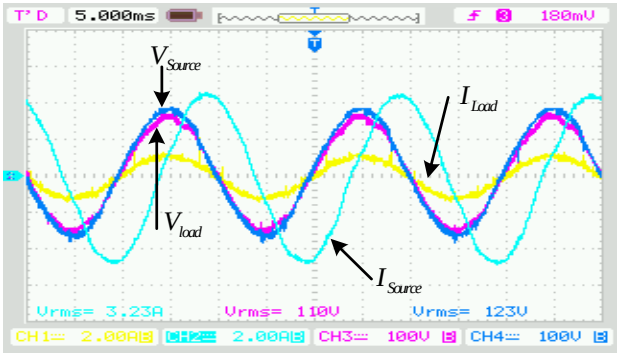
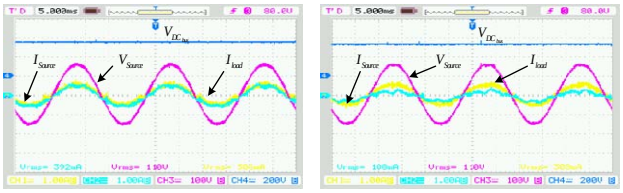


Fig.8. Compensated Overvoltage at 123 V

C. DC Bus Testing

In 3rd the experiment, the DC bus is charged at the beginning of program in accordance with the setting as of 416 V. The results are given in Fig. 9. The results show that after the program can detect fault. In addition, DC bus voltage is still regulated as 416 V compensated by DC-DC booth converter.



(a) **(b)**

Fig.9. DC Bus Charge Signal, (a) Before Voltage Compensation (b) After Voltage Compensation

4.2 SSCB protective device testing

The SSCB in Fig. 10 is tested together power quality controller of renewable energy electric hybrid generation. The system voltage signal is investigated. The voltage detection is shown in per unit for both overvoltage and undervoltage situations as given in Fig. 9. The voltage magnitudes are compared in order to identify normal and abnormal situation. In the abnormal state, when the voltage is out of 0.9-1.1 p.u. with the period 1 minute long, the control circuit will command to open the circuit by SSCB. However, if the system turns to normal stage that longer than 1 minute, the control device will command to close the circuit again.

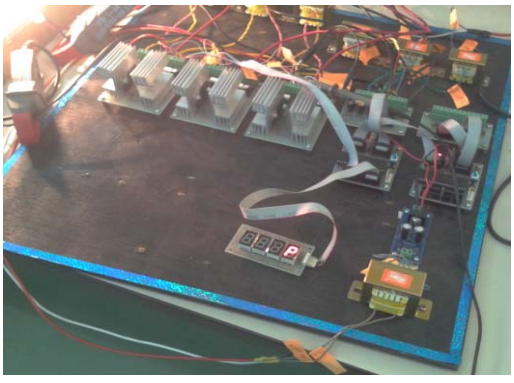


Fig.10. Hardware Prototype of the Proposed SSCB

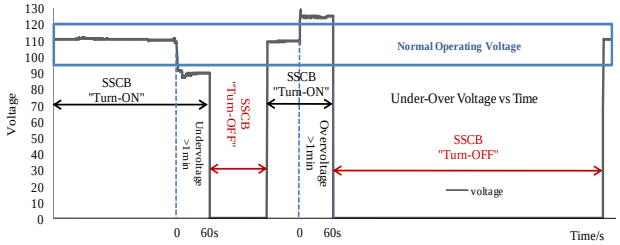


Fig.11. SSCB Testing in Cases of Overvoltage and Undervoltage

5. CONCLUSION

In this paper, the STATCOM acts as power quality controller of electric hybrid generation in renewable energy system. It is applied to regulate voltage signal from wind generation according to the IEEE standard 1159 -1995 [5] in condition of short duration voltage variations as well as voltage sag or voltage dip and voltage swell or voltage surge within 1 minute time duration. The SSCB is developed as protective device of the system according the same standard in condition of long duration voltage variations in overvoltage and undervoltage with the period 1 minute long. The results show the well performance of the devices that can fast control and maintain the system voltage.

6. ACKNOWLEDGMENT

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Failure Frequency Analysis of Power Circuit Breaker for Preventive Maintenance

Thanapong Suwnansri, Warunee Srisongkram, and Cattareeya Suwanasri

Abstract*—This paper presents an analysis of historical failures of HV circuit breakers in Thailand's transmission network. The historical data of circuit breakers installed since 1989 to 2011 at three voltage levels as 115 kV, 230 kV and 500 kV are analyzed. The data has been classified into different types of circuit breakers and components. The main components are classified as major HV components, operating mechanism, and control circuit and others whereas the sub-components are also differentiated. The failure frequencies of those sub-components are then assessed in order to observe their failure characteristics in form of Bath-tub pattern, which is classified into three zones as teething, random and ware-out zone. The results show failure frequency of sub-components of only 230 kV circuit breakers. Finally, the preventive maintenance for the circuit breakers can be effectively managed due to actual failure behavior. Consequently, the failure rate of the equipment can be reduced resulting in better power system reliability.*

***Keywords*— Circuit breaker, failure rate, failure frequency, bath-tub pattern, failure pattern, preventive maintenance.**

1. INTRODUCTION

Nowadays, failure of HV equipment causes a power interruption in power system and effects both technical and economical aspects. The frequent failures lead to higher electricity interruption and then lower system reliability. The preventive maintenance carried out at predetermined intervals or according to prescribed criteria and intended to reduce the probability of failure or the degradation of the functioning of an item whereas the condition based maintenance is based on information from monitoring equipment which predicts when maintenance is necessary rather than on time in service or number of operations [1] in order to reduce unplanned downtime, to lower overall maintenance costs, to improve system reliability, prevent problems before they occur, extend life of equipment, ensure personnel safety, and etc.

The electric utilities currently pay attention in the collecting and analyzing historical failure data of HV equipment such as power transformer, HV circuit breaker, and etc. By incorporating reliability considerations in the operation and maintenance of such equipment, then the effective maintenance planning can be improved. To obtain useful results from system reliability assessments, failure frequency of equipment need to be analyzed.

Therefore, this paper proposes the failure data analysis of circuit breakers in 230 kV power substation of the Electricity Generating Authority of Thailand (EGAT). The objective aims to determine the failure pattern of the HV circuit breaker components. The components are divided into four groups such as major HV components, operating mechanism, control circuit, and others. In group components, the sub-components are also categorized. The failures are analysed and plotted in the bath-tub form, that the failure frequency is divided in three zones such as teething, random and wareout. The failure pattern of each component is analyzed. The weak component can be determined with the identified age in teething, random, wareout zone. Finally, the performance of preventive maintenance of the equipment is expected to be improved.

2. POPULATION OF CIRCUIT BREAKERS

In this paper, the statistical records of population of HV circuit breaker in different types are analyzed in terms of types, locations, and causes of failures. The historical failure data of total 2,898 numbers of 115 kV, 230 kV and 500 kV are assessed during the period 1989 to 2011. However, to observe the failure characteristic, only historical failures of 230 kV are plotted and analyzed in form of failure patterns. Consequently, the expected failure versus age can be predicted. Finally, the condition based maintenance can be taken to repair or replace the components before the failure occurs and cause the huge damage to the system.

2.1 Numbers of Circuit Breakers

From statistical records, population and types and of circuit breaker are categorized as shown in Table I. The types of circuit breaker include bulk oil (Bulk.Oil), mineral oil circuit breaker (Min. Oil), gas circuit breaker (GCB), vacuum circuit breaker (VCB), vacuum switch circuit breaker (VSW), and circuit breaker in gas insulation substation (GIS) in three different voltage levels in Thailand transmission network. In Table I, GCBs were installed as the highest population numbers compared with all three voltage levels due to its advantages of SF_6 gas insulation. For clearly explanation, the percentage of population is plotted as presented in Fig. 1.

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Table 1. Number of circuit breaker in three voltage level

Voltage Level	Types of CBs						Total
	Bulk.Oil	GCB	GIS	Min.Oil	VCB	VSW	
115 kV	24	1673	13	3	1	1	1715
230 kV	14	940	102	3	0	0	1059
500 kV	0	73	51	0	0	0	124
Total Number CB							2898

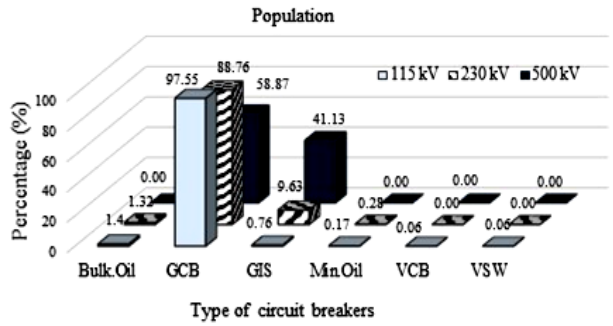

Fig.1. Percentage of HVCB Classified in Different Voltage Levels

2.2 Number of Failure of Circuit Breaker Components

The components of circuit breaker are classified into four groups as major HV components, operating mechanism, control circuit, and others. In each group the sub-components are detailed. For example, the group of major HV components consists of main insulation to earth, making and breaking unit, and auxiliary interrupters. Their failure numbers are counted.

Table 2. Number of Failure of HVCB Components

CB components	Details	Number Failures (times)		
		115kV	230kV	500kV
Major HV components	Main insulation to earth	31	20	1
	Making and breaking unit	60	31	2
	Auxiliary interrupters	0	3	2
Operating mechanism	Actuator (converting hydraulic energy into mechanical energy)	68	128	14
	Compressor unit (compressors, motors, pump, pipe and others)	119	105	34
	Control elements	6	13	1
	Damping device	57	28	0
	Energy storage (accumulator, spring, air reservoir)	35	24	1
	Counter unit	4	-	0
Control circuit	Contactors unit	97	100	5
	Gas density supervision	27	25	1
	Tripping and closing circuit	20	11	4
	Auxiliary switch	12	11	0
	Mechanical transmission (latch, link, gear, chain, coupling)	86	44	0
	Non-return device	8	1	0
Others	Others	256	171	23
Total		886	715	88

In addition, the failure records are presented in percentage of failures for all three voltage levels as given in Fig.2. The results show that the most failures occurred at the control circuits with the high percentage as 43%, 48% and 57% in 115 kV, 230 kV, and 500 kV, respectively. In contrast, the major HV components are the smallest group of failures; however, they cause power interruption because it is major switching devices.

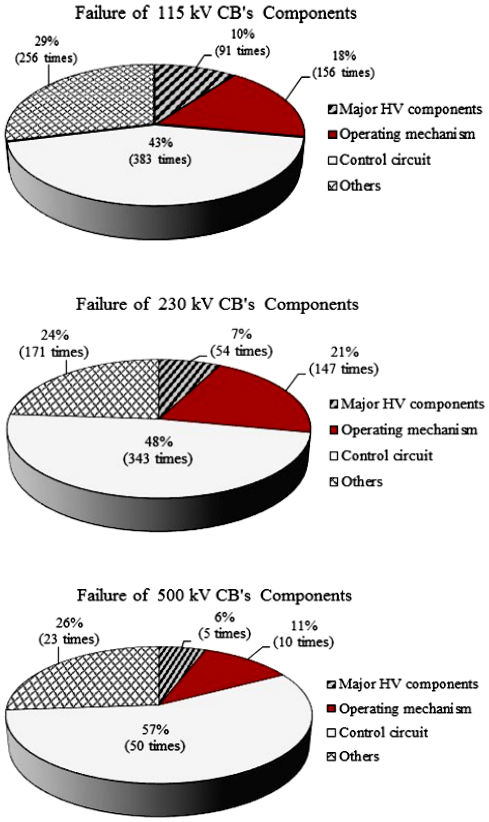

Fig.2. Percentage of Failures of HVCB's Components

2.3 Number of Failure of Circuit Breaker by Age

It is important that failure frequency should be classified in the different ages in order to observe the failure frequency characteristics. Fig. 3 shows the summation of failure events of each voltage level. The result shows that the circuit breakers in 115 kV face the highest numbers, especially during ages 13-17 years. This highest failure results from the highest population of 115 kV circuit breakers in the power system compared to other levels.

Fig.3. Failure Frequency of HVCB in Different Ages

3. FAILURE FREQUENCY PATTERNS

Failure of the equipment occur in various lifetime of equipment. Failure frequency characteristics can therefore be defined in different patterns and shown in Fig. 4 [1, 2, 3]. Teething failure means the failure occurs within the first two years of service of a new or prototype design of equipment. Random failure means random problem which, does not depend on age or operation. Wearout failure describes wearout problems which are increased by progresses operating time. Operational failure means problem which appears due to operation. Aging failure means the failure whose probability of occurrence increases with the passage of time, as a result of processes inherent in the item. Bath-tub curve is a combination of teething till wareout. Example on failure frequency versus age in bath-tub waveform of scattering failure data for a HV component is given in Fig. 5.

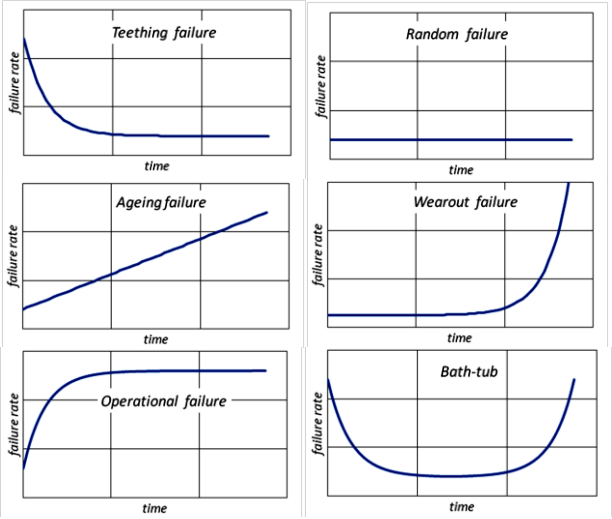

Fig.4. Failure frequency patterns

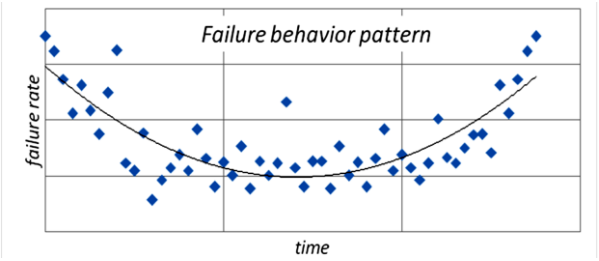

Fig.5. Example on Failure Frequency Patterns

In Fig.5, the x-axis refers to age of equipment failure. For example, if age is equal to "1" means that after the equipment was installed within a year then the failure occurred. The y-axis refers to failure frequency of equipment failures at the considered age. The calculation of failure rate [4] is given in Eq. (1) and Eq. (2)

$$\lambda_i \left(\text{freq./year}\right) = \frac{\sum N_{F,i}}{\sum N_{t,i}} \qquad (1)$$

$$\text{Failure rate}\left(\text{freq./100 CBs year}\right) = \lambda_i \times 100 \qquad (2)$$

where λ_i is failure rate of equipment failed within the considered age, $N_{F,i}$ is number of failure event (time), $N_{t,i}$ is total number of circuit breakers (unit), and i is age of circuit breaker (year).

The polynomial function is applied for fitting curve pattern according to the bath-tub curve characteristic. The bath-tub pattern is then categorized into three zones as teething, random and wareout zone.

4. RESULTS AND DISCUSSION

The circuit breaker's components in the evaluation are classified as follows. The first is major HV components, which are mainly used as HV switching circuit. The second is operating mechanism components that are applied for mechanical operation. The third is control circuits, which are used as the electronic or control devices. The last is other components that are other parts in circuit breaker. In the analysis, failure record includes both major and minor failure. The failure frequency patterns of each part are then evaluated. However, due to the limitation of failure data availability, the equipment encounters different failure spans.

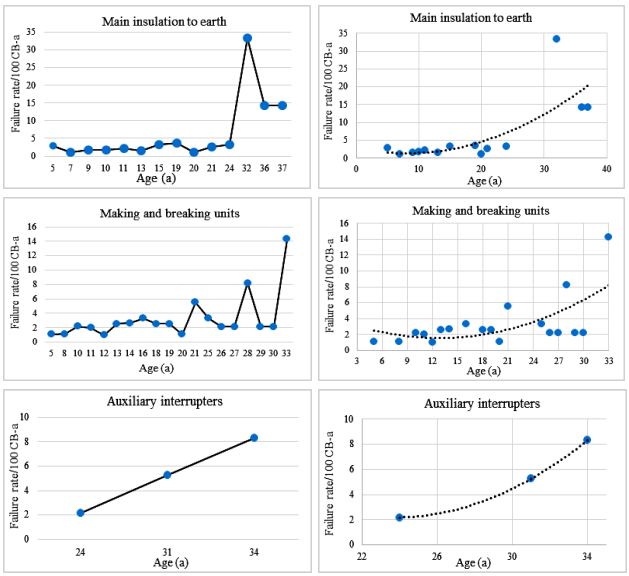

Fig.6. Failure Patterns of Major HVCB Components

As presented in Fig. 6 to Fig. 10, the life recorded of main insulation to earth reaches to 37 years whereas of the making and breaking unit reaches only to 33 years. The random problem is the major problem for failures of the major HV components with the high failure rate. However after 25 years, the failures trends to be wareout because the equipment is obsoleted.

In Fig.7, the operating mechanism components such as damping device and mechanical transmision as well as the control elements encounter teeting problem from installation and commissioning of new units. This occurs at the first period of operation and commonly caused by defective components in the control unit or by hydraulic oil leaks in the device. The aging failure is a common problem to other components, when the equipment is in ware-out period such as actuator compressor unit in Fig.7 and other components in Fig.8.

Finally, the failure pattern of overall circuit breaker is concluded as given in Fig.10. The overall 230 kV circuit breaker encounters the random failure because HV circuit breakers are replaced before or at the beginning of the -

ware-out period. However the aged HV circuit breaker over 35 years are ware-out.

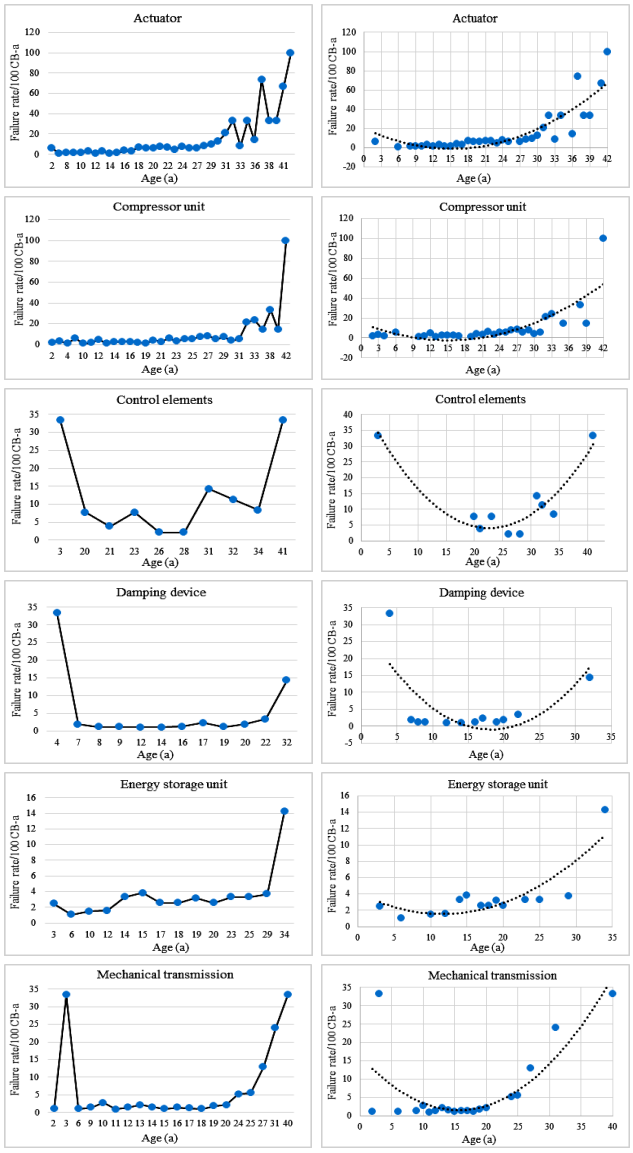

Fig.7. Failure Patterns of Operating Mechanisms

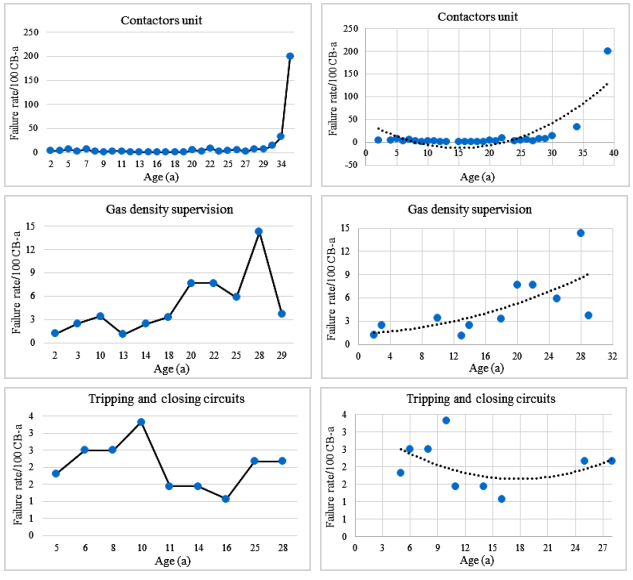

Fig.8. Failure Patterns of Control Circuit Components

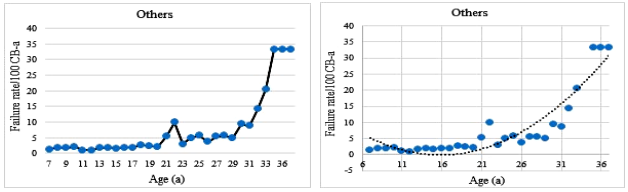

Fig.9. Failure Patterns of Other Components

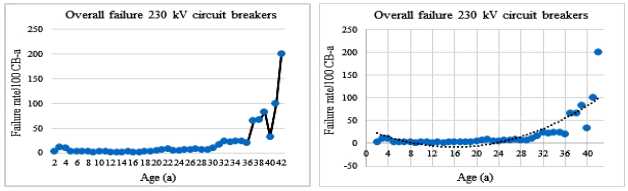

Fig.10. Failure Pattern of Overall HVCB's Components

5. CONCLUSION

The failure record of a utility in Thailand has been analyzed to determine the critical component of power circuit breaker. The high percentage of failure arises from the control circuit. The failure patterns of every component in three main groups, major high voltage component, operating mechanism and control circuit, are subsequently determined by using the polynomial function a pattern of curve fitting according to the well-known bathtub curve. Finally, the determination of the overall failure pattern of a 230 kV circuit breaker can be achieved, which is the useful information for failure prediction of preventive maintenance.

ACKNOWLEDGMENT

The authors gratefully acknowledge the Transmission System Maintenance as well as the Research and Development Division at the Electricity Generating Authority of Thailand for data support as well as the Rajamangala University of Technology Suvarnabhumi, Thailand for scholarship support to Mrs. Warunee Srisongkram during her doctoral program at TGGS, King Mongkut's University of Technology North Bangkok.

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Simulation of Potential and Electric Field Due to Defective Insulator in 115 kV Transmission Line

Siamrat Phonkaphon and Pramuk Unahalekhaka

Abstract— *This paper described to study the potential and electric field of suspension insulator in 115 kV transmission line associated with ANSI type 52-3. The suspension insulator type 52-3 was used by Provinical Electricity Authority (PEA) in Thailand. The suspension insulator was the disc insulators; it is an assembly of one or more shells with metallic fittings. This structure can enabled them form the insulator string by fitting into themselves one another as per voltage requirement. A suspension insulator set complete with the fittings was used to carry a line conductor or conductors at its lower end. The top of insulator string was fixed to the cross arm of the tower. The potential and electric fields were simulated by using the Finite Element Analysis (FEA) program. This simulation was compared the characteristic of suspension insulator due to defective insulator between normal and abnormal condition. The defective insulator was based on percentage of damage and surface pollution levels. However, the percentage of damage and surface pollution influence on the dielectric behavior of the insulators has been examined in order to reduce the effect of system.*

***Keywords*— potential field, electric field, suspension insulator, Finite Element Analysis**

1. INTRODUCTION

Nowadays, PEA had a problem in the transmission line due to defective insulator, which was based on the damage of insulators and consideration of surface pollution level located nearby the sea and in industrial areas. The transmission line insulators are used to support the high voltage carrying conductors. The dimensioning of insulators must be such as to prevent flashover when the highest overvoltage occurs on the power line. Due to the geometry of the line and insulator the voltage distribution along the length of the insulator is non-uniform. This has been analysed theoretically in closed form for clean glass or porcelain disc insulator strings [1].

The insulators, which are used for the suspension of overhead transmission lines, constitute one of the most important parts of the transmission lines as flashover effects in polluted insulators can cause the breakdown of a transmission network. The electric field distribution within and around high voltage insulators is a very important aspect of the design of the insulators. Also the knowledge of the electric field could be useful for the detection of defects in insulators [2]. The lumped parameter representation of an insulator string consists of C_{sn} and C_{gn} C_{sn} is the self-capacitance of an insulation unit and C_{gn} is the ground stray capacitance between the tower and an insulator cap [3].

In the present paper, the insulator model was verified for several surface pollution levels. The surface pollution levels can divided into three levels which consist of light, moderate, and heavy pollution level follow to IEC standard [4]. This model was used in 115 kV system of PEA in Thailand as shown in Fig. 1

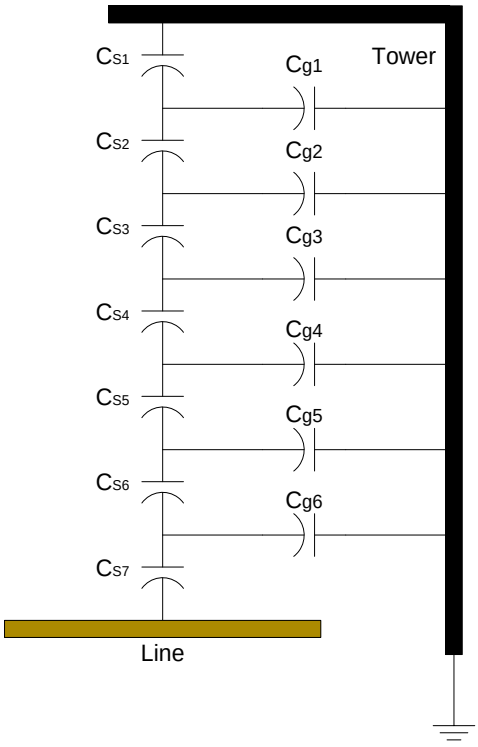

Fig.1. The lumped parameter of an insulator string

2. SUSPENSION INSULATOR

The insulators standard of suspension insulators with high mechanical and electrical strength are designed to meet the most modern demands of high voltage transmission line usage today. The insulators makes one of the widest ranges of ANSI approved Ball–Socket and Clevis type distribution suspension insulators for overhead transmission systems in the world.

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For the present study, the type of suspension insulator type 52-3 is chosen. The dimension of suspension insulator type 52-3 is used for the study as shown in Fig. 2. Technical data of suspension insulator type 52-3 are reported in Table 1.

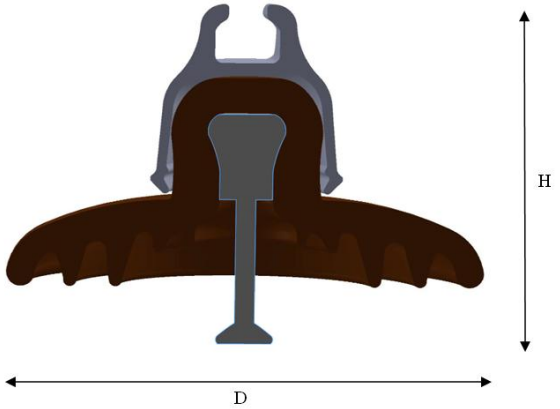


Fig.2. The dimension of suspension insulator type 52-3

Table 1. Technical data of suspension insulator type 52-3

Class ANSI	52-3
Main Dimensions D	273mm
Main Dimensions H	146mm
Creepage distance	292mm
Power frequency puncture voltage	110 kv
Frequency dry flashover voltage	80 kv
Frequency wet flashover voltage	50 kv
Critical impulse flashover pos	125 kv
Critical impulse flashover Neg	130 kv
Test voltage to ground	10 kv
Maximum RIV at 1000HZ	50 uv
Electromechanical Load	6750kg
Mechanical Impact Strength in-1b(N-m)	55
Time Load Test Value1b	4500kn
Weight	4.6 kg

3. VOLTAGE DISTRIBUTION OF SUSPENSION INSULATOR

The transmission line is considered that the important issue of the suspension and the voltage insulator division of the disk of insulator string. The most of the disk and the metal pin comprising porcelain insulators.

The voltage across insulator strings are equally active in the division as well as a string of calculated predominates Capacitance. The voltage distribution of suspension insulator is defined by:

$$m = C_s/C_g \quad (1)$$

$$V_n = I_n/\omega C_{sn} \quad (2)$$

where:

m is capacitance ratio of C_s and C_g
V_n is voltage across each unit
I_n is current in each unit

In this paper, the overhead line suspension Insulator consists of 7 units. Transport and land are the differences between the 66.4 kV splendors. If the land in each insulators mutual Capacitance and Capacitance ratio 5:1. The voltages across each unit are reported in Table 2 and Fig. 3.

Table 2. Calculation of the voltage across each unit

Unit	Voltage across the insulator (kV)
1	2.72
2	3.26
3	4.46
4	6.55
5	9.95
6	15.34
7	23.80

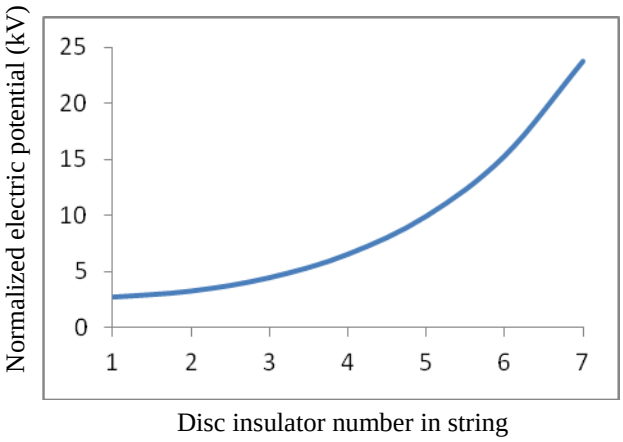


Fig.3. Normalized electric potential distribution

4. MATHEMATICAL MODEL

A simple model for the evaluation of the flashover process of a polluted insulator consists of a partial arc spanning over a dry zone and the resistance of the pollution layer in series. The critical voltage V_C, which is the applied voltage across the insulator when the partial arc is developed into a complete flashover, is given by the following formula (3):

$$V_C = \frac{A}{n+1} \cdot (L + \pi \cdot n \cdot D_m \cdot F \cdot K)$$

$$\cdot\left(\pi\cdot A\cdot D_m\cdot\sigma_S\right)^{-\left(\frac{n}{n+1}\right)} \quad (3)$$

where L is the leakage distance of the insulator, D_m is the maximum diameter of the insulator disc and F is the form factor. The arc constants A and n have been calculated using the least square method. Their values are A=131.5 and n=0.374. The surface conductivity $\sigma_S\,(\text{in }\Omega^{-1})$ is given by

$$\sigma_S=\left(369.05\cdot C+0.42\right)\cdot 10^{-6} \quad (4)$$

where C is the equivalent salt deposit density (ESDD) in mg/cm^2. The coefficient of the pollution layer resistance K in case of cap-and-pin insulators is given by

$$K=1+\frac{n+1}{2\cdot\pi\cdot F\cdot n}\cdot \ln\left[\frac{L}{2\cdot\pi\cdot R\cdot F}\right] \quad (5)$$

where R is the radius of the arc foot and is given by

$$R=0.469\cdot\left(\pi\cdot A\cdot Dm\cdot\sigma_S\right)^{\left(\frac{1}{2\cdot(n+1)}\right)} \quad (6)$$

In case of stab-type insulators, K is defined as follows:

$$K=\frac{N\cdot(n+1)}{2\cdot\pi\cdot F\cdot n}\cdot\left[\ln\left[\frac{4\cdot L}{\pi\cdot N\cdot R}\right]-\ln\left[\tan\frac{\pi}{2\cdot(n+1)}\right]\right] \quad (7)$$

where N is the number of sheds.

5. POTENTIAL AND ELECTRIC FIELD MODELING

The finite element method (FEM) is a numerical technique for finding approximate solutions to boundary value problems for differential equations. It uses variational methods (the calculus of variations) to minimize an error function and produce a stable solution.

Analogous to the idea that connecting many tiny straight lines can approximate a larger circle, FEM encompasses all the methods for connecting many simple element equations over many small subdomains, named finite elements, to approximate a more complex equation over a larger domain.

The potential and electric field surrounding the insulator and the conductor is modelled using the Finite Element Analysis (FEA) program. This program is a computerized method for analysis to draw the potential and electric field contours superimposed upon the drawing. The suspension insulator type 52-3 and the cutting plane of the suspension insulator model as shown in Fig. 4.

6. SIMULATION AND RESULTS

The paper discusses the application of two and three dimensional by using the FEA for the modeling of the insulators, that a comparison between normal and abnormal condition results from two dimensional analysis of the insulator strings is presented. Disk insulators of the string structure, which are used for the suspension of 115 kV overhead transmission lines, are simulated. The normal condition results of the potential and electric field distribution simulations are given in Figs. 5 and 6.

Table 3 expresses the comparison of the voltage across each unit between normal and abnormal condition. An abnormal condition was based on percentage of damage and surface pollution levels. The surface pollution levels can divide into three levels which consist of light, moderate and heavy pollution. The comparison of electric potential distribution each unit was shown in Fig. 7.

Fig.4. The suspension insulator type 52-3 and the cutting plane of the suspension insulator model

Table 3. Voltage across each unit with and without pollution level (kV)

Unit	Normal condition without pollution	Abnormal condition with pollution level		
		Light	Moderate	Heavy
1	2.72	0.50	1.00	0.94
2	3.26	1.60	1.22	1.19
3	4.46	2.90	1.54	1.52
4	6.55	4.80	2.35	2.25
5	9.95	8.06	4.59	4.30
6	15.34	15.50	16.10	14.00
7	23.80	33.80	39.60	42.20

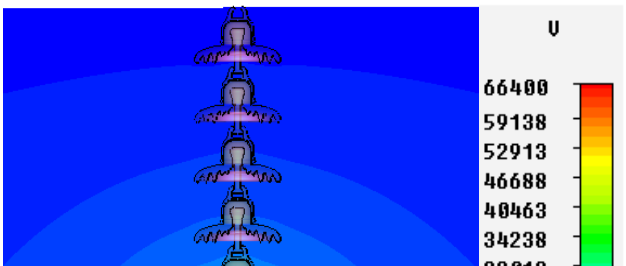


Fig.5. Potential field of normal condition

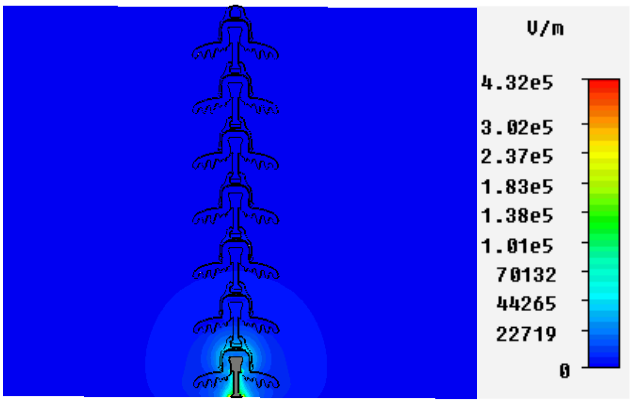


Fig.6. Electric field of normal condition

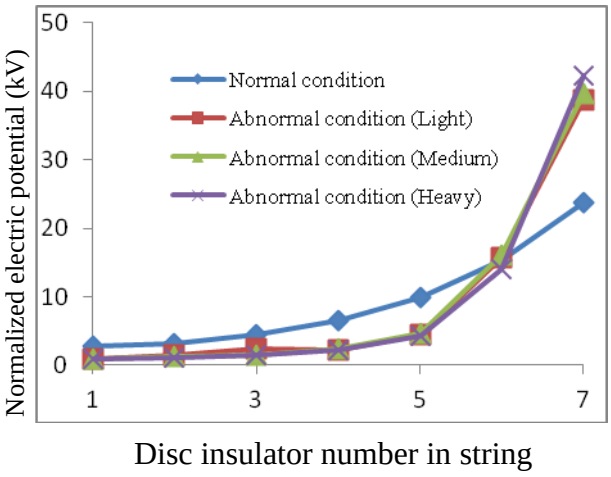
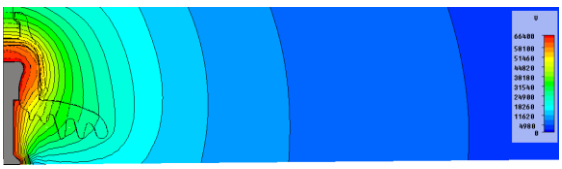
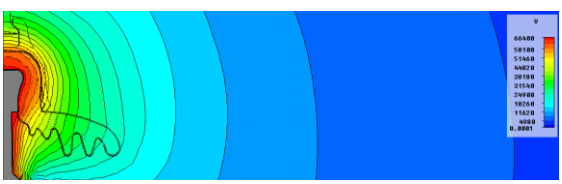


Fig.7. Comparison of electric potential distribution

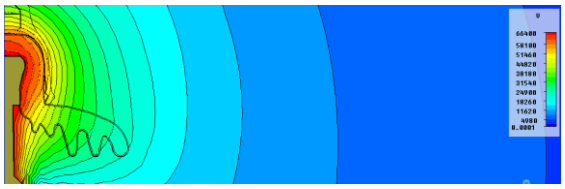
Fig. 8 and Fig. 9 indicated that the electrical potential contour and electric field distribution with pollution and without pollution respectively.



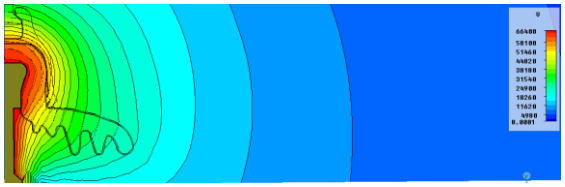
(a) Non-pollution



(b) Light pollution



(c) Moderate pollution

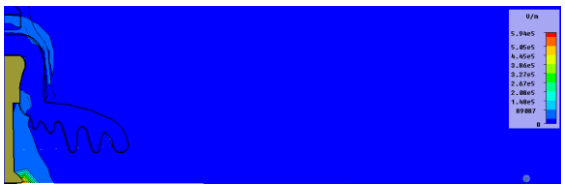


(d) Heavy pollution

Fig.8. Electrical potential contour with and without pollution

(a) Non-pollution

(b) Light pollution



(c) Moderate pollution

(d) Heavy pollution

Fig.9. Electric field distribution with and without pollution

The computations results concerning the critical voltage of a cap-and-pin suspension insulator upon the equivalent salt deposit density (ESDD) .The computation of critical voltage (V_C) can divide into 3 levels consist of light, moderate and heavy level as shown in table 4. The critical voltage for insulator against ESDD without and with surface pollution level is shown in table 5 and 6 respectively.

Table 4. The critical voltage for insulator against ESDD

ESDD (mg/cm^2)	V_C (kV)	Pollution level
0.01	37.65	Light

0.10	23.348	Moderate
0.30	19.24	Heavy

Table 5. The critical voltage for insulator without surface pollution (kV)

percentage of damages	Critical voltage
0	57.86
10	55.84
20	53.74
30	51.51
40	49.12
50	46.51

Table 6. The critical voltage for insulator with surface pollution (kV)

percentage of damages	Critical voltage		
	Light	Moderate	Heavy
0	37.66	23.35	19.25
10	36.58	22.76	18.81
20	35.44	22.13	18.35
30	34.25	21.48	17.86
40	32.96	20.77	17.33
50	31.56	20.00	16.76

From table 3 and 5, the comparison of the critical voltage of insulator near the conductor without surface pollution based on percentage of damage was in the range of acceptable values.

From table 6, the critical voltage of insulator can use acceptably with percentage of damage and surface pollution levels within 30% and light pollution level.

7. CONCLUSION

The studied approach is applicable to an insulator type 52-3. The potential and electric field along polluted suspension insulators have been analyzed in this paper. This simulation analysis showed that the effect of the surface pollution levels on a suspension insulator is to line arise the potential distribution along the length of the insulator. The defective insulator which was based on both the percentage of damage and surface pollution levels (ESDD), it may be influenced on the dielectric behavior of the insulators has been examined in order to reduce the effect of system. The result have been shown that it can use acceptably with percentage of damage and surface pollution levels within 30% and light pollution level respectively.

However, the work needs to be focused on obtaining accurate technical data for the materials constituting the insulator in order to simulate and calculate the acceptable result.

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SPP Loss Allocation by Cooperative Games

Sopa Heng, Onurai Noohawm* and Dulpichet Rerkpreedapong*

Abstract*— *This paper presents the calculation method of transmission loss allocation including active and reactive losses when an SPP sells electrical power to its customers through 115 kV PEA networks. The concept of circuit theorem and cooperative game theory are together employed in the proposed method. Then, power losses can be allocated to each power producer by using the Shapley value method, and the simulation is performed by the PowerWorld Simulator. From the results, it is found that the SPP location is the key factor of loss allocation. In addition, impartial and reasonable results of loss allocation have been obtained from verifying the effectiveness of the proposed method.

***Keywords*— loss allocation, cooperative game theory, Shapley, SPP, current injection.**

1. INTRODUCTION

In the past, SPPs (Small Power Producer) could sell electrical power to EGAT (Electricity Generating Authority of Thailand) only. Now SPPs are allowed to sell electricity to their own customers directly. Most of the SPPs are located in PEA (Provincial Electricity Authority of Thailand) service areas so this can result in a redundant investment in power distribution infrastructure between PEA and SPPs. To mitigate such a problem, PEA has allowed SPPs to sell electrical power to their customers through PEA distribution and transmission networks, and SPPs are charged for PEA infrastructure usages.

Currently, SPP wheeling charges are calculated from the amount of power demand regardless of the SPP location. This way might not be truly reasonable because the SPP location has a significant impact on power losses of the system. Generally, SPPs often increase power losses of networks due to their power flows. On the contrary, some SPPs can reduce the power losses.

The cooperative game theory is a new method to loss allocation among participants in electricity market [1] – [5]. This method is effective in terms of giving impartial results for loss allocation. In [1], the equivalent current-injected generation and constant-impedance load models were used with the concept of Shapley value from cooperative game theory to allocate power losses to all participants. [2] – [3] proposed the procedures for active and reactive power loss allocation in transmission networks, and at the same time those losses were allocated to individual sources and loads. In [2], the equivalent nodal injection currents of sources and loads were tested with the designed two-step cooperative game together with the Shapley value to allocate power losses. It was a direct analytical method which can be simply understood. In this work, the power losses were decreased by counter-flows generated from capacitive sources. As a result, both sources and loads who contributed in loss reduction should be rewarded a decrease in loss allocation as an economic incentive. In [3], the circuit theory and Aumann-Shapley value for loss allocation was proposed. The network losses were divided into two equal parts, and each of them was allocated to load and generator sides respectively. In this method, the grid system was considered as a black box such that grid parameters were not required for loss allocation. However, the Aumann-Shapley method was rather complicated to understand and calculate.

The method of loss allocation proposed in [4] used the cooperative game theory and Shapley value. Both sources and loads were considered as the players of game. This method used Thevenin theorem to transform the sources to equivalent voltage sources, and loads to impedances.

In [5], the method of loss reduction allocation was applied to distributed generation (DG) units in distribution systems. The participation of each unit in reducing the amount of power losses was found, and the cooperative game theory is used to allocate the benefits to each DG. In this paper, the τ method and the Shapley value were compared, and the results were about similar.

This paper presents a method to allocate both active and reactive power losses in PEA's networks to PEA and SPPs, when the grid-connected SPPs are selling electrical power to their customers. The proposed method employs the circuit laws and cooperative game theory to find the losses contributed from each participant in the game. To allocate the losses, the Shapley value method is applied while the players of the game are current injection sources and loads of all nodes. This method has been tested with the 5-bus, 115-kV system. It is found that the SPP's location notably affects the amount of losses allocated to all participants.

2. COOPERATIVE GAME THEORY

In electricity market, the cooperative game theory was widely applied to solve problems regarding cost and loss allocation of transmission networks to their users because this method is convenient to use, and offers impartial and reasonable results. For an n-participant cooperative

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game, the number of coalitions of n players is equal to 2^n. For an example of three players ($n=\{1,2,3\}$), it results in eight coalitions as follows. $S=\{\},\{1\},\{2\},\{3\},\{1,2\},\{1,3\},\{2,3\},\{1,2,3\}$ when S is subsets of set n.

In this paper, the Shapley value is used to allocate the amount of current and transmission loss to each player. The player k will receive payoff allocation as shown in (1).

$$\phi_k(v)=\sum_{\substack{S\subseteq n\\ k\in n}}\frac{(n-|S|)!(|S|-1)!}{n!}\left[v(S)-v(S-\{k\})\right] \quad (1)$$

where: ϕ_k = payoff allocation to player k

S = group of players as subsets of n including player k

$v(S)$ = characteristic function of coalition S

3. METHODOLOGY

In this paper, the methodology presented in [2] is used to allocate losses because of its practicality. It could simultaneously allocate both active and reactive power losses which satisfy all circuit laws. In this method, the players are nodal injection currents which play two cooperative games. In the first game, current allocation for branch *l* is performed. In the second game, the losses are allocated to all players. The procedure is illustrated as follows:

1. Let a player of the game be injected current at node *k* ($\bar{I}_k^n$) including injections from sources and loads, when n is the number of players or number of nodes excluding the ground node. It can be calculated from the complex power equation in (2).

$$S_k=\bar{V}_k\hat{I}_k \quad (2)$$

where: S_k = complex power injected at node k

$\bar{V}_k$ = phasor voltage at node k

$\hat{I}_k$ = complex conjugate of injected phasor current at node k

Thus, the equation of injected current at node k is given by (3) – (5).

$$\bar{I}_{k_S}^n=\frac{(P_{Sk}-jQ_{Sk})}{\hat{V}_k},\ k=1,2,\cdots,n \quad (3)$$

$$\bar{I}_{k_D}^n=\frac{(-P_{Dk}+jQ_{Dk})}{\hat{V}_k},\ k=1,2,\cdots,n \quad (4)$$

$$\bar{I}_k^n=\bar{I}_{k_S}^n+\bar{I}_{k_D}^n,\ k=1,2,\cdots,n \quad (5)$$

where: $\bar{I}_{k_S}^n,\bar{I}_{k_D}^n$ = injected phasor current from source and load respectively at node k

P_{Sk},Q_{Sk} = active and reactive power injected at node k respectively

$\bar{I}_k^n$ = injected phasor current at node k

2. Calculate the current of branch l using Ohm's law as expressed in equation (6)

$$\bar{I}_l^b=\frac{(\bar{V}_i^n-\bar{V}_j^n)}{\bar{Z}_l} \quad (6)$$

where: $\bar{V}_i^n,\bar{V}_j^n$ = phasor voltages at node i and j

$\bar{Z}_l$ = impedance of branch l

$\bar{I}_l^b$ = phasor current of branch l

3. Calculate the responding current of branch l from the current injection into node k both from sources and loads by using Ohm's and Kirchhoff's laws as given by (7) – (10).

$$\bar{V}^n=\bar{Z}^n\bar{I}^n \quad (7)$$

where: $\bar{V}^n$ = column vectors of the bus voltages

$\bar{I}^n$ = column vectors of the injection currents entering the buses

$\bar{Z}^n$ = bus impedance matrix

The matrix in Eq. (7) can be formulated in terms of equations as given by (8).

$$\bar{V}_i^n=\sum_{k=1}^{n}\bar{Z}_{ik}^n\bar{I}_k^n,\quad i=1,2,\cdots,n \quad (8)$$

where: $\bar{Z}_{ik}^n$ = element in the *i*th row and *j*th column of the bus impedance matrix

Thus, the the responding current of branch l from the current injection into node k both sources and loads is given by (9)

$$\left.\begin{aligned}\bar{I}_l^b&=\frac{(\bar{V}_i^n-\bar{V}_j^n)}{\bar{Z}_l}=\frac{\sum_{k=1}^{n}\bar{Z}_{ik}^n\bar{I}_k^n-\sum_{k=1}^{n}\bar{Z}_{jk}^n\bar{I}_k^n}{\bar{Z}_l}\\&=\frac{\sum_{k=1}^{n}(\bar{Z}_{ik}^n-\bar{Z}_{jk}^n)\bar{I}_k^n}{\bar{Z}_l}\end{aligned}\right\} \quad (9)$$

Let $\bar{I}_{kl}^b$ be the total responding current of branch l from injection current ($\bar{I}_k^n$) at node k. It is given by (10).

$$\bar{I}_{kl}^b=\frac{(\bar{Z}_{ik}^n-\bar{Z}_{jk}^n)}{\bar{Z}_l}\bar{I}_k^n,\quad k=1,2,\cdots,n \quad (10)$$

Substituting Eq. (5) into Eq. (10) results in (11).

$$\bar{I}_{kl}^b=\frac{(\bar{Z}_{ik}^n-\bar{Z}_{jk}^n)}{\bar{Z}_l}\left[\bar{I}_{k_S}^n+\bar{I}_{k_D}^n\right],\quad k=1,2,\cdots,n \quad (11)$$

The total responding current of branch l ($\bar{I}^b_{kl}$) is decomposed into two parts including those from source and load as given by (12)-(15).

$$\bar{I}^b_{k_S l} = \frac{\left(\bar{Z}^n_{ik} - \bar{Z}^n_{jk}\right)}{\bar{Z}_l} \bar{I}^n_{k_S} \tag{12}$$

$$\bar{I}^b_{k_D l} = \frac{\left(\bar{Z}^n_{ik} - \bar{Z}^n_{jk}\right)}{\bar{Z}_l} \bar{I}^n_{k_D} \tag{13}$$

where: $$\bar{I}^b_{kl} = \bar{I}^b_{k_S l} + \bar{I}^b_{k_D l} \ , \quad 1,2,\cdots,n \tag{14}$$

and $$\bar{I}^b_l = \sum_{k=1}^{n} \bar{I}^b_{kl} \tag{15}$$

4. Start the first cooperative game such that the player of game is the injected current at node k ($\bar{I}^n_k$), and the number of players is equal to the number of nodes (n). The characteristic function of game is $\bar{I}^b_l(S)$, when S is the group of players of the game.

Next, the current of branch l is allocated to each player using the Shapley value according to Eq. (1). The current fraction of player k can be calculated by Eq. (16).

$$\bar{I}^n_{kl}\left(\bar{I}^b_l\right) = \sum_{\substack{S \subseteq n \\ k \in n}} \frac{(n-|S|)!(|S|-1)!}{n!} \left[\bar{I}^b_l(S) - \bar{I}^b_l(S-\{k\})\right] \tag{16}$$

From Eq. (16), the player k will receive current fraction of branch l equal to $\bar{I}^b_{kl}$ according to Eq. (11).

5. Next, begin the second cooperative game. In this game, the characteristic function of game is active and reactive power losses on branch l. To find the loss fraction of each player ($\bar{I}^b_{kl}$), it can be calculated from step 4 as follows.

Rewrite $\bar{I}^b_{kl}$ as (17)

$$\bar{I}^b_{kl} = a_{kl} + jb_{kl} \tag{17}$$

From the power loss equations, the characteristic function of game is given by (18)-(19).

$$P_l(S) = \left|\sum_{k \in S} \bar{I}^b_{kl}\right|^2 r_l = \left|\sum_{k \in S} a_{kl}\right|^2 r_l + \left|\sum_{k \in S} b_{kl}\right|^2 r_l \tag{18}$$

$$Q_l(S) = \left|\sum_{k \in S} \bar{I}^b_{kl}\right|^2 x_l = \left|\sum_{k \in S} a_{kl}\right|^2 r_l + \left|\sum_{k \in S} b_{kl}\right|^2 x_l \tag{19}$$

where: P_l, Q_l = active and reactive power losses on branch l

r_l, x_l = resistance and reactance of branch l

Then, the losses on branch l are allocated to each player using the Shapley value. The loss fraction of player k can be calculated by Eq. (20).

$$L^P_{kl}\left(P_l\right) = \sum_{\substack{S \subseteq n \\ k \in n}} \frac{(n-|S|)!(|S|-1)!}{n!} \left[P_l(S) - P_l(S-\{k\})\right] \tag{20}$$

From Eq. (20), the loss fraction of total active power on branch l of player k (L^P_{kl}) is expressed by (21).

$$L^P_{kl} = r_l a_{kl} \sum_{h=1}^{n} a_{hl} + r_l b_{kl} \sum_{h=1}^{n} b_{hl} \ , \quad k = 1,2,\cdots,n \tag{21}$$

Eq. (21) can be expressed in dot product form as (22).

$$L^P_{kl} = \left(\bar{I}^b_{kl} \bullet \bar{I}^b_l\right) r_l \ , \quad k = 1,2,\cdots,n \tag{22}$$

where: $\bar{I}^b_{kl} = \left[a_{kl} \ b_{kl}\right]^T$

$$\bar{I}^b_l = \sum_{k=1}^{n} \bar{I}^b_{kl}$$

Substituting Eq. (14) into Eq. (22) leads to (23)-(24).

$$L^P_{k_S l} = \left(\bar{I}^b_{k_S l} \bullet \bar{I}^b_l\right) r_l \tag{23}$$

$$L^P_{k_D l} = \left(\bar{I}^b_{k_D l} \bullet \bar{I}^b_l\right) r_l \tag{24}$$

Eq. (23) and (24) express the loss fraction of total active power on branch l of player k from source and load.

6. From the above equations, find the loss fraction of total active power of player k at all branches ($L^P_{k_S}, L^P_{k_D}$) in the network using (25)-(26).

$$L^P_{k_S} = \sum_{l=1}^{b} L^b_{k_S l} \tag{25}$$

$$L^P_{k_D} = \sum_{l=1}^{b} L^b_{k_D l} \tag{26}$$

7. Similarly, the loss fraction of total reactive power on branch l of player k from source and load is given by (27)-(28).

$$L^Q_{k_S l} = \left(\bar{I}^b_{k_S l} \bullet \bar{I}^b_l\right) x_l \tag{27}$$

$$L^Q_{k_D l} = \left(\bar{I}^b_{k_D l} \bullet \bar{I}^b_l\right) r_l \tag{28}$$

And the loss fraction of total reactive power of player k at all branches ($L^Q_{k_S}, L^Q_{k_D}$) in the network is given by (29)-

(30).

$$L^{Q}_{k_S} = \sum_{l=1}^{b} L^{b}_{k_S l} \quad (29)$$

$$L^{Q}_{k_D} = \sum_{l=1}^{b} L^{b}_{k_D l} \quad (30)$$

8. Finally, the total losses allocated to SPPs and their customers are added up to find the total active and reactive power losses. The total losses for PEA can be calculated in the same way.

4. CASE STUDY

The test system is the 5-bus, 115-kV system including 7 transmission lines and 5 high-voltage customers. The customers at bus 2 and 3 are purchasing power from the SPP, and the others are PEA's customers as shown in Figure 1. This paper presents 2 case studies to analyze the effects of SPP's location. Source, load and line data are given in Table 1 to 3 respectively.

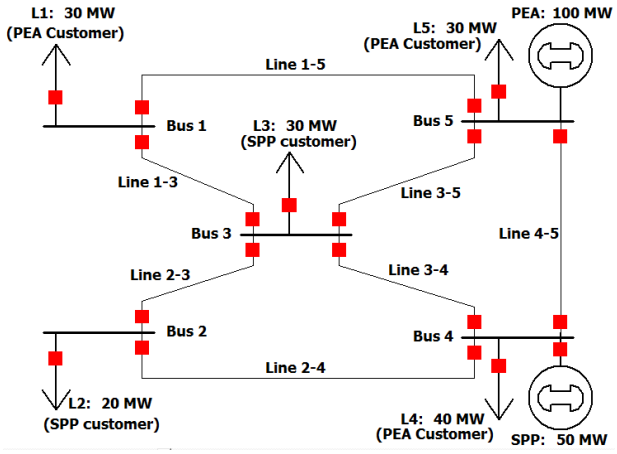

Fig.1. A 5-bus, 115-kV transmission system. (Base MVA = 100 and Base kV = 115 kV)

Table 1. Source Data

Case	Bus	Generator (MVA)	Power providers
I	4	50.00 + j0.00	SPP
	5	100.77 + j97.94	PEA
II	1	50.00 + j0.00	SPP
	5	101.03 + j99.41	PEA

Table 2. Load Data

Bus	Load (MW)	Power providers
1	30.00 + j18.59	PEA
2	20.00 + j12.39	SPP
3	30.00 + j18.00	SPP
4	40.00 + j24.78	PEA
5	30.00 + j18.35	PEA

Table 3. Line parameters

l	Line	R (Ohm)	X (Ohm)
1	1-3	0.01719	0.12200
2	1-5	0.02149	0.15250
3	2-3	0.01719	0.12200
4	2-4	0.02149	0.15250
5	3-4	0.01504	0.10675
6	3-5	0.01504	0.10675
7	4-5	0.02149	0.15250

Case I: The SPP located at bus 4 results in active and reactive power loss allocation to sources and loads as shown in Table 4. The results of total active and reactive power loss fractions of SPP and PEA are given in Table 5.

Table 4. Case I: Sources and Load Loss allocation Results

Bus		Bus Power (MVA)	Loss Fractions (MVA)
Source	4	50.00 + j0.00	-0.1613 - j1.1443
	5	100.77 + j97.94	0.9185 + j6.5176
Total		**150.77 + j97.94**	**0.7572 + j5.3733**
Load	1	30.00 + j18.59	0.0730 + j0.5181
	2	20.00 + j12.39	0.0823 + j0.5838
	3	30.00 + j18.00	0.0566 + j0.4018
	4	40.00 + j24.78	0.0236 + j0.1672
	5	30.00 + j18.35	-0.1703 - j1.2082
Total		**150.00 + j92.11**	**0.0652 + j0.4627**
Total System Loss			**0.8224 + j5.8360**

Table 5. Case I: SPP and PEA Loss allocation Results

Power Providers	Bus		Bus Power (MVA)	Loss Fractions (MVA)
SPP	Source	4	50.00 + j0.00	-0.1613 - j1.1443
	Load	2	20.00 + j12.39	0.0823 + j0.5838
		3	30.00 + j18.00	0.0566 + j0.4018
Total Loss				**-0.0224 - j0.1587**
PEA	Source	5	100.77 + j97.94	0.9185 + j6.5176
	Load	1	30.00 + j18.59	0.0730 + j0.5181
		4	40.00 + j24.78	0.0236 + j0.1672
		5	30.00 + j18.35	-0.1703 - j1.2082
Total Loss				**0.8448 + j5.9947**
Total System Loss				**0.8224 + j5.8360**

Case II: The SPP is relocated to bus 1, and results in active and reactive power loss allocation to sources and loads as shown in Table 6. The results of total active and reactive power loss fractions of SPP and PEA are shown in Table 7.

Table 6. Case II: Sources and Load Loss allocation Results

Bus		Bus Power (MVA)	Loss Fractions (MVA)
Source	1	50.00 + j0.00	-0.0348 - j0.2469
	5	101.03 + j99.41	1.0255 + j7.2764
Total		**151.03 + j99.41**	**0.9907 + j7.0295**
Load	1	30.00 + j18.59	-0.0854 - j0.6059
	2	20.00 + j12.39	0.1090 + j0.7737
	3	30.00 + j18.00	0.0497 + j0.3528
	4	40.00 + j24.78	0.1559 + j1.1066
	5	30.00 + j18.35	-0.1916 - j1.3595
Total		**150.00 + j92.11**	**0.0376 + j0.2677**
Total System Loss			**1.0283 + j7.2972**

Table 7. Case II: SPP and PEA Loss allocation Results

Power providers	Bus		Bus Power (MVA)	Loss Fractions (MVA)
SPP	**Source**	1	50.00 + j0.00	-0.0348 - j0.2469
	Load	2	20.00 + j12.39	0.1090 + j0.7737
		3	30.00 + j18.00	0.0497 + j0.3528
Total Loss				**0.1239 + j0.8796**
PEA	**Source**	5	101.03 + j99.41	1.0255 + j7.2764
	Load	1	30.00 + j18.59	-0.0854 - j0.6059
		4	40.00 + j24.78	0.1559 + j1.1066
		5	30.00 + j18.35	-0.1916 - j1.3595
Total Loss				**0.9044 + j6.4176**
Total System Loss				**1.0283 + j7.2972**

The results given in Table 5 and 6 show that the SPP location at bus 4 results in a negative loss fraction (-0.0224-j0.1587 MVA) because of this location generates counter flows. While the SPP located at bus 1 results in a positive loss fraction (0.1239 + j0.8796 MVA). Therefore, the SPP location has significant effects to power losses in the system. The appropriate SPP location can reduce losses as shown in Case I.

5. CONCLUSION

The application of the cooperative game and Shapley value to complex loss allocation is performed. The results show the losses are allocated reasonably and impartially to all players. The loss fraction is positive if it flows in the same direction of the branch's dominant current. Otherwise, it is negative. The allocation method using the Shapley value reveals the benefits in terms of loss reduction caused by the player of the game as shown in Case I. In other words, the player or SPP at bus 4 reduced the complex losses of the system. As a result, the SPP should be rewarded a decrease in costs resulted from loss allocation. The results of both case studies also show that the network loss allocation depends on the SPP location and network topology. At last, this method is appealing to an SPP to choose a suitable location for minimizing costs regarding loss allocation, and transmission losses in the network.

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Outage Cost Modeling of High Energy Consumption Industries

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***Abstract*—** This paper presents modeling of customer outage cost of large industries in Thailand considered from electrical energy consumptions. The selected industries are classified into six Thai Standard Industrial Classification (TSIC) customer groups consisting of foods, textiles, chemical and rubber, iron and steel, cement and fabricated metals industries. The 279 factories in the central region of Thailand were surveyed to collect information for outage cost evaluation. Next, customer outage costs of those factories are modeled by using the statistic regression and fuzzy regression methods. Then, both modeling are analyzed and compared using statistical techniques. Finally, the method of selection between both modeling is presented in order to obtain a better model for industrial customers of each TSIC. Consequently, the customer outage cost assessment can be achieved from the proposed methodology, which is simple and offers a fit model for individual industries.

***Keywords*— Customer outage cost, Fuzzy regression, Industrial customer groups**

1. INTRODUCTION

All electric power utilities in Thailand aim to provide services to their customers with high efficiency, reliability and safety. A number of megaprojects have been implemented on power distribution infrastructures such as smart grids, risk and asset management, overhead to underground system conversion, microgrids, etc.

Customer outage cost is widely used by most utilities to make a decision on system investment. The outage cost is described as the damage costs due to power interruptions related to customers and utilities. The utilities can use it to prioritize locations or service areas for reliability improvement [4-6]. Also, it can be used by industries to evaluate the cost-benefit of the future projects [3,10].

The methods of outage cost modeling used in this paper are statistic regression and fuzzy regression. Generally, statistic regression is an effective tool to develop a mathematical model, in terms of regression parameters or regression coefficients, from the relationship between input and output data [8]. Meanwhile, the modeling resulted from statistic regression may result in a serious inaccuracy when the number of data is insufficient, or there is vagueness of the relationship between input and output variables [20]. On the other hand, many researches have shown that fuzzy regression can help fix these problems. Some applications of fuzzy regression are found in business pricing, health assessment [1], industrial process control [2], oil consumption forecasting and peak load estimation [12-16]. In this paper, the outage costs of customers by TSIC are modeled using both techniques. Then, the better fit model is to be selected by statistical techniques for outage cost assessment of each TSIC.

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2. METHOD

Customer Damage Function

Customer damage function is used to assess customer outage cost. Generally, sector customer damage functions (SCDF) are used to develop composite customer damage function (CCDF) [4]. SCDF is developed from data collected from customers via questionnaires. The damage costs are surveyed and evaluated for several outage durations, i.e., 1, 30, 60 minutes, etc. In this paper, the individual customer damage functions (CDF) as given in equation (1) are derived from the collected data of surveyed factories, and then the SCDF could be produced from those functions.

$$CDF(t) = DC.t + IC \qquad (1)$$

where

CDF(t) = Customer damage function (Baht/Interruption)

IC = Initial outage cost (Baht)

DC = Duration outage cost (Baht/hour)

t = Outage duration (minute /Interruption)

Initial outage cost (IC) represents sudden losses and product impairment of industrial customers when the lines of production are interrupted due to both momentary and sustained interruptions. In this paper, the initial outage cost is expressed in Baht per interruption, associated with the loss of production opportunity during the restart process. Duration outage cost (DC) represents duration losses caused by only sustained power interruptions

including loss of production opportunity during a period of power outages.

Fuzzy Regression

Fuzzy linear regression is first developed by Tanaka et al [12]. This method is based on the principle of fuzzy sets (L.A. Zadeh) [11]. Statistic regression is based on probability theory, while fuzzy regression is based on possibility theory and fuzzy set theory [6]. Equation (2) shows the fuzzy regression model.

$$Y = A_0 + A_1x_1 + A_2x_2 + ... + A_nx_n = A_x \qquad (2)$$

where Y are fuzzy outputs or dependent variables
A are fuzzy parameters
x are independent variables

Then, linear programming is used to optimize the performance index (J) as shown in equation (3).

$$\text{Minimize } J = \sum_{j=0}^{N}\left(c_j \sum_{i=1}^{M}\left|x_{ij}\right| \right)$$

$$\text{Subject to} \quad \sum_{j=0}^{N}\alpha_j x_{ij} + (1\text{-}h)\sum_{j=0}^{N} c_j\left|x_{ij}\right| \geq y_i \qquad (3)$$

$$\sum_{j=0}^{N}\alpha_j x_{ij} - (1\text{-}h)\sum_{j=0}^{N} c_j\left|x_{ij}\right| \leq y_i$$

$$c_j \geq 0, \quad \alpha_j \in \Re, \quad j = 0, 1, 2, ..., N \qquad x_{i0} = 1, \quad i = 0, 1, 2, ..., M \qquad 0 \leq h \leq 1$$

The performance index J is minimized subject to constraints as given in (3) where h as the membership value between 0 and 1 is the threshold level, and determines the degree of fitting with human decision making. C_j is the width or spread, and α_j is the center of triangle base. For fuzzy parameters, x is independent variables, and y is dependent variables where M is the number of data and N is the number of x (independent variable).

Conventional Regression

Conventional regression or statistic regression is regression analysis. This method is based on the analysis of relationship between the variables [7-9]. Simple linear regression could be modeled from dependent variables and independent variables. If there are many independent variables the it would be modeled by multiple linear regression as presented by equation (4).

$$Y = \beta_0 + \beta_1X_{1i} + \beta_2X_{2i} + ... + \beta_pX_{pi} + u_i \qquad (4)$$

where Y is dependent or response variable
$X_1, X_2, ..., X_p$ are independent variables
$\beta_0, \beta_1, ..., \beta n$ are constants or the model partial regression coeffients
u_i is random disturbance term
p is number of independent variables
i is number of observations

Analysis of variance

Single factor analysis of variance (ANOVA) or one way ANOVA is the analysis of differential level of data by considering only one factor. The objective of analysis of variance is the test of the several means of populations to compare between the groups of populations. The number of population groups have to be equal or greater than three groups of populations or treatments [9,14,19].

First, determine the null hypothesis H0: $\mu_1 = \mu_2 = \mu_3 = \mu_n$. Next, write the alternative hypothesis H1: $\mu_i \neq \mu_j$ at least one pair of means, $i \neq j$, i,j = 1, 2, ..., n. Then, specify the α level: $\alpha = 0.05$. Lastly, calculate the appropriate statistic

where μ_1, μ_2, μ_3 and μ_n are the means of populations
n is number of group of populations
α is the significance level.

Test of hypothesis

If the significance level in ANOVA results less than 0.05, the null hypothesis will be rejected. Tukey test is chosen for hypothesis test because it is the pairwise comparison method to test significant differences between groups [14,19].

3. CALCULATION

Data Collection

The 279 surveyed factories can be classified into 6 TSIC groups including 10 subgroups as shown in Table 1. The key factors to be considered in regression models are customer outage cost per interruption, electricity peak demand, distribution transformer kVA, backup generator kVA, number of staff and restarting time of production process.

Table 1. TSIC Code and descriptions of surveyed factories

TSIC	Group	Type / sub-group	Frequency	Percent
31	Food, beverage and tobacco	TSIC 31149 : Preserved and canned seafood	55	19.71
32	Textiles and leather products	TSIC 32113 : Spinning cotton and synthetic fibers TSIC 32115 : Weaving and textlies	24	8.60
35	Chemical and rubber	TSIC 35130: Synthetic resin, plastic materials and synthetic fibers, except glass TSIC 35510: Tire rubber and inner tube TSIC 35609: Other plastic products	85	30.47
36	Non metallic mineral	TSIC 36921: Cement	17	6.09
37	Basic material	TSIC 37110: Iron, steel production and steel mills	22	7.89
38	Fabricated metals	TSIC 38320: radio, television and communication product TSIC 38439: Automotive and machinery part	76	27.24
Total			279	100

* Reference as TSIC manual guide book on B.E.2549 (2006).

Variables

The key factors mentioned above are used as the input and output variables of the regression models as follows.

One output variables is:

- $y_{TSIC\ i}$: Industrial customer outage cost (Baht/interruption) where i is TSIC Code

and five input variables are:

- x_1 : Distribution transformer kVA (kVA)
- x_2 : Number of staffs (persons)
- x_3 : Generator kVA (kVA)
- x_4 : Peak demand (kW)
- x_5 : Restarting time (minutes).

Outage Cost Estimation

The high energy consumption industrial customers of PEA were surveyed in 2009. The data were collected by questionnaires including some from postal mails and onsite interviews. Then, these data as classified by TSIC groups are performed to develop CDF of each factory. The resulting CDF is the time dependent function where the time duration of interruptions is used in this case. To get the numerical results of CDF, the time duration is used at 36 minutes which comes from the average interruption duration of power distribution systems in the central area of Thailand [17]. Then, those CDF are used to evaluate the outage cost per interruption assigned as the dependent output variable ($y_{TSIC\ i}$) of the regression models against five independent input variables, which are distribution transformer kVA (x_1), number of staff (x_2), generator kVA (x_3), peak demand (x_4) and restarting time (x_5).

First, modeling the TSIC outage cost by multiple linear regression, a version of statistic regression, is performed. Next, modeling based on fuzzy regression is achieved for a comparison. The latter technique will get an advantage when inadequacy of data, vagueness of data, or distortion of data are present. Therefore, an algorithm to select the better fit modeling for each group of industrial customers is required. In this paper, the analysis of variance (ANOVA) and hypothesis testing are employed to analyze the collected data. There are three populations or treatments for ANOVA. The first one is the outage cost estimated by fuzzy regression (FR), and the second is those from statistic regression (SR). The last one is the actual outage cost (AC) of each factory. The conditions of hypothesis testing are given as follows.

The null hypothesis $H_0: \mu_{AC} = \mu_{FR} = \mu_{SR}$
The alternative hypothesis $H_1: \mu_i \neq \mu_j$
for at least one pair of outage cost values where $i \neq j$, and i, j = AC, FR, SR.

To be able to conclude whether the null hypothesis is accepted or rejected, the ANOVA results are considered as follows. If the P-value is higher than α level: $\alpha = 0.05$, the hypothesis is not rejected. Then, the values of Mean Absolute Percentage Error (MAPE) of both FR and SR models are determined. Which model has a lower value of MAPE will be selected. On the contrary, if the hypothesis is rejected. All pairs of outage cost values among FR, SR and AC will be compared by using hypothesis testing with Tukey method to select the better model from the statistic or fuzzy regression method according to the P-value of each pair.

4. RESULTS AND DISCUSSIONS

The histograms and probabilities plots of dependent variable or $y_{TSIC\ i}$ are shown in Fig. 1 to display the line of normal curve of dependent variable for each TSIC group from multiple linear regression.

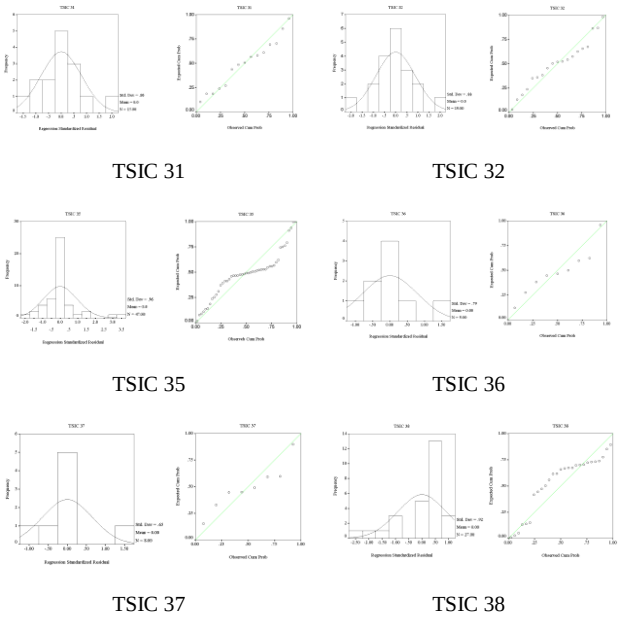

Fig.1. Distribution Histogram and Probability Plots

Table 2. Mean Absolute Percentage Error

TSIC Code	Mean Absolute Percentage Error (MAPE)	
	Fuzzy Regression	Statistic Regression
31	7.19	4.36
32	30.68	3.54
35	20.68	5.62
36	0.73	0.58
37	69.66	115.36
38	2,608.64	9,305.95

After the customer outage costs of six TSIC groups are modeled using fuzzy regression and statistic regression, the MAPE resulted from both models are calculated and presented in Table 2.

A summary of statistical values of industrial customer outage costs from AC, FR, and SR for each TSIC group are shown in Table 3, Table 5, Table 7, Table 9, Table 11 and Table 13.

Table 3. Staticical Values of TSIC 31

Groups	*Count*	*Sum*	*Average*	*Variance*
AC	55	12,259,514	222,900	379,370,284,797
FR	55	16,402,109	298,220	221,789,199,603
SR	55	5,303,731	96,431	210,807,647,982

Table 4. ANOVA results of TSIC 31

Source of Variation	*Sum square*	*Degree of freedom*	*Mean square*	*F*	*P-value*
Between Groups	1,143,745,430,683	2	571,872,715,342	2.1129	0.1242
Within Groups	43,846,225,148,604	162	270,655,710,794		
Total	44,989,970,579,287	164			

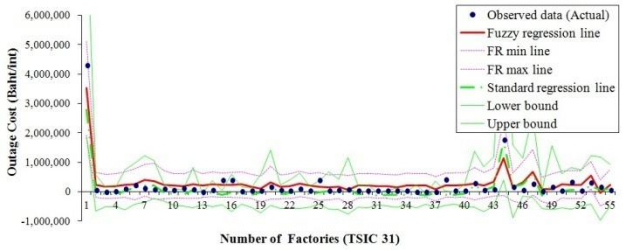

Fig.2. FR and SR Estimation for TSIC 31

According to ANOVA results in Table 4, the P-value is greater than 0.05 so the null hypothesis is accepted for TSIC 31. Then, MAPE of statistic regression in Table 2 is found lower than that of fuzzy regression, so the SR model is selected for TSIC 31 customer group.

Table 5. Staticical Values of TSIC 32

Groups	*Count*	*Sum*	*Average*	*Variance*
AC	24	1,597,643	66,568	14,450,594,062
FR	24	3,761,034	156,710	37,013,285,472
SR	24	1,083,947	45,164	3,426,610,590

Table 6. ANOVA results of TSIC 32

Source of Variation	*Sum square*	*Degree of freedom*	*Mean square*	*F*	*P-value*
Between Groups	168,207,583,377	2	84,103,791,688	4.5966	0.0134
Within Groups	1,262,481,272,873	69	18,296,830,042		
Total	1,430,688,856,250	71			

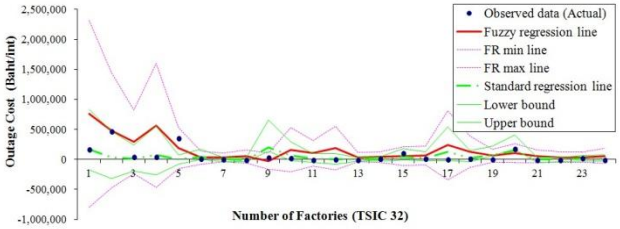

Fig.3. FR and SR Estimation for TSIC 32

According to ANOVA results in Table 6, the P-value is less than 0.05 so the null hypothesis is rejected for TSIC 32. Thus, the hypothesis testing by Tukey method is used to compare the pairs of treatments. The results are shown as follows:

	P-value	Result
AC and FR	0.0613	$\mu_{AC} = \mu_{FR}$
AC and SR	0.8478	$\mu_{AC} = \mu_{SR}$
FR and SR	0.0154	$\mu_{FR} \neq \mu_{SR}$

The significant results of pairs AC and FR, AC and SR have the P-value greater than 0.05 so both statistic and fuzzy regressions are applicable. However, the model resulted from statistic regression is better recommended for TSIC 32 customer group because of a lower of P-value.

Table 7. Staticical Values of TSIC 32

Groups	*Count*	*Sum*	*Average*	*Variance*
AC	85	5,447,058	64,083	19,666,687,385
FR	85	18,682,428	219,793	228,580,296,986
SR	85	7,545,328	88,769	134,504,363,257

Table 8. ANOVA results of TSIC 35

Source of Variation	*Sum square*	*Degree of freedom*	*Mean square*	*F*	*P-value*
Between Groups	1,190,638,241,045	2	595319120522	4.6661	0.0102
Within Groups	32,151,113,200,718	252	127583782543		
Total	33,341,751,441,762	254			

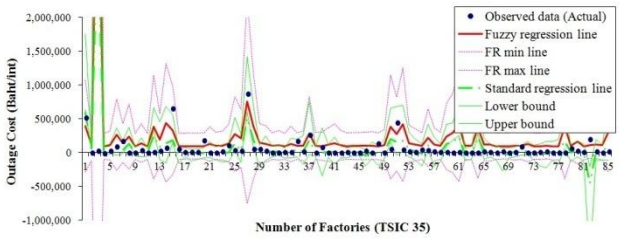

Fig.4. FR and SR Estimation for TSIC 35

According to ANOVA results in Table 8, the P-value is less than 0.05 so the null hypothesis is rejected for TSIC 35. Thus, the hypothesis testing by Tukey method is used to compare the pairs of treatments. The results are shown as follows:

	P-value	Result
AC and FR	0.0134	$\mu_{AC} \neq \mu_{FR}$
AC and SR	0.8942	$\mu_{AC} = \mu_{SR}$
FR and SR	0.0460	$\mu_{FR} \neq \mu_{SR}$

The significant result of pair AC and SR has the P-value greater than 0.05 so the model resulted from statistic regression is selected for TSIC 35 customer group.

Table 9. Staticical Values of TSIC 36

Groups	*Count*	*Sum*	*Average*	*Variance*
AC	17	9,379,412	551,730	1,126,985,471,107
FR	17	9,024,046	530,826	991,094,786,265
SR	17	9,116,261	536,251	1,133,541,051,991

Table 10. ANOVA results of TSIC 36

Source of Variation	*Sum square*	*Degree of freedom*	*Mean square*	*F*	*P-value*
Between Groups	4,000,718,421	2	2,000,359,210	0.0018	0.9982
Within Groups	52,025,940,949,810	48	1,083,873,769,788		
Total	52,029,941,668,231	50			

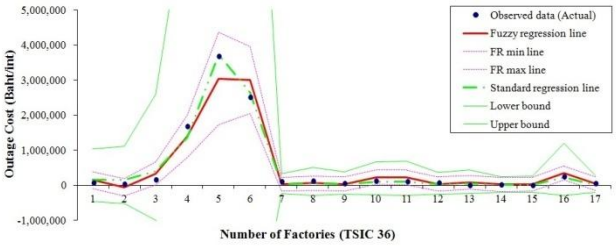

Fig.5. FR and SR Estimation for TSIC 36

According to ANOVA results in Table 10, the P-value is greater than 0.05 so the null hypothesis is accepted for TSIC 36. Thus, MAPE in Table 2 is considered. It is found that the MAPE of statistic regression is lower than that of fuzzy regression, so the SR model is selected for TSIC 36 customer group.

Table 11. Staticical Values of TSIC 37

Groups	*Count*	*Sum*	*Average*	*Variance*
AC	22	11,727,237	533,056	2,445,715,349,382
FR	22	14,957,018	679,864	1,652,806,416,678
SR	22	-9,587,286	-435,786	959,107,950,584

Table 12. ANOVA results of TSIC 37

Source of Variation	*Sum square*	*Degree of freedom*	*Mean square*	*F*	*P-value*
Between Groups	16,169,139,959,289	2	8,084,569,979,645	4.7955	0.0115
Within Groups	106,210,224,049,522	63	1,685,876,572,215		
Total	122,379,364,008,811	65			

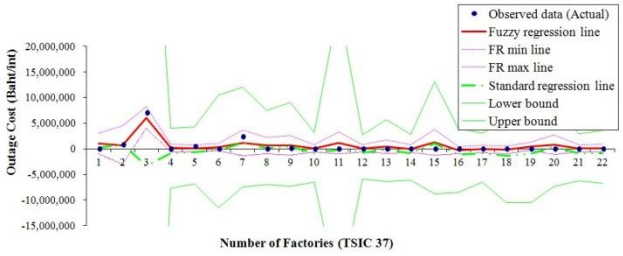

Fig.6. FR and SR Estimation for TSIC 37

According to ANOVA results in Table 12, the P-value is less than 0.05 so the null hypothesis is rejected for TSIC 37. Thus, the hypothesis testing by Tukey method is used to compare the pairs of treatments. The results are shown as follows:

	P-value	Result
AC and FR	0.9255	$\mu_{AC} = \mu_{FR}$
AC and SR	0.0419	$\mu_{AC} \neq \mu_{SR}$
FR and SR	0.0161	$\mu_{FR} \neq \mu_{SR}$

The significant result of pair AC and FR has the P-value greater than 0.05 so the model resulted from fuzzy regression is selected for TSIC 37 customer group.

Table 13. Staticical Values of TSIC 38

Groups	*Count*	*Sum*	*Average*	*Variance*
AC	76	73,361,764	965,286	16,286,343,096,486
FR	76	96,958,818	1,275,774	5,898,747,682,194
SR	76	30,497,494	401,283	11,862,743,385,749

Table 14. ANOVA results of TSIC 38

Source of Variation	*Sum square*	*Degree of freedom*	*Mean square*	*F*	*P-value*
Between Groups	29,874,008,986,360	2	14,937,004,493,180	1.3161	0.2702
Within Groups	2,553,587,562,332,150	225	11349278054810		
Total	2,583,461,571,318,510	227			

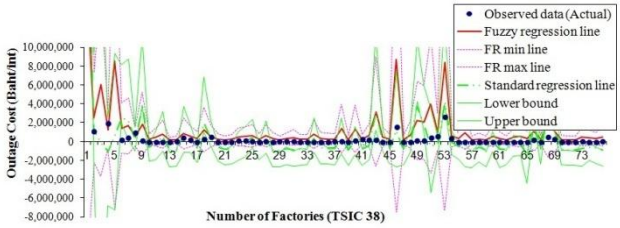

Fig.7. FR and SR Estimation for TSIC 38

According to ANOVA results in Table 14, the P-value is greater than 0.05 so the null hypothesis is accepted for TSIC 38. Thus, MAPE in Table 2 is considered. It is found that the MAPE of fuzzy regression is lower than that of statistic regression, so the FR model is selected for TSIC 38 customer group.

5. CONCLUSION

This paper presents the modeling of customer outage costs as classified into six TSIC groups. From the above results, the statistic regression method is appropriate for modeling the customer outage costs of TSIC 31, TSIC 35 and TSIC 36. On the other hand, the fuzzy regression method is suitable for modeling the customer outage cost of TSIC 37 and TSIC 38, while that of TSIC 32 may be modeled by fuzzy or statistic regression.

The customer outage cost models of the six TSIC groups result in the outage cost in Baht per interruption. Those models are simple to apply, although some of input variables are not available. Especially for fuzzy regression models, the constant parameter (A_0) alone can be used to

assess the outage costs with an acceptable error. Also, outage cost models classified by TSIC will offer a higher accuracy that is very helpful to electric utilities for making a decision on maintenance planning and reliability improvement projects.

ACKNOWLEDGMENT

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On-line Monitoring for Bushing of Power Transformer

Thanapong Suwnansri, Agkapon Pongmanee, and Cattareeya Suwanasri

Abstract*— *This paper presents the on-line monitoring system for bushing of large power transformer. The system is aimed to detect the degradation of bushing and provides the alarm before bushing failure. Generally the high voltage bushing is produced as a condenser type bushing, consisting of several paper insulation layers separated with conductive foils for each layers. Thus the degradation of internal insulation will affect the value of capacitance and power factor of insulation. These two parameters can be monitored on-line by installing the sensing device at the test tap of bushing. Then the changing of insulation capacitance will lead to the change of leakage current value through bushing insulation. In case of perfect bushing, the leakage current of each bushing should be equal and the summation of all three phase leakage current should be zero. If one bushing has problem with internal insulation, the leakage current will be higher. This makes the summation of current to be greater than zero. This knowledge is used to develop the detection and decision making algorithms in microcontroller and the hardware will be developed to implement as on-line monitoring system for bushing of large power transformer in transmission system.

***Keywords*— Bushing, leakage current, on-line monitoring, power transformer**

1. INTRODUCTION

Power transformer is one of the key equipment in transmission network. The failure of power transformer is catastrophic that leads to wide area power supply interruption. From the international survey and failure statistics recorded from Thailand transmission system, bushing failure is approximately 20 percent of transformer's failures. The main cause of failure is the aging of seal and gasket due to environmental heat and temperature variation. Moreover, the human error during maintenance can cause the loosen test tap, through which the moisture can pass to the inside insulation of bushing. Thus, the ingress moisture is the main reason of bushing failure.

Therefore, this paper presents the on-line monitoring system for bushing of large power transformer. The system is aimed to detect the degradation of bushing and provides the alarm before bushing failure. Generally the high voltage bushing is made as a condenser type bushing, consisting of several paper insulation layers separated with conductive foils for each layers. Thus the degradation of internal insulation will affect the value of capacitance and power factor of insulation. These two parameters can be monitored on-line by installing the sensing device at the test tap of bushing. Then the changing of insulation capacitance will lead to the change of leakage current value through bushing insulation. In case of perfect bushing, the leakage current of each bushing should be equal and the summation of all three phase leakage current should be zero. If one bushing has problem with internal insulation, the leakage current will be higher. This makes the summation of current to be greater than zero. This knowledge is used to develop the detection and decision making algorithms in microcontroller and the hardware will be developed to implement as on-line monitoring system for bushing of large power transformer in transmission system.

2. CONDENSER BUSHING

Construction

Generally, the bushing of power transformer is made as condenser type, consisting of several paper insulation layers separated with conductive foils for each layers as shown in Fig. 1.

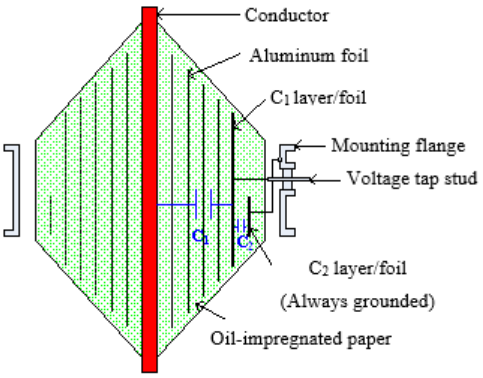

Fig.1. Construction Detail of Typical Condenser Type Bushing

The function of conductive aluminum foil in each layer is to obtain the equal voltage distribution in each layer. The space between internal surface of porcelain insulation and condenser set is filled with the insulation oil.

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Therefore, this condenser type bushing is called as oil impregnated paper or OIP bushing. The high voltage bushing consists of main capacitance C_1 and tap capacitance C_2 as shown in Fig. 2.

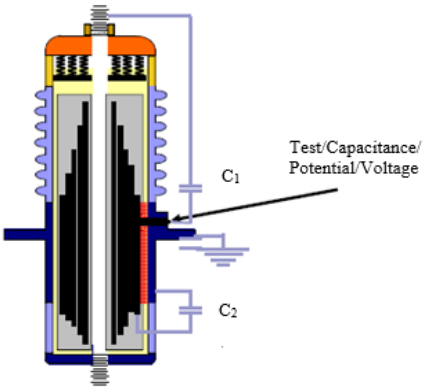

Fig.2. Main Capacitance of Condenser Type Bushing

Under normal condition, C_1 is connected to ground via voltage tap cover between tap stud and mounting flange, while C_2 is connected to ground without any voltage stress. The degradation of internal insulation will affect the value of capacitance C_1 and power factor of insulation. These two parameters can be monitored on-line by installing the sensing device at the test tap of bushing. C_1 and C_2 will perform as voltage divider and the voltage drop across C_2 can be used with potential device. Then, the changing of insulation capacitance will lead to the change of leakage current value through bushing insulation. In case of perfect bushing, the leakage current of each bushing should be equal and the summation of all three phase leakage current should be zero. If one bushing has problem with internal insulation, the leakage current will be higher. This makes the summation of current to be greater than zero. The summation of three phase leakage current will be compared with the commissioning value or observed the increasing trend in order to set the alarm level. This knowledge is used to develop the detection and decision making algorithms in microcontroller and the hardware will be developed to implement as on-line monitoring system for bushing of large power transformer in transmission system.

Dielectric Loses

Dielectric losses are measured in units of watt loses whereby heat is generated due to these losses. Losses are created by the following causes.

- Natural resistance of the material
- Type of the material
- Polar molecules such as moisture
- Ionization of gases (partial discharge)

Losses will vary by the amount of dielectric material. Since bushing are not the same size and composition, comparison of watt losses between different manufactures, sizes, etc. is difficult. Therefore, the industry uses the power factor to quantify the condition of the bushing insulation system. As loss increases due to any the above causes, the power factor will be also increased. The tap is usually connected to the outer most foil and in some cases to the second to last foil. The C_2 capacitance is the capacitance from the tap to ground. Typically, the tap is grounded; therefore, the C_2 capacitance is not in the circuit during normal operation.

Table 1 shows the capacitance of C_1 in bushing of power transformer (Oil-impregnate, paper-insulated type) rated 500 pF, 30.74 V.

Table 1. Capacitance of C_1 in Bushing of Power Transformer Rated 500 pF, 30.74 V

Case	C_1(pF)	ΔC_1	$V_{test\ tap}$ (V)	$\Delta V_{test\ tap}$	Decision
I	500 - 505	$1\% \le \Delta C_1$	30.74 - 31.05	$1\% \le \Delta C$	Normal
II	506 - 515	$1\% < \Delta C_1 \le 3\%$	31.06 - 31.66	$1\% < \Delta C \le 3\%$	Warning
III	516 - 525	$3\% < \Delta C_1 \le 5\%$	31.67 - 32.28	$3\% < \Delta C \le 5\%$	Alarm(Low)
IV	526 up	$\Delta C_1 > 5\%$	>32.28	$\Delta C > 5\%$	Alarm(High)

Power Factor

Power Factor (PF) is the phase angle relationship between the applied voltages across a capacitance. The total current through the capacitance is given in Fig. 3.

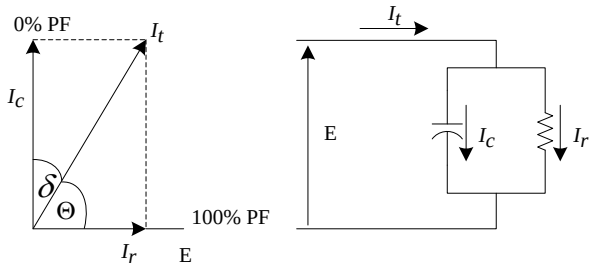

Fig.3. Power Factor Calculating Circuit

For example, power factor can be calculated as follows. Power is equal to Voltage(E) × Current(I_t) × Cosine(θ). Then it is similar to that Watts = E × I_r or Watts = E × I_t × Cosine(θ). Then power factor is calculated as in Eq. (1):

$$PF = Cos(\theta) = \frac{Watts}{E\ x\ I_t} = \frac{E\ x\ I_r}{E\ x\ I_t} = \frac{I_r}{I_t} \qquad (1)$$

The variation of power factor should not vary out of the limitation zone (+0.02/-0.04). New bushing condition according to IEEE Std C57.19.01-2000) is given in Fig. 4.

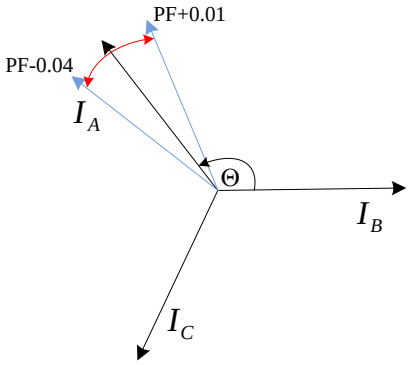

Fig.4. Change in Phase Angle

3. BASIC THEORY

Bushing On-line Monitoring

In past decades, the off-line monitoring method was used to determine the quality of the bushing insulation. The bushing tests were performed and compared the measured power factor and capacitance to nameplate

values or previous tests. Presently, the on-line monitoring method is introduced in order to observe performance of the bushing in real time. Some parameters for both methods are listed as shown in Table 2.

Table 2. Basic Testing Parameter Comparison

Parameters	Off-line Testing	On-line Testing
Applied Voltage	X	
Leakage Current	X	X
Phase Angle between Voltage and Leakage Current	X	
Frequency	X	X

Current Summing

By far, the most common method to monitor bushings is the sum of current method. Fig. 5 shows the installed bushing sensor that use for measure the $V_{test\ tap}$. The concept of measurement has shown in Fig. 6 a block diagram of a bushing monitoring system that uses the sum of currents method. During commissioning the indicator is balanced to zero. The purpose of the balancing circuit is to take into account the differences in system voltages and phase fluctuations and bushing characteristics. As a defect develops the complex conductivity of the bushing insulation changes and the current and its phase angle in one of the phases also changes. Therefore, the indicator will no longer be zero. The amplitude of the change reflects the severity of a problem. Three phase angle indicates in which phase is experiencing the change.

Fig.5. Installed Bushing Sensor

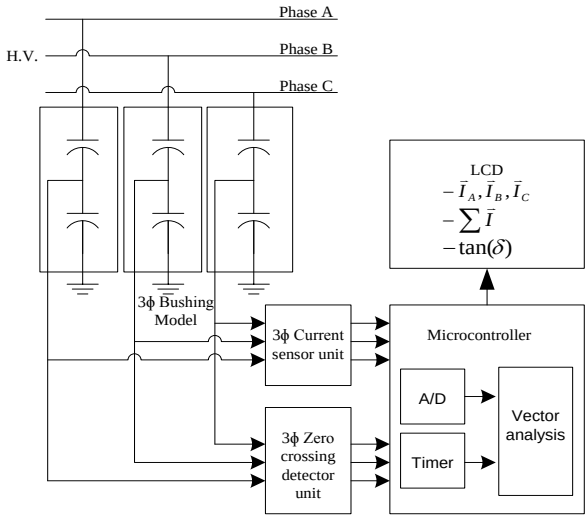

Fig.6. Current Detection from Voltage Tap Circuit

The change in the sum of currents can be approximately represented by Eq. (2) under the assumption of a single defective phase:

$$\sum I = \frac{\Delta I}{I_0} \approx \sqrt{(\Delta \tan \delta)^2 + \left(\Delta C_1 / C_1^0\right)^2} \qquad (2)$$

Where:

$\sum I$ - Parameter Sum of Currents

$\Delta \tan \delta$ - Tangent Delta Change,

$\Delta C_1 / C_0$ - Relative Change in Bushing Capacitance,

C_0 - Initial Capacitance Reading,

I_0 - Initial Sum of Current Value.

Ideally, the sum of the three bushing currents should be zero. In reality, not all parameters are equal from each phase. Therefore during commissioning of the system, the monitor is placed in a balancing mode, and the monitor self-adjusts so the sum of the currents is equal or close to zero.

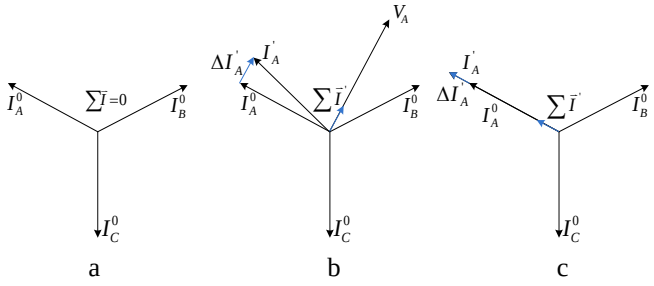

Fig.7. Current Summing Difference Mode

Figures 7(a), 7(b), and 7(c) explain the method in vector format. Figure 7(a) shows all three currents from the bushing test taps perfectly balanced and the sum equal to zero. If there is a change in tangent delta in the phase-A bushing, an additional active current will pass through the phase-A bushing insulation and the new current I'_A, thus throws the system out of balance. The consequent imbalance vector is equal to the tangent delta change and directed along the phase-A voltage vector in Fig. 7(b). A change in capacitance is shown in Fig. 7(c). This additional current is perpendicular to the phase-A voltage. The consequent imbalance is now positioned along the vector I^0_A.

Voltage Magnitude Trend

The magnitude of the change is an indicator of the problem's severity, and the vector change indicates that bushing is going bad as shown in Fig. 8 whether the power factor or capacitance is changing. The chart and plot shown in Fig. 9 show a recent example of a bushing that is going bad.

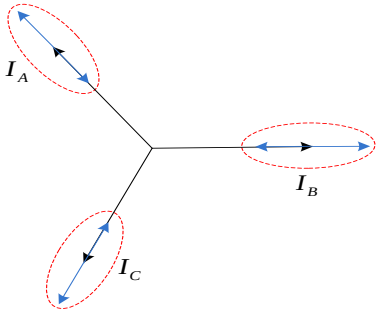

Fig.8. Change in Amplitude

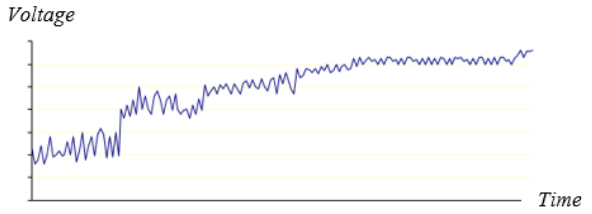

Fig.9. Investigation on Voltage Magnitude Trend

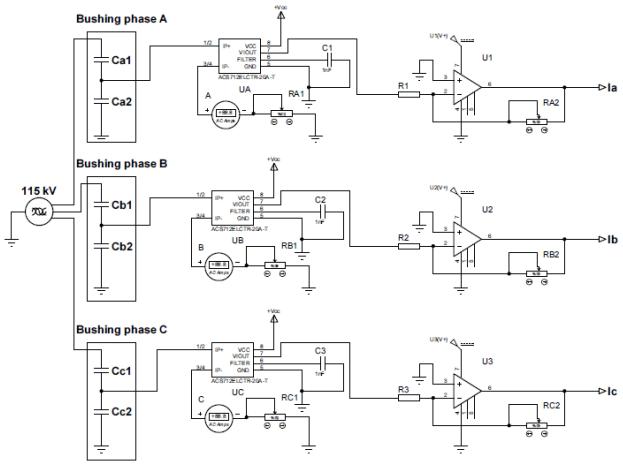

Fig.10. Sensor Circuit

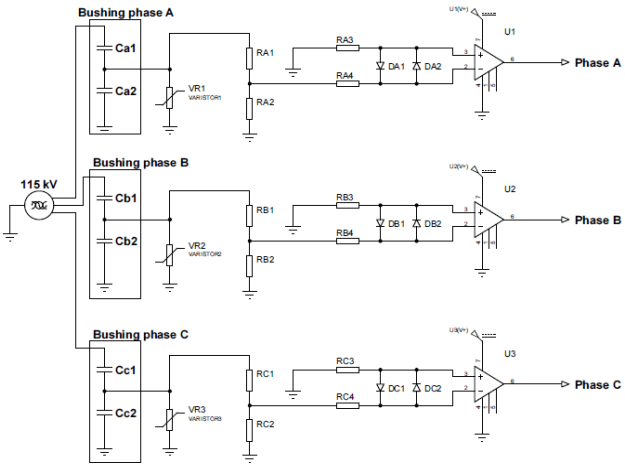

Fig.11. Zero Crossing Detector Circuit

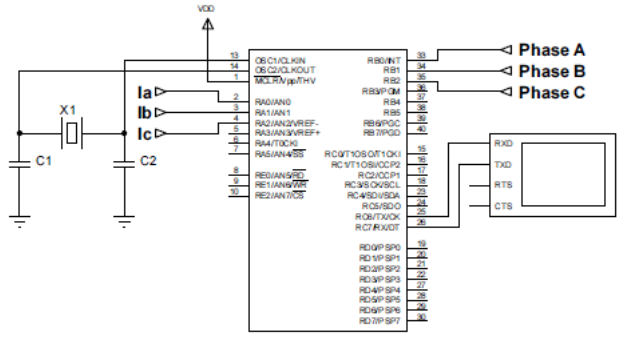

Fig.12. Microcontroller Circuit

When performing on-line monitoring, the key diagnostic factor is the sum of currents and the phase angle of the sum. Only estimates of the power factor and capacitance can be made since all the data required to calculate the absolute power factor and capacitance is not available, as it is for off line tests. For this reason, on-line bushing monitoring provides relative calculation of power factor and capacitance. When the system goes out of balance, estimates are made on the change of power factor and/or capacitance. Fig. 10 shows the sensor circuit that use to detect the voltage at test tap. The $V_{test\ tap}$ is a key of capacitance measurement. Similarly, the phase angle can be detected via the zero crossing detection technique as shown in Fig. 11. These values are then added/subtracted to baseline values (nameplate or recent test values) entered into the system. The vector analysis will be calculated by microcontroller as shown in Fig. 12. The microcontroller will get data from both sensor circuit and zero crossing detector circuit and indicate on LCD for help local maintenance know the status of bushing.

If a user has a three phase off-line test set, all the data required is available. For on-line monitoring the following conditions apply:

- The line voltage at the bushing terminals is assumed to be constant on all three phases.
- The phase angles between the phase voltages are constant.
- In additional to the leakage current, the phase angles between Phase A-B and A-C are also measured and frequency is measured.

4. RESULT AND DISCUSSION

The capacitor testing was done in four different cases. The results are given in Table 3. These four different cases have a same capacitance rating as 500 pF at 30.74 V.

Table 3. Measured Capacitance of C_1 from Measurement System, Rated 500 pF, 30.74 V

Case	C_1(pF)	ΔC_1	$V_{test\ tap}$ (V)	$\Delta V_{test\ tap}$	Decision
I	503	0.60%	30.92	0.60%	Normal
II	509	1.08%	31.29	1.08%	Warning
III	519	3.80%	31.91	3.80%	Alarm(Low)
IV	528	5.60%	32.46	5.60%	Alarm(High)

From the Table 3, the capacitance value of C_1 will directly effect to $V_{test\ tap}$. So, the capacitances changing from 4 cases different are described as bellows.

Case I: The capacitance of C_1 changed from 500 pF to 503 pF mean that the delta capacitance increases to 0.60%. Then it can be concluded that the bushing was in normal condition because the delta capacitance is not more than 1%.

Case II: The capacitance of C_1 changed from 500pF to 509 pF mean that the delta capacitance increases to 1.08%. Then it can be concluded that the bushing was in "warning" condition because the delta capacitance is in length of $1\%<\Delta C_1\leq 3\%$. So the operator should be keep real time monitor.

Case III: The capacitance of C_1 changed from 500pF to 519 pF mean that the delta capacitance increase to3.80%. Then it can be concluded that the bushing was in "Alarm (Low)" condition because the delta capacitance is in length of $3\%<\Delta C_1\leq 5\%$. So the operator should be follow system shutdown procedure and change the new busing into system.

Case IV: The capacitance of C_1 changed from 500 pF to 528 pF mean that the delta capacitance increases to 5.60%. Then it can be concluded that the bushing was in "Alarm (High)" condition because the delta capacitance is more than 5%. So the system will emergency shutdown.

5. CONCLUSION

The diagnostic technique for on-line monitoring of bushing is presented in this work. The degradation of internal insulation will affect the value of capacitance and power factor of insulation. Then the changing of insulation capacitance will lead to the change of leakage current value through bushing insulation. The technique continuously monitors the sum of current in three phases in order to detect the change in value of high voltage capacitance. The sensor circuit and vector analysis in microcontroller has been developed to simulate the degradation of transformer bushing. The status of bushing is indicated in the display as well as warning signal to inform the maintenance officer to correct the problem before bushing failure. The developed system has been tested for several simulation cases and can be further implemented into the hardware for practical application with power transformer in transmission system.

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Investigation on Overvoltage during No-Load Energization of 115 kV Underground Cable

Chaiwat Apithanawit and Asawin Rajakrom

Abstract*—There are several failure causes of power cable and its accessories during operation in MEA sub-transmission system. With an assumption that one of the root causes of XLPE insulation failure is the electrical stress resulting from switching overvoltage during no-load energization. Therefore, this paper presents a hypothesis regarding the 115 kV underground cables which damaged as a result of switching overvoltage. By applying the ATP-EMTP program, the maximum magnitude of the transient overvoltage between sending end and receiving end of MEA sub-transmission under consideration is investigated. The simulation results are then compared with the measurement results in order to investigate the cause of XLPE insulation failure based on the hypothesis.*

***Keywords*— ATP-EMTP, cross-linked polyethylene (XLPE), no-load energization, slow-front overvoltage (SFO)**

1. INTRODUCTION

Presently, due to an increasing in demand for electricity in urban areas, technical loss reduction, lower electricity tariff when connecting to 115 kV system as compared to 69 kV system, limit of space and safety issue as well as the better technology development of XLPE insulation, the Metropolitan Electricity Authority (MEA) launches strategy to implement underground cable project using XLPE insulation for sub-transmission system. The 115 kV sub-transmission line named RDT791 between Ratchadapisek HV-substation and Din-Daeng substation was constructed as a primary line for supplying the load of Din-Daeng substation. The route diagram illustrated in Figure 1 consists of a combination of an overhead line of 1.1 km long and an underground cable of 6.7 km long. It reveals that the length of underground cable is quite long as compared with the other of 115 kV underground cables in the MEA's sub-transmission system.

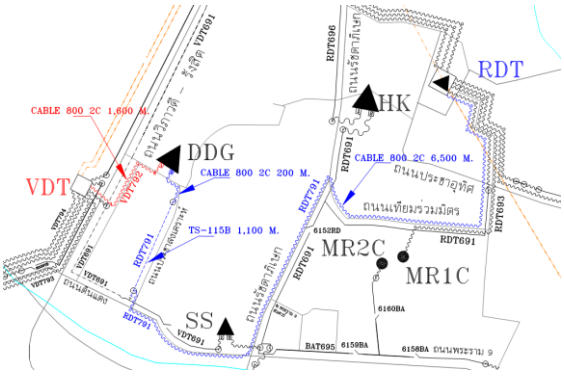

Figure 1. RDT791 sub-transmission line route map

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2. PROBLEM STATEMENT

According to an agreement between the MEA and the Electricity Generating Authority of Thailand (EGAT), a newly constructed sub-transmission line shall be firstly energized by MEA's grid in order to prevent any damage posed on EGAT's transformer due to cable faults. The energization of RDT791 line was made by closing the circuit breaker named DDG7022 at Din-Daeng substation (DDG) as illustrated in Figure 2. This cable circuit was in turn energized by the existing 115 kV transmission line named VDT792. However, the problems occurred to underground cables as following cases.

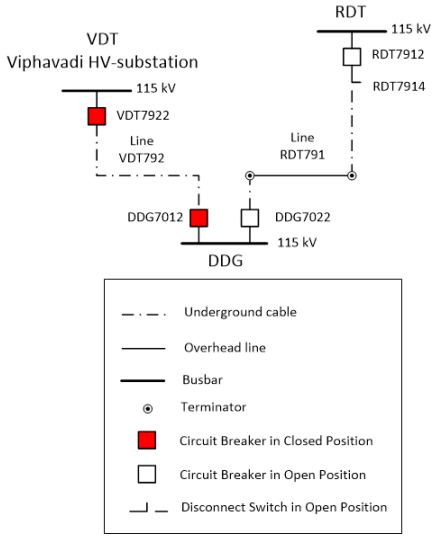

Figure 2. RDT791 single line diagram

On October 24th, 2012, 11:03 AM the circuit breaker DDG7022 was closed via SCADA system in order to energize the RDT791 sub-transmission line. The system state had been normal until 11:54 AM when the circuit breaker DDG7022 tripped by the line protection. The line patrolled result revealed that the cable joint on Y-phase inside manhole number 26 was damaged as depicted in Figure 3 and 4.

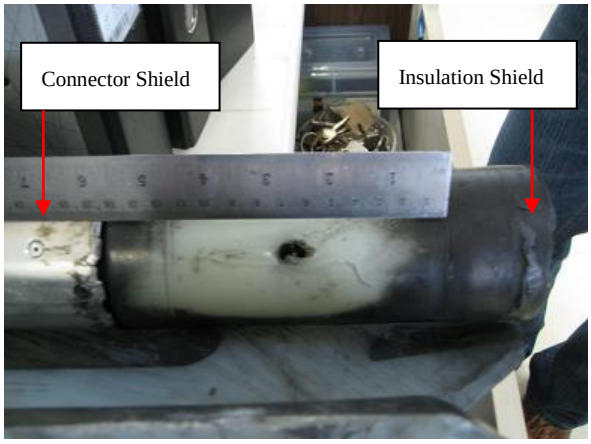

Figure 3. Damaged XLPE cable (Y-phase)

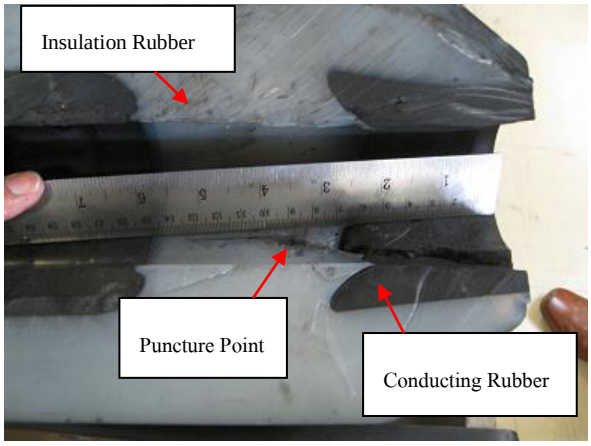

Figure 4. Damaged cable joint (Y-phase)

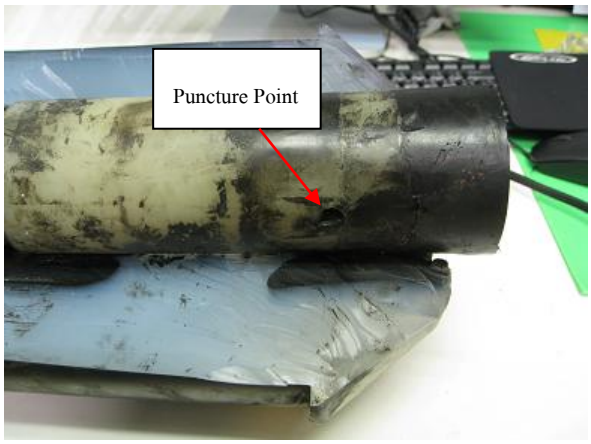

Figure 5. Damaged XLPE cable (B-phase)

Figure 6. Damaged cable joint (B-phase)

On December 15th, 2012, the RDT791 sub-transmission line had been re-energized after the damaged parts were repaired. At 00:42 AM the circuit breaker DDG7022 was closed. The system state had been normal until 00:47 AM, when the circuit breaker DDG7022 tripped by the line protection. The line patrolled result found that the cable joint on B-phase inside manhole number Tr12 was damaged as depicted in Figures 5 and 6.

The failure of such cables not only impacts the MEA system reliability improvement plan but also affects the loss of opportunity to reduce the operating cost by purchasing the electrical energy at 115 kV voltage level from EGAT. Observing, the failure time of XLPE insulation had occurred during line energization. Therefore the switching overvoltage during no-load energization was hypothesized as the root cause of damage [1]. The ATP-EMTP program was then employed to investigate the case.

3. SUB-TRANSMISSION SYSTEM MODELLING [2]

Table 1 shows the 115 kV sub-transmission system data used in this study. For instance, a voltage source, a short-circuit impedance, circuit breaker, underground cables, an overhead line and metal-oxide surge arresters.

Table 1. The 115kV sub-transmission system data

Parameter	Rating
Voltage Source	115 kV (nominal system voltage), 50 Hz (rated frequency)
Short-Circuit Impedance	Z_0/Z_1 at Din Daeng substation derived by PSS/ADPET
Circuit Breaker	3 phase switch with time controlled
Underground Cables	2 × 800 mm^2 XLPE copper cable/phase, U_m=123kV, BIL=550 kV
Overhead line	2 × 400 mm^2 AAC per phase and 38.32 mm^2 OHGW
Metal-oxide surge arresters	Max. system voltage: 123 kV Rated voltage: 96 kV Nominal discharge current : 10 kA

These data were then used to model the RDT791 sub-transmission line as illustrated in Figure 7. And the model was consequently simulated in ATP-EMTP program to study the switching overvoltage at sending end and receiving end bus.

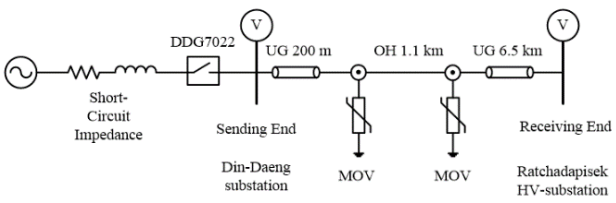

Figure 7. The 115 kV sub-transmission system

4. CASE STUDY AND CONDITIONS

The physical arrangement of underground cables and overhead lines including the electrical characteristics (e.g.

line geometry, conductor radius, material data) was formed in accordance with MEA standard. ATP LCC program is capable of calculating the line/cable parameters to perform a simulation based on three basic modeling techniques. These three models are good enough for determining the switching overvoltage under this study. The models are as the followings [3]:

Case 1: simple PI

Case 2: frequency independent (Bergeron)

Case 3: frequency dependent (J.Marti)

A simple series RLC resonant circuit being switched on an AC voltage is considered [4]. The maximum magnitude of the transient voltage at the capacitor terminals can occur if energizing at the peak voltage. This is similar to energizing no-load line at the peak voltage which in turn produces the maximum magnitude of the transient overvoltage. For the convenience of all cases in the study, the circuit breaker DDG7022 was supposed to close at the peak voltage of the middle phase (Y-phase). The sending end and receiving end bus voltage were monitored in terms of the phase-to-ground voltages.

5. SIMULATION RESULTS

The results from three different models which are (1) the line energizing by simple PI model, (2) line energizing by frequency independent model and (3) line energizing by frequency dependent are shown in Figure 8 to 10.

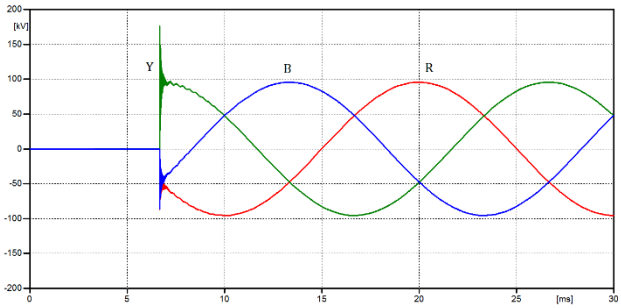

Figure 8 a. Sending end bus voltage: Case 1

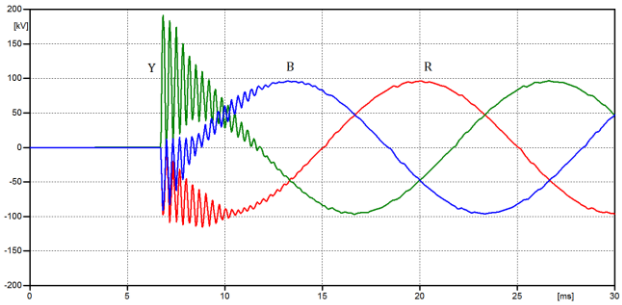

Figure 8 b. Receiving end bus voltage: Case 1

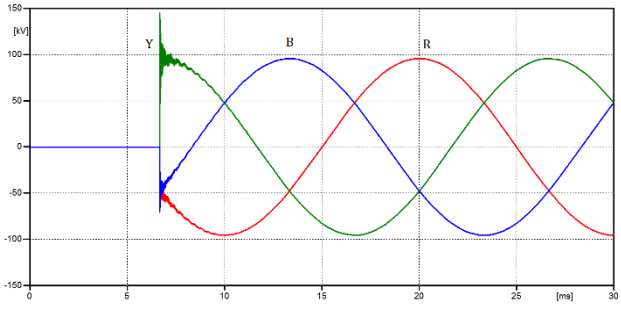

Figure 9 a. Sending end bus voltage: Case 2

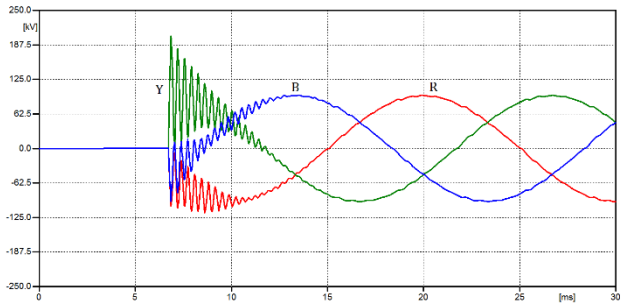

Figure 9 b. Receiving end bus voltage: Case 2

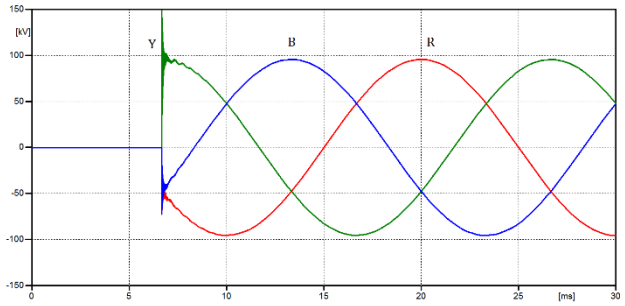

Figure 10 a. Sending end bus voltage: Case 3

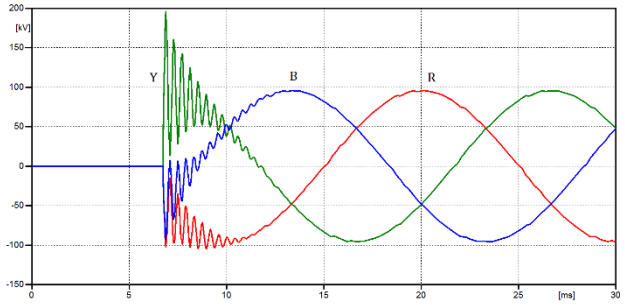

Figure 10 b. Receiving end bus voltage: Case 3

When comparing the accuracy of the simulation results, it can be seen that the highest accuracy is the frequency dependent model, the second is the frequency independent model and the lowest accuracy is simple PI model [5]. However, it was also found that the simple PI model is adequate to represent the MEA line/cable parameter when taking the line length into account. The reason bases on the fact that the average of line/cable length does not exceed the short line model.

The voltage waveforms during no-load energization were observed as illustrated in Figure 8 to 10. The maximum magnitude of the transient voltage on Y-phase can be considered in absolute value of per unit quantity (1 p.u. : $\sqrt{(2/3)} \times 115$ kV) and summarized in the chart illustrated in Figure 11. It appeared that the maximum magnitudes of the transient voltage at sending end bus were lower than the maximum magnitudes of the transient voltage at receiving end bus in all cases.

When considering the maximum magnitude of the transient voltage occurred on Y-phase only, the voltage values at the sending end bus obtained from the simple PI, frequency independent and frequency dependent model equal to 1.88, 1.54 and 1.55 p.u. respectively. However, when examining the transient voltage at the receiving end, the highest value of 2.21 p.u. ocuured with the frequency independent model, not a simple PI model. So this value would be used as a reference for further analysis.

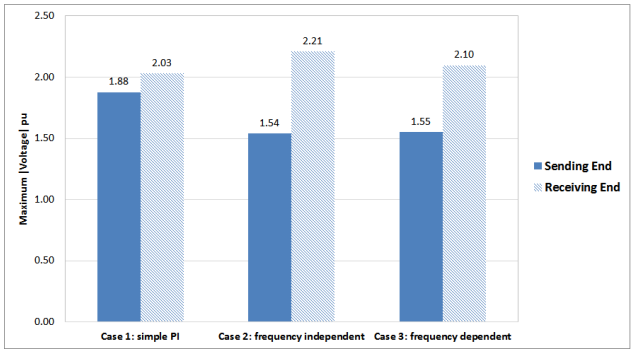

Figure 11. The maximum magnitudes of transient voltage on Y-phase

6. MEASUREMENT RESULTS

The third energization was conducted on April 19th, 2013, after the damaged parts were repaired. This time, the power quality analyzer (HIOKI: PW3198) was installed on the potential transformer at the sending end bus in order to measure the switching overvoltage before switching operation taking place. However the receiving end bus voltage was not monitored due to the difficulty in accessing bus potential transformer.

The measurement results in Figure 12 show that the maximum magnitude of the transient overvoltage occurred on the negative peak voltage on Y-phase which equivalent to the circuit breaker being closed when approaching the negative peak voltage.

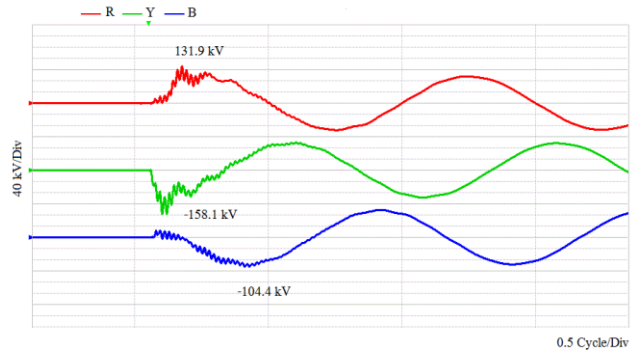

Figure 12. Measurement results of switching overvoltage at sending end bus

7. ANALYSIS AND CONCLUSION

From measurement results, the maximum magnitude of the transient overvoltage occurred on Y-phase is 158.1 kV or equivalent to 1.68 in absolute value of per unit. This value stays within the range of simulation results. To represent the worst-case scenario, the transient overvoltage appeares at the receiving end bus on Y-phase, determined by the frequency independent model would then be regarded as the possible highest value of the maximum magnitude of the transient overvoltage that could occur in the RDT791 sub-transmission line.

According to the IEC 60071-2 standard [6], the switching overvoltage this line energization case is regarded as a slow-front overvoltage. So the value of the maximum magnitude of the transient overvoltage of 2.21 p.u. is then used to calculate the required withstand voltage (U_{rw}) and convert it into the rated short-duration power frequency withstand voltage (SDW).

It appears that the SDW from calculation result somehow stays within the criteria of 230 kV which is the short-duration power frequency withstand voltage (U_w) of the XLPE insulation cable under study (Um=123 kV and BIL=550 kV). Furthermore, when considering the fact that the location at which the damaged cables are found, is not near the receiving end bus; therefore, the XLPE insulation should not be affected by the highest value of the maximum magnitude of the transient overvoltage.

In conclusion, the XLPE insulation should not be harmed by switching overvoltage occurring in no-load energization conditions as hypothesized.

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The Effect of Inter-Distance of the Main and the Auxiliary Grounding System in MEA's Power Distribution Substation

A. Phayomhom, K. Kveeyarn, W. Kulwongwit and J. Thamjaroen

Abstract— This paper presents the electrical effect of two neibouring distribution substation during the construction phase. The study performed in the paper can be divided in 3 parts. 1) The effect of unconnected grids versus their inter-distances and soil resistivity: the greater their inter-distance, the more the ground potential rise (GPR) and maximum touch voltage, but the less the maximum step voltage. 2) The effect of connected grids versus their different inter-distance and soil resistivity: *All the three voltages are trend to decrease when the grids are connected, with the exception that when the grids' inter-distance is short and the grid conductor buried in the two-layered soil that the upper soil layer resistivity is lower and the size of auxiliary grounding system (auxiliary ground grid) is equal or smaller than the main ground grid, their maximum touch voltages will not come down but go up instead. 3) The effect of size of grid of auxiliary grounding system: the bigger the size of auxiliary grounding grid, the lower the GPR, maximum touch and step voltage, with the exception that when the two grids are unconnected, i.e. the bigger the size of auxiliary grounding grid, the higher the maximum step voltage. The results in this paper could be served as design guideline of grounding system, and perhaps remedy of some troublesome grounding grids in MEA's power system.*

***Keywords*— Ground grid, Ground potential rise, Step voltage, Touch voltage, Two neighbouring substations**

1. INTRODUCTION

Metropolitan Electricity Authority (MEA) is an electric utility that is responsible for power distribution covering an area of 3,192 square kilometers in Bangkok, Nonthaburi, and Samutprakarn provinces of Thailand. MEA serves approximately 32.10 % of the whole country power demand in 2012. MEA's networks consist of transmission, sub-transmission and distribution systems. The transmission line voltage is 230 kV, while the 69 and 115kV used in sub-transmission systems and 12 and 24 kV in the distribution feeders.

This paper focuses on grounding grid performance during construction phase of new permanent distribution substation in order to renovate existing one, while the other substation has not yet been removed. During the time of two ground grids left disconnected, the effect of 'auxiliary grounding system' (de-energized electrical power site's) to the main station which remains energized cannot be ignored. Because it will help create high ground potential rise (GPR), especially, the boundary waveform is very steep between the ground grids. For safety purpose, ground grid design for the safety of personal working around the vicinity of substation construction site should be ensured.

To achieve this, modeling and simulation are carried out on the Current Distribution Electromagnetic interference Grounding and Soil structure (CDEGS) software package. Safety step and touch voltage are analyzed with reference to safety criteria based on body weight defined in IEEE Std. 80-2000.

2. EFFECTS OF NEARBY AUXILIARY GROUNDING SYSTEM OF SUBSTATION

Many a time, a new distribution substation is under construction while the existing substation is still in operation and has not yet been removed. There are two grounding systems in close distance, and are left disconnected. The ground grid of the substation that is still energized is called main ground grid (energized electrical power site) whereas that of the under construction substation (temporary or permanent distribution substation) is called auxiliary grounding system (auxiliary ground grid). During the time of disconnecting of these ground grids, the under construction distribution substation is de-energized, the substation surrounding area then exposes to the risk of high GPR caused by the main distribution substation which is still in operation. The GPR's steepness is located between the main and auxiliary ground grid.

3. DEFINITION OF TOLERABLE VOLTAGE

According to [1], the following definitions for various voltages considered in this paper are given as follows:

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Ground Potential Rise (GPR)

Ground Potential Rise (GPR) is the maximum electrical potential relative to a distant grounding point assumed to be at the remote earth that a substation grounding grid can withstand. This GPR is equal to the maximum grid current times the grid resistance.

$$GPR = I_G \times R_g \tag{1}$$

where GPR is ground potential rise (V)
I_G is maximum grid current (A)
R_g is resistance of grounding system (Ω)

In the process of designing the ground grid system, safety criteria is firstly calculated to specify a safety level, then the maximum touch and step voltage are calculated to compare with the safety criteria to determine whether it is safe to work on the area of substation. This part will show a calculation of safety criteria, touch and step voltage.

Touch Voltage

Touch voltage is the potential difference between the point where a person is standing and the person's hand in contact with a grounded structure.

The tolerable touch voltage in volts is defined as [1]

$$E_{touch} = I_B \times \left(R_B + 1.5\rho_s\right) \tag{2}$$

where E_{touch} is tolerable touch voltage for human (A)
R_B is resistance of the human body (Ω)
ρ_s is surface layer resistivity ($\Omega \cdot \mathrm{m}$)

$$I_B = \frac{k}{\sqrt{t_s}} \tag{3}$$

where I_B is current through the body (A)
k is 0.116 for 50 kg body weight
0.157 for 70 kg body weight
t_s is duration of current expose (s)

The safety of a person depends on how to prevent the critical amount of shock energy from being absorbed by the body, before the fault is cleared and the system de-energised. To ensure safety, the magnitude and duration of the current conducted through a human body should be less than the value that can cause ventricular fibrillation of the heart. Fibrillation current is assumed to be a function of individual body weight. The tolerable body current limits for body weights of 50 kg and 70 kg are listed in IEEE std 80-2000.

Step Voltage

Step voltage is the potential difference between two points of 1 (one) meter apart and on which a person is bridging with his feet without contacting any other grounded object.

The tolerable step voltage in volts is defined as [1]

$$E_{step} = I_B \times \left(R_B + 6\rho_s\right) \tag{4}$$

where E_{step} is tolerable step voltage for human (V)

Maximum of Mesh and Step Voltage

The maximum touch voltage within a mesh of a ground grid [4] is calculated by

$$E_m = \frac{\rho_a K_m \cdot K_i \cdot I_G}{L_m} \tag{5}$$

where E_m is mesh voltage (V)
ρ_a is apparent resistivity of soil (Ω-m)
K_m is mesh factor defined for n parallel conductors
K_i is corrective factor for current irregularity
I_G is maximum rms current flowing between ground grid and earth (A)
L_m is effective length of $L_C + L_R$ for mesh voltage (m)

For grids with or without ground rods, the effective buried conductor length, L_s, is

$$L_s = 0.75 \cdot L_C + 0.85 \cdot L_R \tag{6}$$

where L_s is effective length of $L_C + L_R$ for step voltage (m)
L_C is total length of grid conductor (m)
L_R is total length of ground rods (m)

The step voltage is determined from

$$E_s = \frac{\rho_a \cdot K_s \cdot K_i \cdot I_G}{L_s} \tag{7}$$

where E_s is step voltage (V)
K_s is mesh factor defined for n parallel conductors

To calculate both maximum touch and step voltage, apparent resistivity factor is required and it can be obtained by applying Wenner arrangement method.

The resistivity of two-layered soil as shown in Figure 1 can be determined by the Wenner method. In this method, the apparent resistivity is calculated using Eqs (7) and (8) [1], [2-4]:

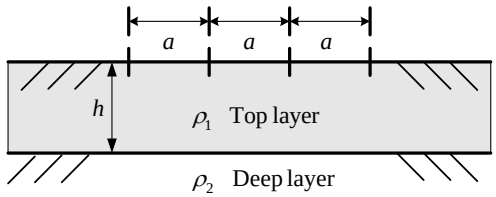


Fig. 1. Two Layered Earth Model

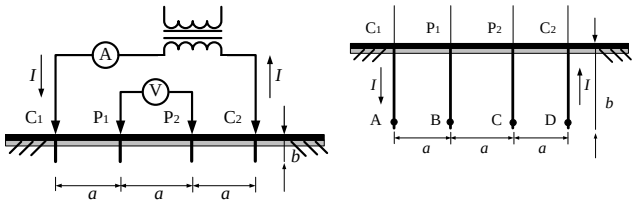
$$\rho_a = \rho_1 \left(1 + 4 \sum_{i=1}^{\infty} \frac{K^n}{\sqrt{1+\left(2n\frac{h}{a}\right)^2}} - \frac{K^n}{\sqrt{4+\left(2n\frac{h}{a}\right)^2}} \right) \quad (8)$$

$$K = \frac{\rho_2 - \rho_1}{\rho_2 + \rho_1} \quad (9)$$

where ρ_a is apparent resistivity of the soil in ($\Omega \cdot$m)
h is first layer height (m)
K is reflection factor
ρ_1 is first layer resistivity ($\Omega \cdot$m)
ρ_2 is deep layer resistivity ($\Omega \cdot$m)

The measurement of apparent soil resistivity within the substation area is applied by the Wenner arrangement method as shown in Eq. (8). After apparent resistivity is obtained, maximum touch and step voltage can be determined accordingly. The Wenner arrangement approach to obtain apparent resistivity is explained as follows:

The four- point method as shown in Figure 2 is one of the most accurate and practical methods in measuring the average resistivity of large volumes of undisturbed earth. In the figure, four electrodes are buried in equally-spaced small holes at points C_1, C_2, P_1 and P_2. The soil resistance R in ohm is calculated from the ratio of V/I, where I is the injected current between the two outer electrodes and V is the measured voltage between the two inner electrodes [1], [3-4].



(a) (b)

(a) Principal diagram of an earth resistivity meter

(b) Current injection into the soil

Fig. 2. Wenner Arrangement

With this arrangement, the resistivity ρ_a can be expressed in terms of a, b and soil resistance as follows:

$$\rho_a = \frac{4\pi a R}{1 + \frac{2a}{\sqrt{a^2+4b^2}} - \frac{a}{\sqrt{a^2+b^2}}} \quad (10)$$

where R is measured resistance (Ω)
a is distance between adjacent electrodes (m)
b is depth of the electrodes (m)

When b is small compared with a, and hence negligible. Eq (10) then becomes

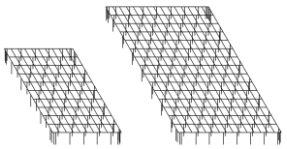
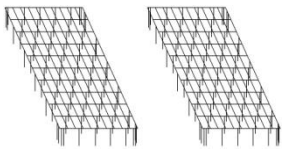
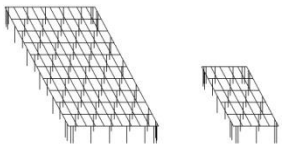
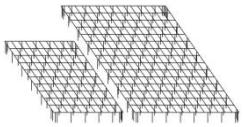
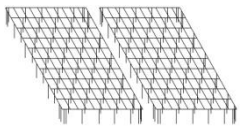
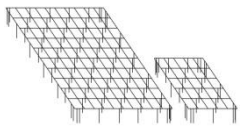
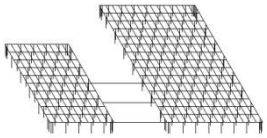
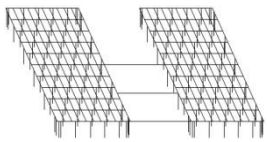
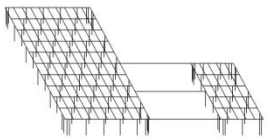
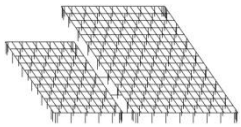
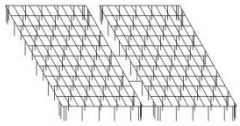
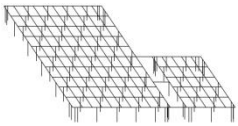
$$\rho_a = 2\pi a R \quad (11)$$

4. CASE STUDY

For all scenarios studied herein, the cross section of the ground grid conductor is 95 mm^2 and 15.875 mm in diameter, ground rod is 3.0 m long. All the ground grid conductors are buried 0.5 m deep in the top layer soil. The ground rods are spread out to cover the grounding area. The auxiliary ground grid has 3 sizes: small (S) 15 m x 15 m; medium (M) 30 m x 30 m; and large (L) 45 m x 45 m, while the main grid has single size: (M) 30 m x 30 m. Table 1 shows all the ground grids configurations.

The value of the soil resistivity is chosen to be 10 $\Omega \cdot$m in case of uniform soil, 10/100 or 100/10 $\Omega \cdot$m in case of two layered soil. The reason why these values are chosen because they are the soil resistivity found in MEA service area. However, the 10/100 $\Omega \cdot$m resistivity is a special case for lower resistivity of top layer soil. The top layer soil normally has more resistivity than the bottom layer's (deep layer) due to number of factors such as soil moisture content, chemical composition, concentration of salts dissolved in the contained water, and grain size [4, 5]. However the 10/100 $\Omega \cdot$m resistivity soil is rarely found in MEA unless in the flood area. The thickness of the soil is determined to be 2 m. Thus, the short circuit current of 25 kA is specified. The inter-distance between ground grids is chosen to be 25 m and 5 m for all combinations of size both connection and un-connection of main and auxiliary grids as shown in Table 1.

Table 1. Two Neighbouring Distribution Substation is Unconnected and Connected Together

Scenario	Configuration		
1	Unconnected 25 m		
		M	L
2			
		M	M
3	Unconnected 25 m		
		M	S
4	Unconnected 5 m		
		M	L
5			
		M	M
6			
		M	S
7	Connected 25 m		
		M	L
8			
		M	M
9	Connected 5 m		
		M	S
10			
		M	L
11			
		M	M
12			
		M	S

Sce: Scenario

The result of the study will be discussed based on 3 parameters: inter-distance, interconnection and size as detailed in each Part:

Part 1: The effect of unconnected grids versus their different inter-distance: 25m (scenario 1 to 3) and 5 m (scenario 4 to 6), and soil resistivity as shown in Tables 2 and 3 respectively.

Part 2: The effect of connected [6] grids versus for different inter-distance 25m (scenario 7 to 9) and 5 m (scenario 10 to 12), and soil resistivity as are shown in Tables 4 and 5 respectively.

Part 3: The effect of size of grid of auxiliary grounding system as shown in Tables 2 to 5.

Table 2. GPR, GPR Ratio, Maximum Touch and Step Voltage of Two Unconnected Grids 25 m Apart

ρ_a $(\Omega \cdot \mathrm{m})$	Sce	GPR (V)		Aux/ Main (%)	Touch (V)	Step (V)
		Main	Aux			
10	1	3,325	663	19.96	2,259	360
	2	3,338	752	22.54	2,342	358
	3	3,348	854	25.51	2,556	357
10/100	1	17,721	6,135	34.62	8,876	1,015
	2	17,936	6,857	38.23	9,416	993
	3	18,136	7,643	42.14	10,974	974
100/10	1	4,466	664	14.86	3,385	682
	2	4,475	753	16.82	3,471	683
	3	4,482	857	19.13	3,687	683

Main: Main ground grid, Aux: Auxiliary ground grid
Sce: Scenario

Table 3. GPR, GPR Ratio, Maximum Touch and Step Voltage of Two Unconnected Grids 5 m Apart

ρ_a ($\Omega \cdot$m)	Sce	GPR (V)		Aux/ Main (%)	Touch (V)	Step (V)
		Main	Aux			
10	4	3,154	1,058	33.54	2,014	427
	5	3,226	1,293	40.07	2,076	406
	6	3,311	1,557	47.01	2,526	383
10/100	4	5,847	9,127	57.59	6,803	1,276
	5	6,701	10,692	64.02	7,258	1,155
	6	7,703	12,234	69.11	10,527	1,086
100/10	4	4,363	1,046	23.98	3,194	738
	5	4,410	1,284	29.13	3,244	723
	6	4,461	1,567	35.13	3,676	695

Table 4. GPR, GPR Ratio, Maximum Touch and Step Voltage of Two Connected Grids 25 m Apart

ρ_a ($\Omega \cdot$m)	Sce	Type of Voltage (V)			Electrode Resistance (Ω)	Length (m)
		GPR	Touch	Step		
10	7	1,651	889	153	0.06605	2,850
	8	2,009	1,319	197	0.08038	1,875
	9	2,468	1,935	272	0.09873	1,329
10/100	7	10,659	3,814	473	0.42637	2,850
	8	12,278	5,967	575	0.49114	1,875
	9	14,178	9,098	743	0.56714	1,329
100/10	7	2,052	1,294	269	0.08206	2,850
	8	2,589	1,896	358	0.10356	1,875
	9	3,322	2,792	516	0.13288	1,329

Table 5. GPR, GPR Ratio, Maximum Touch and Step Voltage of Two Connected Grids 5 m Apart

ρ_a ($\Omega \cdot$m)	Sce	Type of Voltage (V)			Electrode Resistance (Ω)	Length (m)
		GPR	Touch	Step		
10	10	1,814	1,084	169	0.07255	2,790
	11	2,258	1,694	217	0.09032	1,797
	12	2,806	2,331	297	0.11224	1,179
10/100	10	11,633	5,003	526	0.46534	2,790
	11	13,693	8,379	657	0.54773	1,797
	12	15,994	11,455	855	0.63976	1,179
100/10	10	2,215	1,488	288	0.08860	2,790
	11	2,846	2,283	391	0.11385	1,797
	12	3,646	3,171	542	0.14583	1,179

***Part 1*:** As per Table 2, the different voltages result from ground grid buried in soil of different resistivity show that: In 10 $\Omega \cdot$m soil resistivity, GPR, maximum touch and step voltage are the lowest compared with 10/100 and 100/10 $\Omega \cdot$m soil resistivity. This is due to all conductors of the grid are buried in the low soil resistivity that can by far withstand the given short circuit current. The 10/100 $\Omega \cdot$m soil resistivity is on the contrary, its GPR, maximum touch and step voltage are the highest, because the grid's ground rod penetrating deeper in the high resistivity soil layer. It can be concluded that, regardless the grids' inter-distance, the GPR, maximum touch and step voltage of 10 $\Omega \cdot$m soil resistivity case remain the lowest as are evident by Table 2 and 3. When bring the effect of grids' inter-distance into consideration for all unconnected grids as per Tables 2 and 3, it should be noted that, for the same grid configuration by shortening the inter-distance to 5 m, the GPR and maximum touch voltage will decrease but the maximum step voltage increase.

Now look at the Aux/Main, it is the ratio of the GPR of auxiliary grounding grid to the GPR of the main ground grid. When we compare the Aux/Main ratio of the grids having the same grid configuration as those listed in Table 2 and 3. For example, Table 2, 10 $\Omega \cdot$m soil resistivity, scenario 1: Aux/Main [7] ratio is 19.6 % while the maximum touch voltage is 2,259 V. but in Table 3, scenario 4, the same grid configuration and soil resistivity, the Aux/Main ratio is 33.54 % while the maximum touch voltage is 2,014 V (Aux/Main ratio is in reverse proportional to its maximum touch voltage). This can be explained that touch voltage is itself the ground potential difference (GPD) between the person's point of standing (GPR) and his hand in touching zero potential (grounding object), therefore, the more the GPR, the higher the touch voltage, but since the GPR is the divisor of the Aux/Main ratio, then the more the GPR, the less the ratio.

Part 2: When the two ground grids are connected as scenario 7 to 12 listed in Tables 4 and 5, all voltages tend to decrease, but it depends on the soil resistivity the grids buried. For example, for Table 2; scenario 1; 10 $\Omega \cdot$m soil resistivity, the resulted GPR, maximum touch voltage are 3,325 V and 2,259 V, the 3D and 2D voltage profile of which is shown in Figures 3 and 4 respectively. But when the two ground grids are connected, Table 4; scenario 7 presents the resulted GPR and maximum touch voltage which comes down to 1,651V and 889 V, its 3D and 2D voltage profile is shown in Figures 5 and 6 respectively. The interconnected grids also make the maximum step voltage decrease. It is found that after connection, GPR of both grids are equalized and more uniform not as steep as it used to be between two grids. Maximum touch and step voltage are equal to 889 V and 153.4V respectively. (Safety criteria for 50-kg person, the touch and step voltage cannot exceed 1,488 V and 5,085 V respectively). This is a safe condition for both values are within the limits, however, care should be taken for safety criteria depends on weight of person, soil resistivity and fault clearing time. One thing should also be noted, the come down of all voltages in Table 4 and 5 are good for soil resistivity 10 and 100/10 $\Omega \cdot$m only but not the 10/100 $\Omega \cdot$m.

For example, Table 3; scenarios 5 and 6; at 10/100 $\Omega \cdot$m, when ground grids are interconnected, its maximum touch voltage does not decrease, instead it increases more than the value when grids are unconnected. This is because even the interconnection of two ground grids together lowers the grids resistance, but their ground rods have to reach the high soil resistivity layer which increases the grids resistance. So when the resulted grids resistance is not low enough, its GPR and touch voltage value will remain high. The interconnected ground grid with 25 m inter-distance as of Table 4 compares with 5 m inter-distance as of Table 5, all the voltages tend to increase when the inter-distance is closer. This is all due to the connected ground grids resistance of Table 4 is lower than that of Table 5 for each soil resistivity and configuration. In other words, the loosely connected ground rods contribute lower total electrode resistance than that of tightly connected ones. We must be careful when handling the ground grid design in the area

of two layered soil - the soil resistivity of lower (bottom) layer is higher than that of upper (top) layer; the grids' inter-distance is closed and the size of auxiliary grounding system is equal to or smaller than that of the main ground grid's, for these conditions, when interconnecting both ground grids together will increase the touch voltage.

Part 3: This part analyzes the effects of sizes of auxiliary grounding grid, regardless the soil resistivity. From Table 2 to 5; scenarios 1, 4, 7 and 10; L size of auxiliary grounding grid provides lowest GPR and lowest maximum touch voltage while scenarios 3, 6, 9 and 12; S size of auxiliary grounding grid provide the opposite results. As per the maximum step voltage, the L size of auxiliary grounding grid provides higher maximum step voltage, until the grids are connected. So we can conclude that the bigger the size of auxiliary grounding grid, the lower the GPR, maximum touch and step voltage, with the exception that when the two grids are unconnected, i.e. the bigger the size of auxiliary grounding grid, the higher the maximum step voltage.

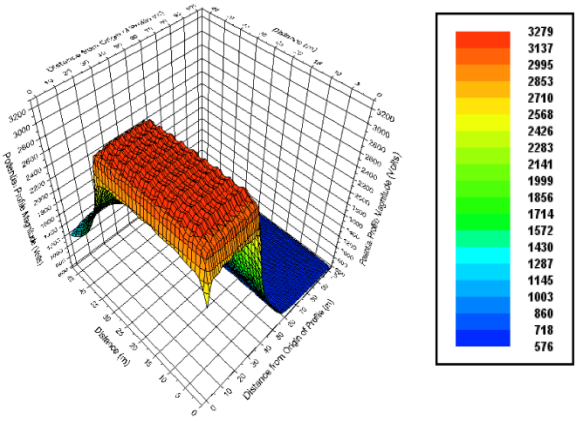


Fig. 3. 3-D Ground Potential Rise for Scenario 1

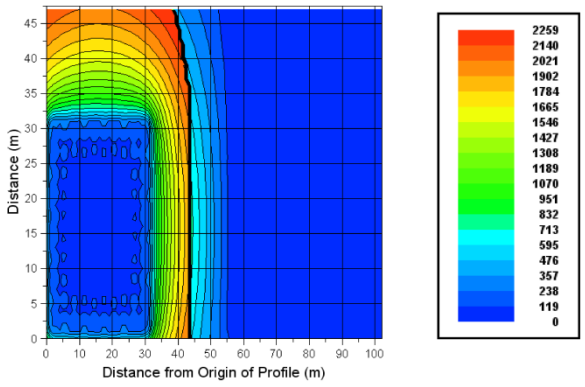


Fig. 4. 2-D Touch Voltage Magnitude for Scenario 1

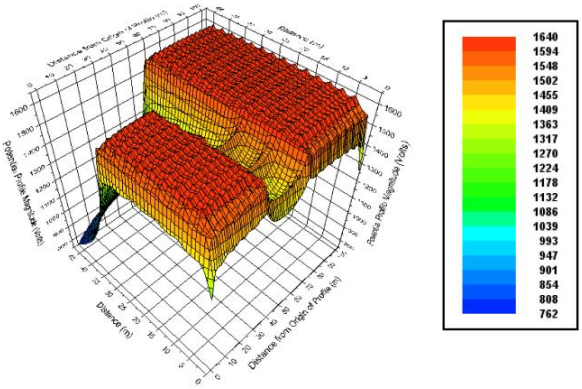


Fig. 5. 3-D Ground Potential Rise for Scenario 7

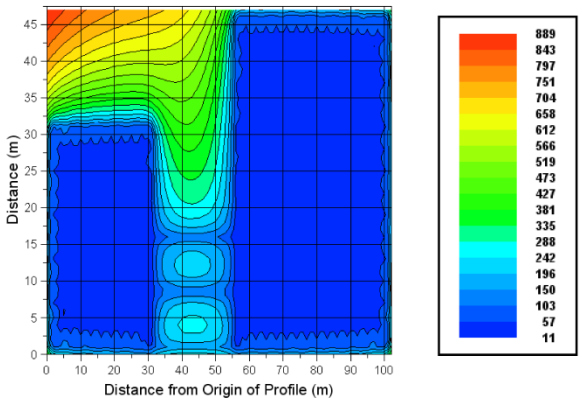


Fig.6. 2-D Touch Voltage Magnitude for Scenario 7

5. CONCLUSION

If the renovation of a distribution substation is planned but either a nearby temporary or old substation still exists and remains energized, the following points should be noted.

1. If two distribution substation ground grids are left unconnected, the more their inter-distance, the higher the GPR and maximum touch voltage, but the maximum step voltage goes the opposite end. The bigger the size of auxiliary grounding system than the main ground grid's, the lower the GPR and maximum touch voltage, again, the maximum step voltage goes the opposite end.
2. Care shall be taken when handling the ground grid design in the area of two layered soil - the soil resistivity of lower (bottom) layer is higher than that of upper (top) layer; the auxiliary and main grid's inter-distance is closed, and the size of auxiliary grounding system is equal to or smaller than that of the main ground grid's. Whenever the interconnection of both grids taking place, it will increase the GPR and the maximum touch voltage.
3. Aux/Main ratio serves as a good figure in considering GPR and maximum touch voltage for constant configuration and soil resistivity but varying grid inter-distance: The greater the Aux/ Main, the lower the GPR and maximum touch voltage. The ratio is also applicable when the configuration and inter-distance are constant and the different soil resistivity is varying, but limit to uniform and two layered soil which upper layer resistivity higher than the lower's. In this paper is 10 and 100/10 $\Omega \cdot m$.

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Implementation on LED Road Lighting in Bangkok

Jarin Halapee

***Abstract*—** *This paper presents the study on implementation of a light-emitting diode (LED) luminaire for road lighting in metropolitan area that is been responsible by the Metropolitan Electricity Authority (MEA), Thailand. The LED luminaire were carefully selected in accordance with the MEA and international standards. This is to ensure that such LED luminaire can provide the same value of illuminance as offering by existing luminaires using High Pressure Sodium (HPS) and High-pressure Mercury Vapour (HQV) lamps; but it consumes much lower power. Upon the study, the DIALux program was used to simulate the roadway illumination in several site installations of different landscapes. Various conditions were carefully selected and implemented. The illumination provided by new LED luminaire was then compared against that by the existing luminaires using HPS 250W and HQV 125W lamps. The result shows that the replacement of HPS 250W by LED 140W can reduce power consumption by 169 W/luminaire, which is accounted for 56.5 % reduction. The energy saving can be achieved by 740.22 kWh/luminaire/year, which corresponds to reduction of CO_2 of 0.444 ton/luminaire/year. Furthermore, the replacement of HQV 125W by LED 55W can also reduce power consumption by 92.7 W/luminaire, which is accounted for 64.4 % reduction. As well, the energy saving can be realized by 406.03 kWh/luminaire/year, which corresponds to reduction of CO_2 of 0.243 ton/luminaire/year. Finally, the total energy consumption and cost from the road lighting load can be effectively reduced.*

***Keywords* — Road Lighting, LED Road Lighting, Energy Saving Lamp.**

1. INTRODUCTION

Presently, a light-emitting diode (LED) technology plays an important role in everyday life; for example in TV monitor, electronic equipment monitor, traffic light, high power torchlight, lighting in building and vehicle as well as road lighting because of its advantages such as low energy conmsumption, longer lifetime, environmental friendliness and so on. It can also be applied to many application according to the user requirement and desiner. Several countries launched LED road lighting project in public area, especially the main significant street in the country. The project applied by LED application is now continuously considered for the future usage [1]. The Metropolitan Electricity Authority (MEA) takes currently consideration on LED technology in the basis of energy conservation in the metropolitan area. Therefore, there is a research project to study, implementation, and installation of LED road lighting in Bangkok [2].

In this paper, the performances of LED luminaire are compared with existing luminaires that are 250W High Pressure Sodium (HPS) and 125W High-pressure Mercury Vapour (HQV) lamps in terms of value of illuminance and energy consumption. The DIALux program was used to simulate the roadway illumination in several site installations of different landscapes. Various conditions based on MEA and international standards [3] were carefully selected and implemented. The illumination provided by new LED luminaire was then compared against that by the existing luminaires using HPS and HQV lamps. The areas in Bangkok taken into the study are Phahurat Road, Chakphet Road and Tri Phet Road, Soi Chidlom, Thetsaban Sai 1 Road.

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2. ROAD LIGHTING REQUIREMENT

2.1 MEA Road Lighting Requirement

LED road lighting replacements for existing lamps must be provided illuminance value on roadway according to MEA road lighting requirement [3] by depending on type of roadway as showed in Table 1.

Table 1. Illuminance of MEA Road Lighting Requirement [3]

Road Category	$E_{h\ ave}$ (lux)	U_h
Main Road	15	0.33
Secondary/Local Road (Road width > 6 m)	9.7	0.33
Soi (Road width < 6m)	4.3	0.33
Personal Road	6.5	0.16

$E_{h\ ave}$ = Average value of horizontal illuminance, lux
U_h = Uniformity ratio of horizontal illuminance
$U_h = E_{h\ min} / E_{h\ ave}$

Table 2. Road Lighting Installation in Case of Installed on Concrete Pole and without Central Reservation

Configuration	HQV 125W	HPS 250W	HPS 250W
Road Width "W" (m)	3 < W < 4	7 < W < 10	10 < W < 13
Luminaire Spacing "S" (MAX.)	32 m	40 m	40 m
Arrangement	Single-Sided Fig.1	Single-Sided Fig.1	Staggered Fig.2
Boom Lenght	1.2 m	1.7 m	1.7 m

2.2 MEA Road Lighting Installation Requirement

Road lighting installation in case of installed on concrete pole and without central reservation for HQV 125W and

HPS 250W according to MEA drawing standard [4] based on installation requirement is shown in Table 2.

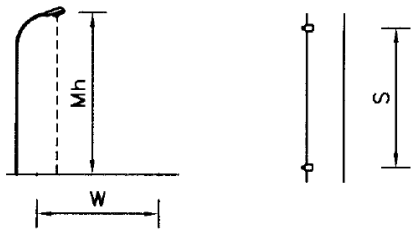

Fig.1. Single-Sided Arrangement

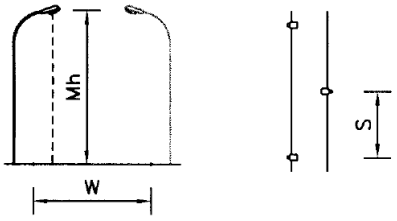

Fig.2. Staggered Arrangement

2.3 Position of Calculation Points

The calculation points according to International Commission on Illumination, CIE 140: 2000 [5] should be evenly spaced in the field of calculation and located as shown in Fig.3.

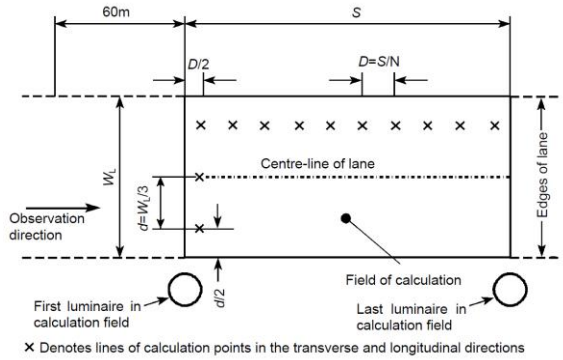

Fig.3. Position of Calculation Points in a Driving Lane

(a) In the Longitudinal Direction

The spacing (*D*) in the longitudinal direction is determined from the equation (1):

$$D = \frac{S}{N} \qquad (1)$$

where: D is the spacing between points in the longitudinal direction (m); S is the spacing between luminaries in the same row (m); N is the number of calculation points in the longitudinal direction chosen such that: for S≤30 m, N=10, for S ≥ 30 m, N is the smallest integer giving D≤3m.

The first transverse row of calculation points is spaced at a distance *D*/2 beyond the first luminaire (remote from the observer).

(b) In the Transverse Direction

The spacing (*d*) in the transverse direction is determined from the equation (2):

$$d = \frac{W_L}{3} \qquad (2)$$

where:d is the spacing between points in the transverse direction (m); W_L is the lane width (m).

The outermost calculation points are spaced *d*/2 from the edges of the lane.

3. LED INSTALLATION AND SITE TEST

To compare the illumination performance and the electrical performance according to standard of MEA, HPS 250W with LED 140W, HQV 125W with LED 55W in case of installed on concrete pole and without central reservation was analyzed by using the ideas that include:

- Analysis of illumination performance of HPS and HQV luminaires by installation and measurement data on site test.
- Analysis of illumination performance of LED luminaire by installation and measurement data on site test.
- Analysis of illumination performance of LED luminaire by calculation using DIALux program.

3.1 Condition for Analysis and Site Test

The detail associated with analysis of illumination performance of road lighting has been shown in Table 3.

Table 3. Detial of Installation and Requirement for Calculation and Testing on Site Test

Luminaire	HPS 250W LED 140W	HQV 125W LED 55W
Arrangment	Single-Sided (Fig.1)	
Road width (m)	8	6
Number of lanes	2	2
Mounting hight (m)	8.5	7.8
Luminaire spacing (m)	40	32(40)*
Overhang (m)	2	1.5
$E_{av\ (@\ MF=0.7)}$ (lux)	15	7.5
U_0 (E_{min}/E_{av})	0.33	0.33

Note:*Luminaire spacing of testing on site test for HQV 125W and LED 55W are 40 m because of limitation of site test.

3.2 Road Lighting Installation Setting for Analysis and Site Test

Site test in the selected site was carried out in MEA distribution area of Samut Prakan province. Three luminaries were set as shown in Fig.4 and Fig.6 and the position of illuminance measurement points as shown in Fig.5 and Fig.7.

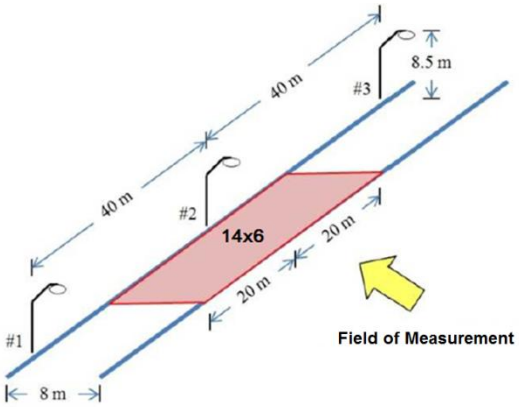

Fig.4. Road Lighting Installation for HPS 250W and LED 140W

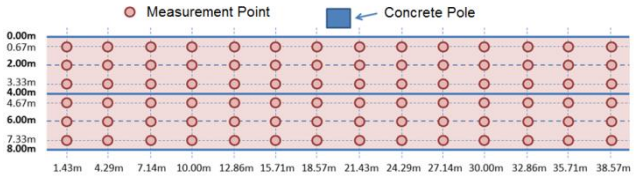

Fig.5. Position of measurement points for HPS 250W and LED 140W

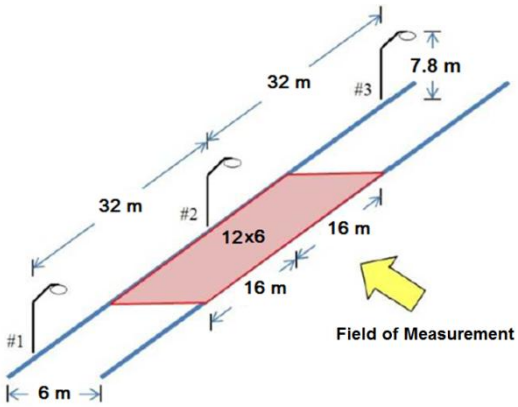

Fig.6. Road Lighting Installation for HQV 125W and LED 55W

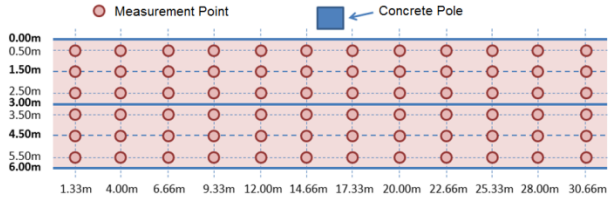

Fig.7. Positions of Measurement for HQV 125W and LED 55W

3.3 Comparative Analysis Result Between HPS 250W and LED 140W

Table 4 shows the comparative analysis result of lighting performance between HPS 250W and LED 140W by following installation and measurement data and using DIALux program on site test with a luminaire spacing as 40 m. Table 5 shows the comparative analysis result of electrical performance between HPS 250W and LED 140W by installation and measurement data on site test. Data was shown as average value per luminaire.

Table 4. Comparison of Lighting Performance between HPS 250W and LED 140W

Parameter	Requirement	HPS 250W	LED 140W
Measurement Result			
$E_{av\,(@\,MF=0.7)}$ (lux)	15	22.07	16.28
U_0 (E_{min}/E_{av})	0.33	0.05	0.29
Calculation Result			
$E_{av\,(@\,MF=0.7)}$ (lux)	15	N/A	14.67
U_0 (E_{min}/E_{av})	0.33	N/A	0.41

Table 5. Comparison of Electrical Performance between HPS 250W and LED 140W (average per luminaire)

Parameter	HPS 250W	LED 140W
Input voltage (V)	230	230
Input current (A)	1.35	0.57
Input power (W)	299	130
Power factor (lag)	0.520	0.985

The results of comparison analysis in Table 4 found that LED 140W had the illumination less than HPS 250W, while providing more than the standard criteriea of MEA, therefore, it can be used replacemented for HPS 250W. Interestingly, comparison in Table 5, LED 140W can reduce the power up to 169 W/luminaire (saving up to 56.5 %).

3.4 Comparative Analysis Result Between HQV 125W and LED 55W

Table 6 shows the comparative analysis result of lighting performance between HQV 125W and LED 55W by following installation and measurement data and using DIALux program on site test with luminaire spacing as 40m and 32m.

Table 7 shows the comparative analysis result of electrical performance between HQV 125W and LED 55W by installation and measurement data on site test. Data was shown as average value per luminaire.

Table 6. Comparison of Lighting Performance between HQV 125W and LED 55W

Parameter	Requirement	HQV 125W	LED 55W
Measurement Result (40 m)			
$E_{av\,(@\,MF=0.7)}$ (lux)	7.5	4.12	7.27
U_0 (E_{min}/E_{av})	0.33	0.302	0.151
Calculation Result (40 m)			
$E_{av\,(@\,MF=0.7)}$ (lux)	7.5	N/A	6.77
U_0 (E_{min}/E_{av})	0.33	N/A	0.246
Calculation Result (32 m)			
$E_{av\,(@\,MF=0.7)}$ (lux)	7.5	N/A	8.39
U_0 (E_{min}/E_{av})	0.33	N/A	0.401

Table 7. Comparison of Electrical Performance between HQV 125W and LED 55W (average per luminaire)

Parameter	HQV 125W	LED 55W
Input voltage (V)	230	230
Input current (A)	1.35	0.23
Input power (W)	144.0	51.3
Power factor (lag)	0.600	0.951

The results of comparison analysis in Table 6 are found that LED 55W had the illumination more than HQV 125W; therefore, it can be concluded that LED 55W can be replaced for HQV 125W. Interestingly, comparison in Table 5, LED 55W can also reduce the power up to 92.7 W/luminaire (saving up to 64.4 %).

4. REPLACEMENT OF EXISTING LAMP BY LED

4.1 Determination on Tested Area

To study and test LED road lighting, the decided areas consist of:

- Phahurat Road, Chakphet Road and Tri Phet Road: replacement of 85 luminaires HPS 250W by LED 140W (Fig.8)
- Soi Chidlom: replacement of 37 luminaires HPS 250W by LED 140W (Fig.9)

- Thetsaban Sai 1 Road: replacement of 20 luminaires HQV 125W by LED 55W (Fig.10)

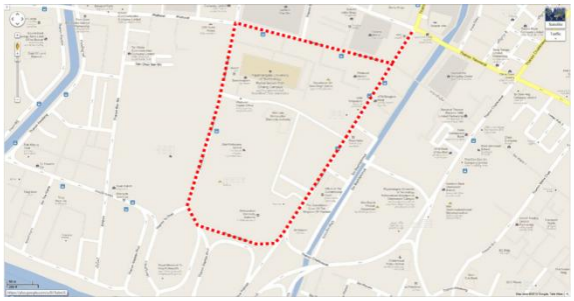

Fig.8. Map of Phahurat Road, Chakphet Road and Tri Phet Road

Fig.9. Map of Soi Chidlom

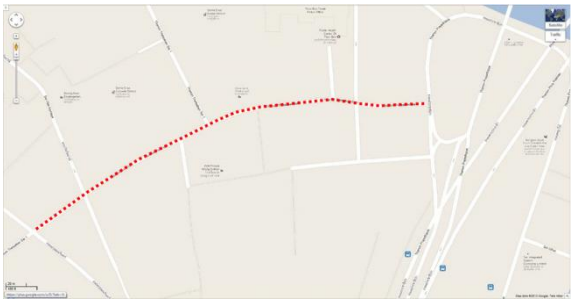

Fig.10. Map of Thetsaban Sai 1 Road

4.2 Illumination Performances Analysis in Test Areas

Table 9 shows the comparative analysis result of lighting performance between HPS 250W and LED 140W by installation and measurement data on Phahurat Road as shown in Table 8. The results show that although LED 140W provides illumination less than HPS 250W, but it still exceeds the standard criteriea of MEA. Therefore, it can be concluded that the HPS 250W can be replaced by LED 140W.

Table 8. Road Lighting Installation Detail on Phahurat Road

Luminaire	HPS250W/ LED140W
Arrangment	Staggered
Road width (m)	14.5
Number of lanes	5
Mounting hight (m)	8.8
Luminaire spacing (m)	36/32
Overhang (m)	2

Table 9. Comparison of Lighting Performance between HPS 250W and LED 140W on Phahurat Road

Parameter	Requirement	HPS 250W	LED 140W
$E_{av\,(@\,MF=0.7)}$ (lux)	15	37.7	30.7
U_0 (E_{min}/E_{av})	0.33	0.35	0.42

The comparative analysis result of lighting performance between HQV 125W and LED 55W by installation and measurement data on Thetsaban Sai 1 Road as shown in Table 10. It is found that the LED 55W has more illumination than the HQV 125W. Therefore, it can be concluded that the HQV 125W can be replaced by the LED 55W.

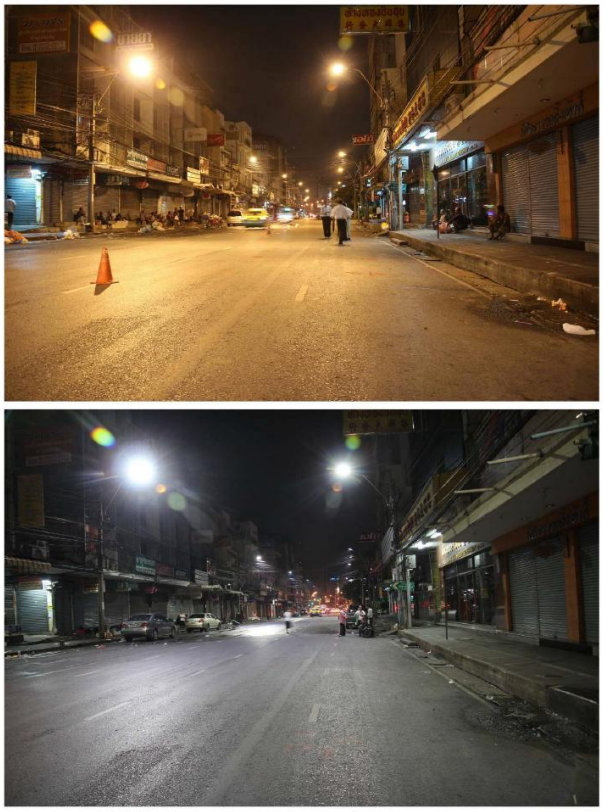

Fig.11. Illumination Comparison between HPS 250W (top) and LED 140W (bottom) on Phahurat Road

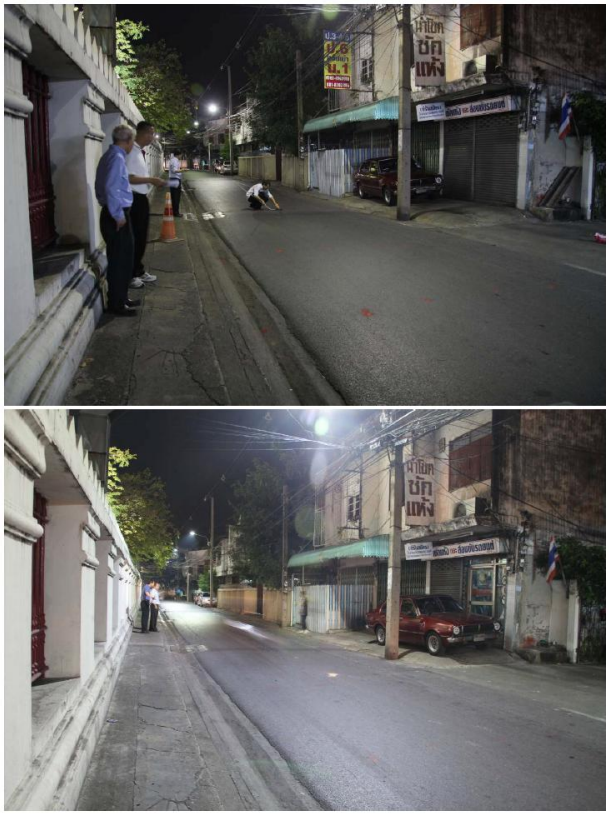

Fig.12. Illumination Comparison between HQV 125W (top) and LED 55W (bottom) on Thetsaban Sai 1 Road

Table 10. Road Lighting Installation Detail on Thetsaban Sai 1 Road

Luminaire	HQV 125W/ LED 55W
Arrangment	Single-Sided
Road width (m)	5
Number of lanes	2
Mounting hight (m)	6.5
Luminaire spacing (m)	33
Overhang (m)	1.5

Table 11. Comparision of Lighting Performance between HQV 125W and LED 55W on Thetsaban Sai 1 Road

Parameter	Requirement	HQV 125W	LED 55W
$E_{av\,(@\,MF=0.7)}$ (lux)	7.5	8.7	15.5
U_0 (E_{min}/E_{av})	0.33	0.25	0.29

Table 12. Energy Consumption in kWh/luminaire/year of Replacement of Existing HPS 250W by LED 140W

Parameter	HPS 250W	LED 140W
Power Consumption (W)	299	130
kWh/year	299x4,380/1,000 = 1,309.62	130x4,380/1,000 = 569.40
Energy Saving (kWh)	N/A	1,309.62 – 569.40 = 740.22
CO_2 Emission (kg/year)	1,309.62x0.6 = 785.77	569.40x0.6 = 341.64
CO_2 Reduction (kg/year)	N/A	785.77 – 341.64 = 444.13

Note: Average value of CO_2 emissions in Thailand is 563.52 g/kWh or approximate to 0.6 kg/kWh [6]

Table 13. Energy Consumption in kWh/luminaire/year of Replacement of Existing HQV 125W by LED 55W

Parameter	HQV 125W	LED 55W
Power Consumption (W)	144	51.3
kWh/year	144x4,380/1,000 = 630.72	51.3x4,380/1,000 = 224.69
Energy Saving (kWh)	N/A	630.72 – 224.69 = 406.03
CO_2 Emission (kg/year)	630.72x0.6 = 378.43	244.69x0.6 = 134.81
CO_2 Reduction (kg/year)	N/A	378.43 – 143.81 = 243.62

4.3 Energy Saving and CO_2 Reduction Analysis

Table 12 shows the energy usage by the HPS 250W as compared to replacement by the LED 140W in kWh/luminaire/year. The results show that LED 140W can save energy up to 740.22 kWh/luminaire/year which in turn reduces CO_2 emission by 0.444 ton/luminaire/year. Thus, if one-hundred of LED 140W are installed, the energy will be saved 74,022 kWh/year and can reduce CO_2 emission by 44.413 ton/year.

Table 13 shows the energy usage by the HQV 125W as compared to replacement by the LED 55W in kWh/luminaire/year. The results indicate that using LED 55W can save energy up to 402.03 kWh/luminaire/year which in turn reduces CO_2 emission by 0.243 ton/luminaire/year. Thus, if one-hundred of LED 55W are installed, the energy will be saved 40,603 kWh/year and can reduce CO_2 emission by 24.362 ton/year.

5. CONCLUSION

Results associated with the replacement of existing lamp by LED can be summarized as below:

5.1 LED road lighting 140W can be replaced for HPS 250W. Moreover, LED road lighting 140W can reduce the power up to 169 W/luminaire or might save energy up to 56.6 %.

5.2 LED 140W replacement for HPS 250W can save energy up to 740.22 kWh/luminaire/year and can reduce CO_2 emission by 0.444 ton/luminaire/year.

5.3 LED road lighting 55W can be replaced for HQV 125W, Moreover, LED road lighting 55W can reduce the power up to 92.7 W/luminaire or might save energy up to 64.4 %.

5.4 LED 55W replacement for HQV 125W can save energy up to 406.03 kWh/luminaire/year and can reduce CO_2 emission by 0.243 ton/luminaire/year.

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The Integrated Energy and Risk Management of Lighting System for Petrol Station in Thailand: A Case Study of LED Technology

Kitti Tirawannavit, Pornrapeepat Bhasaputra, Woraratana Pattaraprakorn, and Suthisak Temkasemsuk

Abstract*— *This paper studies risk management of replacement the lighting with LED in petrol station. The comparison of existing fluorescent lamp and metal halide with LED lamp luminaries was investigated and verified the best lighting system for canopy area light and C-store in the petrol station. The investment cost, economics and financial analysis of different cases were evaluated to clarify the opportunities for investment. However the unit cost of LED is still higher than that of the existing lamps; the replacement plan with the appropriate time schedule and portion is concerned. Longer operating time per day is the first priority. The results from this study show that LED can be applied for energy saving which can reduce 51.77- 63.62% of energy depending on the type and service hour of the existing lighting.

***Keywords* — Petrol Station, LED Technology, Lighting system, Energy conservation, Risk management**

1. INTRODUCTION

In Thailand, there are 6,000 petrol stations in year 2013[1], consisted of 3 kinds: Oil, LPG, and NGV stations.[2]. A large number of petrol stations are in northern and northeastern of Thailand; the most market share is PTT petrol station. Electricity usage in petrol stations can be divided into 2 parts: inside air conditioning area (i.e. convenient store) which air conditioner, lighting and electrical devices are the main consumption sources. Outside air conditioning area which lighting is the main electrical consumption source. Although "air conditioners" are the most power consumption sources, "lighting system" are quite interesting to investment, with less initial cost - comparing to air conditioning system.[3]

Nowadays, "lighting systems" are utilized as supporting tools of marketing work, and an essential factor for customer's consideration to select the fuel stations. In addition, high competition of convenient stores inside the fuel stations, power conservation of lighting system is a very interesting issue coincident with high development of LED technology[4] with continuous price reduction. Energy saving in petrol station sector will decrease the operating cost and increase the electrical usage efficiency of the business, and also macro economic of the country. Electricity usage in petrol stations is intended to focus on lighting system by replacing the existing with new technology.

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2. CHARACTERISTIC FOR LIGHTING IN PETROL STATION

2.1 Electricity consumption in Thailand petrol station can divided 3 areas; first of all, petrol station building (canopy) as shows in figure 1; second, convenient store (C-Store) as shows in figure 2 and finally, general area (Area light) as shows in figure 3.

Figure 1 Canopy Area

Figure 2 C-Store Area

Figure 3 Area Light

Table1 Energy Consumption in Petrol Station

TYPE	AIR CONDITION	LIGHTING	ELECTRIC APPLIANCES
CANOPY	-	90 %	10 %
C-STORE	60 %	30 %	10 %
AREA LIGHT	-	100 %	-

2.2 Electricity consumption in each area as shown in Table 1. In canopy area, 90% of electricity consumption is for the lighting system. In the C-store, electricity consumptions of air conditioner and lighting are 60% and 30%, respectively. In area light, all of electricity consumptions are for the lighting system.

2.3 Service hour per day of Thailand petrol station

- 24 hour per day
- 06:00 AM to 10:00 PM

2.4 Luminance standard of Thailand petrol station[5]

- Canopy 300 lux, Average every 2x2 M, Height 0.75M.
- Area light 30 lux, Average every 2x2 M, Height 0.75M.
- C-Store 500 lux, Average every 2x2 M, Height 0.75M.

2.5 The existing lighting system in Thailand petrol station as summarized in Table 2. Metal halide lamps are used in canopy area and area light while fluorescent lamps area used in C-store.

Table 2 Replaced lamp in petrol station

	EXISTING	REPLACEMENT
CANOPY	METALHALIDE 250 WATT	LED CANOPY 100 WATT
C-STORE	FLUORESENT T8 36 WATT	LED T8 20 WATT
AREA LIGHT	METALHYDIE 400 WATT	LED STREETLIGHT 180 WATT

3 FEASIBILITY OF LED INVESTMENT

To compare electricity consumption between the existing lighting with LED and luminance standard; therefore this study replaced the existing lighting to LED in the selected petrol station to analyse feasibility of LED project in Thailand petrol station.[6]

Therefore, in the canopy area 100 W LED can be used instead of the existing metal halide bulbs 250 W. Area Light: 180 W LED lamps can be used for the existing metal halide lamps 400 W. C-Store: 20 W LED can be replaced to the existing Fluorescent T8 36W.

Table 2 Luminance Standard in Thailand Petrol Station

					TYPE OF LAMP		ENERGY CONSUMPTION (baht/year)		
OPERATING TIME		ILLUMINACE	QUANTITY	SERVICE HOUR	EXISTING	LED SYSTEM	EXISTING	LED SYSTEM	SAVE (%)
24 Hr.	CANOPY	300	30	12	METALHYDIE 250 WATT	CANOPY LED 100 WATT	131,853.77	47,968.01	63.62
	AREA LIGHT	30	10	12	METALHYDIE 400 WATT	STREET LIGHT 180 WATT	69,072.60	29,959.20	56.63
	C-STORE	500	132	24	FLUORESENT 36 WATT	T8 LED 20 WATT	182,218.51	87,880.32	51.77
						TOTAL	383,144.88	165,807.53	
6.00 am.-22.00 pm	CANOPY	300	30	4	METALHYDIE 250 WATT	CANOPY LED 100 WATT	43,951.26	15,989.34	63.62
	AREA LIGHT	30	10	4	METALHYDIE 400 WATT	STREET LIGHT 180 WATT	23,024.20	9,986.40	56.63
	C-STORE	500	132	16	FLUORESENT 36 WATT	T8 LED 20 WATT	121,479.01	58,586.88	51.77
						TOTAL	188,454.46	84,562.62	

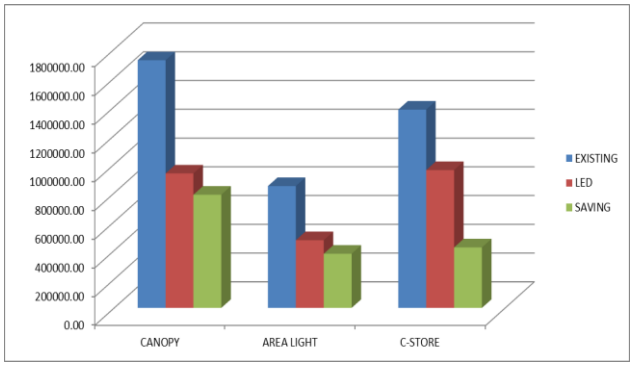

Figure 4 LCC of the Existing Lighting and LED

4 INVESTMENT RISK MANAGEMENT OF LED PROJECT

Investment risk management of LED project have to studies in term of electricity price increasing, LED price decreasing, service hour per day changing and interest rate changing. In addition, the financial indices are NPV (Net Present Value), IRR (Internal Rate of Return), B/C (Benefit Cost Ratio) and P/B (Payback Period or Break Even Point).

Figure 5 shows NPV through LED life cycle in canopy area. NPV of this project is more than zero in every

electricity cost and service hour per day. In addition, the electricity cost and service hour per day increase, NPV also increases. The minimum and maximum of NPV are 4063.86 and 23274.03 Baht

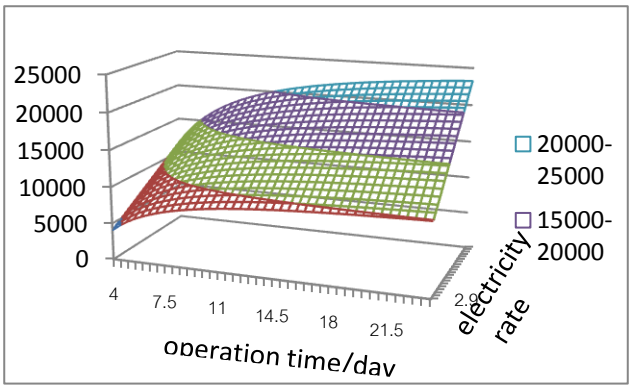

Figure 5 NPV of LED 100W in Canopy Area

Figure6 shows P/B through LED life cycle in canopy area. In addition, the electricity cost and service hour per day increase, P/B will faster. The minimum and maximum of P/B are 1.71 and 14.02 years.

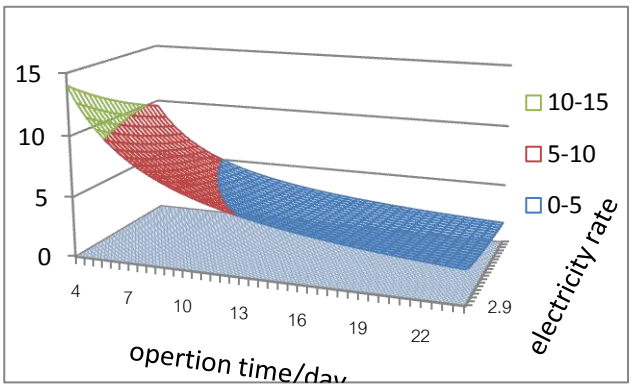

Figure6. P/B of LED 100W in Canopy area

Figure 7 shows IRR through the LED lift cycle in canopy area is 7.17 to 54.30 percent.

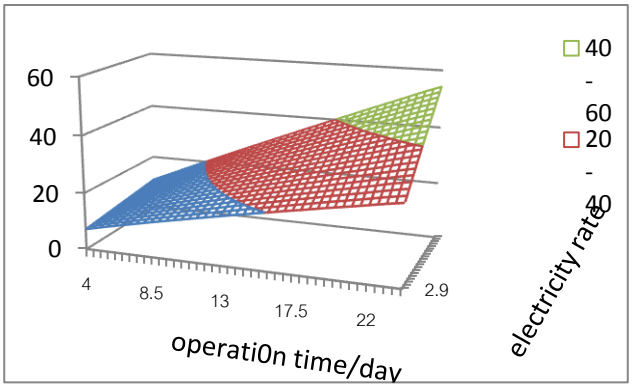

Figure7. IRR of LED 100W in Canopy Area

Figure8 shows NPV through the LED life cycle in area light. NPV of this project is more than zero in all ranges of electricity cost and service hours per day. In addition, the electricity cost and service hour per day increase, NPV also increases. The minimum and maximum of NPV are 4878.84 and 32238.77 Baht.

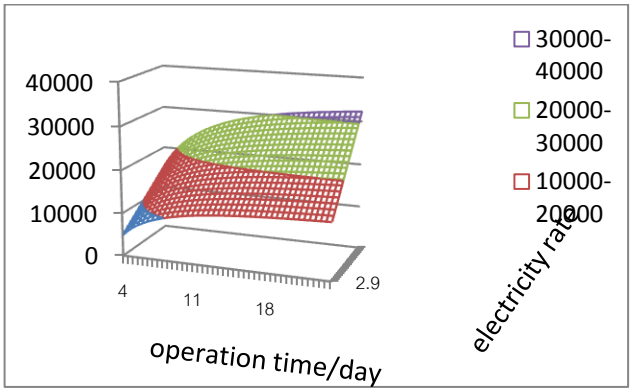

Figure8. NPV of LED Street Light 180 W.

Figure9 shows P/B through the LED life cycle in area light. In addition, the electricity cost and service hour per day increase, P/B will faster. The minimum and maximum of P/B are 1.80 and 14.64 years.

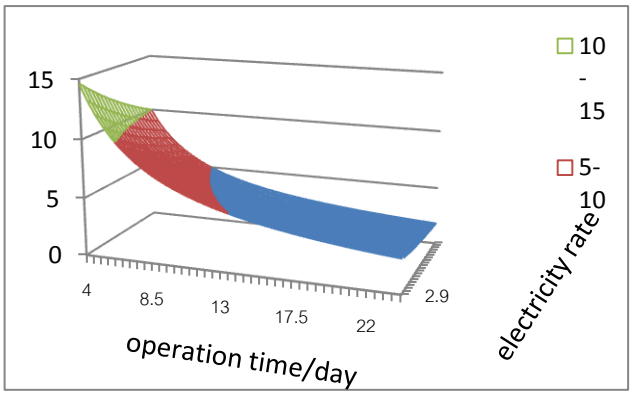

Figure9. P/B of LED Street Light 180 W.

Figure 10 shows IRR through the LED lift cycle in area light is 6.76 to 50.93 percent.

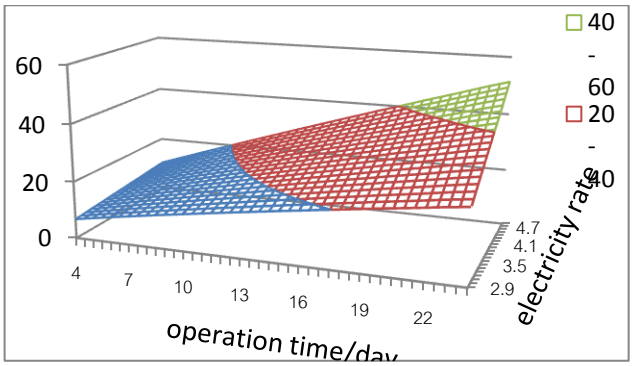

Figure10 IRR of LED Street Light 180 W.

Figure11 shows NPV through the LED life cycle in C-Store. NPV of this project is more than zero in every electricity cost and service hour per day. In addition, the electricity cost and service hour per day increase, NPV also increases. The minimum and maximum of NPV are 947.14 and 3275.64 Baht

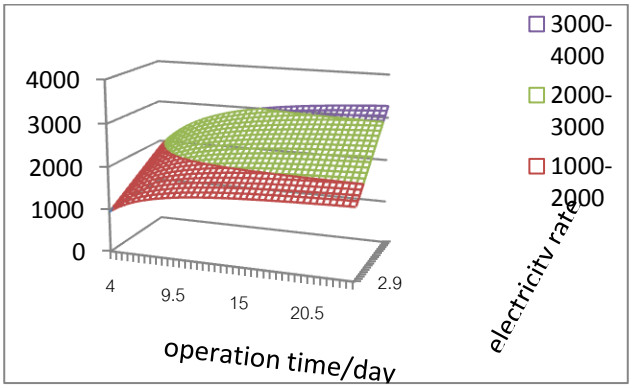

Figure11. NPV of LED 20 W.

Figure12 shows P/B through the LED life cycle in C-Store. In addition, the electricity cost and service hour per day increase, P/B will be faster. The minimum and maximum of P/B are 1.19 and 10.19 years.

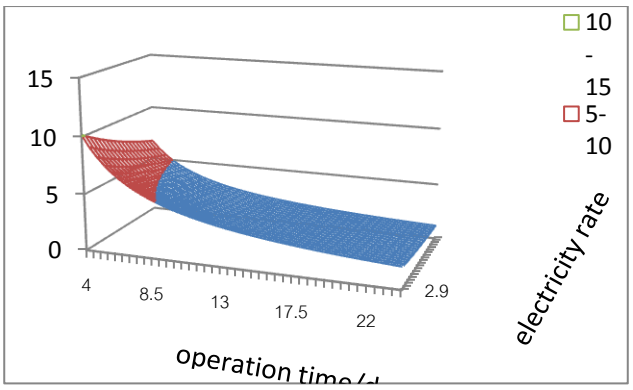

Figure12. P/B of LED 20 W.

Figure14 shows IRR through the LED lift cycle in C-Store is 10.55 to 83.03 percent.

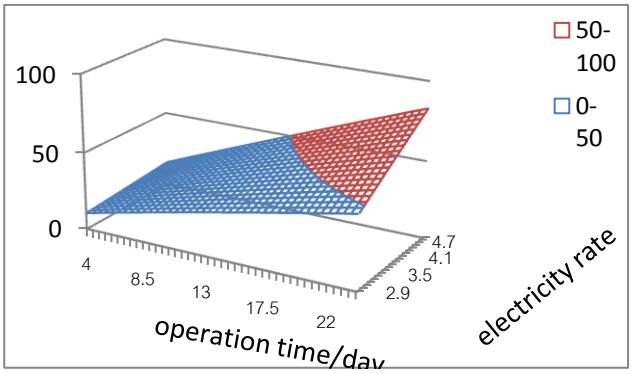

Figure14. IRR of LED 20 W.

3 CONCLUSION

According to various types and service hours of lighting system in a selected Thai petrol station, the appropriate redesign for lighting system is needed to enhance the energy management ability. The simulation results show that LED lamp can reduce the energy consumption up to 65%. Therefore, energy cost saving of the lighting system in Thai petrol station has to increase the total net profit. Finally, the additional benefit of LED lamp is environmental friendly in term of mercury reduction.

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Effects of Feed Velocity on Efficiency of Cassava Starch Separation using Sieve Bend Screen

Nut Chaiatchanarat, Ruenrom Lerdlattaporn, Wiwat Ruenglertpanyakul,
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Abstract*—In this research, lab-scale sieve bend screen machines were designed and constructed to investigate the effect of feed velocity of cassava starch slurry on the separation efficiency and capacity. Experiments were conducted with the machines with one and two nozzles of feed inlet. Inlet velocities were varied at 0.65, 1.16, 2.61, and 10.44 m/s for one nozzle, and at 0.33, 0.58, 1.31, and 5.22 m/s for two nozzles. Experimental results showed that as the feed velocity increased, starch at undersize increased due to the reduction of cake formation and subsequently cake resistance on the screen. Moreover, the amount of starch loss with oversize gradually decreased. The optimum feed velocities for separating cassava starch from fine pulp for the sieve bend screen with 120° screen arc were 2.61 and 1.31 m/s for one and two nozzles, respectively.*

***Keywords*— Cassava Starch, Sieve Bend, Screen, Fine Pulp, Extraction**

1. INTRODUCTION

Thailand is the world's largest producers and exporters of cassava starch. In 2012, the value of cassava starch export from Thailand was about 1.67 billion USD [4]. Cassava starch production process consists of several steps, i.e. receiving raw materials from suppliers, screening, washing/cutting, rasping/grinding, extracting, separating, dewatering, drying step and packing. In the process, coarse and fine extractors or basket screen centrifuges are normally used to separate cassava starch granules from pulps. Conical basket screen centrifuges act as filtering machines for starch-pulp separation. Smaller starch particles pass through the screen, while larger particles are retained. The goal of this research is to consider a new alternative, a sieve bend screen, to replace basket-screen centrifuges in the fine extracting unit.

The sieve bend screen machine is constructed with a series of parallel welding vee-wire on rod support. The primary purpose of the sieve bend screen is to separate starch granules from fine pulps. Cassava starch slurry is fed by pressure force through a set of nozzles and is flown along the surface of sieve bend. The smaller particles (or cassava starch granules) are passed through the aperture of sieve bend called 'undersize' and the larger particles (or fine pulps) are pushed to the edge of sieve bend called 'oversize'.

This research investigated the effects of feed velocity on cassava starch separation efficiency in the lab-scale sieve bend screen machine.

2. MATERIALS AND METHOD

Experimental design

In this research, lab-scale sieve bend screen machines were constructed to investigate the effect of feed velocity of cassava starch slurry on the separation efficiency and capacity (Fig. 1). Table 1 shows the design configuration of a sieve bend screen [2]. The flow rate of cassava starch slurry and screen arc were fixed at 12.3 L/min and 120°, respectively.

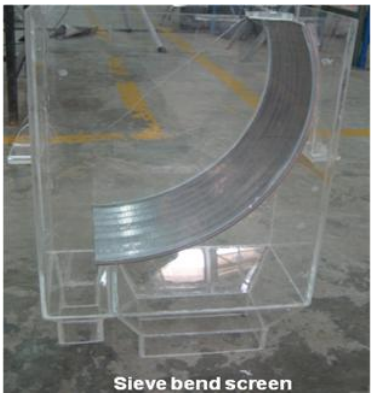

Fig. 1. A lab-scale sieve bend screen

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Table 1. Configuration of a lab-scale sieve bend screen machine

Data sheet	Value
Screen surface length (mm)	531.0
Screen arc (deg.)	120.0
Screen chord length (mm)	438.2
Screen chord length (mm)	126.5
Screen width (mm)	195.0
Opening size (mm)	0.1
Profile wire size (mm)	1.5
Support rod size (mm)	2.5
Screen radius (mm)	253.0

Experiments were conducted sieve bend machines with one and two nozzles. Inlet velocities were varied at 0.65, 1.16, 2.61, and 10.44 m/s for one nozzle, and at 0.33, 0.58, 1.31, and 5.22 m/s for two nozzles.

Experimental Set-up

Fig. 2 presents a schematic diagram of the experimental set-up consisting of the lab-scale machine (#1 in the diagram), pump, valve and pipe. The gate valve (#6 in the diagram) was used to drain slurry. The feed velocities were varied by changing diameter of nozzle (#9 in the diagram).

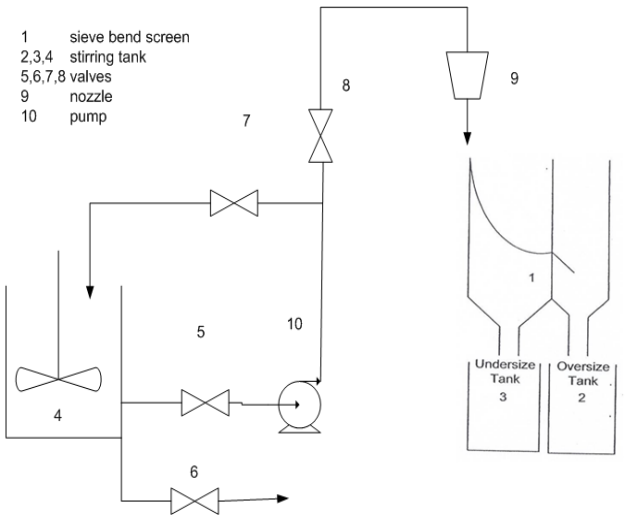

Fig. 2. Schematic diagram of experimental apparatus

In order to investigate the effects of feed velocity on efficiency of cassava starch separation, %starch content and %fine pulp content of feed, undersize, and oversize were measured and analyzed.

Determination of Starch Content

Starch content of samples was measured by optical method based on starch-iodine reaction (AOAC, 1995). It was measured at 570 nm by Spectrophotometer (Model UV-2101PC, Shimadzu, Japan).

Determination of Fine Pulp Content

Fine pulp content of samples was measured by TIS 274-2521 method.

3. RESULTS AND DISCUSSION

Experiments were conducted with lab-scale sieve bend screen machines with one and two nozzles. Two experiments were performed at a constant feed flow rate of 2.05×10^{-4} m^3/s. Inlet velocities were varied by changing the diameter of nozzle at 0.65, 1.16, 2.61, and 10.44 m/s for one nozzle, and at 0.33, 0.58, 1.31, and 5.22 m/s for two nozzles. Filtration area and feed velocity were varied regarding the feed velocity (Table 2).

Table 2. Filtration area and feed velocity with one and two nozzles.

One Nozzle		Two Nozzles	
Feed Velocity (m/s)	Filtration area (cm^2)	Feed Velocity (m/s)	Filtration area (cm^2)
0.65	221	0.33	705
1.16	257	0.58	711
2.61	324	1.31	718
10.44	413	5.22	726

The efficiency of seive bend screen was determined from percentage of starch at undersize, starch loss with fine pulp and pulp removal.

Effect of feed velocity of cassava starch slurry on volume flow rate, mass flow rate, cake formation and extraction efficiency at undersize

In cross flow filtration, as cross flow velocity of feed increases, filtrate flow rate increases due to the reduction of shear force from feed, reducing cake formation on screen [1].

$$J = \frac{\Delta P}{(\mu(R_m+R_c))} \quad (1)$$

where:

J is a liquid flux or filtrated cassava starch

ΔP is the pressure drop on sieve bend screen

μ is the fluid velocity

R_m is the filter medium resistance

R_c is the cake resistance

From eq.1, increasing feed velocity decreased cake formation on the screen, so cassava starch slurry could easily flow through the screen. Consequently, the filtrate or volumetric and mass flow rate at undersize increased as shown in Fig. 3 and 4. Filtration area of one and two nozzles also differed depending on feed velocity and number of nozzles due to different shapes of feed initially on the screen.

As The volumetric and mass flow rate per filtration area at undersize increased with increasing feed velocity of cassava starch slurry due to an increase inperpendicular

force acting on screen. This result agreed with the experiment of Choi *et al.,* 2004 who studied the influence of cross-flow velocity on membrane performance during filtration of biological suspension. Their results showed that mass flow rate per filtration area did not linearly increase but rather increased slightly and became plateau because of the equally distribution mass flux through the total filtration area.

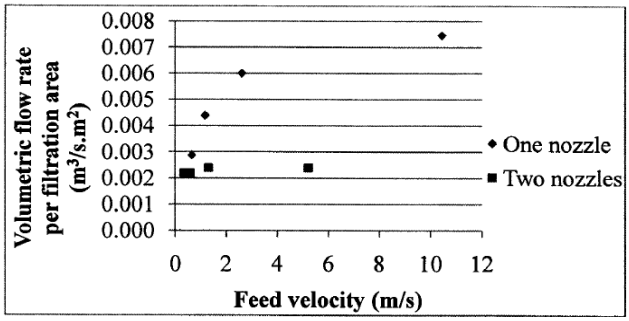

Fig. 3. Effect of feed velocity of cassava starch slurry on volumetric flow rate per filtration area at undersize with one and two nozzles

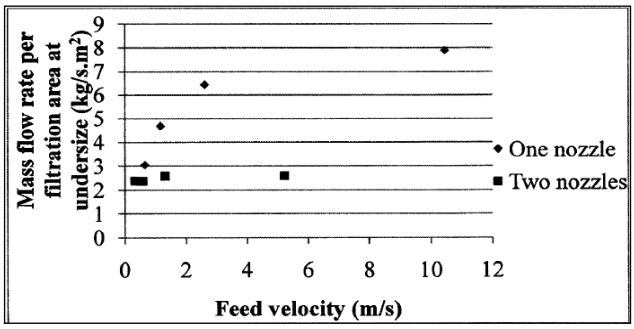

Fig. 4. Effect of feed velocity of cassava starch slurry on mass flow rate per filtration area at undersize with one and two nozzles

Fig. 5 shows the effect of feed velocity of cassava starch slurry on starch extraction efficiency at undersize with one and two nozzles. The starch efficiency at undersize increased with increasing mass flow rate per filtration area. For one nozzle, at the mass flow rate per filtration area of 3.05-6.44 kg/s.m^2, the starch efficiency was increased because of the removal of cake on sieve bend screen resulting from a higher feed velocity of cassava starch slurry. However, at the mass flow rate per filtration area of 7.89 kg/s.m^2 or at the highest feed velocity, the starch efficiency decreased due to the short circuit resulting in a less retention time of starch on the screen.

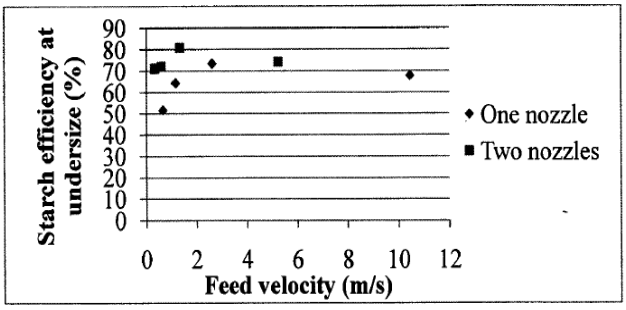

Fig. 5. Effect of feed velocity of cassava starch slurry on starch extraction efficiency at undersize with one and two nozzles

Further, the starch efficiency, for two nozzles, at the mass flow rate per filtration area of 2.38-2.60 kg/s.m^2, increased. The optimum feed velocity for separating cassava starch from fine pulp for the sieve bend with 120º screen arc was 2.61 and 1.31 m/s for one and two nozzles, respectively.

Effect of feed velocity of cassava starch slurry on volume flow rate, mass flow rate, cake formation and extraction efficiency at oversize

Normally, increasing feed velocity increased shear force on the screen resulting in the cake removal. Further, the amount of cassava starch loss with oversize decreased due to the reduction of volumetric and mass flow and cake formation on the sieve bend screen (shown in Figs. 6 and 7).

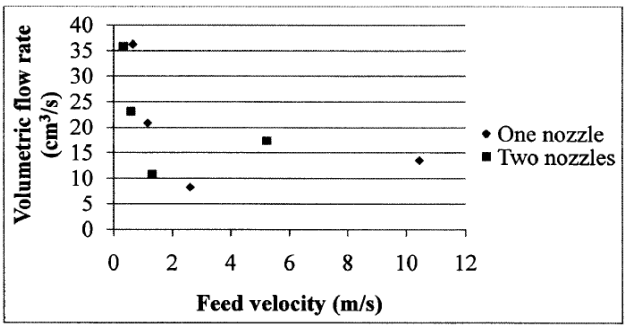

Fig. 6. Effect of feed velocity of cassava starch slurry on volumetric flow rate at oversize with one and two nozzles

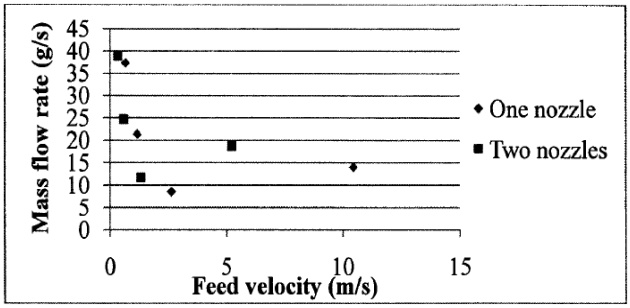

Fig. 7. Effect of feed velocity of cassava starch slurry on mass flow rate at oversize with one and two nozzles

At a higher velocity than 2.61 m/s, the amount of cassava starch loss with oversize increased. The optimum feed velocity for separating cassava starch from fine pulp for the sieve bend with 120º screen arc was 1.31 m/s for two nozzles (Fig. 8).

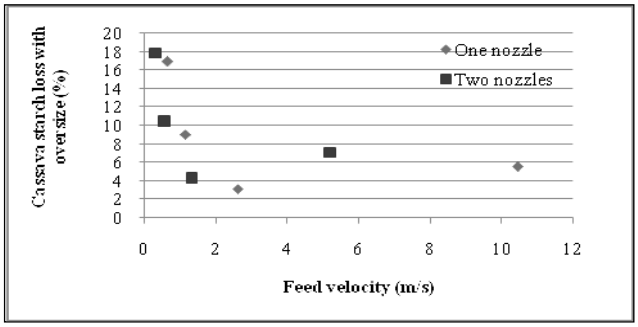

Fig. 8. Percentage of starch loss at oversize

Effect of feed velocity of cassava starch slurry on fine pulp removal

The fine pulp removal efficiency is the amount of fine pulp which can be removed from cassava starch feed slurry.

In all experiments, the fine pulp removal efficiency was higher than 90% as presented in Table 2. The results showed as increasing feed velocity of cassava starch slurry, the efficiency of fine pulp removal was insignificantly different.

Table 2. Effect of feed velocity of cassava starch slurry on fine pulp removal

One Nozzle		Two Nozzles	
Feed Velocity (m/s)	Fine Pulp Removal Efficiency (%)	Feed Velocity (m/s)	Fine Pulp Removal Efficiency (%)
0.65	94.76	0.33	92.91
1.16	93.68	0.58	93.11
2.61	93.20	1.31	92.75
10.44	93.08	5.22	92.08

4. CONCLUSION

As feed velocity increased, cassava starch at undersize increased due to the reduction of cake formation on the sieve bend screen. Moreover, the amount of cassava starch loss with oversize gradually decreased.

The efficiency of sieve bend screen on fine pulp removal was more than 92%. The efficiency of fine pulp removal of one and two nozzle was similarly due to the high filtration area and mass flux.

The optimum feed velocity for separating cassava starch from fine pulp for the sieve bend with 120º screen arc was 2.61 and 1.31 m/s for one and two nozzles, respectively.

5. ACKNOWLEDGMENT

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The Effect of Si/Al Ratios on the Properties of Geopolymers Prepared from Water Treatment Residue (WTR) Containing Heavy Metals

N. Waijarean, S. Asavapisit, K. Sombatsompop, and K.J.D. MacKenzie

***Abstract*—** *The aim of this research was to develop a geopolymer cementing material using water treatment residue)WTR (as the aluminosilicate source, with the addition of rice husk ash)BHA(as a source of crystalline silica, and a heavy metal added to the binders)WTR and NaOH (at 30, 50 and 70% by weight. The geopolymers were prepared by NaOH activation of WTR and BHA mixtures of eight different compositions, followed by curing at ambient temperature. The compressive strengths of the geopolymers were determined up to 60 days. The samples cured for 28 days were examined by microstructure. The samples prepared with a Si/Al ratio of 2.00 without heavy metal and with 30% heavy metal were found to produce the greatest strength at all curing times. After 28 days, all samples had gained 30% greater strength than the 7 day-samples. XRD revealed the presence of sodium aluminum silicate hydrate, and sodium zinc silicate, sodium iron silicate oxide and sodium aluminum hydroxide chromium oxide in geopolymer matrices, while an FTIR vibration band related to the geopolymer product shifted to 1002 cm^{-1}. WTR and BHA are useful waste materials for geopolymer synthesis and produce useful products for applications such as heavy metal immobilization.*

***Keywords*— Black husk ash, Geopolymer, Si/Al ratios, Water treatment residue.**

1. INTRODUCTION

Geopolymers (GPs) are inorganic materials that can be synthesized from a variety of industrial by-products and wastes, including sludge from water treatment plants, blast furnace slag, coal fly ash, mining waste and steel slag. They are formed by alkaline activation with controlled water content and suitable molar compositions [1]. The Si/Al ratios of the starting material play a key role in geopolymerization process and the geopolymer properties. MacKenzie et al. have reported that optimal properties of the products are achieved with the molar ratios in the range SiO_2/Al_2O_3 < 3.3, H_2O/Na_2O <10 and Na_2O/SiO_2 <0.3 [2-4]. Geopolymer technology is proving useful for utilization of wastes streams to produce materials that are more environmentally-friendly than ordinary Portland cement (OPC), and have a number of other applications such as the immobilization of toxic and radioactive wastes, or thermal insulation of buildings [5].

Water treatment residue (WTR) is a waste product from water treatment plants, where it is used for dewatering or similar solid-liquid separation processes. It contains a high proportion of clay minerals, principally kaolinite, in addition to aluminium and iron salts removed from the water by coagulation, and organic polymers used to remove organic matter and suspended solids from the water supply. Two hundred tons of WTR are generated per day and disposed of directly into landfills due to the high cost of managing the disposal process. Reuse of WTR to manufacture ceramics and bricks has been considered as an alternative to dumping in landfills, and its major chemical components (silicon and aluminum) suggest that its aluminisilicate ratio could make it a suitable raw material for geopolymer production [6].

Rice husk is a by-product available in rice–producing countries that is widely used as a biomass fuel in rice mills and electricity power plants by burning the husks under controlled conditions [1-2]. Such combustion processes produce on average about 18% rice husk ash (RHA), either as black husk ash (BHA) with a high carbon or white husk ash with a low carbon. BHA consists of >90 wt% of highly crystalline silica with a very large specific surface area (about 50-100m^2/g) and is very chemically reactive [7]. RHA is a well-known pozzolan that can be used in building materials and other applications such as steel insulation powder, insulation material or as a fuel supplement in the manufacture of OPC and fertilizer. This research uses BHA as a silica supplement in the production of geopolymers from WTR.

Previous research has focused principally on the production of geopolymers from raw materials such as coal fly ash, clay minerals, and blast furnace slag [1-2, 6-8]. Very little work has been done on the use of WTR as the aluminisilicate source, with the Si/Al ratios adjusted

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with BHA silica source. The goal of this research is to utilise two waste materials, WTR and BHA to develop a new cementing material with a potential application to immobilize heavy metals in the metal hydroxide sludge from an electroplating facility. The geopolymers under development would provide an environmentally-friendly approach to waste management by reducing the amount of waste disposed of in landfills.

2. EXPERIMENTAL PROCEDURE

Materials

The water treatment residue (WTR) is waste product obtained from a water treatment plant at Bangkaen, Bangkok Province, Thailand. WTR was thermally activated by calcining in an electric furnace at 800 °C for 1 hour, and then ground to be retained on sieve no. 325. (45µm). The chemical composition of the WTR calcined at 800 °C determined by XRF is presented in Table 1. The contents of WTR to report that SiO_2, Al_2O_3, and FeO_3, were 54.00, 30.40, and 9.18 %wt. dry, respectively, indicating that there is suitable aluminosilicate source in the initial material. The crystalline phases of WTR calcined at 800 °C were determined by XRD to be quartz (JCPDF no. 03-065-0466) and mica (JCPDF no. 03-065-0466) (Fig. 1).

The black husk ash (BHA) used was a by- product from controlled buring of rice husks from a dried paddy factory in Nakompratom Province, Thailand. The BHA was fired in a cyclonic furnace under controlled temperature above 850 °C for 1 hour to remove carbon and volatile organic compounds, followed by grinding in a Los Angeles abrasion machine for 6 hours to produce a particle size less than 34% on a 45 µm mesh by wet-sieved. The chemical composition of BHA determined by XRF is shown in Table 1. The high silica content (over 90% wt.dry) suggests that BHA could be a good silicate source. XRD showed an amorphous phase of SiO_2 in cristobalite (JCPDF file no. 04-007-4907), in addition to some phosphide oxide (P_2O_5: JCPDF file no. 04-007-2296) (Fig. 1).

Electroplating Sludge (EPS) was brought from the eletroplating facility located at Nongkham, Bangkok Province, Thailand. The EPS was generated from the waste water treatment plant by adjusting the pH of the wastewater to transfrom the soluble metals into metal hydroxide, followed by dewatering of EPS. EPS was dried before reducing to a particle size less than 50 mm. The concentation of heavy metals in EPS was measured by atomic absorption spectrophotometry (AA-6300 series no. A305246). Zinc, iron and chromium were found to be the major metals present at 216.45, 81.8, and 22.40 mg/kg dry sludge, respectively.

Table 1: The chemical compositions of WTR calcined at 800°C and BHA

Content	**Elements as an oxide**										**%M**	**%LO**	**Si_2O/Al_2O_3**
(wt% dry)	SiO_2	Al_2O_3	Fe_2O_3	K_2O	CaO	MgO	TiO_2	SO_3	Na_2O	MnO	**C**	**I**	**ratio**
WTR*	53.90	30.40	9.18	2.42	0.93	1.01	0.85	0.39	0.24	0.18	0.41	1.86	1.78
BHA	94.00	0.16	0.13	3.38	0.77	0.32	0.01	0.14	0.04	0.13	2.50	7.00	-

WTR* = WTR calcined at 800°C

%MC = % moisture content

% LOI= %Loss on ignition at 950°C

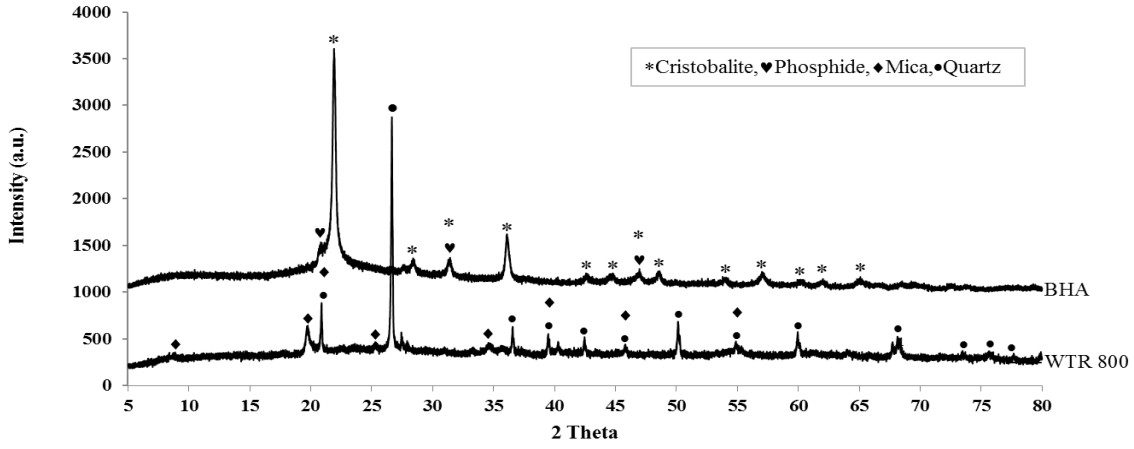

Fig. 1 XRD patterns of crystalline phase to compare with BHA and WTR calcined at 800 °C

Geopolymer synthesis

The geopolymer were synthesized from WTR calcined at 800 °C. The molar ratios of the reaction mixtures were different binders (WTR and BHA). Different content of WTR and BHA were used to give SiO_2:Al_2O_3 ratios of 1.78 and 2.00, and followed adjustment a heavy metal (EPS) to the binders. EPS was added at levels of 0, 30, 50 and 70% by weight. The compositions of these mixtures are shown in Table 2. The geopolymers were prepared by NaOH solution activation of WTR, BHA and EPS mixtures for 15 min. The water content of all samples were determined by ASTM method C187-68 [9]. The homogenised mixtures were transferred into cylinderical PVC molds, and shaken for 5 min to remove air bubbles, followed by curing at ambient temperature (29±2°C) for 24 hours in a plasstic bag to prevent the loss of water mixed. After this time the samples were demolded and kept in a plasstic bag to avoid carbonation until mechanical testing was carried out after 7, 28, 42, and 60 days.

Compressive strength test

The cylindrical samples with an average diameter of 35 mm and height of 70 mm were determined by ASTM C39)a standard testing for concrete specimens(. The compressive strength was measured by the unconfined compressive strength (UCS) test after curing for 7, 28 ,42, and 60 days. Six replicates of each sample were measured, to give a standard deviation in the range of ±0.5. The surfaces of all samples were flat and parallel. A fragment of the GPs after testing was retained for microstructural analysis.

Microstructural characterizations

The GPs samples were analysed using XRD, FTIR and SEM to study the mechanism of geopolymerization after curing for 28 days. Dried-powder of each sample was analysed under follow conditions

1. The crystalline phases were examined by XRD (PAN alytical series X′Pert PRO) with a graphite monochromator and CuKα radiation source. The sample was step scanned from 4 to 80° 2 theta at a rate of 0.04°2 theta step, at a counting time of 0.4s per step.
2. The functional groups of the GP were studied FTIR spectroscopy (Perkin-Elmer, version 2000). The spectral data were collected in the range between 400 and 4,000 cm^{-1}.
3. The morphology characterization of the products were studied by SEM (JEOL JSM-6610LA) at 15 kV. All samples were coated with carbon.

3. RESULTS AND DISCUSSION

3.1 Effect of immobilization of a heavy metal on strength test of WTR-based geopolymer

The strength development of WTR–based geopolymers containing different types and amounts of EPS is shown in Fig 2. The compressive strengths of these synthetic geopolymers were determined by testing after 3, 7, 28, and 60 days. All the samples developed strength at all curing times. The geopolymer matrixes prepared with a Si/Al ratio of 2.00 without EPS gained the highest compressive strength at 10.27 MPa at 60 day curing. This Si/Al content also produced the strongest material containing 30% EPS (5.63 MPa). The geopolymer synthesized with a Si/Al ratios of 1.78 and 2.00 adjusted with 70% EPS did not appear to developed significant strength during geopolymerization. The incorporation of a higher amount of EPS was associated with a decrement in the compressive strength of the geopolymer product at all curing times. This phenomenon appeared indicating retardation in the adsorption of a metal waste in geopolymer structure by immobilization.

Table 2: Compositions of geopolymers from WTR and BHA immobilization heavy metal waste

Sample ID	Binders (%wt. dry)			Activator	Molar Ratios		H_2O
	WTR	BHA	EPS	NaOH (gram)	Na_2O:SiO_2	SiO_2/Al_2O_3	
GPWTR1.78	700	0	0	121.25	0.25	1.78	364
GPEPS1.78-30	490	0	210	84.87	0.25	1.78	273
GPEPS1.78-50	350	0	350	60.62	0.25	1.78	217
GPEPS1.78-70	210	0	490	36.38	0.25	1.78	213
GPWTR2.00	655	45	0	127.15	0.25	2.00	357
GPEPS2.00-30	458	32	210	89.00	0.25	2.00	266
GPEPS2.00-50	327	23	350	63.57	0.25	2.00	224
GPEPS2.00-70	196	14	490	38.14	0.25	2.00	215

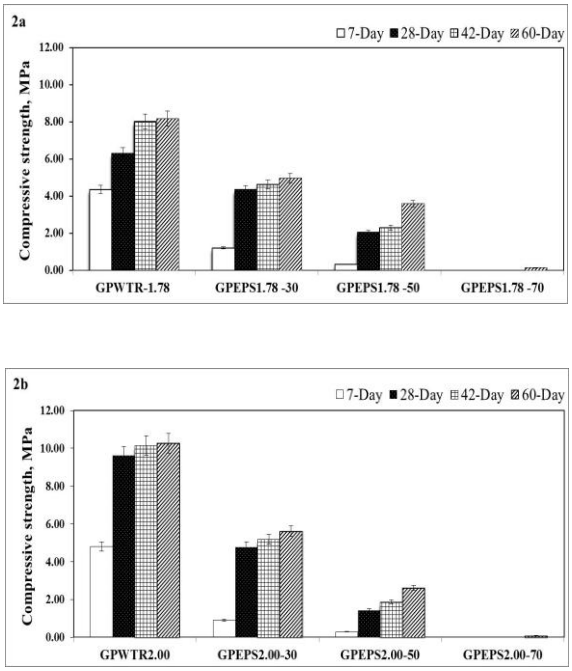

Fig 2 Compressive strength of synthetic geopolymer containing different type and amount of heavy metal wastes 2a geoplymer synthesized without BHA, 2b geopolymer synthesized with BHA

3.2 Effect of immobilization of a heavy metal on microstructural characterizations

XRD

Fig 3 shows the XRD diffraction patterns of geopolymers synthesized from WTR and BHA with different amounts of EPS at 0, 30, 50, and 70 % dry weight cured for 28 days. The peak of quartz (PDF no. 03-065-0466) is clearly presented as an unreacted component in all samples, while silicon oxide as cristobalite phase (PDF no. 04-008-7827) is only present in the geopolymer with a Si_2O/Al_2O_3 ratio adjusted to 2.00 with BHA, both with and without EPS. The crystalline phase of muscovite (PDF no. 04-011-5121), vermiculite (PDF no. 00-060-0340), and aluminium silicate oxide (PDF no. 01-074-1976) are observed in the geopolymer product. It is possible that this aluminosilicate clay mineral is inactive in geopolymerization. The apparent phase of sodium aluminium silicate hydrate (NASH: PDF no. 04-014-2162) through faujasite (PDF no. 00-012-0246) in geopolymer product, indicating that the reaction between NaOH activator and aluminosilicate material under this condition occurred.

Other crystalline phases in the geopolymer products synthesized with EPS include sodium zinc silicate (PDF no. 00-030-1267), iron oxide (PDF no. 00-001-1223), sodium iron silicate oxide (PDF no. 04-002-8286), zinc oxide (PDF no. 04-014-0085), sodium zinc silicate oxide (PDF no. 00-019-1262), sodium aluminum hydroxide chromium oxide (PDF no. 01-077-0064), and sodium aluminium iron hydrate silicate (PDF no. 01-083-2369). These are indicative of insoluble forms of a heavy metal waste incorporating into the aluminosilicate structure, meaning that it is possible that they will be a part of chemical bond due to play role in the immobilization of EPS in WTR- based geopolymer with and without BHA [8, 10, 11].

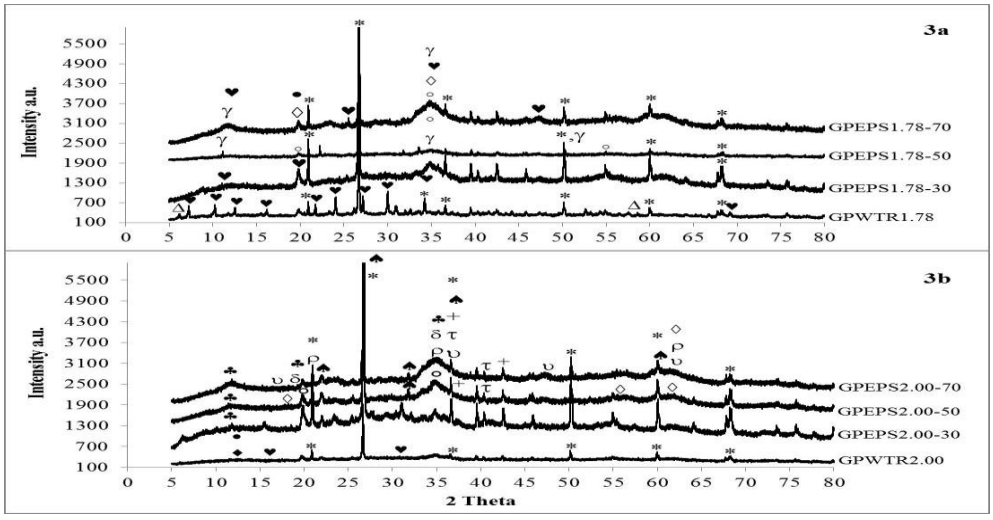

Fig 3 XRD diffraction patterns of geopolymers synthesized from (3a) with WTR and (3b) WTR+BHA cured for 28 days. Key: ∗= quartz, •= aluminium silicate oxide, ♥= NASH, ♦= faujasite, Δ= vermiculite, ♠= cristobalite, °= sodium zinc silicate, ♣= Muscovite, += iron oxide, ◊= sodium iron silicate oxide, τ= zinc oxide, δ= sodium silicate oxide, ρ= sodium zinc silicate oxide, υ=sodium aluminum hydroxide chromium oxide, γ= sodium aluminium iron hydrate silicate

FTIR

Fig 4 shows the FTIR spectra of the binders (WTR and BHA) reacted without EPS and with different amount of EPS activated with 0.25 $Na_2O:SiO_2$, which was reported in the wavenumber regions at 4000 to 400 cm^{-1}. The center of a vibration band of all samples was shown dominately in regions around 1000 cm^{-1} assigned to Si-O-

T (T= tetrahedral Al or Si) due to associated solidification of geopolymer product [1]. The vibration bands at 3398 to 3432 cm^{-1} and 1639 to 1654 cm^{-1} were observed that correspond to the water molecule and the OH group, respectively [1, 8, 12-13]. Other bands at about 798 cm^{-1} indicate the presence of Si-O-Si and symmetric and asymmetric stretching of tetrahedral AlO_2 and SiO_4 units in the geopolymers [8]. The new band in the region around 1375 cm^{-1} was observed in geopolymer mixed with EPS, and it may possibly be associated with insoluble metal hydroxide.

SEM-EDS

The morphology characterization of the geopolymer product synthesized without BHA and with 50% EPS is shown in Fig 5, illustraing the inhomogeneity on the surface area after reaction with NaOH solution and curing for 28 days. This is revealed in some areas of insoluble iron, zinc and chromium ion as determined by EDS analysis, which throught XRD analysis was shown to be composed of a heavy metal hydroxide form. The heavy metal ions were retained in the geopolymer product with the percent mass of zinc, iron and chromium, which are reported in Table 3. It can be seem that the heavy metals were incorporated in the aluminosilicate stucture, but the bonds on Al and Si tetrahedral building blocks in geopolymer were also unaffected. It may be cause due to the strength development in geopolymer matrix during geopolymerization [8, 10, 14-15]. This may be investigrated higher effectively immobilization a heavy metal waste as EDS in sodified geopolymer under this condition.

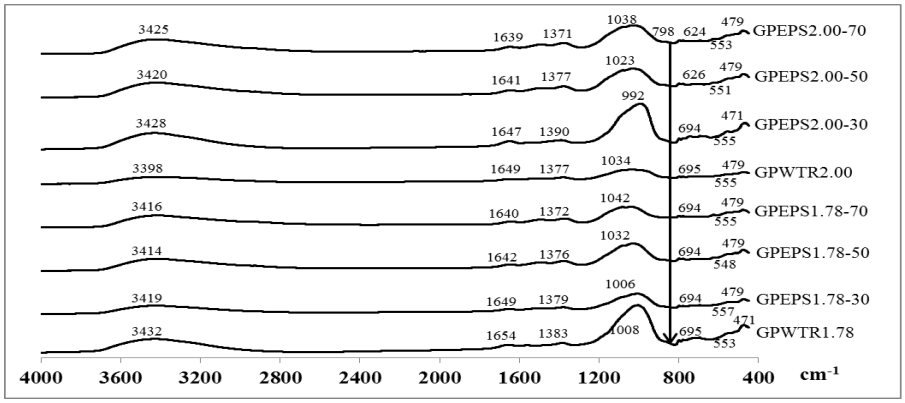

Fig 4 FTIR spectrum of geopolymer synthesized with and without EPS

Table 3: EDS analysis of WTR-based geopolymer synthesized with 50% heavy metal waste, curing at 28 days

Sample	% Mass of elememts															
	Si	Al	Na	Zn	Fe	Cr	K	Mg	Ca	Ti	P	S	Cl	O	C	**Total**
GPEPS 1.78-50%	17.16	12.29	7.50	7.59	6.54	1.79	1.91	0.47	1.16	0.37	0.63	1.28	1.30	21.56	18.46	100.0

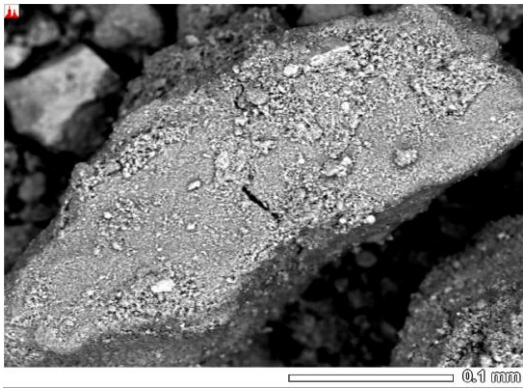

Fig 5 SEM image of WTR-based geopolymer synthesized with 50% heavy metal waste

4. CONCLUSIONS

In this study the development of a new cementing material from waste material was achieved. WTR and BHA as the aluminosilicate source are solid waste products and useful raw materials for geopolymer synthesis under activation with NaOH ($0.25Na_2O:SiO_2$). The utilization of two waste materials, WTR and BHA, to develop a new cementing material with a potential application to immobilize heavy metals as EPS from an electroplating facility was achieved with investigation of the strength development and microstructural characterization during geopolymerization. The Si/Al ratio of 2.00 without EPS and with 30% EPS were found to produce the greatest strength at all curing times. The reaction products identified by XRD patterns included

sodium aluminum silicate hydrate, sodium zinc silicate, sodium iron silicate oxide, sodium zinc silicate oxide, sodium aluminum hydroxide chromium oxide, and sodium aluminium iron hydrate silicate were observed, and a GPs formation was confirmed by FTIR vibration band at about 1000 cm^{-1}. SEM imaging showed the inhomogeneity on the surface area in geopolymer synthesized from WTR with 50% EPS cured after 28 days, which revealed retention of insoluble of EPS in accordance with EDS analysis. This study indicates that the binders, WTR and BHA, are suitable raw materials for geopolymer synthesis, and powerful product for immobilization of EPS in geopolymer matrix under this condition.

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Carbon Dioxide Emission in Khon Kaen University

Ratchaphon Suntivarakorn, Wasakron Treedet, and Phumiphat Sudsuk

Abstract*—This research presents a study of an approach to reduce carbon dioxide emissions in Khon Kaen University. The quantity of Carbon Dioxide emission was calculated by using the data collected from electrical energy consumption, fuel consumption quantity of waste and animal manures in the Khon Kaen University. The calculation was based on IPCC Guidelines of National Greenhouse Gas Inventories, 2006. From the study, it was found that Khon Kaen University has the quantity of carbon dioxide emission of 45,867. 31tCO_2/year. The average emission per person is 0.855 tCO_2/man/year. The sector which emits the highest of carbon dioxide emissions is the energy sector, which is 39,135.62 tCO_2/year. The next highest sector is the waste sector which has the emission of 6,889.76 tCO_2/year. On the other hand, the agricultural sector and forest areas can absorb carbon 308.38 tC/year. To reduce the carbon dioxide emissions, Khon Kaen University should 1) determine the obvious policy to reduce carbon dioxide emission, 2) increase green areas, 3) encourage and promote a earnestly energy conservation, 4) develop an alternative energy from waste water and animal manure by using biogas technology and 5) develop a bio-fuel from energy crop in the University.*

***Keywords*— Carbon dioxide, Emission, Energy consumption, IPCC**

1. INTRODUCTION

Currently, the global warming has increased a violence, which this problem had a cause from an emission of a high quantity of greenhouse gas. Carbon Dioxide (CO_2) is one of the major greenhouse gases which had affected to global warming. Owing to a high fossil consumption of combustion process in a present day, there is a high concentration of CO_2 In atmospher. The interaction between CO_2 and ozone in atmosphere was made the greenhouse effect on the earth which increased temperature on the earth's surface. [1]

From the global warming, many countries began focus to this situation and participatory to reduce CO_2 emission in each country. Thailand is also the country that had the national policy on climate change in 2008. The policy was focusing to the economic development with friendly environment. Khon Kaen, which is one of the provinces in Thailand, have signed the declaration of the global warming on the year 2009. The objective of this policy is to prevent the climate change in the city. The result of the policy is expected to receive the reduction of energy consumption, increasing the green zone, and leading Khon Kaen to be Eco-City [2].

Khon Kaen University (KKU), which is one of the main goverment sector in Khon Kaen province, should be a leader of state agency to reduce CO_2 emission, so that everyone is aware of the threat of global warming and leading to broader cooperation. Therefore, this research were studied of CO_2 emission and prepared of a plan to reduce carbon dioxide emissions in KKU which will be used as a guide to reduce global warming and a model for other state agencies.

2. CARBON DIOXIDE EMISSION CALCULATION

The calculation of CO_2 emission and absoption were based on IPCC Guidelines of National Greenhouse Gas Inventories, 2006 [3-5]. The calculation of CO_2 emission in KKU can be divided of 3 parts as an energy consumption, a quantity of waste and animal manures. At the same time, the CO_2 absorption can be found from the area of forest.

CO_2 emission calculation from energy consumption

Carbon dioxide emission from energy consumption will be divided in 3 parts as electrical energy consumption (CE_1), energy from combustion of non moving machines (CE_2) and energy from combustion of moving machines (CE_3), which can be expressed in equation (1) to (3).

$$CE_1 = EF_1 \times FC_1 \quad (1)$$

$$CE_2 = EF_2 \times FC_2 \quad (2)$$

$$CE_3 = EF_3 \times FC_3 \quad (3)$$

where CE, EF and FC were carbon dioxide emission, emission factor and fuel consumption, respectively. The emission constant factor (EF) in the several cases in this study was expressed in Table 1.

CO_2 emission calculation from waste

A carbon dioxide emission from waste can be found from a quantity of methane gas (CH_4), which one kg of methane gas is equal to 21 kgs of carbon dioxide gas. A methane emission can be devided in three parts. The first part was a methane emission from solid waste disposal (

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ME_1), which was calculated by equation (4).

$$ME_1 = \left[\left(MSW_T \times MSW_F \times L_o\right) - R\right] \times \left(1 - OX\right) \quad (4)$$

where MSW_T, MSW_F, R and OX were total solid waste per year (Gg/yr), ratio of solid waste disposal at the landfill, reused CH_4 and CH_4 transformed by the oxidation reaction, respectively.

The methane potential generation (L_o) can be expressed in equation (5).

$$L_o = 1.33 \times MCF \times DOC \times DOC_F \times F \quad (5)$$

where MCF, DOC and F were ratio of waste that produces methane, ratio of biodegradable organic carbon and ratio of CH_4 in biogas.

Table 1. Constant Emission Factor of CO_2 Emission.

	Source	Value	Unit
EF_1	Electricity [6]	0.4321	tCO_2/MWh
EF_2	Benzene	69,300	kg CO_2/TJ
	Heavy oil	77,400	kg CO_2/TJ
	Diesel	74,100	kg CO_2/TJ
	NGV	63,100	kg CO_2/TJ
	LPG	63,100	kg CO_2/TJ

The second part was a methane emission (ME_2) from waste water treatment and discharge, which was calculated by the equation (6).

$$ME_2 = \left[\left(U \times T \times B_o \times MCF\right)\left(TOW - S\right)\right] - R \quad (6)$$

where U, T, B_o, MCF were income groups of the population, waste water treatment, CH_4 production and correction factor of CH_4, respectively.

The total organic waste of several type water (TOW) can be expressed in equation (7).

$$TOW = 0.365 \times P \times BOD \times I \quad (7)$$

where P, BOD and I were population in area, BOD value per man per area and correction factor of BOD, respectively.

The last part of methane emission (ME_3) calculation was from a biological treatment of solid waste, which was shown in equation (8). The emission of carbon dioxide in this case will be found from a quantity of methane gas.

$$ME_3 = \left(M \times EF_o \times 10^{-3}\right) - R \quad (8)$$

where M and EF_o were amount of total organic waste and emission factor of organic waste, respectively. The constant emission factor of waste water treatment, total organic waste and animal manures were shown in Table. 2

CO_2 emission calculation from animal manures

A carbon dioxide emission from animal manures will be found from quantity of methane gas (CH_4) which can be calculated a methane emission from animal manures (ME_a) by equation (9)

$$ME_a = \sum \frac{\left(EF_a \times N\right)}{10^6} \quad (9)$$

where EF_a and N were emission factor by animal manures and a number of animals of each species, respectively.

Table 2. Constant Emission Factor of CH_4 Emission.

	Source	Value	Unit
EF_w	Wastewater treatment	0.12	$kgCH_4$/kgBOD
EF_o	Total organic waste	1	$gCH_4/kg_{\text{waste treatment}}$
EF_a	Poultry	0.02	$kgCH_4$/head/year
	Buffalo	2	$kgCH_4$/head/year
	Dairy cattle	31	$kgCH_4$/head/year
	Beef cattle	1	$kgCH_4$/head/year
	Pig	7	$kgCH_4$/head/year

CO_2 absorption calculation from an area of forest

A carbon dioxide absorption (CA) from forest can be calculated from an area of forest in KKU, which can be expressed in equation (10)

$$CA = \left[A \times \left(G_W \times \left(1 + R\right)\right) \times CF\right] \quad (10)$$

where A, G_W, R and CF were an area of forest (hectare), average growth-up rate of biomass per year, the ratio of below per above on the ground of biomass and amount of carbon of dry wood, respectively.

3. RESULTS AND DISCUSSIONS

The evaluation of carbon dioxide emission and absorption was used by a surveying method which the data was collected in order to know the energy consumption, waste animal manures and the area of forest in KKU. Results from this study can be shown in the following.

CO_2 emission from energy consumption

From a surveying and analysis of energy consumption in the year of 2011, it was found that the maximum of energy consumption was electrical energy which had an energy consumption of 233.18 TJ/year. The next order of energy consumption were heavy oil, benzene, NGV, diesel and LPG which consumed a quantity of 37.83, 35.89, 10.83, 3.54 and 0.83 TJ/year, respectively. The total energy consumption of KKU was 322.1 TJ/year, and the electrical energy consumption had a highest ratio of 72.39% as shown in Table 3. and Figure 1. The energy consumption from combustion of non moving machines were heavy oil and LPG, which were used in steam boiler and gas stove in university cafeteria. The energy consumption from combustion of moving machines were benzene, diesel and NGV which were used by all vehicles such as motorcycle, car and shuttle bus in KKU. The energy consumption from all vehicles were collected by usig 400 questionaires. The number of questionaires were calculated by Yamane method [7] with 95% of confidence

level from the total population of 53,637 people.

The result of carbon dioxide emission calculation from energy consumption was shown in Table 4. It was found that electrical energy consumption had the highest quantity of carbon dioxide emission of 26,788.39 tCO_2/year. The next highest carbon dioxide emission were from the moving machines and non moving machine, which were 9,418.28 and 2,979.98 tCO_2/year, respectively.

Table 3. Energy Consumption of KKU.

Energy (Unit)	Energy Consumption		
	Unit/year	TJ/year	%
Electricity (kWh)	61,995,808	233.18	72.39
Heavy Oil (L)	1,070,426	37.83	11.75
Benzene (L)	3,614,989.2	35.89	11.14
NGV (L)	2,747,943	10.83	3.36
Diesel (L)	310,560.25	3.54	1.10
LPG (kg)	210,374.4	0.83	0.26
Total		322.1	100

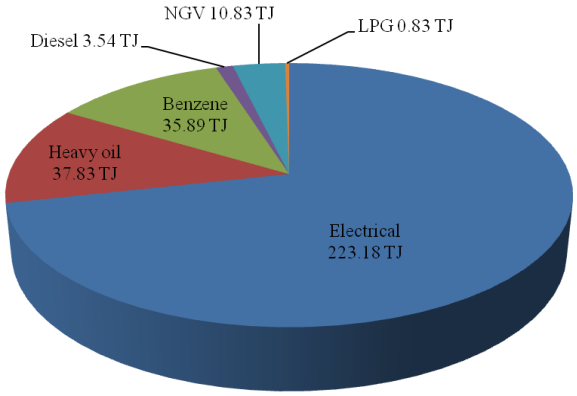

Fig. 1. Energy consumption in KKU.

Table 4. A Quantity of Carbon Dioxide Emission from Energy Consumption.

CO_2 emission	Value (tCO_2/year)
Electrical energy consumption	26,788.39
Non moving machines	2,979.98
Moving machines	9,418.28

CO_2 emission from waste and animal manures

From the surveying, it was found that the total of quantity of waste water from KKU was about 2,679,400 m^3/year. The waste water treatment system is facultative oxidation ponds. The solid waste disposal in KKU was about 28.7 ton/day or 10,475.5 tons/year. The total organic waste, which was collected from all cafeterias, was about 340,892 kg/year [8]. Consider the animal manure, the number of animals was surveyed and the weight of each animal dung per head was shown in Table. 5 and 6. Using the above data with equation (4) – (9), the carbon dioxide emission from waste and animal manures were calculated and shown in Table. 7. From Table 7, the result was shown that the maximum of CO_2 emission from waste and animal manures was garbage waste, which had a quantity of 6,703.20 tCO_2/year. The next highest waste were waste water and dairy cattle, which had a quantity of 179.40 and 78.12 tCO_2/year, respectively. The total CO_2 emission from waste and animal manures was 6,989.04 tCO_2/year.

Table 5. A Number of Animal in KKU.

Animal Type	Quantity (head)	Quantity of Dung/Head (kg/head)
Poultry	1,100	0.03
Buffalo	40	8
Dairy cattle	120	16.83
Beef cattle	150	5.44
Pig	108	1.17-1.83

Table 6. A Quantity of Waste and Animal Manures.

	Value	Unit
Waste water	684,226.40	kg BOD/year
Total organic waste	340,892.20	kg/year
Poultry	29.33	kg/year
Buffalo	320	kg/head/year
Dairy cattle	2,020	kg/head/year
Beef cattle	817	kg/head/year
Pig	140	kg/head/year

Table 7. Quantity of Carbon Dioxide Emission from Waste and Animal Manures.

CO_2 emission	Value (tCO_2/year)
Waste water	179.40
Garbage waste	6,703.20
Total organic waste	7.16
Poultry	0.46
Buffalo	1.68
Dairy cattle	78.12
Beef cattle	3.15
Pig	15.87
Total	6,989.04

CO_2 absorption from forest land

Khon Kaen university had an area of 928 hectare (ha), and the area of forest was about 141 ha. A growth rate of a biomass, the ratio of below per above on the ground of biomass and amount of carbon of dry wood in Khon Kaen univesity had a average of 3.4 ton/ha/year, 0.37 tRoot d.m./tShoot d.m. and 0.47 tC/t d.m., respectively. Thus, a forest area in Khon Kaen university can be adsorpt a CO_2 which can be calculated to a quantity of CO_2 absorption of 308.39 tCO_2/year.

Comparison of CO_2 emission between Thailand and Khon Kaen Univesity

Table 8 was shown a comparison of carbon dioxide emissions between Thailand and Khon Kaen university in a year of 2011. The results was found that Thailand had a maximum of carbon dioxide emission from the electricity sector, which was 82,033,000 tons/year. Khon Kaen University had an emission in this sector equal to 26,788 tons/year which was 0.033% of total emission from electricity. The next highest sector were transportation, industrial and household ans commercial sectoes, respectively. From Fig. 8, the result was revealed that the emission in Khon Kaen university was 0.02% of the total CO_2 emission in Thailand.

Table 8. Comparision of Carbon Dioxide Emissions between Thailand and Khon Kaen university.

(Unit: 1,000 tons)

Sector	Thailand	Khon Kaen University	Proportional (%)
Transportation	53,645	9.418	0.017
Electricity	82,033	26.788	0.033
Industrial	43,965	2.927	0.006
Household and Commercial	7,811	0.005	0.00006
Other	10,024	-0.209	-0.002
Total	*197,508*	*38.925*	*0.020*

Table 9. Total Quantity of Carbon Dioxide Emission from Khon Kaen University

CO_2 emission	Value (tCO_2/year)
Electrical energy consumption	26,788.39
Non moving machines	2,979.98
Moving machines	9,418.28
Wastewater treatment	179.40
Garbage waste	6,703.20
Total organic waste	7.16
Manure	99.28
Forest land	-308.38
Total	*45,867.31*

4. CONCLUSION

This paper presents a study of carbon dioxide emissions in Khon Kaen University which the results from this study will be used to prepare of a plan to reduce carbon dioxide emissions in the Khon Kaen University. The evaluation a carbon dioxide emission and absorption was done by using a surveying method and CO_2 emission calculation based on IPCC Guidelines of National Greenhouse Gas Inventories, 2006.

From the results of carbon dioxide emission calculation, it was found that Khon Kaen University had the total quantity of carbon dioxide emission of 45,867. 31 tCO_2/year. The average emission per person was 0.855 tCO_2/man/year. The sector which emitted the highest of carbon dioxide emissions was the energy sector, which was 39,135.62 tCO_2/year. The next highest sector was the waste sector which had the emission of 6,889.76 tCO_2/year. On the other hand, the agricultural sector and forest areas can absorb the carbon of 308.38 tCO_2/year as shown in Table 9.

A comparison of carbon dioxide emissions between Thailand and Khon Kaen university in a year of 2011 showed that the ratio of total carbon dioxide emissions between Khon Kaen university and Thailand was 0.02.

To reduce the carbon dioxide emissions in Khon Kaen University, the activities were proposed as following :

1) Determine the obvious policy to reduce carbon dioxide emission.

2) Increase more green areas.

3) Encourage and promote an awareness of energy conservation, and conduct the energy conservation measures.

4) Develop an alternative energy from waste water and animal manure by using biogas technology.

5) Develop a bio-fuel from energy crop in the university.

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Adoption of Near Zero Waste Concept for the Tapioca Starch Production Industry: A Case Study in Thailand

Ruenrom Lerdlattaporn, Kanchana Saengchan, Worapod Lerdlattaporn, and Warinthorn Songkasiri

***Abstract*—** *Tapioca starch industry is a major agro-industry in Thailand. However, the industry's growth has resulted in a large amount of solid waste and wastewater. This research implemented the near zero waste concept in the tapioca starch industry to reduce starch loss, raw material, water and energy consumption. Six native starch factories in Thailand have adopted the near zero waste concept. This paper presents a case study of one factory in the Eastern region of Thailand. Its starch production efficiency or yield was increased 2.6% from the reduction of starch loss in wastewater and pulp. Further, water and electricity consumption were reduced from 11.8 to 8.5 m^3 of fresh water and from 236.7 to 193.9 kWh of electricity per ton of starch produced, respectively.*

***Keywords*— Tapioca Starch Production Process, Zero Waste in Thailand**

1. INTRODUCTION

Tapioca is one of the most important starch sources used in production of different foods and industrial applications. Thailand is the 1st producer and exporter of tapioca products in the world. Most starch exported products can be classified into three types, which are native starch, modified starch, and sago. The exporting value of native starch increased from 0.2 billion USD in 2001 to 1.3 billion USD in 2012 [8].

Tapioca starch production process generally has 9 steps as follows: receiving raw materials from suppliers, screening, washing/cutting, rasping/grinding, extracting, separating, dewatering, drying step and packing. Our previous work reported that, from the overall step, starch is lost approximate 5.0 to 24.0% [7]. The starch loss during the extraction step is approximately 0.2-15.0% and the loss during the separation step is approximately 0.2-6.2% of the total starch input. This loss is equivalent to approximately 1.3-6 million USD/factory/year for a 200-ton starch factory. The tapioca starch manufacturing process consumes freshwater approximately 8.3 to 29.7 m^3 per ton of starch produced and electricity approximately 110.0 to 236.7 kWh per ton of starch produced [7].

The zero waste concept is the concept of reuse and recycle of all wastes that were produced from a process [9]. For the tapioca starch industry, air pollution was not considered so this concept here was called the near zero waste concept.

This research implemented the near zero waste concept in the tapioca starch industry to reduce starch loss, raw material, water and energy consumption. Six native starch factories in Thailand have adopted the near zero waste concept. This paper presents a case study of one factory in the Eastern region of Thailand.

2. MATERIALS AND METHOD

Data Collection

Primary data was obtained from one native factory in the Eastern region of Thailand during June 2012 - March 2013. The production capacity of the factory was 250 tons of starch/day.

Method

In this study, a systematic methodology to achieve a better environmental performance of the tapioca starch industry consists of three steps as follows.

Step 1: Overall production efficiency of each processing unit was collected and analyzed in terms of energy and resource consumption, waste and wastewater generation, and production yield.

Step 2: Appropriate approaches were selected for prevention and minimization of waste generation.

Step 3: Near zero waste concept was implemented .

Data on water consumption were collected from the factory's water meters, while data on electricity consumption were recorded by a power meter. Fuel oil consumption data were obtained from the plant information. Starch losses and waste water generation were measured.

3. RESULTS AND DISCUSSION

Before an adoption of the near zero waste concept, the factory's starch production efficiency or starch yield was approximately 95.0%. 1 ton of starch was produced from

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4.4 tons of tapioca roots, 11.8 m^3 of water and 236.7 kWh of electricity. Wastes from production process consisted of 0.17 tons of sand, 0.05 tons of peels, 2.6 tons of pulps, 8.4 m^3 of wastewater and 0.004 tons of lower-grade starch (shown in Fig.1).

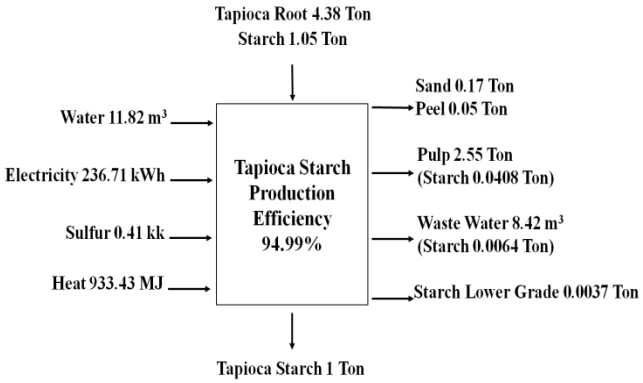

Fig. 1. Resource consumption and waste generation for producing 1 ton of tapioca starch at the demonstration site before apply the near zero waste concept

In this factory, since its starch yield was acceptable already, two main problems consisting of starch loss in pulp and a high amount of fiber in the final product were identified. Fig.1 also shows that the starch loss in pulp was approximately 0.041 ton per ton of starch produced and the starch loss in wastewater was approximately 0.006 ton per ton of starch produced. Starch loss in pulp occurs mainly in an extraction step.

However, appropriate approaches were selected for reducing starch loss in pulp and improving starch quality by experimenting at the extraction unit.

In an extraction process of the tapioca starch manufacturing process, conical-screen centrifuges are used to remove fiber or pulps from tapioca starch granules.

Mechanisms in the extraction process consist of 2 mechanisms-- centrifugation and filtration. Filtration is a process of separating a mixture using a filtering medium. The fluid and small particles can pass through the filtering medium or screen. Large particles are retained. Water facilitates most starch particles to pass through the filter medium. Pulps are retained on the medium. Centrifugation generates centrifuge force to overcome adhesive force between starch granules and pulps and facilitates a better filtration through the medium.

This research further investigated the effects of design, operating and feed variables of each processing unit, especially a unit in the extracting stage. The design variables are angle basket and screen size [1, 3, 4 and 6]. The operating variables are feed flow rate and rotational speed of extractor and the feed variables are crushed tapioca size, L/S ratio and varieties of tapioca [1, 2, 3, 4 and 5].

Previous researches showed that optimum conditions of design were 800 µm of screen size, .rotational speed of 600-800 rpm, and liquid-to-solid (L/S) ratio of 5-7:1 [1, 2, 3, 4, 5, 6].

The extraction efficiency comprises of two efficiencies -- starch extraction efficiency and fiber or pulp removal efficiency.

Reduction Tapioca Starch Loss in Pulp

To reduce the starch loss in pulp, this study was emphasized on the coarse extraction stage. The factory's coarse extraction stage consists of 5 steps, coarse extractor#1- 4 for extraction tapioca starch from pulp and screw press for reduce moisture content in pulp (shown in Fig. 2).

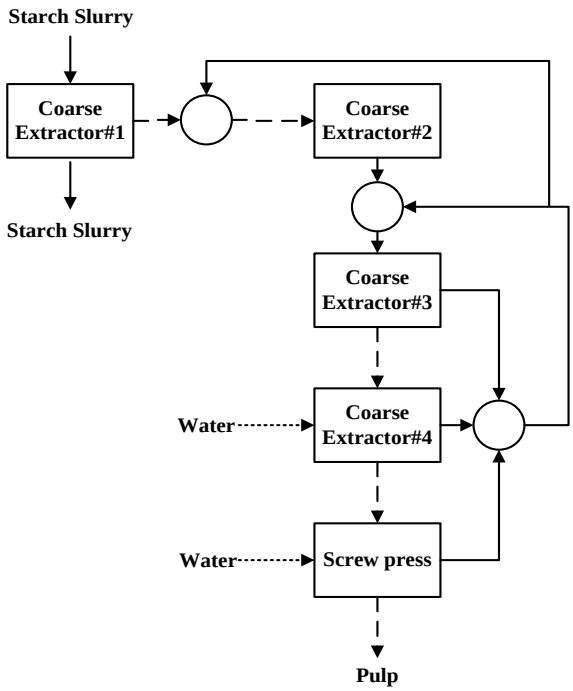

Fig. 2. Coarse extraction stage

Experimental results from the improvement of each processing unit showed that starch extraction efficiency of the first and second coarse extractor were 56.49% and 41.9% respectively. The starch loss occurred from a low liquid-to-solid (L/S) ratio and a clogging of screen by fibers and pulps [4]. Some starch granules and fibers were attached and deposited on the screen, resulting in clogging. After an appropriate L/S ratio adjustment, starch extraction efficiency of the first and second coarse extractor increased to 95.06% and 73.24% respectively (shown in table 1).

Table Table 1. show starch extraction efficiency of the third pulp extractor was 27.67%. The starch loss occurred from a high L/S ratio and high moisture content in pulp. In the extraction mechanism, water facilitates the starch particles to pass through the filter medium. This result agreed with the experiment of Thanomsaksri *et al.* 1999. Water injection in the third coarse extractor was reduced from 37.4 to 15.0 m^3 per hour. After an appropriate L/S ratio adjustment, starch extraction efficiency of the third pulp extractor increased to 45.20%.

After an appropriate L/S ratio adjustment, Starch extraction efficiency of the forth pulp extractor decreased to 11.11% due to reducing of L/S ratio. Water injection in the forth coarse extractor increased water consumption and moisture content of pulp. However, the total efficiency was slightly changed (shown in table 1).

Table 1. Starch extraction efficiency and moisture content in each extraction steps before and after production process improvement.

Extraction Unit		L/S ratio	Starch Extraction Efficiency (%)	Moisture content (%)
Coarse extractor#1	Before Production Process Improvement	5.57	56.49	86.86
Coarse extractor#2		10.27	41.93	93.27
Coarse extractor#3		13.86	10.80	97.36
Coarse extractor #4		36.88	27.67	86.52
Screw press		6.42	8.97	79.70
Coarse extractor #1	After Production Process Improvement	6.11	95.06	79.43
Coarse extractor #2		13.90	73.24	86.35
Coarse extractor #3		20.19	45.20	86.03
Coarse extractor #4		19.70	11.11	88.35
Screw press		7.58	1.51	79.55

Reduction Fiber from Pulp in Final Product

To reduce the fiber content in the starch final product, the fine extraction stage was emphasized. Before the improvement, the amount of fiber in the starch final product was 64.0 ppm. Fiber content in tapioca starch product indicates quality of product. The fine extractor is required for removing fine fibers and pulps from the starch granules.

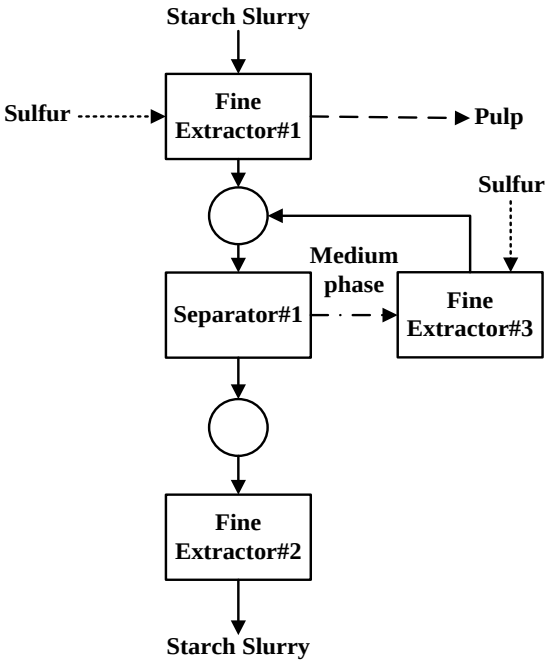

Fig. 3. Fine extraction stage

In this factory, fine extraction stage consists of 3 steps--fine extractor#1 receiving slurry from coarse extraction#1, fine extractor#2 receiving slurry from fine extraction#1 and fine extractor#3 that extract starch from wastewater in separation#1. Table 3 Shows that the fiber removal efficiency was too low because the L/S ratio of fine extractor#3 was not appropriate.

In a starch extraction mechanism, water facilitated starch granule-pulp separation through the screen so water injection in the third fine extractor was increased to 12.0 m^3 per hour. Therefore, the fiber extraction efficiency increases from 11.5% to 66.6%. Fiber in the final product was reduced to 40.0 ppm so the quality of product was better.

Table 3. Fiber removal efficiency in each fine extraction steps before and after production process improvement.

Extraction Unit	Before production process improvement		After production process improvement	
	L/S ratio	Fine Removal Efficiency (%)	L/S ratio	Fine Removal Efficiency (%)
Fine extractor #1	9.04	28.32	8.26	13.41
Fine extractor #2	3.39	30.26	3.69	34.34
Fine extractor #3	10.78	11.46	10.31	66.07

After applying the near zero waste concept, the starch production efficiency or starch yield was increased to 97.6%. Tapioca root was reduced to 3.7 tons per ton of starch produced. Water was reduced to 8.5 m^3 per ton of starch produced. Electricity was reduced to 193.9 kWh per ton of starch produced. Therefore, wastes from production process were reduced to 2.5 tons of pulps, 7.3 m^3 of wastewater and 0.0013 tons of lower-grade starch (shown in Fig.4)

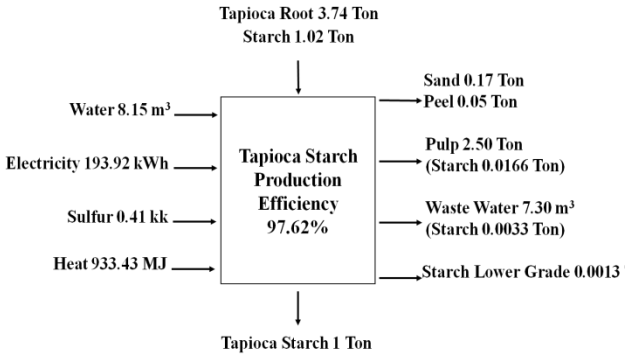

Fig. 4. Resource consumption and waste generation for producing 1 ton of tapioca starch at the demonstration site after apply the near zero waste concept

4. CONCLUSION

After adopting the near zero waste concept, the starch

production efficiency was increased to 97.6%. The amount of fiber in the starch final product was decreased to 40.0 ppm so the quality of starch product was increased. Further, water and electricity consumptions were reduced to 8.5 m^3 per ton of starch and 193.9 kWh per ton of starch produced, respectively.

5. ACKNOWLEDGMENT

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Estimation of Greenhouse Gas Emission from Landfill in Luangprabang, Lao PDR

Xaysackda Vilaysouk and Sandhya Babel

Abstract*— *Greenhouse gas (GHG) emission from municipal solid waste (MSW) management contribute to 3% of GHG globally. GHG from treatment and disposal of MSW is of significant concern. Social-economic activities and seasonal variation are strongly correlated with the composition and the amount of MSW. Luangprabang (LPB), a tourist city, located in north of Lao PDR, is facing challenges due to lack of proper MSW management. This study aims to estimate GHG emission from landfill in LPB, considering the amount and characteristic of MSW at disposal year. International Panel on Climate Change (IPCC) 2006 model is used in this study. Result from this study indicates that from 57.75 Gg/year of MSW disposed on landfill, of which 83% is biodegradable material (food waste, garden waste, paper and textile), 2.42 Gg CH_4 as GHG is produced. As Lao PDR has agriculture oriented economy, and as most waste is biodegradable, composting can be adopted. This can reduce amount of MSW disposed on landfill and give the compost and also reduce amount of GHG emission.

***Keywords*— Municipal Solid Waste, Landfill, Composting, Tourism, Greenhouse Gas Emission, IPCC Model.**

1. INTRODUCTION

MSW disposal and treatment are considered as the urban problem that has appeared globally. Population increase, change in living style as well as economic development, plays an important role in rapidly increasing amount of MSW. GHG emission from landfill and other MSW treatment technology is about 3% of anthropogenic GHG globally [1, 2]. Landfilling is the common practice of MSW disposal in less developed countries and including developing countries as this is a cheap process and requires less professional skills. GHG emission, especially CH_4, occur in landfill due to anaerobic conditions. This is of concern due to following reasons such as the potential of methane explosion in landfill, and also global warming potential of CH_4 is higher than carbon dioxide (21 times) [2].

Tourism industry is one of the fastest growing industries in the world in last decade [3, 4]. Tourism creates employments, and also comes along with the environmental problems. MSW management issue is one of the environmental problems that was contributed by the tourism [5]. According to previous study [6], there are strong correlations between the social-economic activities, especially tourism, and seasonal variations on solid waste composition and quantity. In the peak season, the fraction of plastic, glass and packaging paper, which represents the characteristic of tourism activities, was found higher.

In Lao PDR, like other less developed countries, the environmental problems are becoming serious. Big cities such as Vientiane, Savannakhet, Pakse, Thakheak and Luangprabang (LPB) are facing environmental problems, especially, MSW management. LPB, representative of tourist area in Lao PDR, is located in the northern Lao PDR. It is well known as UNESCO's Heritage city and it is a popular destination liked by tourist all around the world [7].

The purpose of this study is to investigate the GHG emission from existing management of MSW in LPB, a tourist place, by using the IPCC 2006 [2]. GHG emission is also calculated based on possibility of incorporating composting due to nature of waste generated.

2. METHODOLOGY

Study location

LPB is selected as representative of tourist place in this study, where solid waste generation is influenced by tourism. LPB is located in the north of Lao PDR, it is well known as UNESCO world heritage city [7]. It is one of the favourite destinations of tourist around the world. In 2005, total tourist arrived at LPB is 261,950 people including 133,569 foreigner and 128,381 local tourist [8]. Several environmental problems, especially solid waste management, come along with large number of tourist. Tourist plays an important role in the characteristics and the amount of MSW in LPB. Large amount of waste comes up with the high number of tourist. In LPB, according to previous study [9], the waste generation rate was 0.60 kg/capita/day. The population in LPB in 2008 was 439,504 [10].

MSW existing situation in LPB

MSW management in LPB shares the same situation with other big cities as well as tourist cities around the world. MSW quantity and composition in LPB is influenced from the residence together with large number of tourist. The composition of MSW in LPB as reported in

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2012, showed that food waste was about 51% followed by garden waste 23% (Fig. 1). Population in LPB is shown in Table 1. Secondary data on MSW generation rate are based on IGES report 2012 [9]. It was also stated that 60% of total MSW generated is disposed on landfill (158.22 tonnes/day) and this is used for calculation of GH_4 emission from landfill. Landfill in LPB is unmanaged and uncategorized. It is assumed that the composition of MSW did not change over the time (2008 to 2012).

Table 1. MSW Information in LPB

Parameter	Result
Generation Rate [(1)]	0.6 kg/capita/day
Population [(2)]	439,504
MSW generated	263.70 tonne/day
MSW disposed on landfill	158.22 tonne/day (60%)

Source: [(1)] Sang-Arun, J., & Pasomsouk, K. (2008) [9]
[(2)] Lao Statistic Bureau (2008) [10]

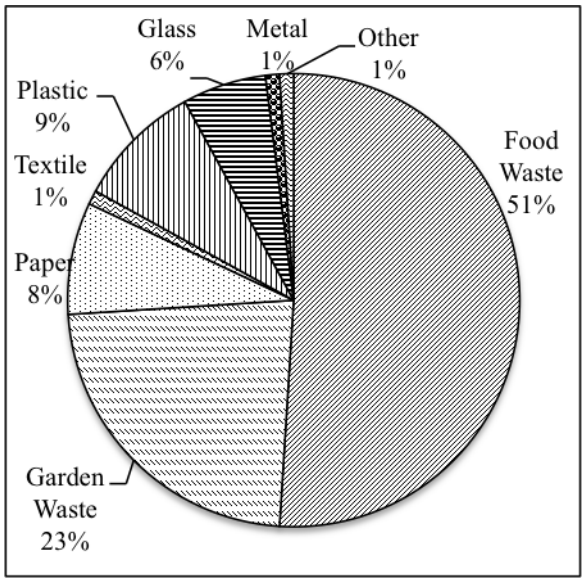


Fig.1. MSW composition in LPB [9]

GHG Emission Calculation from Landfill

IPCC 2006 model is the GHG inventory tool that is internationally used for calculating the GHG emission as it is simple and flexible with regards to availability of input data. IPCC 2006 model is mainly used in this study to investigate the amount of GHG emission from existing MSW management in LPB, with focus on estimation of methane from landfill.

CH_4 emission from landfill in single year was calculated by equation 1, in accordance with the secondary data as shown in Table 1 [9, 10]. CH_4 emission calculation from landfill in IPCC 2006 model depends on amount of the waste disposed; methane correction factor (MCF); the fraction of organic carbon content (DOC) in MSW; fraction of degradable organic carbon (DOC_f), the fraction of organic carbon that decomposed and emitted as GHG in the LF; fraction of CH_4 in generated landfill gas (LFG); CH_4 recovery and Oxidation factor.

$$CH_4 \text{ emission } (GgCH_4/year) = (MSW_T \times MSW_F \times MCF \times DOC \times DOC_F \times F \times 16/12 - R) \times (1\text{-}OX) \quad (1)$$

Where, MSW_T is total MSW generated (Gg), MSW_F is the fraction of MSW disposed (fraction), MCF is CH_4 correction factor, DOC is degradable Organic Carbon (Gg C/Gg MSW), DOC_F is fraction of DOC (fraction), F is the fraction of CH_4 (fraction), 16/12 is conversion ratio, R is amount of CH_4 recovery (Gg CH_4), OX is oxidation factor.

GHG emission estimation from landfill in IPCC 2006 model has 3 tiers, which drives the accuracy of results. Tier 1 is default model that is based on the default data provided by IPCC. Tier 1 is suitable for countries where information of MSW is lacking. Tier 2 use first order decay method with some default parameters and required good quality of country specific MSW activities data. Tier 3 is based on the use of good quality country-specific activity data and the use of either the FOD method with nationally developed key parameters, or measurement derived country-specific parameters. Based on the availability of the data in study area, Tier 1 is selected and used in this study.

Table 2. MSWDS Classification and Methane Correction Factor (MCF)

Type of SWDS	MCF
Managed – anaerobic	1.0
Managed – semi anaerobic	0.5
Unmanaged – deep (5m > waste) or high water table	0.8
Unmanaged – shallow (5m<waste)	0.4
Uncategorized SWDS	0.6

Table 3. MSW Composition and DOC in LPB

Waste Component	Waste Composition[(1)] (%)	DOC_i [(2)] (Fraction)	DOC (Gg C/Gg MSW)
Food	51	0.15	0.077
Paper/cardboard	8	0.40	0.032
Garden waste	23	0.43	0.099
Textile	1	0.24	0.002
Rubber	-	0.39	-
Plastic	9	-	-
Metal	1	-	-
Glass	6	-	-
Other	1	-	-
		Total:	0.210

Source: [(1)] IGES, 2012 [9] [(2)] IPCC, 2006 [2]

The amount of total MSW generated and amount of MSW disposed in LPB are shown in Table 1. As the landfill in LPB is simple, unmanaged and uncategorized, as per the classification of landfill provided by IPCC,

MCF equal to 0.6 is selected in this study (Table 2). DOC from the landfill is based on each portion of MSW disposed in landfill. The calculation of DOC is done by equation 2 and the results of calculation are shown in Table 3.

$$DOC = \sum_i DOC_i \times W_i \qquad (2)$$

Where, DOC is fraction of degradable organic carbon in MSW (Gg C/Gg MSW), DOC_i is fraction of degradable organic carbon in MSW type i, W_i is fraction of MSW type i in MSW (fraction).

DOC_F is the fraction of degradable organic carbon that can degrade in landfill that depends on many factor of landfill such as: temperature, pH, moisture and MSW composition. IPCC 2006 model provided the default value as DOC_F equal to 0.5 for countries that DOC_F data is lacking. The fraction of CH_4 generated in landfill (F) value used in this study is the model default data, which is F equal to 0.5. Oxidation factor indicate the reaction between CH_4 and oxygen in soil or cover layer of the waste. According to the condition of landfill in this study, OX equal to 0 is used.

GHG emission from composting of MSW

Composting technology is one of the popular MSW treatment method that is suitable for biodegradable material [11]. It can reduce 50% - 85% of MSW by volume [12]. IPCC 2006 model provided the GHG estimation method from the composting technology [2]. In this study, GHG emission from composting scenario was calculated based on the equation 3 as shown below:

$$CH_4 \text{ Emission} = (M_i \times EF) \times 10^{-3} - R \qquad (3)$$

Where, M_i is amount of biodegradable waste (Gg), EF is emission factor (g CH_4/ kg MSW), R is CH_4 recovery (Gg CH_4).

Table 4. Amount of MSW and CH_4 emission in each scenario

Scenario	Amount of MSW (Gg)		CH_4 Emission (Gg CH_4)			
	LF	CP	LF	CP	Total	% Change
S0	57.75	-	2.423	-	2.423	0
S1	33.50	24.26	1.405	0.097	1.502	- 38

Scenario Development

In this study, one scenario was developed to see the impact on GHG emission. The existing MSW management in LPB was considered as baseline scenario (S0). About 60% of total MSW generated was disposed on the landfill. Scenario (S1) was developed with the assumption of 50% of biodegradable waste, which was disposed on landfill, divert to composting process and the rest disposed on the landfill. Composting was considered as this can lead to CH_4 reduction and is also suitable and practical MSW management technology based on the characteristic of MSW in LPB. The amount of MSW in each scenario is shown in Table 4.

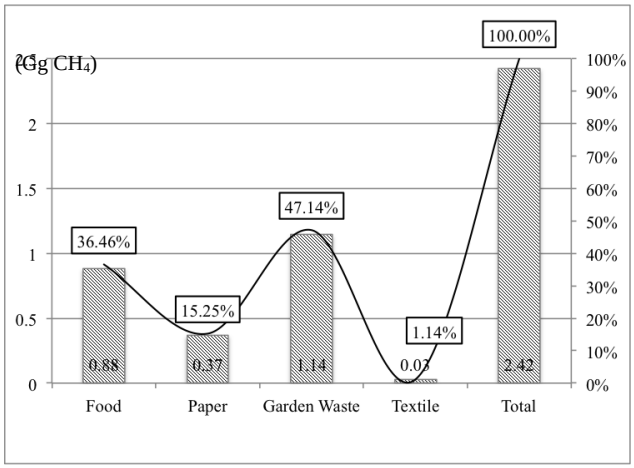
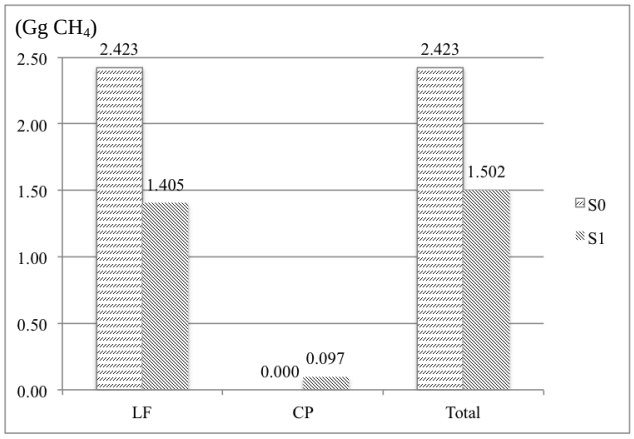


Fig. 2. Methane Emission from Landfill in LPB



* LF - Landfill, CP - Composting, S0 - Baseline Scenario, S1 - Composting Scenario

Fig. 3. Total CH_4 emission from MSW management in LPB

3. RESULTS AND DISCUSSIONS

Results of this study show that the composition of MSW in LPB contains the high fraction of food waste (51%) and about 24% of paper, plastic, glass, metals; which might be influenced by tourists. Total amount of MSW generated in LPB was 96.25 Gg/year and 57.75 Gg/year was sent to dispose at landfill. Amount of CH_4 emission from landfill was 2.42 Gg CH_4 (Table 5) that equal to 50.82 Gg CO_2 equivalents (Global warming potential conversion factor

Table 5. CH_4 Emission Calculation from Landfill in LPB

MSW_T	MSW_F	MCF	DOC	DOC_F	F	Conversion Ratio	L_0	R	OX	CH_4 Emission (Gg CH_4)
96.251	0.600	0.600	0.210	0.500	0.500	1.333	0.042	0	0	2.423

MSW_T – Total MSW generated, MSW_F - the fraction of MSW disposed (fraction), MCF - CH_4 correction factor, DOC - degradable Organic Carbon (Gg C/Gg MSW), DOC_F - fraction of DOC (fraction), F - the fraction of CH_4 (fraction), Conversion ratio – 16/12, R - amount of CH_4 recovery (Gg CH_4), OX is oxidation factor.

is 1 tonne CH_4 emission equal to 21 tonnes CO_2 equivalents [2]). The potential of CH_4 emission from this study is 41.96 tonnes CH_4/Gg MSW compare to 67.67 tonnes CH_4/Gg MSW of study on GHG emission from landfill in whole Thailand in 2008 [13]. The difference in emission of GHG in the two studies indicate that the composition of MSW and disposal method play important role.

As depicted in Fig. 2, CH_4 emission from landfill in this study is significantly influenced from the portion of garden waste, which contributes to 47.14% of total CH_4 emission. Food waste, with 51% of total MSW generated, contribute to 36.46% of total CH_4 emission. The difference in CH_4 emission from each portion of MSW is due to the degradable organic carbon content (DOC). The garden waste has the DOC value of 0.43 Gg C/ Gg MSW and food waste of 0.15 Gg C/ Gg MSW. Hence, even the food waste in total MSW disposed in LPB is higher, but it still contributes to lower CH_4 emission.

From developed composting scenario (S1), the result of CH_4 emission, are shown in Table 4. The total CH_4 emission from scenario S1 is 1.502 Gg CH_4. Approximately 38% reduction in CH_4 was observed as compared to baseline scenario S0 (Fig. 3). The CH_4 emission from composting process is dramatically lower than CH_4 emission that occurs in landfill. Amount of MSW treated by composting is 24.26 Gg, and contribute to only 6.45% of total CH_4 emission.

Composition of MSW in LPB, when compared with other tourist city such as Phuket, Thailand, is different. The biodegradable portion in LPB is higher as 83% compared to 66% in Phuket [5]. In Phuket, according to characteristics of MSW, source separation of waste for bio digestion, recycle and incineration process was suggested [5]. Considering to the composition of MSW in LPB, which mostly contains biodegradable materials, treatment and disposal technology that suitable with biodegradable material such as bio digestion and composting need to be integrated in MSW management system in LPB. The composting and bio digestion technology could be integrated in MSW management system to reduce the amount of MSW that will be sent to the landfill and also could reduce GHG emission. However, composting can be easily adopted by local people and is thus purposed.

4. CONCLUSIONS

LPB share the same situation of MSW management issues as many tourist place around the world. In 2008, 96.25 Gg of MSW was generated and 57.75 Gg was sent to unmanaged landfill. The composition of MSW in LPB is mainly biodegradable, and thus differs from other tourist places. The biodegradable waste was 83% of total MSW. In this study, CH_4 emission from landfill was evaluated by IPCC 2006 model. CH_4 emission (50.82 Gg CO_2 equivalent) from landfill in LPB in single year was significantly influenced by garden waste (47.14%). GHG emission from MSW management sector depends on the characteristics, treatment and disposal method of MSW. Based on the characteristics of MSW in LPB (83% biodegradable waste) and agriculture oriented economy in Lao PDR, composting could be adopted which requires less professional skills. From developed scenario in this study, assuming 50% of biodegradable will be diverted to composting process, 38% reduction of total CH_4 from MSW management in LPB is observed, and this will also reduce the amount of waste disposed on landfill.

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Carbon Emission from Marine Capture Fisheries in Thailand Based on a Carbon-Balanced Model

Withida Patthanaissaranukool and Chongchin Polprasert

Abstract— *Marine capture fisheries have been the main subsector of captured fisheries in Thailand for the past two decades, contributing to 89 percent of the total capture products. Hence, the concept of a carbon-balanced model was applied to evaluate the carbon movement occurring in the marine harvest sector and its downstream industries. Field surveys in major fisheries piers of the country were carried out so as to determine the unit amounts of energy and materials used and produced. They were analyzed and interpreted into the carbon equivalences, which can be categorized into three groups – namely, carbon emission, fixation, and reduction. The equivalent carbon emissions from the marine capture were found to be 1078±332 kg CE/ton fish captured, due to the use of fossil energy in harvesting in the deep sea and transportation of the products to the piers. Major source of emission comes from diesel fuel used to operate the trawlers. Carbon transfer efficiency of marine capture was computed to be equal to 27%, indicating that fisheries activities emit to the atmosphere the carbon amount larger than that fixed in the products captured. From the findings of this research, it is recommended that more research on culturing of several marine fisheries be carried out so as to compensate for the decreasing amount of marine products captured from the sea.*

Keywords— **Carbon-balanced model, Carbon emission, Marine capture fisheries**

1. INTRODUCTION

Fisheries play a significant role in Thailand in terms of sustaining food security and contributing to the local and national economies. It's products represent a very valuable source of protein and essential micronutrients for balanced nutrition and good health (FAO, 2012). Acordingly, the average per capita consumption of fish in Thailand was reported to be 32.3 kg/year in 2009 (DOF, 2009). This is significantly higher than the world average of 18.6 kg/year and reflects the importance of fish in food security, as well as the general preference for fish as a source of protein in Thailand (FAO, 2010).

Generally, fisheries are divided into two main sectors: capture and culture fisheries. Marine capture fisheries are all types of harvest of naturally occurring living resources in marine environments; while the cultures are those grown in a confined environment provided with the feed. Since 1945, marine capture fisheries have developed significantly and have expanded rapidly in many developing states of the South China Sea region, including Thailand. This development is mainly because of the introduction of modern technologies and techniques for fishing, including the increased motorization of fisheries boats (FAO, 2008). In 2010, total marine capture in Thailand was reported to be 1,601 metric tons, accounting to about 52 % of total fisheries production. Meanwhile total culture production of 1252 metric tons was found to contribute to 41% of total fisheries production in Thailand, as shown in Table 1 (DOF, 2013). From Table 1, total capture fishesies production from marine is decresing every year because of the National Fishery Development Plan for sustaining fisheries development and management. It was predicted that total fisheries production should be maintained no less than 3.5 million tons per year through the sustainable fisheries development plan. For marine fisheries management aspects, rehabilitation of fisheries resources has been implemented (FAO, 2000).

Table 1. Fisheries productions in Thailand by sub-sectors.

Year	Fisheries productiom (×1000 tons)				
	Capture		Culture		total
	Marine	Inland	Coastal	Freshwater	
2004	2636	204	736	524	4100
2005	2616	199	765	539	4119
2006	2485	214	827	527	4053
2007	2079	226	845	525	3675
2008	1645	229	808	523	3204
2009	1664	207	895	522	3287
2010	1601	209	755	497	3063

Source: DOF (2013)

Since the fishing sector is an important branch within the food sector of any country, large amount of marine fishes will be harvested to support the need of consumer. However, many researcher indictaed that marine fishery as one of the major contributors to environmental impacts since it is a large consumer of both energy and natural resources (Edwards-Jones et al., 2008; Foster et al., 2006). Therefore, researchers are keen on studying the environmental impact from fisheries, using the Life Cycle Assessment (LCA) method (Garnett, 2008; Hospido et., al 2006). However, carbon is the main substance in the biosphere, and its organic forms support the lives of almost all heterotrophs (Stanier et al., 1986).

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Whereas, if there is too much inorganic CO_2 in the atmosphere, it will cause the problem of global warming (IPCC, 2007). Moreover, marine captured fisheries activities consume very large amount of fossil fuel, especially diesel for running boat's machines. This may result in increasing of carbondioxide (CO_2) in the atmosphere. Therefore, this work was carried out with the objectives of (1) quantifying the equivalent carbon emission from the resources used, and (2) identifying the main paths of carbon transfer in the activities of marine capture, following a carbon-balanced model.

2. METHODOLOGY

Field survey and data collection

Data collection from the field survey was carried out with questionnaires and interviews in order to obtain all the necessary information from seven fishermen in different major piers located in Songkhla, Ranong, and Samut Prakarn provinces. Also, three ice plants, three fish meal and two feed mills were surveyed to collect data from downstream industries. Quantities of energy and resources used in marine capture fisheries and downstream industries were gathered. The annual marine captures of the country for the past five years were obtained from the Department of Fisheries.

Conversion factors of carbon equivalence

Data values on material input and output were interpreted in terms of Carbon Equivalence (CE) by using conversion factors. Following a carbon-balanced model, CE was categorized into carbon emission, fixation, and reduction as shown in Figure 1. Details of carbon transfer in each path can be described as follows.

- **Carbon fixation** is the product of photosynthetic reaction in which atmospheric CO_2 is combined with H2O to form organic carbon. It will then be mobilized horizontally to satisfy human need. Finally after consumption by humans, it returns to the atmosphere, resulting in no emission through this pathway. However, to fulfill the human need of consumption of organics for living purposes, adequate and suitable land areas are required for the photosynthetic reactions to take place.

- **Carbon emission** comes from the anthropogenic use of fossil energy and other fossil-derived materials. As it was photosynthesized two billion years ago, fossil matter underneath the earth surface is mined and used to facilitate human activities. After this, it remains in the atmosphere as the incremental CO_2, thereby adding the greenhouse effect on the earth.

- **Carbon reduction** is the amount of carbon involved with any recovery, recycling, and reuse of waste. It is considered a carbon reduction because it helps conserve the use of natural raw materials and fossil energy (Pimentel et al., 2010).

The carbon cycle in Figure 1 can be scrutinized further so as to depict the major human activities of carbon interchange between earth's atmosphere and lithosphere, called a Carbon-Balanced Model (CBM) shown in Figure 2. In most tropical countries like Thailand, products of photosynthesis serve not only as food for living, but are also important key economic drivers in every market, both local and international. Apart from the forest areas, agricultural lands in Figure 2 are grouped, based on photosynthetic products, into three types of lands for the production of staple food (rice grain), non-staple food (fresh fruits, cassava, and sugarcane), and non-food (palm fruit and Para rubber). The amounts of products in excess of domestic consumption are exported in exchange for the imported crude oil and machinery from abroad. As such, the imported fossil energy is used mostly by both the industrial sectors and domestic households in the urban areas. Therefore, understanding the CBM would enhance public participation in reducing the carbon emission, thereby leading to a win-win approach - not only mitigating the global warming problem, but also saving more foreign currencies from reduced crude oil import.

However, enormous amount of photosynthetic products are produced from carbon fixation in the sea. Therefore, fuel is nesessary to be used for harvesting such the biomass product from the sea to support human need. A carbon-balanced model for agriculture and fisheries contries is shown in Figure 2. Carbon is fixed in plant plankton and transferred to small and, then, big fishes, respectively. Finally, seafood products will be harvested by human to support protien sources for living.

Conversion factors of carbon equivalence were obtained from a carbon-balanced model proposed by Polprasert and Chaiyachet (2007). CE conversion factor of fossil energy compound can be calculated using the stoichiometric ratio of carbon contained in the chemical formula.

The CE conversion factor of electricity generation from the grid network was calculated using the emission factor reported by the Environmental Division, Electricity Generating Authority of Thailand, to be equal to 0.58 kg CO_2/kWh (EGAT, 2010). With the molecular weight ratio of C to CO_2 equal to 0.27, hence, 0.16 kg CE/kWh was the conversion factor used to determine the carbon equivalence from electricity consumption.

The electricity used in ice production was found to be 124±18 kWh/ton ice. Therefore conversion factor of ice is 15.6±2.7 kg CE/ton ice. In addition, the authors consider the world's human population as a carbon mobilizer that causes carbon movement to satisfy their need. Therefore, it is not included in the determination of carbon equivalences in this study.

3. RESULTS AND DISCUSSION

Carbon equivalences and main paths of carbon transfer from marine capture fisheries

A schematic flow diagram of carbon transfer in marine capture fisheries and downstream industries is presented in Figure 3. After harvested, fishes are transported to the market of end-product consumers. Some parts of them are used as raw material for fish meal industries.

The total equivalent carbon emission from marine capture fisheries was found to be 1078±332 kg CE/ton fishes. The most significant emission come from fossil-diesel used, which contributed to 93% of total emissions

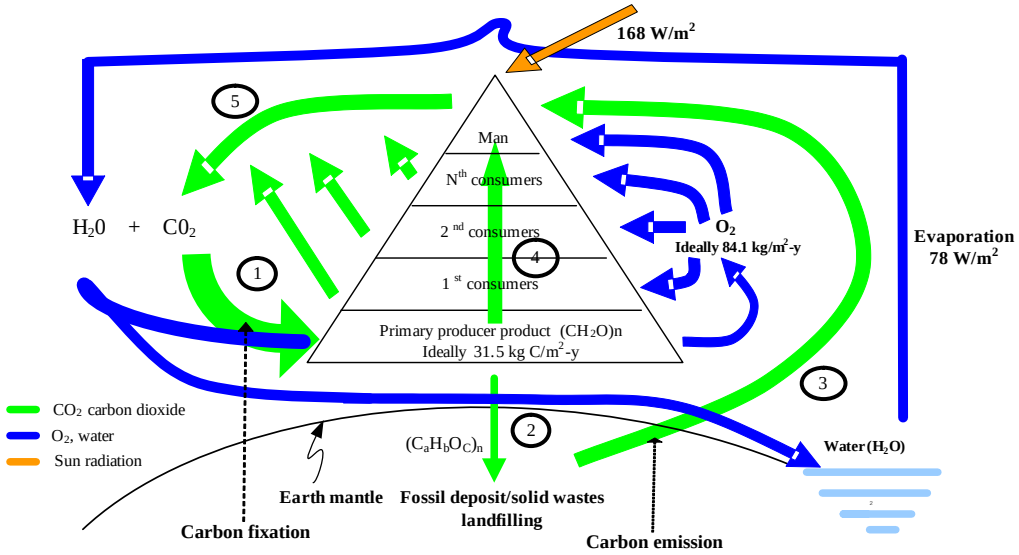

Fig. 1. Global carbon cycle (modified from Polprasert and Chaiyachet, 2007)

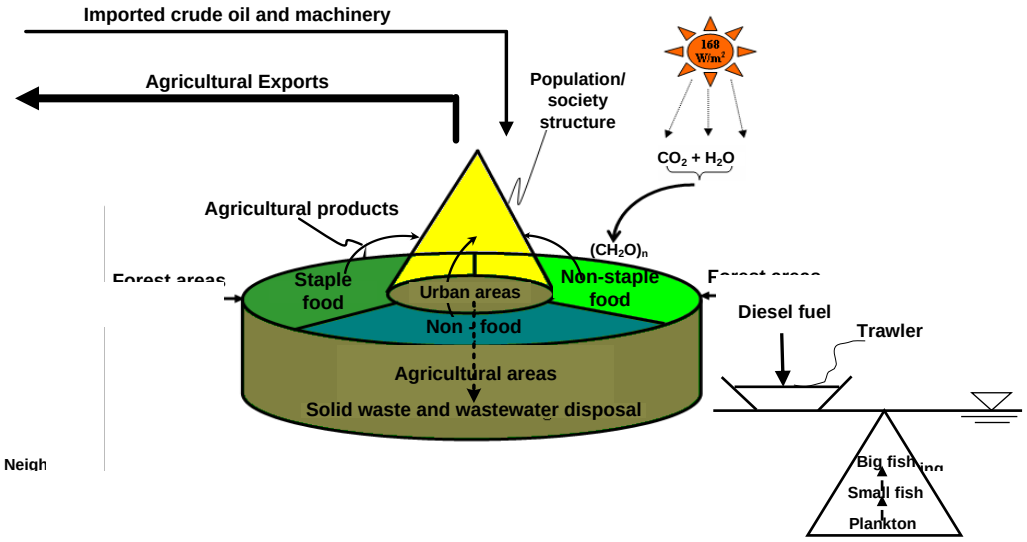

Fig. 2. A carbon-balanced model in agriculture and fisheries countries

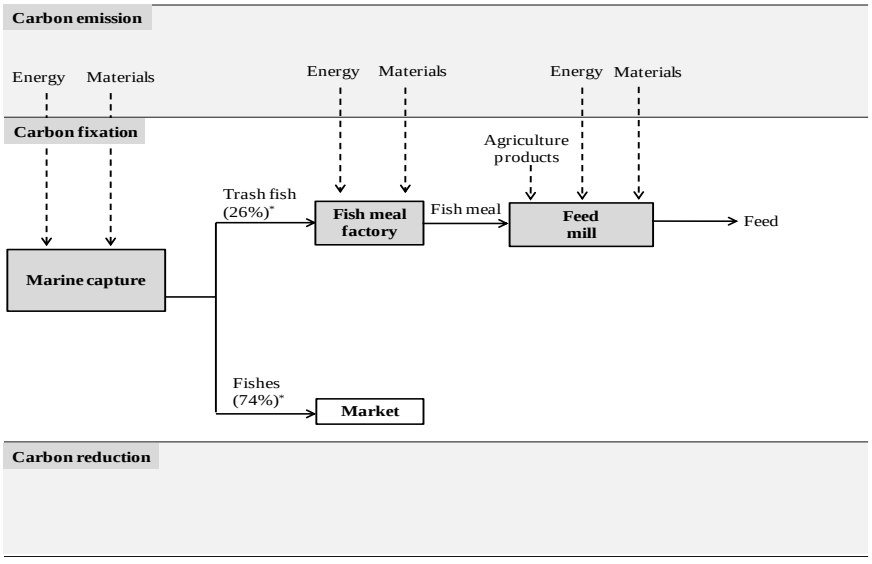

Fig. 3. Schematic diagram of carbon transfer from marine capture activity
Remark: *averaged data in 2010)
Sourec: DOF (2013).

(988 kg CE/ton fishes). This is because marine fishing required intensive energy throughout the period of operating time in the sea (Wilson, 1999). The amount of diesel consumption depends on distance and harvesting time. Moreover, small amount of carbon emission come from ice used for fish preserving as shown in Table 2. Average diesel and ice used for marine capture fisheries was found to be 1352±417 L/ton fishes and 5.42±1.67 tons/ton fishes, respectively. Obviously, replacement of fossil diesel by biodiesel may enormously reduce carbon emission from marine catching. As calculated, the 100% increase in biodiesel application may reduce the carbon emission from 1078±332 to 90±28 kg CE/ton fishes, representing a 93% decrease in the emission. However, plantation of oil palm area for biodiesel production would be needed to replace diesel fuel from marine fisheries activities. Moreover, land area equivalent for this implementation were calculated to be 0.39 ha/ton fishes. Such the above-mentioned implementation would help, not only reduce carbon emitted to the atmosphere, but increase food security for Thai people, also.

The equivalent carbon fixation in the fish captured can be computed to be equal to 400 kg CE/ton fishes. It considered as carbon fixation because it consume products from natural photosynthesis reaction in the sea for living. From statistical data of marine capture fisheries production and number of fishing boats registered during 2005-2009 (DOF, 2010), average captured fishes per boats was found to be 155±42 ton/year. Accordingly, carbon fixation per fishing boats were found to be 62±17 ton C/year. In 2009, total fishing boats was 16,891 boats. Therefore, total carbon fixation from marine capture was 1.05 million tons C /year.

Table 2. Carbon equivalences for marine capture fisheries

Resources used/ biomass capturing	Carbon equivalences (kg CE/ton fish captured)	
	Carbon emission	**Carbon fixation**
Diesel fuel	988 ± 305	-
Ice	90 ± 28	-
Fishes captured	-	400
Total	**1078 ± 332**	**400**
Carbon transfer efficiency (%)	**27.06**	

Carbon transfer efficiency

Carbon transfer efficiency can be estimated, using Equation 1, as follows.

$$\text{Carbon transfer efficiency (\%)} = \frac{\text{Carbon fixed in final product}}{\text{Carbon fixed in final product} + \text{net carbon emitted}} \times 100 \quad (1)$$

The carbon fixed is determined by multiplying the quantity of products with 0.4 (the stoichiometric ratio of $C:CH_2O$ in the chemical equation of photosynthetic reaction). In the sense of emission control, when the efficiency drops below 50%, it would be somewhat uneconomical to produce this product as its emission flux exceeds that of carbon fixed in the product. If it exceeds 100%, this carbon mobilization will help to reduce carbon emissions, not only from its own production process, but from other activities also.

From the computed result shown in Table 2, carbon transfer efficiency of marine capture fisheries is found to be 27%. This indicates that fisheries activities emit large quantities of carbon to the atmosphere, comparing with plant cultivation and animal husbandry. Therefore, consumption of other protein sources, such as cultured fishes, should be promoted as to substitute marine captured products. However, products from marine capture are still required in the market. Therefore, renewable energy should be used to replace fossil diesel fuel in the harvesting process.

Carbon equivalences and main paths of carbon transfer from downstream industries

After harvesting, Products of marine capture fisheries were sent to the market to support the need of consumer. However, some part of product from the sea such as trash fish can be considered as a raw material for fishmeal process.

The total equivalent carbon emission from fish meal production was found to be 100 kg CE/ton fish meal. Most of emission comes using of fuel (Liquid Petroleum Gas; LPG) for boiler. However, the total carbon emission rate starting from harvesting until fish meal production was found to be 4671±531 kg CE/ton fish meal. It indicates that the important sources of carbon emission come from trash fish harvesting. Therefore, downstream industries of fishmeal should seek other protein sources to replace fishmeal such as soybean. This suggestion can help reduce carbon emissions from feed mill.

4. CONCLUSION AND RECOMMENDATION

The equivalent carbon emissions from the marine capture were found to be 1078±332 kg CE/ton fishes captured, due to the use of fossil energy for harvesting and transportation of fishes. Major source of emission comes from diesel for running boat's machine in the sea. In addition, some products of marine captured, especially trash fish are used as raw material for feed production in shrimp and tilapia farming, resulting in a high amount of carbon emission in downstream industries. Carbon transfer efficiency of marine capture was found to be 27%, indicating marine capture fisheries activities emit large quantities of carbon to the atmosphere.

Therefore, it is recommended that more research on culturing of several marine species should be carried out so as to seek the feasibility of their commercial businesses to compensate for the decreasing amount of marine products captured from the sea and maintain the food security of the country, as well. Moreover, biodiesel fuel is recommended to be used in the operation of all trawlers in the marine capture as it can help reduce large amount of carbon emitted to the atmosphere.

ACKNOWLEDGEMENT

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Sustainable Consumption and Production Policy and Waste Management in Thailand

Alice Sharp and Siriporn Boonpa

***Abstract*— *Changing of consumption patterns has resulted in an increasing of municipal solid waste (MSW) quantity and have become an issue for urban and rural municipalities. One method for dealing with municipal solid waste is converting it into energy. This paper presents an overview of consumptions patterns and trends both at global and country levels. Current policies on waste management and renewable energy were also discussed. More than 15 million tons of solid waste is generated annually and very limited amount were being recovered back for utilization. However, this requires an enormous budget allocation for waste management. Currently the budget is insufficient to provide adequate solid waste management services. Thailand has adopted sustainable and environmentally sound ways of processing municipal solid waste. In order to increase the efficiency in solid waste management, waste-to-energy technologies are provided as a solution towards a successful policy. Waste-to-energy is perceived as a means to dispose of municipal solid waste, produce energy, recover materials, and free up scarce land that would otherwise have been used for landfill. Thailand considers waste-to-energy, incineration, refuse derived fuel (RDF), anaerobic digestion, pyrolysis and gasification, and landfill gas recovery to be a renewable technologies. While the available waste-to-energy technologies would suggest that the cost of waste-to-energy is somewhat higher than other renewable sources, it should be kept in mind that waste-to-energy facilities serve a dual role of waste disposal and energy production. Although the cost per municipal waste of capacity may be greater than other renewable sources, the benefits of waste management, energy and metals recovery, and reduction of greenhouse gas (GHG) emission need to be considered.*

***Keywords*— Renewable energy, sustainable consumption and production, Thailand, waste management policy.**

1. INTRODUCTION

Urbanization together with the changing of consumption patterns has resulted in increasing quantity of solid waste that is needed to be disposed. An increasing quantity of waste has put pressure on local government who is responsible for waste management and disposal of waste. Local governments spend large portion of their budget on solid waste management. This is mainly due to the fact that most cities in the developing countries focus on capital and technology intensive end-of-pipe solutions. These technologies are expensive to build, require technical skill of staff in operation and maintenance.

In recent years, many local governments have shifted their waste management priority from end-of-pipe disposal technology to waste minimization and waste utilization. Such activities can reduce amount of waste to be disposed in landfill, save municipalities operating expenses, and even generate revenue from recovered materials. In addition to direct benefits to local government offices, proper solid waste management can also reduce greenhouse gas emission, especially when biodegradable portion of solid waste are removed from waste streams.

This paper aims to assess the trends in resource usage and the consumption and waste generation pattern in Thailand. Current status of waste management in Thailand as well as the policy options used will be reviewed in order to promote paradigm shift from disposal to 3R (reduce, reuse, recycle) approach.

2. RESOURCE USE TRENDS

2.1) Global resource constraints

During the last century, the global materials consumption increased by 8-fold. In 2005, world population consumed 500 exajoules of primary energy and 60 billion tonnes of raw materials. Approximately 60-80% of these materials consumption were attributed to cities (Krausmann et al., 2009). Cities were believed to be responsible for the consumption of 75% of natural resource extracted and for the production of approximately 70% of CO_2 emission [1].

In terms of fossil fuels, the International Energy Agency (IEA) forecasts that global demand for oil will rise by 45% by the year 2030, while the discovery of new oil reserves has shown downwards trend[2]. Increasing oil prices has impacted several points on the supply chain: production process and transportation, for instance. IEA also reported that growth in oil consumption can be found in emerging economies, particularly from transportation sector[3]. It is noteworthy that the needs for water in energy production process are set to grow at twice the rate of energy demand.

Decreasing water sources together with the diversion of water for other uses (i.e. energy production) have resulted in almost one billion people do not have access to clean drinking water. Water demand in cities will become a challenge both in terms of quality and quantity.

Growing cities demand for more food and food

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availability depends on arable land and water. Most urban dwellers do not have ability to produce their own food and rely on food market. There is a strong link between oil price and food price, as can be seen in 2007-2008 when fuel price rose and contributed to food and commodity prices increased.

With increasing city population and modern consumption patterns, quantity of solid waste generated has also increased. For developing countries, increasing amount or solid waste leads to development of new landfill sites. When landfills are inadequately managed, it became major source of greenhouse gases emissions.

All information mentioned above has led us to see the connection between resources. Over consumption or the mismanagement of resources will also have adverse impacts on other type of resources. Solving one of the resource constrains may result in problems in other types of resources. Thus, efficient use of all resources is obligatory.

2.2) Resource consumption in Asian countries

At the beginning of the 21st century, the Asian and Pacific region was the world's largest resource consumer. The region consumed approximately 60 per cent of estimated 60 billion tons of annual global material use. In terms of resource required to produce one unit of GDP, the region required three times the input of resources compared to other regions of the world. The material flow database for Asia and the Pacific has covered four main material categories; biomass, fossil energy carriers, metal ores and industrial minerals, and construction materials. Figure1 shows that resource consumption pattern has changed in both quantity and quality aspects.

In 1970, the Asia-Pacific region's materials use was largely based on biomass. Agricultural crops, animal feed, fuel wood and timber for construction comprised of more than 50 per cent of all materials used. This has changed dramatically over the last three decades. Construction minerals represent about 50 per cent of all materials used.

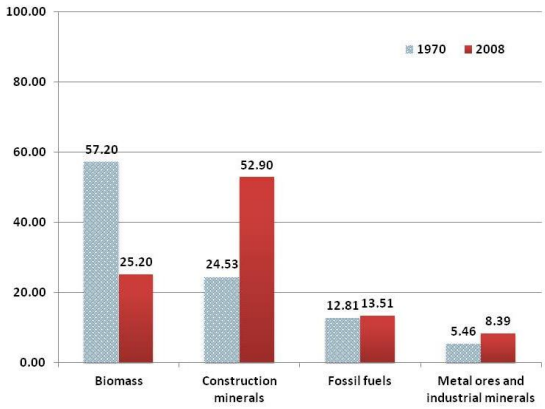

Figure 1 Change in consumption patterns in the Asia-Pacific region between 1970 and 2008.
Source: [4]

The Physical Trade Balance (PTB= Net Import – Net Export) of the region has shown a trend towards increasing net imports, which suggest that exploitation of the region's resource is no longer sufficient to support the fast growing economy. Net imports of fossil fuels were around 12% of the domestic extraction. When breaking down fossil fuels into subcategories: coal, natural gas, and petroleum, it can be seen that petroleum net import was 140% of domestic extraction.

In terms of efficiency, per capita domestic material consumption (DMC) continues to grow in the Asia-Pacific. DMC for Southeast Asia continues to increase from almost 3 tonnes/capita in 1970 to slightly more than 6 tonnes/capita in 2005, however, still lower than that of Asia and the pacific average at 8.6 tonnes/capita (UNEP, 2013). Material Intensity (DMC/GDP) of the region is increasing per unit of economic output, 2.4 kg per USD of GDP in 1970 to 3.1 kg in 2005. This has shown that the region is becoming less efficient in resource utilization. In order to stabilize the pressure on natural resources, the MI has to be decreased to the rate of increase of GDP.

As for energy demand, China, India, and Southeast Asian economies has influence the shift in global energy market to be centered in Asia due to their increasing demand. The energy use in the region increased from less than 45 exajoules in 1970 to approximately 170 exajoules in 2005. Southeast Asia's energy demand increases by over 80% between today and 2035 [5]. To meet increasing demand, the power sector of the region relies heavily on low efficiency (34%) coal fire power plants that also release CO_2 and other air pollutants. Energy intensity of the region reverses the decreasing trend for the rest of the world by remaining at 18 megajoules per US dollar of GDP in 2005 [1].

With growing economy, the region has consumed significant amount of water resource and at the same time produce huge quantity of wastewater. Only 15-20% of the wastewater receives some levels of treatment before discharged into natural water ways. The remaining wastewater was directly discharged into the natural environment with all the toxic pollutants [6]. Most of the water resources in the region are now facing the quality problems due to aforementioned reason and the degradation of other environmental resources, poor management of watershed areas, and industrialization.

2.3) Resources Consumption in Thailand

As for Thailand, the country has experienced significant economic growth since the 1970s. Drastic fossil fuel consumption can be observed. Apart from changing material consumption patterns, the statistic also shows an increasing trend in per capita material use from 8.51 tons per capita in 1990 to that of 11.34 tons per capita in 2005.

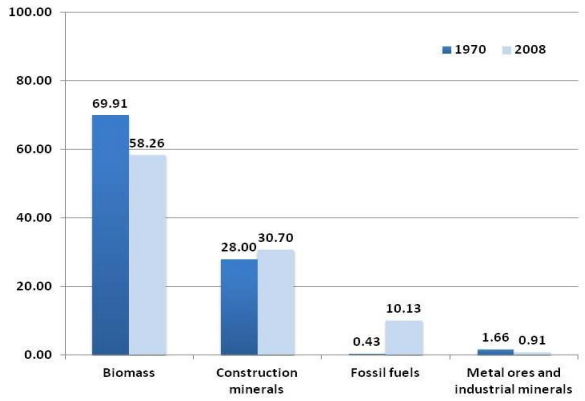

Figure 2 Changes in material consumption pattern of Thailand between year 1970 and 2008.
Source: [4]

In addition to material consumption, per capita energy use for Thailand is also increasing from 32.44 gigajoules per capita in 1990 to 66.60 gigajoules per capita in 2005. An energy intensity, which is a measurement of energy consumption per unit of GDP has also risen during the same period of study. Increasing energy intensity reflects low efficiency in energy consumption, together with the rising fossil fuels consumption in Figure 2, it can be seen that there can be an improvement in material consumption pattern of Thailand.

3. WASTE GENERATION AND UTILIZATION

Rising material consumption implies that there will be a considerable amount of waste generated. The waste generation in Thailand has also increased (**Figure 3**). However the utilization of waste is still low compared to the total waste amount. Utilization of waste materials has been done in three main ways; recovering of recyclable materials (82%), compost and biogas production (15%) and electricity and renewable energy generation (3%). There is a room for both waste utilization and renewable energy generation from waste materials.

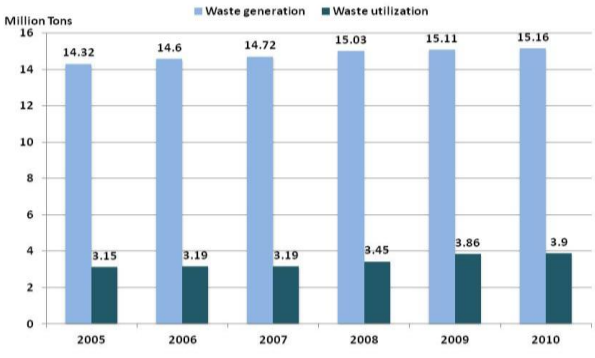

Figure 3 Waste generation and utilization (million tons) in Thailand between 2005 and 2010.
Source: [7]

4. RESOURCE EFFICIENCT TRENDS

The shift in production system from traditional to modern production style involves the change in material consumption patterns, as the technological progress does not change at the same speed. This comes with greater amounts of bulk flows, new type of pollution, and new waste streams, creating new challenges for environmental policy for all levels.

Figure 4 depicts the current trend in resource utilization. Waste should be perceived as resource in order to minimize new resource extraction. However the study by UNEP [8] has suggested that only resource efficiency may not be sufficient for sustainable consumption and production. Efficient resource use will stabilize materials and energy use for two decades before resuming growth again. However, the resource efficiency is needed as primary action towards sustainability.

System innovation involving new industrial infrastructure and technology development together with resource efficiency will result in long-term sustainable consumption and production.

Although it is clear that resource efficiency alone may not be a long-term solution for sustainable consumption and production but it is a prerequisite to it, therefore, government should start implementing policy that will promote resource efficiency.

Figure 4 Solid waste management for sustainable consumption and production.

5. POLICY OPTIONS

For waste sector, policy options to promote resource use efficiency in order to reduce quantity of waste entering disposal sites as well as to recover materials from waste streams requires a shift in perspective on waste. Proper waste management provides climate benefits as it will help reduce greenhouse gas emission. In addition, waste materials can be turned into source of renewable energy and provide employment for recycling industry.

5.1) Policies on municipal solid waste management

National policy framework on solid waste management involves 4 major policies;

- Applying 3Rs for achieving waste reduction and utilization;
- Promoting the integrated waste management system to reduce the landfill areas, increase waste utilization, and generate the renewable energy;
- Encouraging the cooperation of adjacent local government for establishment of waste management facility;

- ❖ Endorsing public and private sectors to participate in waste management project.

It should be noted that, the Thai government has aims to promote the conversion of municipal solid waste into renewable energy sources.

The growth of Thailand' economy has led to fast industrial expansion and rapid growth in population. Consequently, energy consumption in all sectors is becoming a much more serious problem. Energy is one of the most important issues and continually affects all human beings directly. The price of crude oil in the world market has increased from time to time and the quantity of crude oil available is decreasing with, shortages of fuel oils in Thailand, therefore, it is essential to urgently seek some substitute resources. Government of Thailand has set renewable energy as a national agenda. This promotes production and utilization of renewable energy by providing incentives.

5.2) National policy in energy

Waste to energy (WtE) ranked the fourth in the national energy policy and development plan. The alternative energy development plan (AEDP 2012 - 2021) [9] have been approved by the Department of Alternative Energy Development and Efficiency, Ministry of Energy on 30 November 2011 as shown in **Fig. 5**. Thailand's Ministry of Energy estimates that the potential of power generation in Thailand from biomass, biogas, and MSW is 4,390 MW. Other sources with good potential are solar and wind (3,200 MW). There is a potential to generate another 1,608 MW of power from hydro-power.

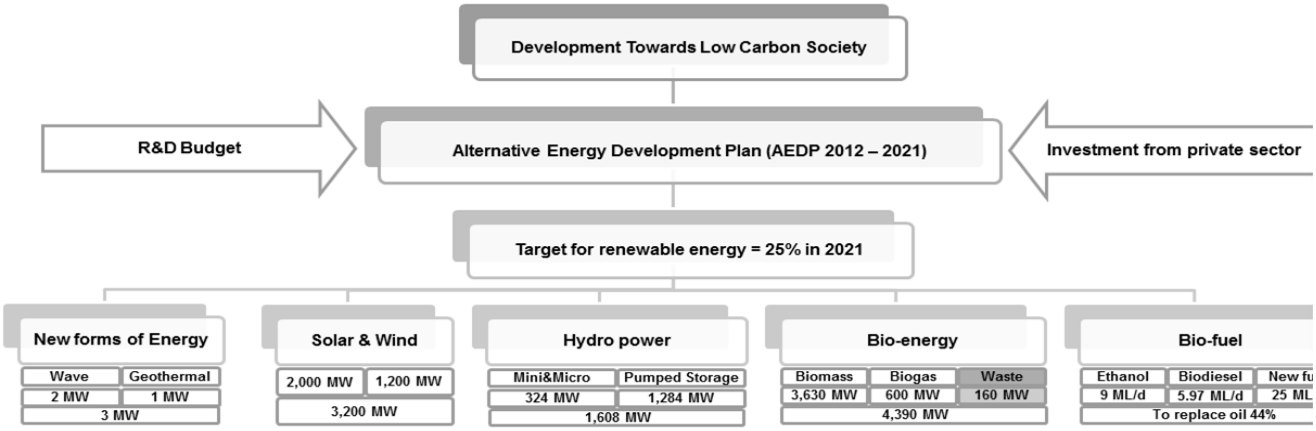

Figure 5 Alternative Energy Development Plan (AEDP 2012 – 2021) for Thailand [9].

6. WASTE TO ENERGY TECHNOLOGY

There are 6 technologies to convert solid wastes to energy in Thailand which are: incineration, refuse derived fuel (RDF), biogas production by anaerobic digestion, pyrolysis, gasification, and landfill gas recovery. Each type is suitable for different areas, depending on various factors including quantity, components and separation practices of solid wastes, number of staff, investment cost, operation cost, land requirement, local potentiality, etc. This section provides an overview of the conversion of WtE such as heat, steam, gases, and oils.

6.1 Incineration with energy recovery

Incineration, also referred to as combustion, is a specialized process that involves the burning of combustible materials in any state to form gases and residue. The basic elements of an incinerator include a feed system, combustion chamber, exhaust gas system, and a residue disposal system. Modern incinerators use continuous feed systems and moving grates within a primary combustion chamber lined with heat resistant materials. The waste must be mixed, dried, and then heated, all for specific amounts of time and at controlled temperatures. Different types of incinerators are in common use, such as mass-fired combustors, refuse derived fuel combustors, and industrial incinerators. Currently there were 3 incinerations for community wastes in Thailand namely Phuket province (250 tons/day), Samui Island (75 tons/day), and Lamphun province (10 tons/day).

6.2 Refuse derived fuel (RDF)

RDF is a fuel produced through the management of MSW. RDF can also be named solid recovered fuel or specified recovered fuel (SRF). The residual wastes after separate collection of recoverable materials are treated through mechanical reprocessing and fractionation. The RDF obtained from this process is traded and co-burnt in installations for power generation or in a manufacturing process where heat is required, such as co-combustion in coal fired boilers, co-incineration in cement kilns, and co-gasification with coal or biomass. Presently, there are RDF production plant in Thailand, using Mechanical Biological Treatment (MBT), in Phitsanulok municipality [10]. This project has been carried out by the Municipality of Phitsanulok and the German Agency for Technical Cooperation (GTZ). A pilot facility was envisaged to treat 50 % of incoming waste in the landfill. In addition, there is another RDF production plant in Nakhon Ratchasima City Municipality which is suspended because the operation cost and the commercial use of RDF has yet to be determined.

6.3 Biogas production by anaerobic digestion

The organic fraction of the waste is mashed and placed in a contained digester to decay without oxygen.

Primarily carbon dioxide and methane are produced as biogas, but also small amounts of hydrogen sulfide, ammonia, and other compounds are produced by this process. The solid material drawn from the anaerobic digester is called effluent. It is rich in nutrients (such as ammonia, phosphorus, potassium, and more than a dozen trace elements) and is an excellent soil conditioner. In Thailand, the purpose of anaerobic digesters is to utilize the biogas produced as a source of fuel for generators and the sludge byproduct as a fertilizer.

6.4 Pyrolysis

Pyrolysis is chemical decomposition by heat in the absence of oxygen converting carbonaceous material into fuel gas that can be used as a substitute for natural gas. The pyrolysis process, like incineration, can be continuous or batch fed, producing char, pyrolysis oils, and gases. The process is conducted at 815ºC, most commonly in what is called a fluidized bed. Cellulose molecules within the municipal waste dissociate instead of burning, due to the absence of oxygen. The fragments of the dissociated molecule form methane, carbon dioxide, hydrogen, carbon monoxide, and water. Currently pyrolysis is used for community wastes in Thailand: Warin Chamrap, Ubon Ratchathani Province (6 tons/day of plastic waste generated 4,500 L/day of fuel oil).

6.5 Gasification

Gasification is a modification of pyrolysis in that a limited quantity of oxygen is introduced, and the resulting oxidation produces enough heat to make the process self-sustaining. Gasification occurs at very high temperatures (greater than 700ºC) and involves the partial combustion of a carbonaceous fuel (combustible, putrescible, and plastic fractions of the waste), which produces combustible fuel gas rich in carbon monoxide, hydrogen, and some saturated hydrocarbons (mostly methane).

6.6 Landfill gas recovery

Generation of methane from a sanitary landfill is similar to anaerobic digestion, but without operational control of the process. The waste is simply left as is, with no efforts made to increase gas production; gas is simply captured as it is generated. Landfill gas typically consists of 50-60% methane, 40-50% carbon dioxide, and trace levels of other gases. Typical landfill gas has an energy equivalent to about half that of natural gas[11].

7. CONCLUSION

Keys to success for the implementation of above-mentioned policies can be listed as followed;

- Resource efficiency and waste minimization concepts should be introduced as first priority in order to ensure the most efficient use of materials.
- There should be technical and financial support from the government.
- The separation of waste at source should be maximized to reduce waste quantity to be managed and to recover as much as possible recyclable materials.
- There should be a proper incentive schemes for stakeholders together with proper regulations and guidelines for standard implementations.
- Selection of technology should be done based on several criteria such as: characteristic of waste, quantity of waste generated, investment and operation costs, and amount of energy produced.
- Other benefits (greenhouse gas emission, food security, etc) of proper waste management should be taken into consideration when selecting the technology.

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Greenhouse Gas Emission from Municipal Solid Waste in Phnom Penh, Cambodia

Chhay Hoklis and Alice Sharp

***Abstract*— *Municipal solid waste generation in Phnom Penh has steadily increased after the civil war in 1979. Currently, Cambodia, particular Phnom Penh, is focused on methods to reduce greenhouse gas emission from the waste sector. GHG emission in this paper was calculated based on the Intergovernmental Panel on Climate Change (IPCC) to estimate the GHG emission from municipal solid waste in Phnom Penh in 2009. The result of this calculation shows that the GHG emissions were 321.71 Gg (CO_2 eq) for CH_4, 325.85 Gg (CO_2 eq) for CO_2, and 6.43 Gg (CO_2 eq) for N_2O. Therefore, two waste management scenarios were proposed. In the actual situation, all the municipal solid wastes are dumped into landfill without any gases captured for electricity generation. In the two proposed scenarios, waste materials will be recycled by separation of waste at landfill, and composting of organic wastes at landfill as well. The result from these scenarios showed that greenhouse gas emission can be reduced by 52.43% for the first scenario and 63.39% for second scenario. This study revealed that the implementation of the proposed scenarios provides tremendous benefits. It can reduce the volume of waste entering landfill site, recycle waste materials, and minimize health problem.*

***Keywords*— Cambodia, Greenhouse Gas, Intergovernmental Panel on Climate Change, Municipal Solid Waste Management, Phnom Penh**

1. INTRODUCTION

Municipal solid waste (MSW) is a complex problem influenced by political, legal, educational, and economic factors. Growth in economic, population, urbanization, and industrialization has led to a large quantity of waste generation in developing countries, including Cambodia. Recently, the municipality of Phnom Penh has been faced with serious environmental and human health problems due to high population growth rate, poor waste treatment technology, and lack of skill of officers.

Up to now, Phnom Penh has only had one sanitary landfill for municipal solid waste, and the treatment technology is still very limited. Most of the methane from landfills and dumpsites is released directly to the atmosphere. It is clear that mismanagement of municipal waste management will result in greenhouse gas emission. Methane (CH_4), carbon dioxide (CO_2), and nitrogen dioxide (N_2O) are the main substances of greenhouse gases.

The aim of this study is to estimate the greenhouse gas emission in Phnom Penh by using the calculator developed by the Intergovernmental Panel on Climate Change (IPCC). GHG emission was calculated based on data collected in 2009. Additionally, two waste management scenarios were developed in order to find a way to reduce GHG emission as well as the volume of waste in landfill. Each scenario is focused on a composting method due to the large amount of organic waste produced in Phnom Penh, and agriculture sector. The factors analyzed in this study include waste generation, waste collection and transportation, waste disposal, and general problems of waste management in Phnom Penh, Cambodia.

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2. CURRENT MUNICIPAL SOLID WASTE MANAGEMENT (MSWM) IN PHNOM PENH

Municipal solid waste management in Cambodia has improved slowly. Waste collection, transportation, and disposal site management are still limited due to lack of budget, and human resources. Therefore, Cambodia needs to develop a proper waste disposal system.

Waste generation

Waste generation in Phnom Penh increased rapidly from 338,647 tons in 2003 to 438,000 tons in 2009 (Table 1), and it was estimated to be 635,000 tons in 2015 (JICA, 2005). According to Institute for Global Environmental Strategies (IGES, 2011), waste generation per capita in Phnom Penh was 0.91 kg/person/day. This rapid growth in waste generation was attributed to population growth and economic development. It should be noted that the solid waste collection in 2004 was 227,910 tons/year which was lower than that of 2003, at 240,859 tons/year. This was not because less waste was generated, but due to low collection efficiency and data management. The waste composition of Phnom Penh city is shown in Table 2. It is revealed that food waste is the main component of waste of the organic fraction with high moisture content. This organic fraction of waste plays important role on

methane gas emission.

Waste collection and transportation

Currently, there is only one private company that is responsible for municipal solid waste management as well as for cleaning services in Phnom Penh city. This company is called CINTRI (Cambodia) Co., Ltd. It is a private waste management firm. Bunrith, S., et al, (2010), reported that CINTRI started its service in 2002, and from 2009 waste collection and transportation service in Phnom Penh has been completely provided by CINTRI. The company now has a monopoly on waste services and a contract of fifty years. Hence, CINTRI definitely fills an important need in the city. However, CINTRI's monopoly means that there is no open market for waste services and no bidding between competitors working to get prices down.

Waste collection and transportation are very useful to enhance waste management. Recently, waste collection in Phnom Penh has improved due to the aim of the Ministry of Environment (MoE) to make the city clean. According to Table 1, almost 84 % of solid waste in this city was collected in 2009. For waste transportation, the city does not have a transfer station. All the collected waste is transported directly to a disposal site.

Waste disposal

Open dumpsites and landfills are the common methods being practiced in Cambodia as well as other developing countries, such as Thailand and Vietnam. The MSWM systems start with collecting, buying, and scavenging of recyclable materials from households and commercial sectors. In Phnom Penh, informal waste pickers collect recyclable materials and sell them to junkshops. Then, these materials such as plastic, paper, cloths, and metal, are put through a simple process (pre-recycle process) before being sent abroad for further recycling processes. If domestic recycling can be done with standardized quality, it will create economic benefits for local citizens.

In the past, most of the remaining wastes were sent to Steung Mean Chey dumpsite located in Phnom Penh, Cambodia with a total area of 6.8 ha. This disposal site is an open dumping site without environmental protection measures. The site has poor planning, and a low level of technology employed. During the rainy season, the area is flooded, and the fetid water submerges the surrounding residential areas. Waste is often burnt in a field to reduce the volume of waste.

At present, waste disposal site has changed from Steung Mean Chey dumping site (SMCDS) to the Dong Kao site. Dong Kao landfill is the first sanitary landfill which was built in Phnom Penh at a total area of 26 ha (11 ha for disposal area) and it has been allowed to be used since 2009. It has a daily soil-covering process to reduce the bad odor and protect the environment. Furthermore, leachate storage ponds have been constructed. Yet, it has no leachate treatment. The leachate is just pumped into the pond and left to evaporate.

3. REVIEW GHG EMISSION FROM WASTE SECTOR

Municipal solid waste that is produced by human activities contributes significantly to greenhouse gas (GHG) emissions. Greenhouse gas from the waste sector has an effect on climate change that creates global problems. The GHGs that are making the largest contribution to global warming are CO_2, CH_4, and N_2O. According to Krzysztof, P.; and Krzysztof, G., (2010), one ton of CH_4 emissions has the same potential effect on global climate change as 21 tons of CO_2. Thus, one ton of CH_4 emissions can be expressed as 21 tons of CO_2 eq. And one ton of N_2O has the same potential effect on global climate change as 310 tons of CO_2.

All three gases are produced during waste management and waste disposal. Emission of methane gas happens when organic waste is left to decay in anaerobic landfills.

4. PROBLEMS RELATED TO CURRENT SITUATION

Municipal solid waste (MSW), produced in Phnom Penh is growing in volume and in toxicity. The MSW recently still is improperly managed. Problems related to solid waste management are summarized as follow:

- The classification of solid waste has not yet been implemented. Mixed solid wastes (industrial and domestic wastes) are disposed of at the same dump site. Moreover, there is no waste segregation for recycling before disposal in the landfill.
- In practice, the landfill does not have environmentally sound management. The knowledge on waste treatment technology and wastewater (leachate) is still limited. Landfill produces negative effects to dwellers that live around dump sites. They cause a risk to public health directly or indirectly, especially to scavengers that seek available things at dumping sites or people who live close to dump sites.
- For the collection service, ineffective solid waste collection and insufficient number of waste collection trucks are the reasons for piles of waste in public areas and market places.
- During rainfall, solid waste and garbage were washed out and clogged sewage systems in urban area, and finally flooded adjacent low-level residential areas.

To conclude, all of these need new approaches in order to manage municipal solid waste properly and use appropriate technology that can be easily maintained and operated.

5. GREENHOUSE GAS ESTIMATION FROM THE WASTE SECTOR

The IPCC calculator is a simple tool for GHG emission estimation that requires only input of a limited set of parameters. This method assumes that all the potential GHG emissions are released during the same year that waste is disposed of without consideration of the timing of the emissions. According to Chart, C.; and Chettiyapan, V., (2008), IPCC is estimated based on the category of the waste, degradable organic carbon (OC) fraction, and methane (CH_4) gas in landfill. CO_2 and N_2O were also determined, but CH_4 is the main gas in GHG emission, following equation (1). For the estimation of GHG emission for this study, the fraction of DOC is equal to 0.143. It is assumed that the fraction of methane in landfill gas equal 0.5. And the OX was assumed to be zero because oxidation of carbon dioxide was not taken in account. There was no recovery or generated methane gas. Thus, R was equal to zero.

Table 1. Waste generation and collection in Phnom Penh

Year	2003[a]	2004[a]	2005[a]	2006[a]	2007[a]	2009[b]
Daily waste generated (Tons/day)	928	986	1,043	1,101	1,159	1,200
Annual waste generated (Tons/year)	338,647	359,717	380,786	401,856	422,926	438,000
Solid waste collected (Tons/year)	240,859	227,910	266,781	324,159	343,657	366,825
Solid waste uncollected (Tons/year)	97,788	131,807	114,005	77,697	79,269	71,175
Uncollected (%)	29	37	30	19	19	16,25

[a] Phong, H., (2010)
[b] IGES 2011

Table 2. Typical composition of MSW in Phnom Penh

Year / Composition (%)	2002[a]	2003[a]	2009[c]
Food/Organic	65	63.3	70
Plastic	13.2	15.5	6
Paper & Cardboard	3.8	6.4	5
Grass & Wood	-	6.8	6
Glass	4.9	1.2	2
Metal	1	0.6	2
Rubber, Leather	0.6	0.1	-
Textile	-	2.5	3
Ceramic & stone	-	1.5	-
Other	11.5	2.1	6

[a] Bunrith, S et al., 2010
[b] IGES, 2011

$$CH_4 \text{ emissions} = (MSW_T \times MSW_F \times MCF \times DOC \times DOC_F \times F \times 16/12\text{-}R) \times (1\text{-}OX), \quad (1)$$

Where :
MSW_T : Total MSW generated (Gg/yr)
MSW_F : Fraction of MSW disposed of in solid waste disposal sites
MCF : Methane correction factor (fraction)
DOC : Degradable organic carbon (fraction) (kg C/kg SW)
DOC_F : Fraction DOC dissimilated
F : Fraction of CH_4 in landfill gas (IPCC default is 0.5)
16/12 : Conversion of C to CH_4
R : Recovered CH_4 (Gg/yr)
OX : Oxidation factor (fraction – IPCC default is 0)

6. SCENARIO DESCRIPTIONS

Two scenarios are proposed to develop municipal solid waste management in Phnom Penh. GHG emission estimation from each scenario and actual situation of waste management are summarized in Table 3.

Actual situation- 100% of waste are disposed of in landfill

Solid wastes are mainly disposed of in landfill, because landfill is the simplest, cheapest and most cost-effective method of disposing waste. For developing countries, almost 100 per cent of generated waste goes to landfill. Even in many developed countries, most solid waste is landfilled. Based on current municipal solid waste management in Phnom Penh, it is assumed that 15% of total waste generation is released to open dumping sites. It is considered as uncollected waste due to road conditions and improper management. About 15% of waste generation was sent to landfill, Steung Mean Chey dumping site. Furthermore, almost 10% of total waste generation that is released to SMC site is considered for open burning, for the actual situation in 2009, Phnom Penh. The remains 5% of waste is assumed to be recycled by scavengers. About 9% of waste material is recycled as composting by some NGOs, such as Cambodian Education and Waste Management (COMPED) and Community Sanitation and Recycling Organization (CSARO). In this scenario, 100% of solid waste is released directly to landfill without separation of the waste material for recycling or gas collection. It is good if gases can be captured from landfills and converted to electricity for supplying the country.

For the other two scenarios, managed landfill and composting were considered to improve waste management and reduce GHG emission. There is no methane collection or recovered energy gas from landfill sites. Moreover, it is assumed that there is no open burning of waste at Dang Kao landfill. The aim to develop these scenarios is that the composting method should be promoted, based on the large amount of organic waste produced in Cambodia, in order to improve the agriculture sector as well as reduce the amount of waste in landfill sites. In addition, reducing waste at landfills is very important to practice in Phnom Penh, in order to recycle waste material.

Scenario 1- Reduction of waste at landfill + 20% of organic waste for composting + landfill

Landfills have negative effects on the environment such as GHG emissions and leachate. So, many countries including Cambodia have concerns over landfill issues, such as an increasing of groundwater contamination, potential release of toxic gases, and odour. A big part of these problems comes from organic waste. That is why this scenario is applied to mix the management practice of compost to minimize these problems.

Waste reduction at landfill is very important to practice in this scenario to remove some materials such as plastic, paper, and metal from the landfill. Recycling of these materials is useful for proper waste disposal. This can reduce energy consumption and pollution, conserve natural resources, and extend valuable landfill space. This

Table 3. Current and future municipal solid waste management

Quantity of waste generation / Type	Actual situation		Scenario 1		Scenario 2	
	Ton/year	% of A	Ton/year	% of B	Ton/year	% of B
Open dump site (<5m depth)	65,700	15	65,693.43	16.5	65,693.43	16.5
Open dumping on landfill (>5m depth unmanaged)	21,900	5	-	-	-	-
Landfill (>5m managed)	267,180	61	271,134.70	68.1	179,163.90	45
Composting	39,420	9	61,313.87	15.4	153,284.67	38.5
Anaerobic digestion	-	-	-	-	-	-
Open burning	43,800	10	-	-	-	-
Total	438,000	100	398,142	100	398,142	100

** A : Total waste generation
B : Total waste after waste reduction at landfill

can also have economic benefits by reducing costs associated with operation at disposal.

Therefore, it is assumed that 70% of paper, plastic, and metal are removed for recycling, and 20% of organic waste is removed for composting. Furthermore, waste material needs to be separated for recycling before release to the landfill. And the remaining wastes from recycling and composting are sent to landfill without gas recovery.

Scenario 2- Reduction of waste at landfill + 50% of organic waste for composting + landfill

In this scenario, there is also waste reduction at landfill by recyclabling material: plastic, paper, and metal. It is assumed that 70% of waste material, such as paper, plastic and metal is removed with 50% of organic waste for composting. The remaining solid waste is released to the landfill. This is quite the same as scenario 1, but it uses composting as much as possible to reduce GHG emission as well as the amount of waste in landfill.

7. RESULT

This study shows that greenhouse gas estimated by the IPCC calculator is 321.71 Gg (CO_2 eq) for CH_4, 325.85 Gg (CO_2 eq) for CO_2, and 6.43 Gg (CO_2 eq) for N_2O in 2009. Waste management should be improved in order to reduce environmental problems as well as reduce GHG emissions. Therefore, two developed scenarios (scenario 1 and 2) were introduced to reduce the greenhouse gas emission from Phnom Penh waste dumpsite. The first scenario is that 20% of organic waste is removed for composting. In the second scenario, 50% of organic waste is removed for composting. In both new scenarios, it is assumed that there are composting and waste reductions at landfill by the removal of recyclable material: plastic, paper, and metal.

Table 4 shows the greenhouse gas emission in Phnom Penh for the actual situation and two developed scenarios. It is revealed that GHG emission can be reduced, if 70% of waste materials, such as paper, plastic and metal are removed, with 20% of organic waste for composting. GHG emission is more reduced in the case that 50% of organic waste is removed for composting. The estimated GHGs of scenario 1 is 304.26 Gg (CO_2 eq) for CH_4 and 6.84 Gg (CO_2 eq) for N_2O. IPCC calculated 222.33 Gg (CO_2 eq) for CH_4 and 17.11 Gg (CO_2 eq) for N_2O for scenario 2. It is noticed that there is no CO_2 emission for these two developed scenarios because it is assumed that there is no open burning in landfill.

These results revealed that greenhouse gas emission reduced 52.43% for the first scenario and 63.39% for the second scenario. This is due to promoting the composting method, and reducing waste at landfill for recycling paper, plastic and metal.

Table 4. GHG emission in Phnom Penh

GHG emission Gg (CO_2 eq)/year	Actual situation	20% compost	50% compost
CH_4	321.71	304.26	222.33
CO_2	325.85	-	-
N_2O	6.43	6.84	17.11
Total	653.99	311.10	239.44
GHG reduction (%)		52.43	63.39

8. RECOMMENDATION TO IMPROVE PROBLEMS

In MSW management practices, not only the end of pipe approach, but also a precautionary approach should be considered, such as waste prevention or waste reduction at source, in order to minimize waste in the final disposal (landfill). Moreover, this prevents emissions of many greenhouse gases, reduces pollutants, saves energy, conserves resources, and reduces the need for new landfills. Waste prevention should be promoted to reduce the amount of waste generation:

- Plan meals to avoid waste generation;
- Bring own shopping bag and use only big ones at the grocery store;
- Buy goods from local farmers' markets;
- Buy, maintain, and repair products;

- Use pink-lotus leaf instead of paper or plastic to wrap things;
- Buy only what you need.

Moreover, there are several recommendations for future improvement of solid waste management in Cambodia, especially Phnom Penh, capital city of the Kingdom of Cambodia.

- Improving public information on municipal solid waste management and waste disposal and treatment. In this case, MoE has to play in important role in collaboration with other ministries like the Ministry of Education or NGOs.
- Improving transportation and solid waste collection service: The transportation and collection service are still weak. That is why they should consider the schedule of collection.
- Installing a sanitary landfill that has technology for treatment of waste materials: In this case, Cambodia will also attract the benefits from solid waste by absorbing methane gas from landfills to transfer into electricity, which can be supplied to the country. Cambodia consumes electricity from neighboring countries. Government should encourage investors like NGOs or private companies to invest in solid waste in Cambodia. In addition, the government should improve and encourage privates companies or NGOs to do the composting because it can reduce the amount of organic waste. Moreover, Cambodia is an agricultural country; most farmers need compost to supply their plants.

In short, all of these need to be supported and implemented by adequate funds for technology and skilled human resources. Officials at the subnational level should be better trained in integrated solid waste management, while funds are needed for waste collection equipment and the development of MSW management. Furthermore, public awareness of MSW management issues could also be improved. Therefore, an integrated solid waste management plan should be developed; each component should be more clearly delegated to the responsible authorities. Moreover, funds should be mobilized towards implementation despite a limited national budget.

9. CONCLUSION

The calculation has shown that good waste management is the basis for reducing GHG emission and minimizing pollutants.

Since Cambodia is a developing country in Asia, the main component of the solid waste generated is organic waste. Composting can be improved and promoted for the agricultural sector. Sanitary landfill should be applied for this country due to population growth as well as increasing waste generated. Incineration is the best method of waste managements to not only protect the environment, but also get a lot of benefits. However, Cambodia does not have enough funds and skill of human resources to apply these methods. Therefore, to reduce the amount of solid waste, the government should initiate more 3R activities in solid waste management policies. The advantage is that the informal sector recycles a portion of the country's urban waste. Finally, the need to reform the solid waste management strategies is an opportunity not just to turn municipal waste into a valuable resource, but also to increase the income of the informal waste pickers, reduce poverty, and contribute towards the mitigation of climate change, by reducing methane emissions. Therefore, the government should consider improving the waste management system and the economic conditions of Cambodia.

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Geospatial Technology for Monitoring Status and Transformation Process of Environmental Quality in Southern Part of Myeik Archipelago Myanmar

V. Manjunatha and Theo Ebbers

Abstract *- Development and establishment of an appropriate management plan for coastal resources and ecosystems requires thorough understanding of the current state of coastal resources their uses and the potential threats they are facing. Monitoring Coral reef and water quality features using contemporary geospatial technology data may prove to be a cost-effective and time efficient tool for reef surveys, change detection, and management. This analysis is to understand current state of coastal habitats and initial mapping of coral reef areas and suspended sediments process in southern part of Kawthaung region in Myeik Archipelago Marine Ecosystem (MAME), Myanmar through the use of Geospatial applications. Multi- temporal Landsat5 Thematic Mapper (TM) images (2000, 2005 and 2010) were used to assess and comprehend temporal variation of water quality (Suspended Sediment (SS)) and habitat shifting/Reef risk. High spatial resolution 2-meter multispectral Thailand Earth Observation System (THEOS) pan sharpened level 2A image (2011) was used to represent the current status of coral reef in the study area. Reef maps produced using supervised multispectral image classification after atmospheric and water column corrections. By Landsat temporal data, we obtained a comparative uniform model for the retrieval of suspended sediment concentrations. Image-Processing techniques ERDAS Imagine and GIS tools were employed to determine the characteristic reflectance values of each habitat. Analysis of remote sensing data resulted in the mapping of coral reefs, current status and potential threats, particularly from sedimentation. Comparison of the classified images from 2000 to 2010 illustrates spatial changes of the habitat (coral reef) and increase of sedimentation in the study area. The result of this study is a good example on how time series analysis of remotely sensed data can be a tool to monitor the changes in the state of critical coastal habitats and eco-systems that are impacted by coastal development and to identify areas exposed to higher risk/threat levels.*

Keywords **— Coastal habitats, Geospatial, Landsat, Sedimentation, THEOS**

1. INTRODUCTION

The Wetlands Alliance (WA) with support from the Swedish International Development Agency (SIDA) brought together the strengths, expertise and experiences of four institutions, i.e. the Asian Institution of Technology (AIT), Coastal Resources Institute (CORIN-Asia), WorldFish Center (WorldFish), and Worldwide Fund for Nature (WWF) in order to create a more integrated and collaborative action to respond to the issues related to the sustainable management of wetlands in the countries of the lower Mekong river basin including Cambodia, Laos, Thailand, Vietnam and recently Myanmar. WA's focus is to strengthen local-level capacity for sustainable poverty focused wetlands management. This is the central point for all actions at all levels regional, national, provincial, commune and community. The Alliance focuses on four main areas of common interest; local development and management, aquatic resources, institutional policy change and securing the resources needed to use the capacity developed.

Studies show that maritime environments are facing threats from many sides and coral reef degradation might be expected [1]. These changes are already having major impacts on the economic performance of coastal countries and on the lives and livelihoods of millions of poor people [2]. Over 80% of marine pollution comes from land-based activities. Most of the waste we produce on land ultimately reaches the oceans, either through deliberate dumping or from run-off through drains and rivers [3]. Terrestrial sediment can increase turbidity, which in turn, decreases light available for photosynthesis and can create physiological stress or even coral mortality [4]. WA believes that the development and establishment of an appropriate management plan for aquatic resources and ecosystems requires thorough understanding of the current state of coastal resources, their uses and the potential threats they are facing.

Local WA activities have been designed from the outset to take advantage of the capabilities provided by Geospatial Technologies. Certain marine and coastal habitats can be mapped or assessed using geospatial technologies including Remote sensing (RS), Geographical Information System (GIS) and Global Positioning System survey (GPS). The application of geo spatial technologies for generating a better

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understanding of coastal ecosystems and ecological, processes has a long history. This study builds on this research history in applying geo-spatial technologies to better understand marine environmental risk in the Kawthaung region of Meyik Archipelago Marine Ecosystem (MAME). In the initial stage, WA selected southern part of Kawthaung region/township in MAME to understand of marine environmental risk especially coral reef.

The study demonstrates the application of RS and GIS in marine ecosystem. It includes analysis of multi- temporal Landsat7 Thematic Mapper (TM) images (2000, 2005 and 2010) and high spatial resolution multispectral Thailand Earth Observation System (THEOS) (2011) image to assess the status of water quality (Suspended Sediments) and habitat shifting/Reef risk

The study demonstrates the potential of applying RS and GIS in marine ecosystems. It includes analysis of multi-temporal Landsat7 Thematic Mapper (TM) images (2000, 2005 and 2010) and high spatial resolution multispectral Thailand Earth Observation System (THEOS) (2011) image to assess the status of water quality (Suspended Sediments) and habitat shifting/Reef risk.

2. GEOGRAPHICAL FOCUS AREA

Myanmar coastal area includes the Bay of Bengal and the Andaman Sea. It can be divided into three regions: the Rakhine, the Irrawaddy Delta and the Thanintharyi coastal regions [5]. The study area is focused on Myeik/Mergui Archipelago Marine Ecosystem (MAME) area, located at the Thanintharyi coastal region in the southern most part of Myanmar (Figure 1).

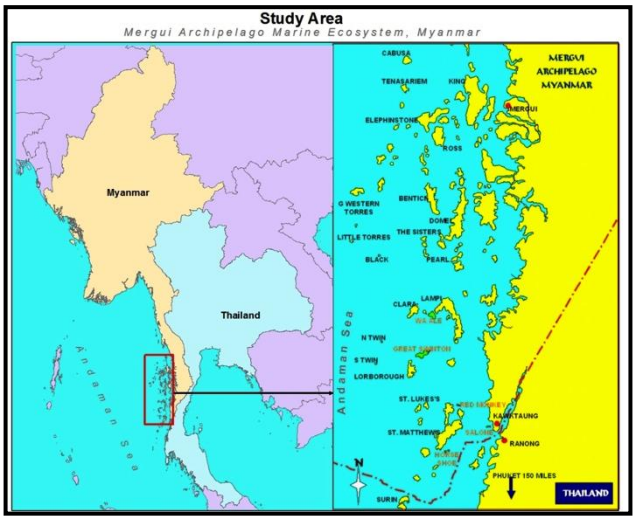

Figure1: Study Area, Myeik Archipelago Maritime Ecosystem

The majority of coral reefs are found in the Myiek Archipelago and Thanintharyi zone. The archipelago contains 800 islands on a shallow continental shelf. Little information is available on the status of coral reefs in the Myiek Archipelago, but it has been reported that there is some human impact on coral habitats [6], [7]. Coral reefs are fragile to persistent stress by humans, and recent studies indicate that during the past 15 years many reefs of the southern delta have suffered much destruction. Dynamite fishing, anchor damage, trampling and over-fishing have devastated the marine flora and fauna associated with the reefs. Sedimentation caused by erosion from the mainland and from the islands also smoother corals and associated animals by burying them. More information on coral reefs MAME still is lacking to assess the ecosystem correctly [7].

Kawthaung is located 10°N and 98.30°E at the mouth of Kyan River on the Malay Peninsula in MAME. On its east side is the Thailand border town of Ranong. On its west and south-west side, the Andaman Sea opens up to the Indian Ocean, and north side, Bokpyin Township. Most of the terrain in the area is mountainous (Figure 2).

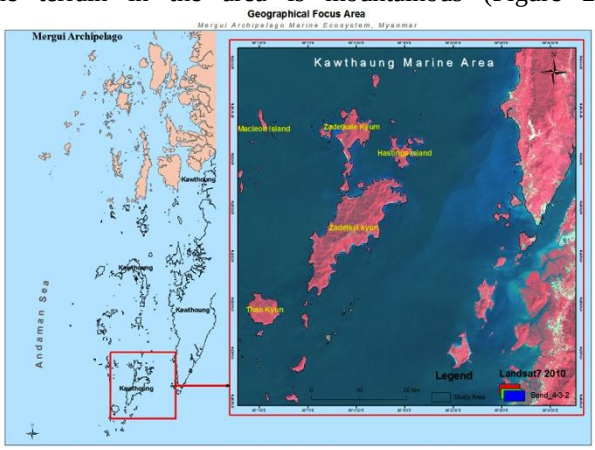

Figure 2: Study Area Extensions

3. MATERIAL AND METHODS

The capabilities of satellite remote sensing techniques have been assessed for generating temporal changes of coastal habitat mapping of southern part of Kawthaung marine ecosystem.

Coral reefs being placed in relatively clear water allow us to use passive optic sensors [8]. The more common satellite sensors that have been used to study this are SPOT, Landsat TM and ETM+ [9], [8], [10]. Studies previously conducted [11], [12] have observed that Landsat and high-resolution images are suitable for mapping corals, sands, and seagrass, depending on their resolution.

The geospatial data used in this study includes Landsat7 TM and two-meter resolution pan sharpened level 2A image of THEOS image (Table 1).

Table 1: Characteristics of Landsat7 and Theos Imagery used

Sensor	Landsat 7	THEOS Image
Data Acquired	3 February 2000, 1 January 2005, 14 February 2010	9 Sept 2011
Spatial Resolution	28.5, 15 m	2 m
Nober of Bands	8	4
Path	130	Datum: WGS-84
Row	53	Projection: UTM
Image Size	185 x 185 km2	22 Kilometers

Image processing

Building on this initial analysis, as a first step Landsat7 images from 2000, 2005 and 2010 and THEOS 2011 were processed. Before conducting the quantitative

analysis of the spatial data, a post-calibration was performed of the constant gain and offset to convert the image Digital Number (DN) to spectral radiance [11]. The spectral radiance was also corrected for atmospheric effects to obtain the surface reflectance values. A geometric correction was not applied in this study because the level of the processing of the Landsat images includes this correction. Only 3 of the 8 bands contained by Landsat were used and THEOS only 3 of the 4 bands (blue, green and red).

One of the most commonly cited difficulties with remote sensing of underwater environments is the confounding influence of variable depth on bottom reflectance [13]. The effects of variable depth water column correction applied [14], [15], [16], [17].

Producing habitat maps, the analyst was advised to manually segment the image in broad zones of interest to avoid areas of different thematic meaning, but with similar spectral signatures [18]. Habitat maps were then produced using supervised multispectral image classification [19]. The potentially risk areas were extracted by comparing the DN values of bands 1 and 2 between February 2000, January 2005 and February 2010 [20]. Using Landsat temporal data, we obtained a comparative uniform model for the retrieval of suspended sediment concentrations [21]. Image classification followed by a posteriori contextual editing. Image-Processing techniques ERDAS 9^X software was employed to determine the characteristic reflectance values of each habitat and GIS system used for producing effective thematic maps.

4. RESULTS AND DISCUSSION

Coral reef mapping

Abundant coral reefs are predicted in many places along the southern coastline of Kawthaung marine area by using earth observation data (THEOS and Landsat Images) in the year of 2011. The Coral reefs area maps obtain three classes altogether namely, shallow reefs, variable depth/non reefs and variable depth reefs. Most of the coral reefs are composed of fringing reefs (originating from mainland, islands or raised sea bottom). Patchy reefs occur on shallow sandy habitats. High concentrations of coral reefs or coral priority areas extracted include Hastings Island (Figure 3), ZadetkylKyun Island (Figure 4), and Zadetkalekyum Island (Figure 5).

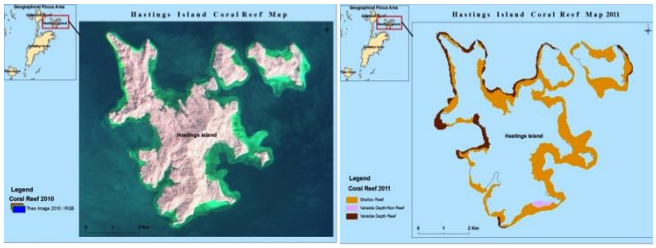

Figure 3: Distribution of coral reefs in Hastings Island

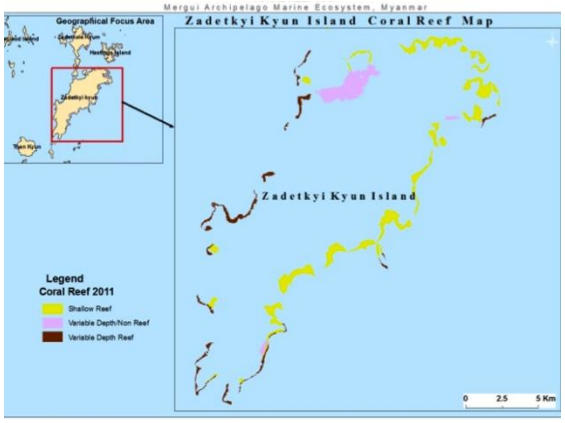

Figure: 4 Distribution of coral reefs in ZadetkylKyun Island

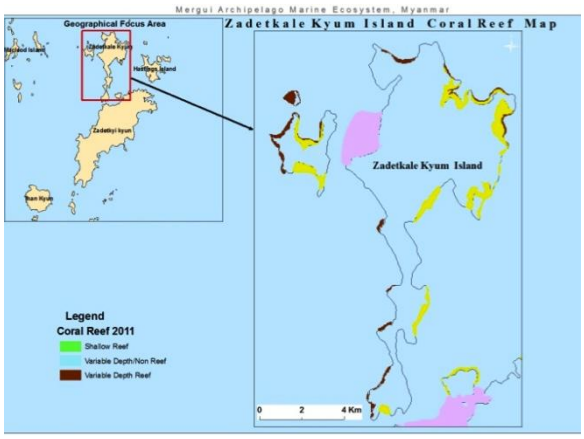

Figure: 5 Distribution of coral reefs in Zadetkalekyum Island

Hastings Island surrounding area has been found rich in coral reefs as compared to other islands (Figure 3) and fewer coral reefs areas were found around ZadetkylKyun Island.

Suspended Sediment (SS) mapping

The correlation between Suspended Sediment (SS) concentrations of marine area and the reflectance obtained from the Landsat images is significant. Through Landsat images obtained a comparative uniform model [21] for the retrieval of suspended sediment concentrations in the Kawthaung marine area, that is

$$\ln SS = a^* (R3/R1)+b \quad (1)$$

Where lnSS is the natural logarithm of the suspended sediment concentration, R1 and R3 are the reflectance coincident with the band 1 and the band 3 in Landsat images, a and b are the regression coefficients. After applying the models above, we obtained temporal (2000, 2005 and 2010) SS distribution in the southern part of Kawthanung marine area (Figure 6, 7 and 8). SS concentration maps get 6 classes altogether.

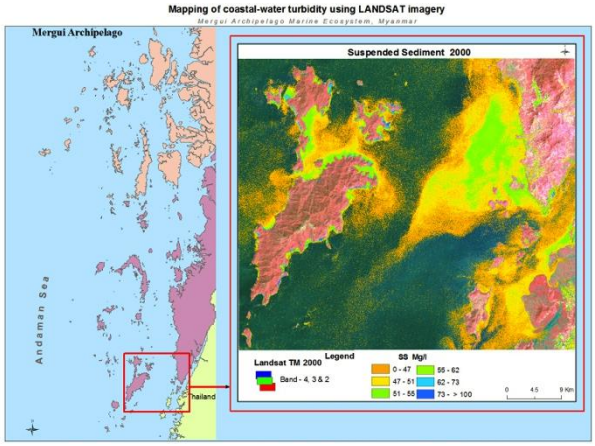

Figure 6: Suspended sediment distribution of Kawthaung marine area (March 2000)

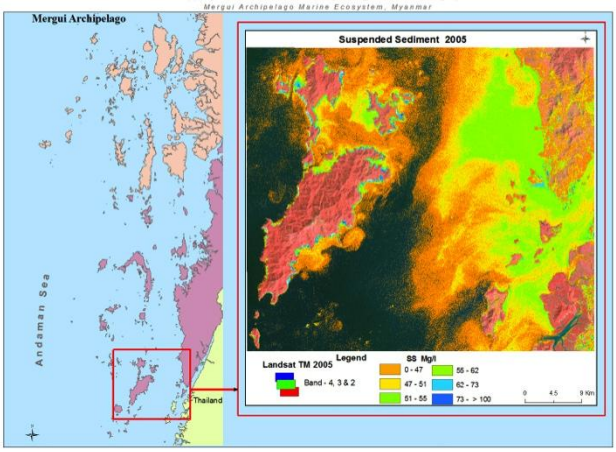

Figure: 7 Suspended sediment distribution of Kawthaung marine area (January 2005)

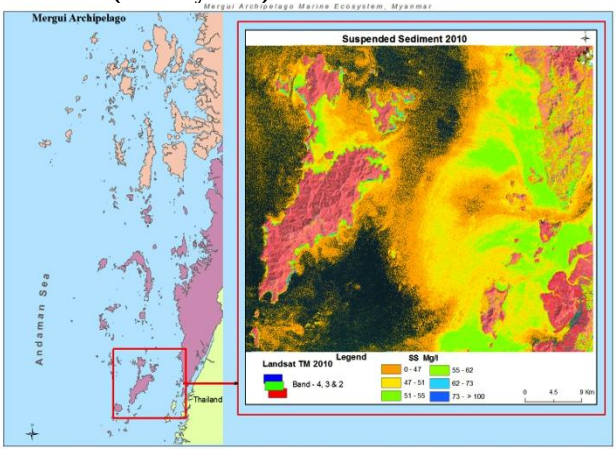

Figure: 8 Suspended sediment distribution of Kawthaung marine area (February 14 2010)

The content of SS is highly connected with the suspended sediment content carried from the islands with high elevations and rivers that are feeding into the sea. If soil erosion is serious in this drainage area, suspended sediment concentrations in the marine area are usually high. Figure 6, 7 and 8 shows that temporal variation of SS concentrations dramatically increasing from 2000 to 2010. In the year of 2010 SS concentration widely scattered (SS <40 to 100 mg/l) towards the islands where abundant coral reefs can be found in this area. In tropical islands with high elevations, terrestrial runoff can pose a severe threat to the health of surrounding coral reefs. The spatial distribution of SS concentration in Kawthanug marine area is clearly reflected by the remote sensing retrieved results.

Coral reef risk mapping

One decision support product is a risk assessment map, which shows to what level of stress the coral reefs are potentially exposed to due to land based pollution and human activities in the coastal area [1]. These risk levels are commonly grouped into three classes, being: low risk, medium risk, and high risk. Both a radiative transfer simulation and an analysis of multi temporal Landsat images were used to monitor reef risk areas. The radiative transfer simulation indicates that the blue and green bands of Landsat7 TM can detect coral reef risk areas. Potential area of coral reef risk in 2010 extracted using the difference of radiance from corals between February 2000, January 2005 and February 2010 in Zadetkale Kyum, Hastings and Zadetkyi Kyun islands in and around the study area (Figure 9, 10 and 11).

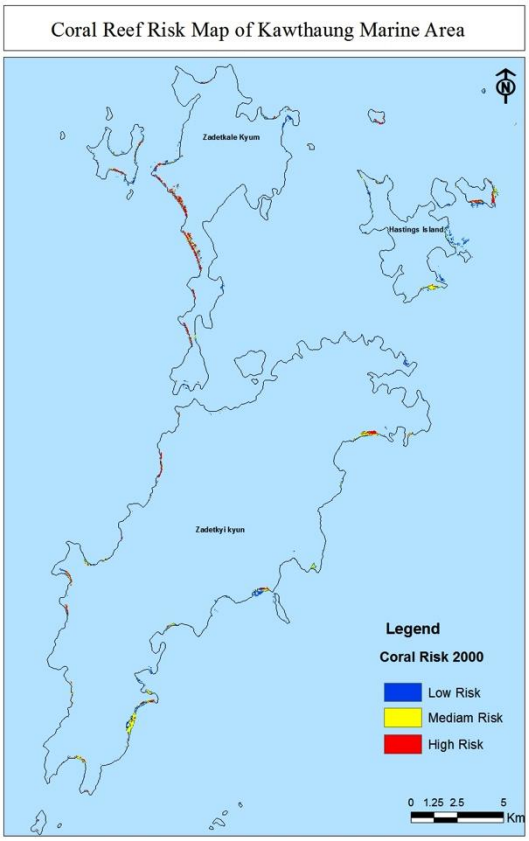

Figure: 9 Coral reef risk Map 2000

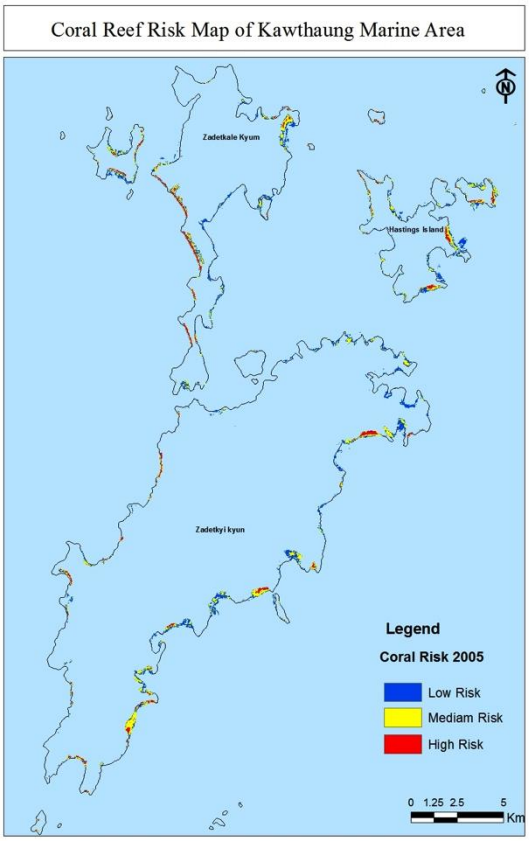

Figure: 10 Coral reef risk Map 2005

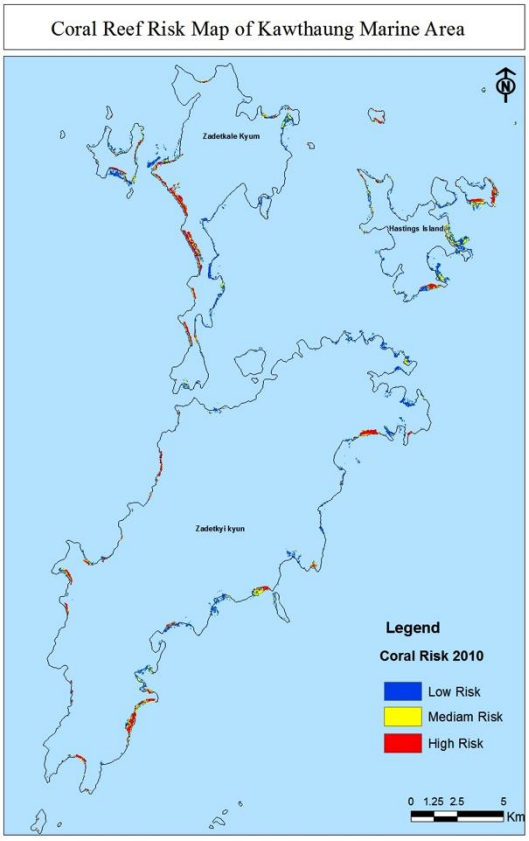

Figure: 11 Coral reef risk Map 2011

Sensitivity analysis on solar zenith angle, aerosol (visibility) and water quality (sedimentation mg/l) quantified the effect of these factors on coral reef risk detection, and thus served as general guidelines for detecting threatened coral reef areas. Coral reefs have been affected in Kawthaung marine area (Figure 9, 10 and 11), as per the evaluation of temporal remote sensing data (2000, 2005 and 2010). Reef risk is gradually increasing with the 2000 map showing less risk areas as compared to 2005 and 2010. The areas might have been partially affected by the Indian Ocean Tsunami of 26th December 2004. At Hasting Island surroundings of possible coral damage in areas with high risk coral coverage is much larger. While comparing temporal data we have found high risk of corals (Figure 11) in Hasting and Zadetkale Kyum islands and surrounding areas.

While there are many causes of coral reef degradation, such as coral mining, fishing with dynamite, or overfishing, coastal development or even careless pleasure diving by tourists, this research identifies areas at risk mainly from sedimentation.

5. CONCLUSION

The study of the multi temporal of Landsat and THEOS data analysis showed correlations between of coral habitats and their status and suspended sediment patterns, and coral areas' responses to changes in estuary environmental zone processes.

Image processing techniques, supervised and unsupervised classification methods have difficulties in detecting subclasses, that is, this type of classifier makes it complicated to detect pixels between shore line, sand and coral reef. When classifying benthonic habitats in the Kawthaung marine area, it was possible to observe that the classes with high concentration of pixels were mask by those with greater amounts object values.

In general, the data from remote sensors are used for mapping reef habitats, SS concentration and coral risk areas. The results show that the Landsat 7 images are able to identify different classes in submerged benthonic environments. Although the classification resulted in visually optimal results, the need to incorporate statistical validation of the data is important, so as to determine the accuracy of the classification performed in comparison to the reality; this was not possible for this study because an adequate database of in situ sampling was not available. However, because of the visual comparison with classes identified by studies and the consistency with the theory of the zonation of benthic bottoms based on depth, it can be concluded that the classifications obtained by image techniques successfully determined the majority of the benthonic cases defined in this study.

The spatial distribution of suspended sediment can clearly be shown in the remote sensing results. The obtained result can be used to estimate sediment loads and their distribution in the marine areas between the Islands and the main land.

It was demonstrated how remotely sensed can be used to detect the changes of coral reefs habitat. Using temporal Landsat images 2000, 2005, 2010; it is possible to monitor the historical changes of the coral reefs environments in the southern part of Kawthang marine areas. There has been coral reefs change between 2000 to 2010 in the study area. The accumulation of suspended sediments from the river and domestic pollution were identified as contributing to the degradation of the coral reef in this area. The result of this study is a good example on how time series analysis of remotely sensed

data can be a tool to monitor the changes in the state of critical coastal habitats and eco-systems that are impacted by coastal development.

Through this type of application of geospatial data analysis, it is possible to classify areas according to their level of exposure to risk/threats such as sedimentation.
This will help in identifying and pin-pointing priority areas for intervention aimed at conserving natural resources.. These data can be used as a basis for monitoring of reef areas. .

ACKNOWLEDGMENT

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Current Status of e-Waste Management in Vietnam: A Case Study of Ho Chi Minh City, Vietnam

Thao Quoc Tran and Alice Sharp

Abstract*—Each year, there are 20 to 50 million tonnes of household electronics and electrical wastes generated worldwide. Ho Chi Minh City (HCMC) also is the major source of e-waste. This paper reviews the e-waste management situation in the past through refurbishment/repair status, collection and disposal processes as well as the status of policy implementation and development. There are many gaps in e-waste management in Vietnam, HCMC in particular. Because the capacity of environmental management institutions in Vietnam remains weak and disproportionate to the tasks, this results in many serious problems. Problems in e-waste management in Vietnam are affected by the increase of industrial production and electronic consumer products, along with changing consumer's consumption trends. The growth in the electronics market will soon result in an increased number of discarded household appliances. The increase in consumer's demand also come with the demand to change to new devices. The study found the e-waste generation and the disposal activities are both rising at an uncontrollable rate in HCMC. The results also indicate that e-waste contributes to environmental contamination through their related activities, such as informal recycling and illegal disposal. The current management situation in HCMC could be improved by focusing on each E-waste management steps to fill the management gaps.*

***Keywords*— Environmental management, e-waste, Flow analysis, Ho Chi Minh City, Vietnam.**

1. INTRODUCTION

Along with the basic science foundation achieved, technology has developed many electrical and electronic devices to support humans in the evolution of mankind. The increasing number of electrical and electronic devices has grown with the "standard of living" and human demand. The change has affected the product life cycle flow. As a result, electronic devices and gadgets became the fastest growing waste stream in many countries from the 1980s to the 2000s.

For many people, electronics such as cell phones, laptops, TVs, and a growing number of gadgets are a part of modern life. With rapid changes of lifestyle or community trends, every year people replace new or updated equipment to support their needs. All of these electronic devices become obsolete or unwanted, often within 2-3 years of purchase. Each year, there are 20 to 50 million tonnes of household electronics and electrical wastes generated worldwide [1].

This paper describes the current status of waste electrical and electronic equipment (WEEE) in Ho Chi Minh City (HCMC), Vietnam.

HCMC, formerly named Saigon, has 19 urban districts and 5 suburban districts. At of the end of 2012, the total population of the city was 7,750,900 people, an increase of 3.1% from 2011 [2].

HCMC is the economic center of Vietnam and accounts for a large proportion of the economic growth of Vietnam. Although the city takes up just 0.6% of the country's land area, it contains 8.57% of the population of Vietnam and accounted for 21.97% of its GDP in 2013 [2]. Additionally, HCMC is also the major source of e-waste, from the Mekong Delta area and illegal import of e-waste from Cambodia. The amount of electronic and electrical equipment (EEE) in HCMC is up to 6,140 tonnes/year (including the "second-hand"), but recycling only about 98 tonnes of e-waste (1.6%), with entirely rudimentary approach [3].

The recommendations from this study will be based on a case study of HCMC e-waste situation put forward to provide better management of e-waste in Vietnam.

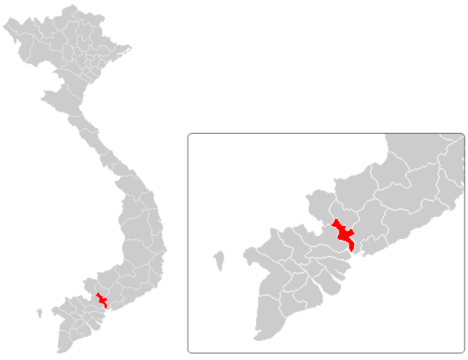

Fig.1. Location of HCMC in Vietnam

2. METHODOLOGY

The study reviews the current solid waste management situation in the past, especially in areas related to the sources and quantities of e-waste generated. In addition, the current management of storage, collection, transportation, treatment, and disposal is also included in order to progress to the next management steps.

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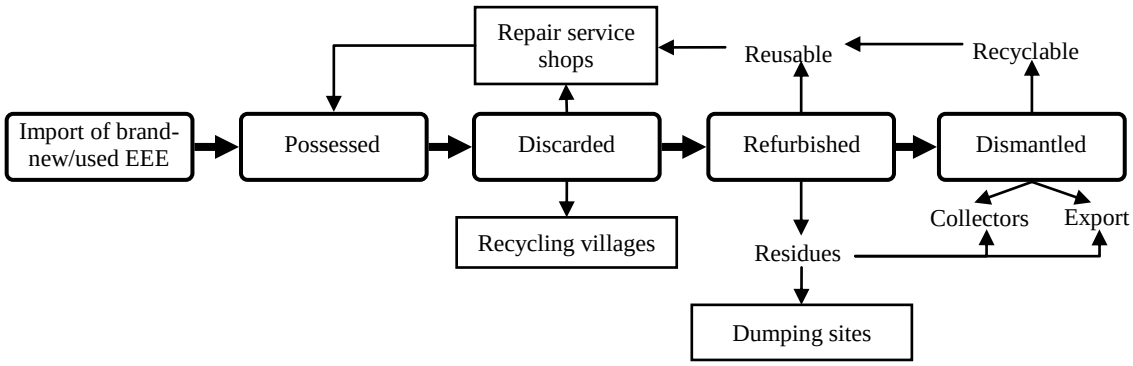

Fig.2. Flow Chart of EEE and WEEE in Ho Chi Minh City in 2012

This study investigates the inventory of e-waste for HCMC, Vietnam. Estimation was done based on the following secondary data:

- Data on amounts of e-waste generation and management of e-waste from some countries, regions in relevant fields of transboundary movement, generation, and import/export of waste electronics.
- Data on the discarded e-waste and collection process in HCMC.

Apart from collecting secondary data on the Vietnam e-waste situation, it is also important to compare the data with related research. The comparison of collected data with different cases will help in understanding the impact of e-waste on the environment, economy, and society.

3. REGULATORY FRAMEWORKS

Generally, the capacity of environmental management institutions in Vietnam remains weak and disproportionate to the tasks. The environmental managers and regulators employed in the system have been deficient both in number and qualifications.

The Law on Environmental Protection of Vietnam – the basis for the legal system of environmental laws, was passed by the Vietnam National Assembly on 27/12/1993 and came into force from 10/01/1994. It generally defines waste, scraps, and hazardous waste (Vietnam differentiates between wastes and scrap materials). The Law does not have a clear demarcation boundary to distinguish WEEE. E-waste was put under the list of hazardous waste. However, this section is now under the review process for amendment and the new Law will be promulgated in mid-2014 (the newest version has one article about the take-back regulation).

Together with this, the Government has also promulgated many laws and regulations concerning environment protection such as:

- Decrees approved by the Prime Minister:
  - Decree No. 80/2006/ND-CP detailing and guiding the implementation of a number of articles of the law on environmental protection;
  - Decree No. 59/2007/ND-CP on Solid waste management;
  - Decree No. 174/2007/ND-CP on the environment charge for solid waste;
  - Decree No. 12/2006/ND-CP, Decree 21/2013/ND-CP promulgating the list of scraps permitted to be imported for use as raw materials for production.
- Decisions by the Prime Minister:
  - Decision No 155/1999/QD-TTg, by the Prime Minister, on management of hazardous wastes: has clearly given the national definition of hazardous waste;
  - Decision No. 15/2006/QD-BTNMT promulgating the list of refrigerating equipment using CFC which are banned from import;
  - Decision No. 23/2006/QD-BTNMT about the list of hazardous wastes: Some e-waste was on the list;
  - Decision No. 20/2006/QD-BBCVT promulgating the list of used information technology appliances banned from import.
- Regulations and standards:
  - QCVN 07: 2009/BTNMT-National Technical Standard for hazardous waste thresholds: used to identify wastes that are suspicious for hazardous waste (replaced Standard for hazardous waste thresholds TCVN 7629: 2007).

4. E-WASTE MATERIAL FLOW

This study reviews the situation of e-waste collection and transportation management in HCMC. The aim is to assess the lifecycle inventory of e-waste through refurbishment/repair status, collection, and disposal processes (Figure 2).

The EEE enters the product lifetime from the EEE manufacturers' factory to user, which might involve one or several consecutive users (consumers), before the product reaches its end-of-life. EEE go through the possession of user/keeper before they are discarded or broken. The distributors and retailers are the producers' interface with the consumers and also are service providers in the repair service shops. In the case of used EEE, there are many sources reported, but the most important one is illegal imported sources, or the smuggling of used EEE.

The smuggling of second-hand EEE in the south of Vietnam is a little bit different from that in the north. In the south, a number of second-hand EEEs have been illicitly imported, mainly from Japan and the United States. Since May 2006, however, the ban on importing

such items has been tightened, and almost all the second-hand EEEs sold in the south now are smuggled in from Cambodia, where control over such items is much less [4].

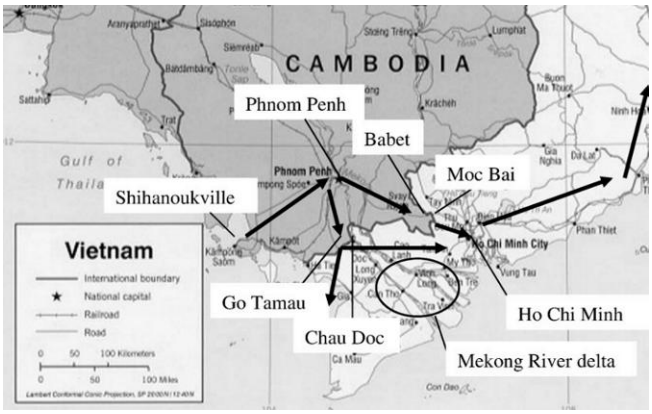

Fig.3. Waste stream of second-hand EEE in the south of Vietnam (Source: [4])

Some of these second-hand EEEs are smuggled into Vietnam through the border areas in the south between Vietnam and Cambodia. There are several smuggling places; huge amounts of second-hand EEE are smuggled, especially between Go Tamau (Cambodia) and Chau Doc (Vietnam), and between Babet (Cambodia) and Moc Bai (Vietnam) (Fig.3). HCMC is one of the best destinations for consuming illegal imported second-hand EEEs in the Mekong Delta River area.

According to the study of Thanh [5], after sorting, the e-waste stream in HCMC is divided into two major paths: domestic and export. The domestic path has a large amount of waste, and is taken to Nhat Tao Market for sale in the form of electrical and electronics components, or finished products with lower prices and quality. The rest is taken to some thrift stores and small repair shops for reassembly. For plastic and metal, they are sold separately to be recycled into other products. As for the export path: damaged circuit boards are purchased by Chinese e-waste traders.

The Nhat Tao market in HCMC is a central market for second-hand EEE. In HCMC Minh, one rarely sees the original imported television sets for sale. In most cases, the glass of the CRTs is polished and the original covers and printed-circuit boards are replaced by new ones [4]. Prices of second-hand equipment (Nhat Tao market) shown in Table 1 indicates the prices for completely damaged devices. But in other cases, used EEEs' prices depend on the conditions of those devices.

For devices that are damaged completely, they are sold for the purpose of material recovering. The size and weight of those devices affect the purchasing price. Besides size and weight, after dismantling of device components, the materials, including plastics, metals, circuit boards, and computer monitors also affect prices of damaged devices.

Table 1. The average prices of completely damaged EEE in Nhat Tao market, HCMC

Types of EEE	Price (thousand VND/unit)
PCs	200
Printers	200
Scanners	300
Photocopiers	500
Laptops	750
Mobile phones	65
Cameras	320
CRT TVs	160
LCD TVs	180
Fridges	400
Air conditioners	500
Washing machines	500

Note: 1 USD = 21,080,000 VND (in August of 2013)

In general, most of the processes involving: collecting, repairing, dismantling, and recycling of e-waste are mostly labor intensive and rudimentary. Most of the recycling, collecting, repairing, and dismantling facilities are very small, or a family-size business. Transportation of each collector depends on bicycles, motorcycles, tricycles, and small trucks (capacity of 0.5 tonnes). The number and types of vehicles depend on the size of the facility. Each facility has only 2 to 7 employees. At the workspace, the collector facilities primarily use their own available space: in-home area and front yard. This situation shows that the collection, removal and disposal of electronic waste in HCMC is spontaneous, self-employed and self-managed.

Despite the collection of e-waste, there is still a significant amount of e-waste disposed of as municipal waste. The method of municipal waste collection varies at different places. In the urban districts, citizens place their waste out on the open gutters of the street in front of their dwelling for urban environmental company (URENCO) employees to pick up. The trash is transported by handcarts that the URENCO collectors push on foot door-to-door. When the handcarts, which have a capacity of 0.4 m^3, are full, they are pushed to a designated transfer station not far away where a waste truck takes the waste to the nearest dumpsite or landfill. In places where there are no transfer points, residents are provided with a communal containers and are responsible for disposing their waste into the containers. A URENCO truck comes by daily to unload the communal container and transport them to the dumpsites. Suburban districts have a similar process.

Generally, material flow of e-waste in HCMC depends on two factors: a user factor and an after-disposal stakeholder factor. A user of an EEE/ household appliance decides how to dispose at e-waste. For the common user's options, there are five main routes for a discarded appliance: sell or pass to another user, recycle at repair

shops, recycle at collector facility, keep at home, and directly dispose of at dumping sites (the owner can dispose of an appliance at designated garbage collection points) [6]. These are generally the common end-of-life options in developing countries. For after-disposal stakeholders, there are 3 sectors that have contributed to collecting, sorting, repairing, dismantling, and recycling of used EEE.

For collection of WEEEs, normally, WEEEs are collected by an in-home service of a facility. The rest is received from personal collectors. After gathering WEEEs, a collection facility conducts classification. After sorting, repairable devices are sold to a thrift store, and the rest are mainly for dismantling.

For repair service shops and thrift stores where components from used EEE are assembled, a majority of collected devices is from households, the rest is from collectors and collection facilities. For equipment that was damaged, it is dismantled at a repair shop, or is sold to collectors and collection facilities. There is almost no disposal as municipal waste in this sector.

For a dismantling facility, currently, the dismantling activity is mainly focused on disassembling of waste electronic devices. Moreover, they still dismantle many kinds of waste that have recoverable material. Most of the dismantling activity is conducted by a collector, collection facility, or repair shop. They sort and sell to other remanufacture facilities (plastic, metal, screen, circuit boards, etc. are the most recyclable materials).

5. E-WASTE GENERATION IN HO CHI MINH CITY

Problems of E-waste management in Vietnam are affected by the increase of industrial production and electronic consumer products, along with changing consumer trends. Vietnamese consumers have changed their lifestyle because Vietnam is in a period of strong economic growth. The growth in the electronics market will soon result in an increased number of discarded household appliances.

Major appliances and media devices indicate the standard of living in urban Vietnam. We can assess the level of urbanization through the level of property and equipment in urban areas. As surveyed by Taylor Nelson Sofres (TNS) market research Company (Fig.4), TNS Vietnam shows that in urban areas, the most commonly used appliances include computers (PC), washing machines (WM), refrigerators (RF), DVD players, cellphones (CP), and color televisions (TV). HCMC is the representative urban model with high-speed urbanization in Vietnam.

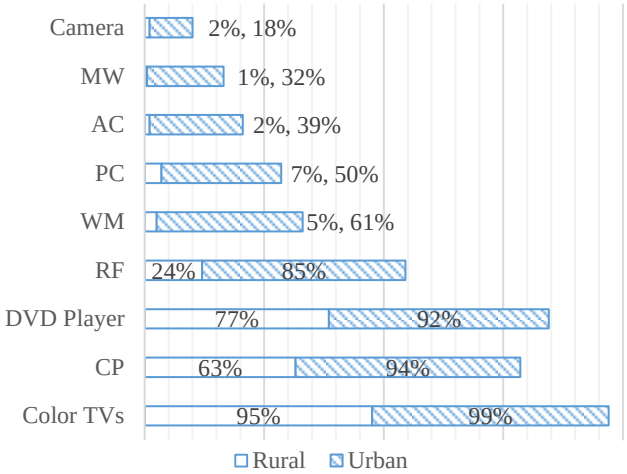

Fig.4. Urban and Rural Durable Ownership (source: [7])

In other research on "Consumer awareness of electronics products" (W&S Online Market Research, 2012), survey results are shown in Fig. 5. Most electronics products that are most widely used as domestic electronic appliances in Vietnam were imported from 4 countries: Japan, China, Korea, and Thailand. Japan has contributed the highest percentage (69%) of imported electronics products. Second place belongs to the domestic consumer electronic products - Vietnam and China, accounting for 8.2% each. Following these were products from Korea (6.1%) and Thailand (3.4%).

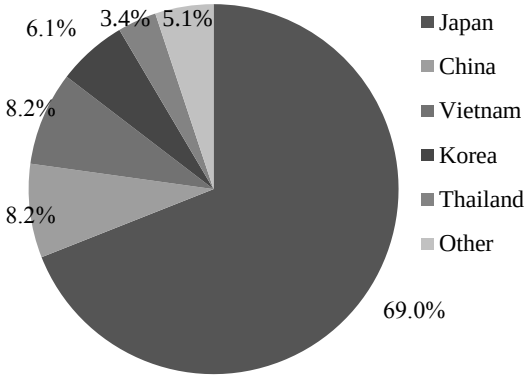

Fig.5. Electronic appliances used the most in Vietnam by country (source: [8])

While consumer electronics products from China are unpopular in the HCMC area (only 8.3%), there are many users in Da Nang (50%) and Hanoi (41.7%) (Fig.6). In Hanoi, consumer electronic products from Thailand and South Korea account for more than two provinces, HCMC and Da Nang.

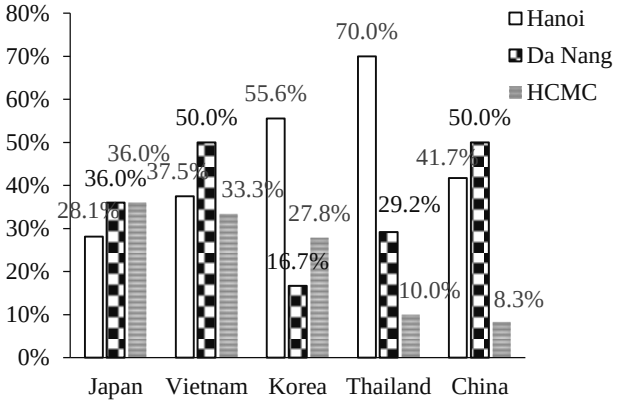

Fig.6. Popular electronics purchase by provinces (source: [8])

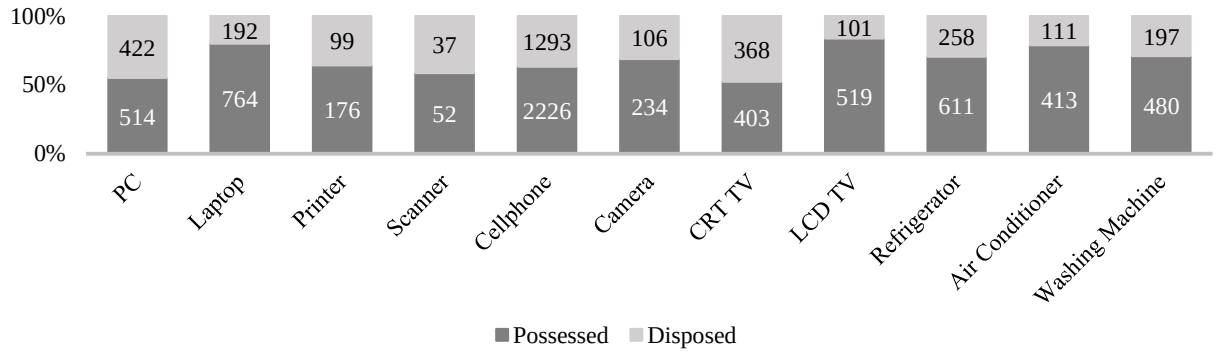

Fig.7. Comparison of Possessed and Disposed EEE in Ho Chi Minh City in 2002 – 2012 (Source: [5])

The Vietnamese industry may struggle to find a place in the domestic market. Foreign investors have already started to close down manufacturing operations in Vietnam due to many government regulations aimed at helping domestic enterprises. By some assessments, the local electronics industry has made little progress in the last 10 years and is limited mainly to assembly and packaging. Most Vietnamese brands lack a distinct identity or wide distribution outside of rural areas. However, those companies that do manufacture find it is hard to compete with a wave of cheaper imports, and some have already announced plans to switch to be distributors for products made abroad. This has increased the amount of imported products in big retail markets of Vietnam. HCMC is one of biggest retail markets in Vietnam.

The proportion between owned and disposed of household devices in HCMC during the past 5 – 10 years (Figure 7) shows that all devices being used are more than double the amount that were discarded. Desktop computers and CRT TVs tend to be used less than laptops, LCD TV, and air conditioning products (accounting for > 80%). Figure 7 also shows the potential waste that will increase quickly in the future. Mobile phones which have the highest amount of possessed units, will be a major source of electronic waste in HCMC.

Therefore, computers and mobile phones are two major sources of used EEE in HCMC. From several market research projects, the development of computer and mobile phone markets is rapid in Vietnam. Particularly, the General Statistic Office (GSO) reports 3 quarters in 2013 for computers, electronic products, and components: 2,107.1 million units, an increase of 14.7%. The business sector foreign investment accounted for 98.5%, up 14.2%; the domestic sector accounted for 1.5%, up 67.9%. The foreign vendors still take a large market share (Table 2).

Table 2. Top 5 PC vendor's market share in Vietnam in 2012 (Source: [9])

PC Vendor	Market share (%)
ASUS	17.8
Dell	15
Acer	10.2
HP	9.1
Lenovo	6.2

Vietnam's PC market grew significantly by 20.5% sequentially and 3.4% year-on-year to reach 638,000 units in the fourth quarter of 2012. According to International data corporation (IDC) Vietnam Quarterly PC Tracker reported that nearly 500,000 PCs were shipped in the first quarter of 2013 (1Q13), a decrease of 20% sequentially but a growth of 13% annually (Figs. 8 and 9).

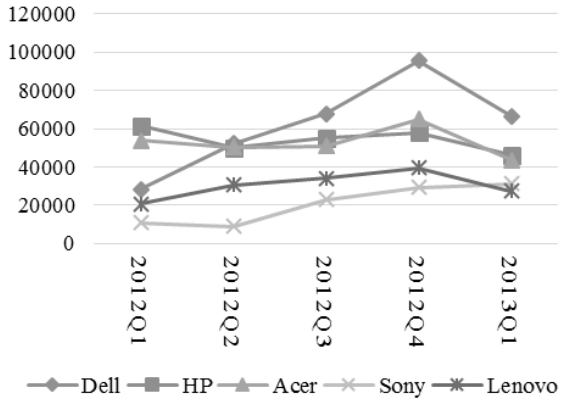

Fig.8. Vietnam Top 5 PC Vendors' Share, 2012Q1 – 2013Q1 (Source: [10])

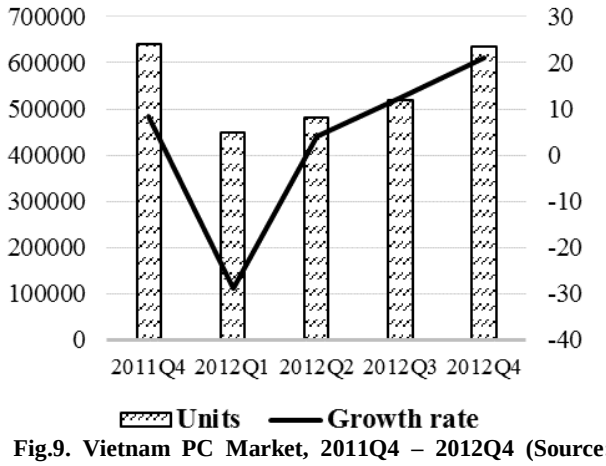

Fig.9. Vietnam PC Market, 2011Q4 – 2012Q4 (Source: [11])

Anticipation of growing consumer demands in Vietnam spurred vendors to increase consumer PC shipments. HCMC's retail market is growing rapidly amid increasing foreign investment and rising personal income.

Desktop sales remained in negative growth territory. The depreciation of Vietnamese dong (VND) restrained demand, leading to higher prices for imported laptops. Vendors reported the number of first-time buyers in the market was relatively limited, with most sales coming

from purchases of lower-priced computers.

PCs entering in Vietnam were estimated by Business Monitor International (BMI) at around 18% in 2011. Notebooks are owned by an estimated 7% of the Vietnamese population. The potential growth of the local PC market lies in rural areas. Currently, Hanoi and HCMC are thought to account for around 85% of notebook sales [12].

Table 3. Computer demand in 2008 – 2016 (Source: [13])

Year	Desktop shipments (thousand unit)	Notebook shipments (thousand unit)
2008	1,042	666
2009	819	887
2010	758	1,186
2011e	692	1,541
2012f	734	1,888
2013f	815	2,319
2014f	907	2,873
2015f	1,038	3,477
2016f	1,197	4,244

e/f = BMI estimate/forecast

The notebooks' share of the total PC market has grown rapidly over the past five years and in 2012 is forecast at around 70% (Table 3). Meanwhile, desktop shipments have seen a corresponding rapid decline in their PC market share and are expected to account for fewer than 30% of units sold in 2012, down from above 70% five years ago [12]. Desktop PCs have become popular and affordable home appliances in Vietnam from past 10 years, but the disposal ratio leans to laptop PCs. Changing possession of desktop PCs by laptop PCs, which have shorter lifespan, will be a potential source of e-waste in the future.

Same as the computer market, mobile phones have had significant development during the past 10 years. A survey of electronic brands in Vietnam in 2007 by URENCO [14] and GSO [15] found that the rising consumer demand began from 2001 and got the leap in 2002 and 2003. The mobile phone market has a steady development from 2005 until now.

A report from research company IDC showed that in quarter 2/2011 Vietnam imported 4.3 million mobile phone handsets, including feature phones and smartphones. That is 22.5% lower compared to quarter 1/2011, and decreased 13.5% compared to the same period last year.

Nokia is still selling a lot of phones in Vietnam, accounting for 52.94% of the market. The Vietnam mobile phone market experienced a sequential decline of 18% in the second quarter of 2012 but still registered double-digit growth of 10.9% annually (Fig.10). This freefall can be summarily attributed to the pause in consumer purchasing in light of inflation and recession, which have hindered disposable income in Vietnam. Feature phone shipments recorded a significant decline at 20.3% while smartphone shipments fell 4.1% despite the continued shift to smartphones amongst Vietnamese consumers.

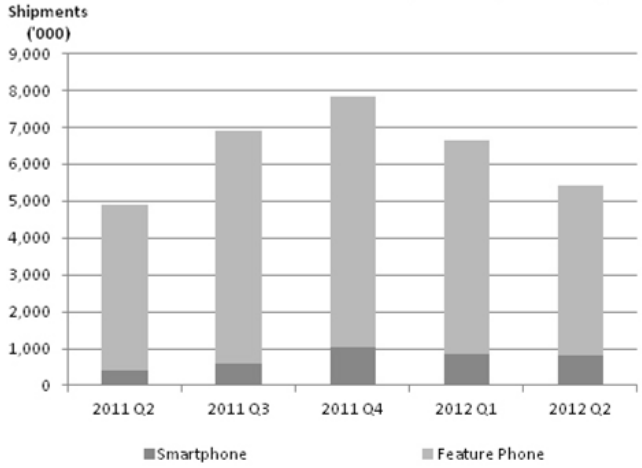

Fig.10. Vietnam mobile phone market, 2011Q2 – 2012Q2 (Source: [16])

Along with IDC, Vietnamese market mobile handset sales are projected by BMI at 17.1 million units in 2012. The addressable market is expected to grow at a compound annual growth rate of 16% to 30.7 million units in 2016 (Table 4). This rate of growth is greater than that of leading neighbor China [12]. Vietnam has a high rate of mobile phone ownership compared with other countries in Asia. According to research by Nielsen market research firm, exactly 58% of urban residents and 37% of suburbanites have a mobile phone. The figure for Hanoi and Ho Chi Minh City is 74%. This compares with country figures of 46% for China and 30% for India [12].

Table 4. Mobile phone demand in 2008 – 2016 (Source: [12])

	Mobile communications subscribers (million)	Mobile access (%)	Domestic handset sales (million)
2008	74.9	87	8.2
2009	98.2	113	8.8
2010	111.6	127	11.5
2011e	117.6	132	14
2012f	122.3	136	17.1
2013f	126.0	139	20.2
2014f	128.5	140	23.5
2015f	131.1	142	27
2016f	132.4	142	30.7

e/f = BMI estimate/forecast

The market is dominated by demand for low-cost phones and total sales in this segment increased in 2011, boosted by expanding local production of low-cost handsets and the presence of low-cost phone vendors such as Mobell, and K-Touch (Table 5). Competition and growth in low-cost phones are also sped up by providing long-term maintenance service and many fake designs similar to other popular brands. However, even if citizens have doubts about the quality control as well as the

reliability of service, these do not significantly affect the growth rate of this sector due to the short lifetime of products and cheap prices. Low-cost phone users are able to change devices easily. This also will contribute to rising e-waste sources in the near future.

Table 5. Top 5 Phone vendor's market share in Vietnam in 2011 (Source: [9])

Phone Vendor	Market share (%)
Nokia	52.94
Samsung	8.73
Viettel	4.68
K-Touch	4.61
Mobell	4.47

Demand for mobile phones is growing fastest in provincial cities beyond the major hubs of Hanoi and HCMC. The investment in network expansion and improvement has had a positive impact on service quality and coverage in rural areas, where three-quarters of Vietnamese live. However, HCMC and Hanoi still comprise more than 40% of total handsets sold, with HCMC accounting for more than 25% of sales [12].

For other devices, TVs have become the most popular and affordable home appliance in Vietnam. The disposal ratio is also the highest among other household appliances [4]. Vietnamese are spending more time in their homes for leisure and entertainment, as most urban Vietnamese all have purchased TV's, Stereo's, VCR's, and fixed line phones over the last decade.

The increase of consumer demand also comes with the changing of old devices which have feature obsolescence and aesthetic obsolescence. Discarded refrigerators, washing machines, and air conditioners are not popular in the low-income groups, and rural areas, which show that the generation of these groups of e-waste is in big cities of urban area, e.g. HCMC. This fact indicates that refrigerators, washing machines, and air conditioners are popular only among high-income households, who live in the developed urban areas.

6. GAPS OF E-WASTE MANAGEMENT IN VIETNAM

The regulation of e-waste management operators, industries, and activities suffers from major gaps in:

- Lack of enforcement and insufficient supervision of waste management practices.
- Limited human resources, unclear mandates, fragmented and overlapping roles of various government agencies, and limited interagency coordination.
- Limited incentives for proper operation of landfills or investments by industries in waste treatment. Allowing inexpensive, unsafe methods of disposal such as open dumping to proliferate.

With special characteristics of e-waste that are a part of the production process, e-waste generation is unavoidable. Finding a solution to E-waste management is necessary.

However, since Vietnam has only outdated treatment systems in craft villages with low capacity and low efficiency, the rapid increase in e-waste will soon cause harmful effects on the environment and public health, as seen in India and China at the present time, unless proper treatment systems are introduced. From the standpoint of material recovery also, Vietnam, in the absence of proper treatment systems, will miss out on acquiring valuable resources of precious metals, which may flow to China, as is the case now. The domestic producers, assemblers, importers and businesses in EEE have a responsibility to take back the products for treatment, known as extended producer responsibility (EPR). However as a study on e-waste inventory in March 2007 by URENCO [14] stated, from over six months of observation, almost all the domestic producers do not have any specific actions for taking back their products in Vietnam.

Recently, the government has provided many regulations and activities to strengthen take-back action in producers. In 2006 the government established new environment police agency to forbid illegal activities related to environmental protection law. Law enforcement activities of environment police agency became more effective from 2009. However, it still could not avoid the restrictions of bureaucratic scandals in recent time.

7. CONCLUSIONS

E-waste has special characteristics, such as the environmental intensity of manufacturing processes that indicate a need for a more systematic management approach. The difficulty in assessment of generation trends is affected by many factors, such as the difficulty to access information sources, and dependency on the interests of government and society. The current management situation in HCMC could be improved by focusing on each e-waste management aspect: informal recycling with a systematic process, generation rate, awareness of reuse, and environmental impact.

While the formation of the legal system remains uncertain, there are many shortcomings of definitions, specific laws and guidelines for e-waste. Emphasis of policy on trade bans has caused negative impacts on employment and the standard of living, and positive impacts on avoidance of pollution. The difficulties in enforcing trade bans seems to be the increased involvement of organized crime, e.g., smuggling of used EEEs and harmful products. In the other hand, the complete ban of second-hand EEE generates loss of reuse values and increases the flow of resource inputs. So the question here is should or should not have the best policy is to prevent completely the circulation of second-hand EEEs and E-waste scrap for the sake of the environment.

Due to the increasing domestic generation of electronics in consumers market in Vietnam, HCMC is the largest economic center of the country, as well as the major source of e-waste. The management of e-waste is not currently focused. The results show that e-waste generation and disposal activities are both rising at an uncontrollable rate in HCMC. The results also indicate that e-waste contributes to contamination through related activities, such as informal recycling and illegal disposal.

Vietnam lacks reliable data, especially in long-term research, as there is a lack of manpower, transportation, instruments, and funding. Currently, the HCMC e-waste

situation is under-researched with very little information on e-waste generation and estimation. The fact remains that unless there is a major change in the environmental conditions, e.g., water pollution in Thi Vai River in September 2009, reaction of responsible organizations is still in a passive state.

In order to ensure that e-waste scrap is not recycled improperly, it is necessary to set up a traceability system as well as improve EPR management systems. In fact, a traceability system has been tested by using GPS equipment, digital cameras, IC tags, and bar codes. Alternatively, eco-friendly product designs can also reduce the environmental pollution caused by recycling e-waste scrap. For EPR, a management role for the government is also highly recommended.

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APPENDIX

Explanation of stakeholder involvement in e-waste material flow:

- The individual collectors will collect used EEE from households and send to the medium and big collectors for repair, refurbishment, and sales. Almost all small collectors do not have any registration for their actions.
- The collection facilities always collect from offices. They are medium and large cooperatives or companies. Contracts for collection facilities will be established after offices call and find the best collectors for used EEE. The collectors will keep in touch with the offices for used EEE collection. Collection facilities also conduct sorting and dismantling activities as well as cooperate with other repair shops to provide more service.
- The dismantling facilities sell recyclable materials to the recyclers and reusable parts to repair and refurbishment shops. There are some residues from this activity and they are disposed of as municipal waste to dump sites or not properly treated. The disposal of such residues is one reason for environmental problems in recycling villages in Vietnam.
- The repair service shops and thrift stores buy used EEE and reusable parts from users, importers, collectors, and dismantlers for repair and refurbishment. Their products are sent back to the market, and the lifetime of used EEE can be increased via this activity. With used EEE, which customers bring to shops for repair only, all EEE repaired by the repairers will be warranted for operational ability, as used EEE.

Microwave-Assisted Solvent-Free Synthesis of Carboxylic Acid-modified Chitosan and Its Application as a Bioadsorbent for Selected Heavy Metals

Nopparat Plucktaveesak and Onnicha Kanchanamayoon

***Abstract*— *In this study, chitosan extracted from shrimp shell wastes was modified with various carboxylic acids via microwave-assisted solvent-free technique. These modified chitosan samples were then applied to act as bioadsorbent for the removal of heavy metal ions from solutions. The heavy metal adsorption ability was investigated with varying two factors namely metal solution's pH and polymer concentration, using UV-visible spectrometer. The results reveal that chitosan samples, modified with different organic acids, show different adsorption selectivity property. To take up Cu(II) or Co(II) ions, succinic acid-modified chitosan shows the best results. On the other hand, adipic acid-modified chitosan gives the highest Ni(II) ion uptake capacity. Compared among heavy metals selected for this study, the polymer exhibits the metal ion uptake capacities for Cu(II) > Co(II) > Ni(II). When compared with unmodified chitosan samples, the organic acid-modified chitosan samples show either comparable or better metal ion adsorption capacities than that of unmodified chitosan samples. The results from this study indicate that organic acid-modified chitosan samples can be easily prepared from wastes with the properties that can be used as a biomaterial adsorbent for the removal of some common heavy metal ions from contaminated water*..

***Keywords*— Biomaterial adsorbent, Contaminated water, Microwave-assisted free-solvent technique, Organic acid modified chitosan.**

1. INTRODUCTION

One of the environmental issues that most countries are facing nowadays is the water pollution caused by the direct or indirect discharge of heavy-metal-containing substances into water without a proper treatment [1]. These heavy metals are non-biodegradable and can accumulate in animals living in that contaminated water or in human beings who either have come into contact directly or indirectly with that contaminated water. The accumulation of these heavy metals in human beings is known to cause various diseases and mutations. One filed of research approaches to tackle this issue is to find better materials that can be used to adsorb those metal ions, so that they can be removed from contaminated water. Numerous studies have been conducted on various types of adsorbents following this approach. Low-cost agricultural and industrial wastes have been the main focus due to their availability, cost efficiency, metal-removal capability and biodegradability [2-3].

Chitosan and its derivatives are among those materials with high potential of being practical biosorbents [4-9]. In many countries especially the world's four largest shrimp producers including Thailand, Vietnam, China, and Indonesia, the chitin-containing wastes such as shrimp and crab shells are abundantly available. These wastes are the good starting material for the preparation of chitosan with low cost. This biopolymer has drawn particular attention due to its binding capacity with metal, availability, low cost, environmental friendly and chemical stability. Although, chitosan already shows considerably high adsorption capacities for various metal ions such as Pb^{2+}, Hg^{2+}, Zn^{2+}, Cu^{2+}, and Pt^{6+}, the adsorption are still too low for some metals such as Cr^{6+}, Ni^{2+}, and Cd^{2+} [3]. Several attempts have been done to improve its metal-removal performance especially by various chemical modifications [2]. The modification of chitosan has been done in broad spectrum ranging from the substitution with various small functional groups to crosslink with complex agents [4].

In this study, we present another class of chemically modified chitosan that can be prepared easily using one-step-environmental-friendly synthesis technique. This technique uses microwave heating without any organic solvent added. The main advantages of this technique over conventional synthesis are shorter reaction time and greener procedure [6]. The obtained modified chitosan samples show a potential to be used as a biosorbent for the removal of those toxic pollutants from water.

2. EXPERIMENTAL

2.1 Materials

Shell wastes from various species of seawater shrimp were collected from local consumption and used without being sorted. These shells were sundried and then crushed using a food processor before being used. Citric acid, succinic acid and adipic acid were analytical grade

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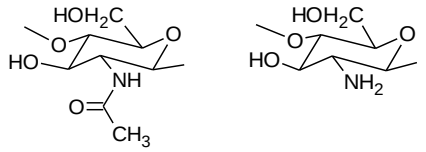
(from Fisher Chemical) and used without any further purification. All heavy metals, i.e., Cu(II), Co(II), and Ni(II) were in the form of nitrate compounds (from Sigma-Aldrich), which were dissolved in deionized distilled water with the concentration range chosen for this study.

2.2 Chitosan extraction

Several extraction procedures previously reported in literatures were employed [10-12]. In general, the procedure was started with the extraction of chitin from dried shrimp shells by performing demineralization and deproteination using diluted HCl and NaOH solutions, respectively. The obtained chitin was dried and then going through deacetylation process using more concentrated NaOH solution at high temperature to remove acetyl group as shown in Fig 1. The crude chitosan was used without any further decolorization.



(a) (b)

Fig. 1. The chemical structures of (a) Chitin and (b) its deacetylated form or Chitosan.

2.3 Finding optimum reaction condition for microwave use

The microwave-assisted solvent-free technique was employed to prepare carboxylic acid-modified chitosan samples. In this technique, a typical household microwave oven was used [6]. The required amount of purchased chitosan sample (from Sigma-Aldrich) was placed in a beaker and mixed thoroughly with each of selected carboxylic acid namely citric acid, succinic acid and adipic acid with the equivalent mole ratio of 1:1. Two factors i.e., power and microwave radiation time, were varies to find an optimum condition for the modification of chitosan. Two heating power sets of microwave radiation were chosen at 100 and 180 watts. At each power set, the radiation time was varied for 5 and 10 min. The obtained samples were washed with deionized distilled water at 60 ^{o}C to remove excess amount of unreacted carboxylic acid and then dried in the oven at 60 ^{o}C before use. With the modification of chitosan with citric acid, the adsorption capacity of Cu^{2+} was highest when chitosan that was modified under the microwave conditions of 180 watts for 10 min was employed. Therefore, we used these conditions for the modification of our own extracted chitosan samples.

2.4 Preparation of organic acid-modified chitosan samples

The procedure to apply the microwave-assisted-solvent-free synthesis to modify chitosan sample was as described above. Four selected organic acids i.e., citric acid, succinic acid, and adipic acid were studied. These organic acids are di-carboxylic acids except citric acid, which contains three carboxyl groups. All of the obtained samples maintained their original colors, which were brown or off-white colors indicating that no decomposition of chitosan occurred during heating. The obtained samples were washed with deionized distilled water at 60 ^{o}C to remove excess amount of unreacted carboxylic acid and then dried in the oven at 60 ^{o}C before use.

2.5 Heavy metal ion adsorption capacity determination

The determination of heavy metal ions i.e., Cu^{2+}, Ni^{2+}, and Co^{2+}, adsorption of modified chitosan samples was done by using UV-Visible spectrophotometry technique. The solutions containing these heavy metal ions with desired concentration and various pH's were prepared. The equal amount of carboxylic acid-modified chitosan samples was added to these solutions, shook at 300 rpm for 10 min. and left overnight to ensure the maximum adsorption had reached, at room temperature. On the next day, the mixture was centrifuged and the liquid part was taken for the adsorption measurement.

3. RESULTS AND DISCUSSION

Table 1 shows the metal ion adsorption of selected carboxylic acid-modified chitosan samples compared with unmodified chitosan at various solution's pH's. The values are the ratio of UV-Visible adsorption at specified wavelength of solution with modified chitosan as adsorbent to that of without any adsorbent.

Table 1. The metal ion uptake (in %) of modified compared with unmodified chitosan at various pH's of metal ion solutions

Metal Ions	pH	Modified Chitosan			Unmodified Chitosan
		Citric Acid	Succinic Acid	Adipic Acid	
Cu^{2+}	1.3	0.0	0.0	0.0	N/A
	2.0	15.2	20.1	20.9	N/A
	4.8	6.4	25.2	20.4	29.1
Ni^{2+}	1.2	0.0	0.0	0.0	N/A
	2.0	1.8	0.0	0.0	N/A
	4.9	3.2	1.6	4.9	0.0
Co^{2+}	1.3	0.0	0.0	0.0	N/A
	2.0	2.1	1.4	0.0	N/A
	3.2	4.5	21.4	9.0	7.3

N/A means the data were not determined.

By comparison between carboxylic acid-modified chitosan and unmodified chitosan for a given pH of solution, the capability to remove heavy metal ions of modified chitosan is either comparable or better than that of unmodified chitosan as shown in Fig. 2.

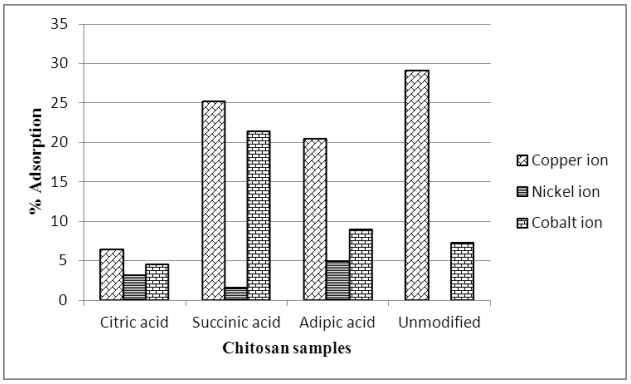


Fig. 2. The metal ion uptake of carboxylic acid-modified chitosan samples compared with that of unmodified chitosan. The pH of metal ion solution was ~3-5.

This partially is due to the fact that our modification is to change some of the hydroxyl groups to carboxyl groups, which can enhance the adsorption capacity of metal ions. However, it is possible that some of amine groups could be changed to amide groups as well. Although, there are no data of how many percentages of each group that had been reacted with added carboxylic acid, we believe that our modified chitosan samples contain all three functional groups i.e., amine, hydroxyl and carboxyl groups.

In particular, the removal of Ni^{2+} by all of modified chitosan samples is more effective than that of unmodified chitosan. In this case, the best choice for adsorbent is adipic acid-modified chitosan at pH~5. Comparing among those modified chitosan samples, succinic acid-modified chitosan is the best sample for the removal of both Cu^{2+} (which is comparable to unmodified chitosan), and Co^{2+} at pH~3-5.

Moreover, as shown in Table 1, the capability of these modified chitosan samples to remove the selected heavy metal ions depends strongly on the pH of solution. At pH~5, which is the original pH of prepared metal ion-containing solutions (except for Co^{2+} solution, whose original pH is about 3), the performance of these modified chitosan samples are the best. The reduction in metal ion adsorption at low pH is probably due to the fact that at low pH metal ion might have to compete with hydronium ion (H_3O^+) to combine with the amine group of chitosan. These results reveal that to apply these modified chitosan for the removal of these metal ions, the pH of the solution has to be checked.

4. CONCLUSION

The modification of chitosan with various types of organic acids via microwave-assisted technique under solvent-free conditions was successfully achieved. The obtained organic acid-modified chitosan samples show a potential for being used as an environmental friendly biomaterial adsorbent for the removal of some heavy metal ions from contaminated water. Although, the obtained adsorbents do have some limitation when applied to tackle certain heavy metal ions, the results do provide some guidelines for further improvement of these materials to be suitable for actual use in wastewater treatment.

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Guidelines for E-Waste Environmental Pollution Prevention and Control of China

Li Liang and Alice Sharp

***Abstract*— *E-waste is a newly emerged solid waste. Due to the advent of technology, electrical and electronic equipment or tools have become a daily necessity worldwide. As such, different countries need to develop policies suited their unique technical, cultural and environmental needs as to how to reduce, reuse, and recycle the e-waste. China promulgated a policy on "Guidelines for Electronic Waste Environmental Pollution Prevention and Control", which has a total of 26 articles in five chapters. The guidelines on dissemblance, utilization, and treatment of e-waste targeting six major groups, including manufacturers, importers, distributers, utilizers, dissemblers, and recyclers were studied. Also studied were the monitoring and management of dissemblance, utilization, and treatment of e-waste; responsibilities of related parties; and the penal codes and enforcement actions. Lack of enforcement data on the actual fines or other enforcement actions taken against violators makes it difficult to evaluate the effectiveness of the guidelines in preventing or controlling environmental pollutions caused by transboundary movement, improper disposal, dissemblance, utilization or treatment of e-waste. Thus, only through comparisons with the comparable laws, rules or guidelines adopted by other countries in the Greater Mekong Sub-region can the strengths or weaknesses of the e-waste management guidelines established in China be better understood.*

***Keywords*— China, dissemblance, e-waste, guidelines, treatment, utilization**

1. INTRODUCTION

E-waste is a newly emerged solid waste. Due to the advent of technology, electrical and electronic equipment or tools have become a daily necessity worldwide. As such, different countries need to develop policies suited their unique technical, cultural and environmental needs as to how to reduce, reuse, and recycle the e-waste. To prevent e-waste from polluting its fragile environment, China promulgated a policy on "Guidelines for Electronic Waste Environmental Pollution Prevention and Control" (hereinafter called guidelines), which was adopted by the State Environmental Protection Administration at its third meeting held on 7 September 2007 [1]. The guidelines became effective on 1 February 2008.

Prior to adopting the guidelines, China has promulgated the Atmospheric Pollution Prevention and Control Law effective 1 September 2000 [2], and the Solid Waste Pollution Prevention and Control Law effective 1 April 2005 [3]. In addition, China has also adopted the Water Pollution Prevention and Control Law effective 1 June 2008 [4], and the Regulations for the Administration of the Recovery and Disposal of Waste Electric and Electronic Products effective 1 January 2011 [5].

This paper is to study the guidelines on dissemblance, utilization, and treatment of e-waste targeting six major groups, including manufacturers, importers, distributers, utilizers, dissemblers, and recyclers. There are a total of five chapters in the guidelines: 1) general provisions; 2) monitoring and management of dissemblance, utilization and treatments; 3) responsibilities of related parties; 4) penal codes, and 5) addenda; each of which has 4, 9, 4, 7, and 2 articles, respectively. This paper presents the results of an in-depth study of these articles.

2. MONITORING AND MANAGEMENT OF DISSEMBLANCE, UTILIZATION, AND TREATMENT OF E-WASTE

Results of the study show that as manifested in nine articles, Chapter 2 of the guidelines sets standards for proper registration of e-waste, record keeping of such information as its sources, types, weights or volumes, collection (acceptance), and the time of dissemblance, utilization, treatment; names of transporters and their addresses; types, weights or volumes, and whereabouts of those not completely dissembled, utilized or treated electronic waste and solid or liquid wastes; and the methods and technologies used to dissemble, utilize, and treat e-waste in an environmentally friendly manner without causing environmental pollution problems. Also specified in this chapter is the prohibition of burial of e-waste in a landfill and the requirement of establishing a name list of those qualified e-waste processing facilities or operations.

The competent authority at the county government level or above, which are responsible for review and approval of the environmental impact assessment documents is required to maintain a temporary record listing electronic dissemblance, utilization, and treatment units (including individual business entities) that meet the following criteria and announce it publicly of: 1) those units have

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successfully completed the required commercial and industrial registration processes and received business operation licenses; and 2) those who have completed and successfully passed the competent authority's inspection of the environmental protection measures instituted under the construction project.

The same competent authority is also required to maintain a temporary record listing of those units not violating the environmental protection law and related rules or regulations more than twice in the past three years and not violating the requirements specified in the guidelines as qualified e-waste dissemblance, utilization, and treatment units. The guidelines require that the competent authority announce the list publicly and make periodic adjustments to the list based on: 1) releasing or discharging pollutants exceeding the nationally or locally established standards for the release or discharge of pollutants; 2) indiscriminately littering or piling of the solid or liquid waste produced; 3) providing or entrusting incompletely dissembled, utilized, or treated e-waste to other comparable units (including individual business entities) or individuals not officially listed involving in dissemblance, utilization, and treatment activities; and 4) falsifying environmental monitoring data or operational records.

A new facility involving in dissemblance, utilization, and treatment of e-waste will not be listed in the temporary record listing if it is determined to have violated the environmental protection law or regulation at least twice in the past three years. The guidelines also require that the temporary record listing clearly show name of the unit and its legally designated representative, address, and the scope of operations.

Individuals are prohibited to interact or cooperate with those units not listed in the subject record (including the temporary record) in conducting activities relating to dissemblance, utilization, and treatment of e-waste. The guidelines allow those who have been involved in the dissemblance, utilization, and treatment of e-waste before the adoption of the guidelines to submit a request for being listed in the temporary name list within 120 days after the guidelines become effective, provided that they show proofs of meeting the following criteria: 1) completion of the legal processes required for the business and industrial registration and successfully obtaining related legal permits; 2) the environmental protection facilities have been duly inspected and approved by the competent authority of the environmental protection agency; 3) meeting, with or without adjustments made, the technical requirements for environmental protection in dissembling, utilizing, and treating e-waste pursuant to the guidelines; and 4) meeting the inspectional requirements for pollutant discharge and for the utilization or treatment of solid or liquid waste produced at the time of the completion of an environmental protection facility.

The competent authority is required by the guidelines to conduct a review of the supportive documents submitted by an applicant within 20 working days after the receipt of the application and also conduct an on-site inspection of the applicant's operation and facility. After the review and inspection, those operations or facilities meeting all the specified requirements are qualified being listed in the temporary name list and announced publicly. However, for those operations or facilities, which are determined not meeting the specified requirements, appropriate reasons with explanations will be provided.

3. RESPONSIBILITIES OF RELATED PARTIES

Chapter 3 delineates the responsibilities of manufactures, importers, and distributers of e-waste and prohibits the transfer of e-waste containing highly dangerous materials such as lead-acid batteries, nickel-cadmium batteries, mercury switches, cathode-ray tubes, and PCB (polychlorinated biphenyl) capacitor to an individual or unit not on the approved name list.

If any one of the following conditions exists, the functions of dissemblance, utilization, and treatment of e-waste are required to be provided or to be entrusted to a unit which is listed in the name list or in the temporary record listing and has comparable operations in e-waste dissemblance, utilization, and treatment: 1) those industrial e-waste generators, who have never employed environmental friendly methods to dissemble, utilize or treat e-waste; 2) those electronic or electrical products or equipment manufacturers, distributors, importers, users, renovators or repairers, or retrofitters who dispose of electronic or electrical products or equipment; 3) those dissemblance or utilization units who are unable to completely dissemble, utilize or treat e-waste; and 4) those illegally manufactured or imported electronic or electrical products or equipment that are confiscated by the competent authority and required dissemblance, utilization or treatment.

4. PENAL CODES

Chapter 4 establishes penal codes and enforcement criteria for assessing monetary fines or incarerations against violations of the guidelines, which are summarized in Table 1.

Table 1. A summary of the penal codes and enforcement actions prescribed in Articles 19, 20, 21, 22, 23 and 24 of the guidelines

Article No.	Violations	Penal codes and enforcement actions
19	Violations deemed as minor in nature, such as, refusal of on-site inspection and failure to comply with the rectification order	Fine of USD 333 to USD 3,333; or incarceration for 5 to 10 days by police
	Severe violation deemed as a criminal act	Prosecuted
20	Illegally dissembling, utilizing, and treating e-waste and receiving a cease and desist order	Fine of USD 16,666
	Unlicensed and banned for dissembling, utilizing,	Fine of USD 83,333 and confiscation of

	and treating e-waste	related properties or tools
21	Involved in dissembling, utilizing, and treating e-waste; but 1) entrusting not completely processed e-waste to illegally licensed individulas or units; 2) not complying with the pollution control standards, technologies or skills; 3) operating e-waste processing sites or facilities; 4) not properly maintaining records or falsifying monitoring data or operational records; 5) not conducting personnel training; or 6) storing e-waste longer than one year	Fine of USD 5,000
22	Legally licensed to process e-waste but 1) deliberately shutting down, idling, or dissembling environmental pollution prevention facilities or sites; 2) not taking appropriate measures or actions for pollution prevention, and deliberately littering or storing generated solid or liquid waste; or 3) causing the dispersion, run off, leaking or other environmetnal pollution activities	Fine of USD 1,666 to USD 16,666
23	Inappropriately operating environmental pollution control facilities	Penalty according to the Water Pollution Prevention and Control Law and the Atmospheric Pollution Prevention and Control Law
	Licensed e-waste operators who violate the Solid Waste Environmetnal Pollution Prevention and Control Law or related laws and administrative rules for: 1) endangering the drinking water sources; 2) causing groundwater contaminations or heavy metal contaminations of soils; 3) causing environmental pollution resulting from dispersion, run off, or diffusion of dangerous waste; 4) causing damage to the environmental functions and rendering the functions to be irreversibly lost; or 5) causing other serious environmental contaminations from the solid or liquid wastes	Ordered to: 1) control the contaminations within three months, restrict production and discharge, and prohibit from increasing the number of projects to increase the total amount of pollutant discharged; 2) be issued a cease and desist order to stop production and rectify the problems within three months if the corrective measures are not completed within the deadline; or 3) shut down the facilities for failure to take the corrective measures within the prescribed time
24	Competent autorities who violate the guidelines	Referred by the industrial and business administration agencies or the police or the justice departments to appropriate authority for disciplinary actions

Table 1 shows that depending on the nature and severity of violations, the guidelines set the criteria for making the determinations and their corresponding levels of penalty. Under the guidelines, the monetary fines range from USD 333 (violation of Article 19) to USD 83,333 (violation of Article 20) and the incarceration duration from 5 to 10 days (violation of Article 19). In addition, violations of Article 20 may result in not only monetary fines but also confiscation of related properties or tools. The guidelines also establish a unique penalty against competent authorities that violate Article 24 by referring the nature and severity of violations to appropriate authority for disciplinary actions.

5. DISCUSSION AND CONCLUSION

The guidelines provide China a legal basis for regulating the budding business or industry in dissemblance, utilization, and treatment of e-waste. Although the guidelines are superseded by the provisions of the Water Pollution Prevention and Control Law [4], the Atmospheric Pollution Prevention and Control Law [2], and the Solid Waste Pollution Prevention and Control Law [3], they would further strengthen or augment the effectiveness of these laws in addressing the potential environmental concerns over the reuse and recycle of e-waste in China. However, lack of enforcement data on the actual fines assessed or other enforcement actions taken makes it difficult to evaluate the effectiveness of the guidelines in preventing or controlling environmental pollutions caused by improper disposal, dissemblance, utilization or treatment of e-waste.

Establishment of a name list of qualified e-waste handlers in the guidelines would enhance the efficiency

and manpower saving in e-waste management in China. Those qualified e-waste handlers, once listed, would be in a position to conduct or be contracted to handle e-waste processing without having to justify their qualifications in each case; thereby reducing the time required for receiving approval for handling e-waste from the competent authority. However, a seemingly weakness was found along with this unique strength of the guidelines in that those listed qualified e-waste handlers are allowed to have two violations in three years prior to being listed. This appears to be quite lenient toward e-waste handlers in that regardless how severe the violations are committed earlier, the handlers are allowed to be on the list as long as not exceeding two violations in the previous three years. Therefore, the efficiency provided in the establishment of a name list may compromise sound e-waste management to prevent environmental pollutions in China.

The penal codes of the guidelines allow for confiscating the properties, in addition to a monetary fine up to USD 83,333 as specified in Article 20, against e-waste handlers who are unlicensed or banned for handling e-waste. A combination of monetary fine and confiscation of properties would serve as a strong deterrent for those unlicensed e-waste handlers or those who are banned for handling e-waste in China.

The penal codes of the guidelines also establish a preventive measure against the officials representing the competent authority who are determined to have violated Article 24 of the guidelines. This preventive measure entails that referring by the Industrial and Business Administration, the police or the justice department, the aforementioned officials may be subject to disciplinary actions taken by appropriate authority. This shows the intent to prevent misuse of power by officials representing the competent authority in enforcing the guidelines. Also intended is to ensure that the management of e-waste in China is conducted in a fair and equitable manner.

Recently, transboundary movements, legal or illegal, of hazardous wastes including e-waste among the Greater Mekong Sub-region (GMS) countries were raised as an issue of concern [6]. Without proper regulations of the transboundary movements of e-waste, a potential environmental disaster may occur; therefore, adoption of the e-waste management guidelines provides a necessary step to promote proper reduce, reuse or recycle of e-waste in China and to prevent China from being an e-waste dumping ground; thereby, lessening the chance for e-waste to become a source of environmental pollution in China.

Learning from China's experience, it is imperative for all other GMS countries to adopt, if they have not yet done so, a similar law, rule or guideline for managing e-waste in their respective countries. Once these similar laws, rules or guidelines have been adopted, comparisons can be made to determine their strengths or weaknesses. Based on the comparisons, the potential effectiveness of the guidelines adopted in China can then be better understood.

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Organic Agriculture Subscription System in University Context

M. Sasananan

Abstract— *This article presents two case studies of organic agriculture subscription system (OASS) in a university environment. A survey was conducted to identify the number of interested persons and the characteristics of system. At the same time, two pilot projects were established at the Faculty of Engineering, Thammasat University. These ongoing projects involve organic rice and vegetables, which are supplied by two different farmer groups. It is found that the rice OASS project is much easier to manage than the vegetable OASS, and that OASS projects in Thailand should be market-oriented.*

Keywords— **Organic agriculture subscription system (OASS), Community supported agriculture (CSA), Moral Rice Project, Teikei system**

1. INTRODUCTION

Organic agriculture subscription system (OASS) is a partnership between farmers and consumers which usually involves agreement between the two parties to share the responsibilities, benefits, and risks of organic farming.

OASS offers opportunity for consumers to buy agricultural produce directly from the farmers without using a third-party trader. In this system farmers set their own prices and receive full profit without passing through dealers while consumers can enjoy safe, organically grown food. Since OASS usually involves produce which are grown organically, it benefits farmers and consumers as well as the environment.

The members provide working capital to the farmer in advance, and buy the produce directly from the farmers. Through direct sales to community members, the farmers can gain better prices for their crops as well as financial security. They can fully dedicate themselves to organic farming without having to worry about marketing.

OASS is different from usual commercial transaction in the notion of shared risks that may occur from such factors as unpredictable weather conditions and insect problems. Consumers are expected to accept the available produce while farmers try to do their best to provide organic fruits and vegetables.

2. LITERATURE REVIEW

Types of OASS

There are three types of organic agriculture subscription system: teikei, box scheme, and CSA. Each system differs in the cultural background and the system's purpose.

The origin of OASS is the teikei system which originated in Japan in the mid 1960s. It can be rooted to the collective nature of the Japanese society. The word "Teikei' means partnership, and it usually involves non-profit partnership between local organic producers and consumers. Each party provides labor and capital to support their own delivery system. Advanced payment is given to the organic producers who promise to deliver produces to the consumers on a weekly basis.

When the idea was adopted in the west, it took various forms to suit the individualistic nature of western society. Two main OASS which are popularly recognized are: the American's CSA, and European's box scheme.

CSA or community-supported agriculture was initiated in 1986 due to the rise of consumer consciousness toward food safety and the search for stable market on the producer side. CSA consists of community of individuals that agree to support organic farming by sharing the benefits and risks that may occur in organic farming system. Generally the members pay up front for the whole season and the producers do their best to provide organic produce weekly.

Box scheme is a common form of OASS that is widespread in Europe. The concept is based on the objective of increasing consumer benefits by providing high quality organic produce at a reasonable price. It also emphasizes consumer behavior that leads to social, economic, and ecological sustainability. Such concept is neither driven by the consumers nor the producers, but it is usually driven by the establishment of complex organization. Such organization is not only limited to distributing organic produce but may also involve other non-organic products and services.

Despite its variability, all types of OASS still maintain the essential element of producer-consumer partnership. It can be stated that the three systems differentiate in the socio-economical and socio-ecological context [1]. In other words, different emphasis is placed along the supply chain as shown in Fig. 1.

According to Fig.1, teikei tends to build collective relationship within the producer's community thus emphasizing the socio-ecological aspect. On the other hand, the box scheme pays attention to the organic producer market and consumer service so it stresses on the socio-economical aspect.

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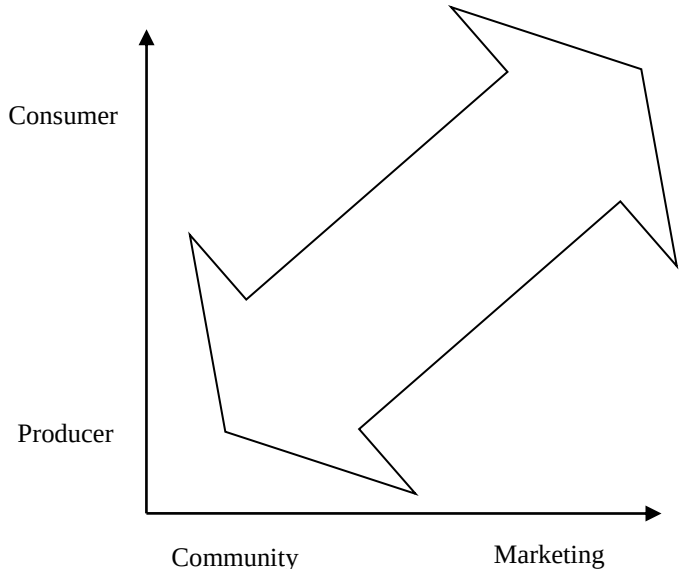

Fig.1. Different types of OASS system

OASS in Thailand

There are very few organic agriculture subscription system projects in Thailand. Examples of tangible projects are (1) Supanburi CSA project, (2) Plook Rak Farm, and (3) Snamchaiket Organic Farmer Group.

1.Supanburi CSA project was initiated in 2002 with 30 famer members. They were certified by the Organic Agriculture Certification Thailand, and distributed their produce via dealers, large retail stores, and specialty shops. This group disintegrated after 3 years due to the failure in negotiating with retail stores, leading to debt problems. Large organic producers then entered the scene and offered to provide them with soft loans on condition that it would be the sole distributor for their products. Ten of their best farmers agreed to leave the group, and eventually the project collapsed.

In 2004, the project leader started to experiment with CSA project with the remaining allies. They recruited members via an alternative school called "Roong Aroon". By organizing two seminars, they managed to attract interests of the parents. Currently there are 70 members under the supply of nine farmer families.

2. Plook Rak Farm. The farm was established in 2000 and was certified by IFOAM and Organic Agriculture Certification Thailand. It distributes the products through large supermarkets throughout Bangkok. Besides organic farming, the farm places significant effort in marketing activities such as establishing box schemes and building customer relationship via on-line media such as emails and facebook.

3. Snamchaiket Organic Farmer Group. The group was founded in 2001. It consists of 50 farmer members in Chachoengsao Province, and is certified by IFOAM. It is one of the most famous organic farming group in Thailand, with a large variety of produce. This group has several distribution channels, i.e. green market at the Regent building and Snamchaiket hospital, green fairs. It also distributes organic vegetables for school lunch at Panyothai school. This group established OASS in 2010 with 16 consumer members.

Organic consumer demographics

Since the perception and experience of organic foods tends to be related to cultural context , the socio-demographic profile of sustainable food consumers may vary depending on the country the research was conducted [2], [3]. Several studies have been conducted in the West regarding organic consumers [4]- [7].

There is a common perception that organic buyers tend to be rather affluent with high income and education. This is reflected in several studies. Reference [8] investigated food and sustainability behavior of CSA members in Arizona, USA. Their findings aligned with the other studies in the same area, i.e. CSA members were older, had attained a professional or higher education degree, and had a higher income compared to the national averages. Reference [9] studied motivations of box scheme consumers in Central England and Southern France. They found that the French customers tend to be middle aged professionals with relatively high income or retirees. The English ones are also high-income professionals with younger age between 26-45 years.

On the other side of the world, the Thai consumers who have made sustainable food choices tend to be those with high education (bachelor's degree or higher) and relatively higher income, with an average age of 42 years old [10]. This profile is similar to the results from studies on organic consumers found from literature review.

While a large number of studies have been conducted on consumer's perception of organic food in the West, little is known in the Asian context [11]-[13]. This study aims to provide insights into this issue by presenting case studies of organic agriculture subscription system and survey results on a community of organic consumers in a Thai university.

3. METHODOLOGY

In an attempt to learn about effective OASS scheme, a questionnaire survey was carried out in January 2012 to identify how many people would be interested in participating in the OASS scheme. The target respondents were faculty members and supporting staff within the Rangsit Campus of Thammasat University, Thailand.

At about the same time, two pilot projects were implemented at the Faculty of Engineering involving organic rice and vegetables subscription system.

4. RESULTS

From 1441 questionnaires that were distributed, 292 professors and staff members replied, giving the response rate of 20.26 percent. Among all respondents, 224 were interested in joining the OASS program. The respondents could be classified into 2 groups: faculty members and supporting staff. The range of age of professors who had good understanding and interest in the OASS project was around 41-50 years old. The percentage of those willing to join the program was 76.27 percent of those who replied, and the rate of accepting the price of organic agriculture was high [14].

As for the supporting staff, it was found that ages of employees were in the range of 31-40 years old, and 76.61 percent were female who might be more health conscious. However the survey revealed that the understanding of the OASS program was quite low (29.6 percent), and 66.5 percent of staff was interested in joining the program.

Consumer preference - As for the type of products, it was found that the products which were most desirable were fruits (26.55%), local vegetables (24.19%) and salad (21.39%).

Prices - Since the production cost of organic produce is higher than chemical produce, the prices of organic products are usually higher than chemical ones by about 20-50% The survey findings revealed that only 23.61 percent would welcome paying a higher price for products. 55.36 percent accepted the same price as the supermarket and 21.03 percent wanted the price to be cheaper.

Ease of buying -The result from questionnaire showed that 81.03 percent wanted the drop-off point to be nearest to them, i.e. at the workplaces. 58.19 percent wished to receive the product once a week, 33.76 percent preferred twice a week. Only 6.47 percent wanted to receive the product once per month

Payment method - The payment method and period of payment were additional factors that affected the buying decision of consumers. The survey showed that 60.34 percent of consumers were not willing to use pre-paid method and 75.20 percent preferred paying by cash. Paying through Thammasat University cooperatives or through bank accounts was supported by only 13.20 percent and 11.20 percent respectively.

Profile of Target Customers

From the survey, the profile of target customers and 4P (Product, Price, Place, Promotion) can be extracted, as shown in Table 1. Even though this seems to fit with the stereotype of ethical consumer being "middle aged, rather affluent, with a high level of education and a prestigious occupation" (Brown et.al, 2009), it should be recognized that the university population already has several traits which are in common with the stereotypical view.

Table 1 Profile of target customers and 4P (Product, Price, Place, Promotion).

	Professor	Staff
Age (years)	41-50	31-40
Willingness to participate	76.27 %	66.15 %
Product	Fruits, vegetables, salads, others	
Price	Same as chemical produce in supermarkets, cash payment	
Place	Drop-off points at the faculties	
Promotion	No prepaid method, weekly delivery	

It can be estimated that OASS implementation in Thammasat University has only a fair prospect of success due to several reasons. Even though there are a relatively large percentage of those who mention that they are willing to participate, however a majority of respondents (60.34%) do not accept the prepaid method. Price is another issue. Since the respondents wish to settle for the same price as chemical produce, it may be difficult to find a producer to participate in the project.

Now that the consumer needs and characteristics are known, pilot projects are implemented within the Faculty of Engineering as discussed in the following sections.

Case studies

Two pilot OASS projects are implemented at the Faculty of Engineering, Thammasat University. Two main kinds of products are involved: organic rice and organic vegetables.

Rice OASS - The organic rice is supplied by the "Moral Rice Project", which is implemented by a group of farmers from 4 provinces in the Northeastern part of Thailand. These farmers follow the King's directive of sufficiency economy in their profession as well as in their private lifestyles. Their organic rice is certified by IFOAM (International Federation of Organic Agriculture Movements). The OASS system was carried out via a consumer network established by TV Burapha Company as part of its corporate social responsibility project. In this scheme, advanced order is placed for a period of one year so that the moral farmers can plan for their crop production. Organic rice is delivered to the members each month. Advanced payment is made to the farmers on an annual basis so they can spend it on their rice plantation. This can help relieve the farmers' debts.

At the Faculty of Engineering, there were 25 members who purchased a total of 89 kilograms of rice per month in the year 2012. The majority of members consisted of professors, most of which were male as can be expected at the Faculty of Engineering. Only 12.1 percent were supporting staff. These members were approached based on the judgment of the facilitator that they might be interested. All of them accepted the invitation, and one of them asked to join the group after hearing about it from a potential member.

In 2013, the member size has dropped to 16 with a purchase volume of 65 kilograms per month. There are several reasons for the decrease in purchase order as shown in Table 2.

Table 2 Reasons for the drop in purchase order (Rice OASS)

- Feel reluctant to participate when first approached.
- Overestimated consumption.
- Could not afford higher price of organic products.
- Lack of awareness of cost-benefit.

From Table 2, it is possible that those who dropped the order in the following year might have initially accepted the invitation due to their being considerate of the facilitator, as usually found in the Asian culture. Thus they accepted the invitation even though they might not really appreciate organic produce.

Another reason is that some members overestimated their consumption so they could not finish consumption by the end of the year. Additionally some staff members felt that they could not afford the higher price of organic products. Even though they could afford it they might not be aware that the health and environmental benefits of supporting organic products significantly outweigh the relatively higher prices.

Vegetable OASS - There are 22 members who join the OASS scheme for vegetables. These members are nearly the same group of people who joined the rice project. The vegetable products are supplied by Rangsit Farm which is one of best organic producer in Thailand. The Farm is certified Organic Thailand by Organic Crop

Institute, Department of Agriculture, Ministry of Agriculture and Cooperatives, Royal Thai Government.

The reason this Farm is chosen for the project is because it has a professional marketing system which facilitates a smooth OASS project. Advanced payment is made to a faculty member serving as facilitator whose responsibilities are to share the list of organic products obtained from the farm each week. The list is shared online via google document where each member can place order using the same form. For each weekly order, the amount of payment is deducted from the member's account. The products are delivered weekly to the Faculty's drop point where each member can conveniently pick up his order.

These projects do not fall under any of the three categories of OASS. The main reason is that there is no formal risk-sharing contracts. Another difference from the textbook arrangement is that in these cases the products are not locally grown, but are supplied from farmers in other provinces.

Although there exists no formal risk-sharing contracts between the two parties, there is an implicit mutual companion between the farmers and consumers. An illustration can be seen during the major flood in Thailand in 2011. The Rangsit Campus of Thammasat University served as the largest evacuation center prior to its own severe flood. The vegetable farmer (Rangsit Farm) donated 200 kilograms of papaya to the evacuation center to help the victims. One week later the entire area of Thammasat University's Rangsit Campus was flooded with 2 meters of water. Most OASS members were devastated since they resided in the Rangsit area. Due to their concern for the OASS members, the rice farmers donated 140 kilograms of rice to the members, equivalent to about 1.5 month of consumption according to the purchase order.

In September of 2012, the rice farmers started a fund-raising project with the aim of establishing Local Seed Bank and Research Center. The members managed to donate 8,000 baht to help the moral rice farmers. This reflects, to some extent, the existence of mutual companionship between the members and the farmers.

It should be noted that among the twenty-two members who join the vegetable CSA program, only 4 members are regularly active. The fact that prepaid method is adopted seems to be no problems for the members since they are preferred customers. However, there are several possible reasons for the inactive members as illustrated in Table 3.

Table 3 Reasons of inactive members (vegetable OASS)

- No time to cook
- Want to choose own varieties
- Seek lower prices
- Prefer local vegetables

From Table 3, one of strongest reasons is that their urban lifestyles do not allow them to enjoy home cooking. Because most time is spent in the office or in traffic, they tend to rely on food from university canteens, restaurants, or take-away food from roadside stands. It is common for most urban families to rely on "plastic bag food" even for families with small children.

For those few people who cook, they prefer to choose their own varieties of vegetables rather than accepting whatever is available from the farm. Some of them want to settle for lower prices even though it is not much different from chemical produce sold in the supermarket.

Another reason is that there is a small variety of local vegetables. The farm is specialized in producing western style salad vegetables, but most customers prefer local (Thai) vegetables.

5. CONCLUSION

Organic agriculture subscription system (OASS) is relatively new in Thailand. Its implementation is limited to people with relatively high education and high income, falling in the middle to high class families.

As expected, the pilot OASS projects have limited success in the case studies. Even though price is not a sensitive issue for the samples of Thai organic consumers as reflected in Roitner-Schobesberger et.al. (2008), this study reveals that the survey respondents wish to settle for the same price as chemical produce. This indicates that there is a need to educate the potential consumers in order to make them realize that they will not only gain health benefits by supporting organic agriculture, but they can also protect the ecosystem.

When the rice OASS is compared with vegetable OASS, it was found that rice OASS is much easier to manage due to the non-perishable nature of the products. Rice is the staple food of Thailand thus it is easy to predict the consumer demand. The customer order remains constant each moth since customers are not usually concerned about rice variety. Advanced payment can be made to the farmers directly, and this helps to relieve the farmers' debts.

Vegetable OASS is more difficult to manage. Due to its perishable nature, customers have to be committed to picking up their order and accept the seasonal supply. Despite all the favorable conditions, the number of customers keeps dropping to as low as four persons.

As reflected in these cases, it can be said that organic agriculture subscription system would be successful in the Thai urban society if it is more market oriented, i.e. one which caters to the need of consumers, rather than to the need of producers. In terms of the three main types of OASS, the box scheme seems to be most appropriate for the Thai context. These results are useful for OASS promoters so that they can improve the targeting of their recruitment.

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Biodegradation Kinetic Coefficients of Hospital Wastewater

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Abstract*—Hospital wastewater is generated from various activities which contains a variety of organic and inorganic substances. To design the wastewater treatment, biokinetic coefficients usually apply in the design of activated sludge processes. This study reported the biokinetic coefficients of activated sludge processes for hospital wastewater. The experiment was conducted by using solids retention time (SRT) with 10-20 day. The biokinetic coefficients were found to be as follows: biomass yield (Y) = 0.6471 mg VSS/mg COD, endogenous decay coefficient (kd) = 0.0509 1/day, Ks = 9.373 mg COD/L and k = 0.3015 1/day. The COD removal was increasing as SRT increased and also produced higher amount of MLVSS. Comparing biokinetic coefficients of municipal wastewater and hospital wastewater with previous studies ,the values of biomass yield (Y) of this study was in the normal range of other reports for both of municipal wastewater and hospital wastewater. Endogenous decay coefficient (kd) of hospital wastewater, the value of this study (0.0509 1/day) was different from the previous study (0.01 1/day), but also μ_{max} (0.1951 < 0.048 1/day) and Ks (9.373 < 121.12 mg COD/L) both values were lower than previous report, although the experiment used the same substrate that was taken from the same source, Khon Kaen hospital center, Khon Kaen ,Thailand. These result may cause from the characteristic of wastewater was changed, due to the activities in hospital may change and chemical used as well as an increasing facilities in hospital area*.

***Keywords*— Biokinetic coefficients, Activated Sludge, Hospital Wastewater**

1. INTRODUCTION

Hospital wastewater contains a variety of organic and inorganic substances from all activities of the hospital such as the operating, laboratory, diagnosis, radiology, kitchen and laundry activities. The wastewater may contain toxic substances that harm to microorganism in wastewater treatment process. The kinetic coefficients of aerobic biodegradation are the important data for wastewater treatment design and operation the treatment processes.

Biokinetic coefficients normally used in the design of activated sludge processes which are specific growth rate(μ), maximum rate of substrate utilization per unit mass of microorganisms (k), half velocity constant (Ks), maximum cell yield (Y), and endogenous decay coefficient (kd). To examine these parameters, the experimental set up will carried out in completely-mixed bioreactor was operated in batch reactor or continuous flow reactor under the different mean cell residence time or solids retention time (SRT). Generally, environmental engineers used these parameters from the guideline of Environmental Engineering Association of Thailand and international text books which was suggested in general rang for various wastewater that are not specific to hospital wastewater [1-3]. Thus this research aimed to carry out the parameters to be supported data for activated sludge process design and control the process in wastewater treatment plant.

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2. MATERIAL AND METHODS

Experimental procedure

Wastewater and seed sludge was taken from equalization tank and aeration tank (Fig.1) of wastewater treatment plant of Khon Kaen hospital center, Khon Kaen ,Thailand. Biokinetic coefficients were determined by collecting data from lab scale experiments in batch reactor which was working volume of 10 liter and vary solids retention time (SRT) with 10-20 day. The experiment was carried out under the room temperature that was about 25 ^{o}C. For keeping aerobic conditions in reactor, stone air diffuser was placed in the bottom of reactor tank. The experiment results will be calculated parameters of biomass yield (Y), endogenous decay coefficient (kd), maximum rate of substrate utilization per unit mass of microorganisms (k), and half velocity constant (Ks). The relationship of these parameters are shown in Equation (1) and (2) and

$$(1/SRT) = YU\text{-}kd = Y\,[(So\text{-}S)/\Theta X]\text{-}kd \quad (1)$$

$$\Theta X\,/(So\text{-}Se) = (Ks/k)/(1/S) + (1/k) = (1/U) \quad (2)$$

where:

SRT = Solids retention time, d

Y = Biomass yield, mg VSS/mg COD

U = Substrate utilization rate, mg COD/mg VSS.d

kd = Endogenous decay coefficient, 1/d

So = Influent substrate concentration, mg COD/L

S = Effluent substrate concentration, mg COD/L

X = Biomass concentration, mg VSS/L

Θ = Hydraulic retention time, d

Ks = Half-velocity constant, mg COD/L

k = Maximum rate of substrate utilization, mg COD/mg VSS.d

Fig.1. Aeration tank of wastewater treatment plant

Analytical method

All samples from the experiment were analyzed for various physical and chemical parameters in accordance with the Standard Methods (APHA, 2005). The results were analyzed and plotted by Microsoft Excel.

3. RESULTS AND DISCUSSION

The experiment results by using solids retention time (SRT) with 10-20 day shows on Table 1 while Fig. 2 and 3 show the determination of coefficients. The biokinetic coefficients were found to be as follows: Y = 0.6471 mg VSS/mg COD, kd = 0.0509 1/day, Ks = 9.373 mg COD/L and k = 0.3015 1/day. The COD removal was increasing as SRT increased and also produced higher amount of MLVSS.

Table 1. Experiment results with various solids retention time (SRT)

Batch No.	MLVSS (mg/L)	So (mg COD/L)	S (mg COD/L)	SRT (day)
1	1092	188.21	11.19	20
2	1069	185.50	10.01	20
3	924	187.39	17.86	14
4	973	186.51	16.20	14
5	779	184.09	20.96	11
6	753	189.68	21.56	11
7	662	184.16	27.67	10
8	669	185.38	29.11	10

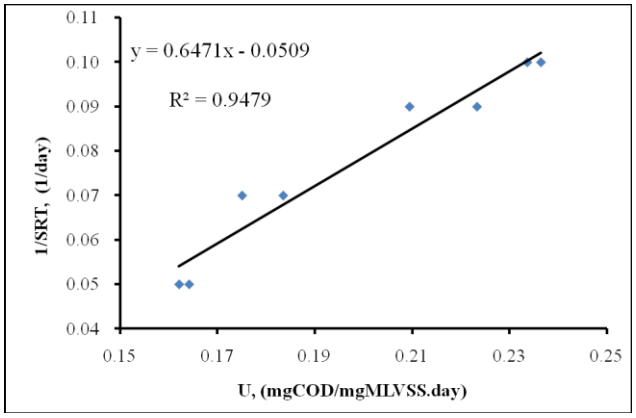

Fig.2. Determination of Y and kd

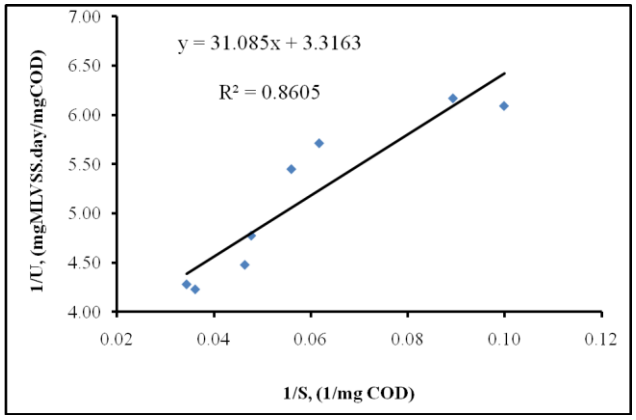

Fig.3. Determination of Ks and k

Table 2. Biokinetic coefficients obtained from different source

Sub-strate	Y (mg VSS /mg COD)	kd (1/day)	μ_{max} (1/day)	Ks (mg COD /L)	Ref.
MWW	0.4-0.8	0.025-0.075	0.8-8	15-70	[2]
MWW	0.49-0.804	0.019-0.026	0.95-0.98	52-71.12	[4]
HWW	0.58	0.01	0.408	121.12	[5]
HWW	0.6471	0.0509	0.1951	9.373	This study

MWW = Municipal Wastewater

HWW = Hospital Wastewater

μ_{max} = maximum specific growth rate = kY , (1/day)

4. CONCLUSION

Comparing biokinetic coefficients of Municipal Wastewater and Hospital Wastewater with previous studies are shown on Table 2. The values of Biomass yield (Y) of this study was in the normal rang other reports both of Municipal Wastewater and Hospital Wastewater. Endogenous decay coefficient (kd) of Hospital Wastewater, the value of this study (0.0509 1/day) was different from the previous study (0.01 1/day), but also μ_{max} (0.1951 < 0.048 1/day) and Ks (9.373 < 121.12 mg COD/L) both values were lower than previous report, although the experiment used the same substrate that was taken from the same source, Khon Kaen hospital center, Khon Kaen ,Thailand. These result may cause from the characteristic of wastewater was changed from the past 10 years ago. The activities in hospital may change and chemical used as well as an increasing facilities in hospital area.

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Case Study of Wastewater Treatment from Fishing Net Softening Process

Weerapong Khantee, Panomchai Weerayutsil, and Kulyakorn Khuanmar

Abstract*—The objective of this research was to examine the optimum dose for pre-treatment wastewater from fishing net softening process by using alum, lime, and polymer. The optimum dose should have a lowest cost of chemical usage and the final mixing of both wastewater sources (wastewater from dyeing process and supernatant form pre-treatment process) in equalization tank should have COD less than 800 mg/L. The experiment results shown that all three type formulas gave pH drop from 7.48 to acidic range of pH 5.42-5.56. Type 1 and Type 2 had shown a lower TDS than TDS of untreated wastewater, only Type 3 gave a higher TDS than original wastewater. COD removal efficieny for three type were 66%, 64%, and 91% respectively. Consider on COD removal, Type 3 was the best condition with final COD of 91%, but it gave high chemical cost and also shown highest TDS which was higher than TDS of untreated wastewater acorrding to the highest alum uasge. Type 1 and Type 2 presented COD removal of 66% and 64% that was removal efficiency unsignificant different, thus Type 1 condition was the most interested formula. Inaddition mass balance of COD loading after mixing in equlization pond, should not exceed 800 mg/L due to the capability of the wastewater treatment plant and the operation control. The calculation of mass balance of COD loading, Type 1 presented a final mixing liquid in equlization pond of 781.54 mg/L that was less than the optimum COD loading of wastewater treatment plant. As a result, Type 1 was selected for pre-treatment process.*

***Keywords*— Softening Wastewater, Alum, Coagulation, Flocculation**

1. INTRODUCTION

Wastewater from fishing net manufacturing process comes from dyeing process and softening process. Dyeing process is making a color on fiber of fishing net. This process produces high volume wastewater while softening process produces low volume but give high concentration of COD. Due to the process generated small volume of wastewater but it contains high amount of COD and turbidity. Thus, pre-treatment by coagulation and flocculation processes are needed before further treatment by biological treatment process (Fig.1-2).

Coagulation and flocculation processes need the coagulant to enmesh nonsettleable colloidal solids to be a rapid-settling floc then this floc is easy to separate from liquid. Consequently, COD will be decreased and available to treat by biological treatment process [1].

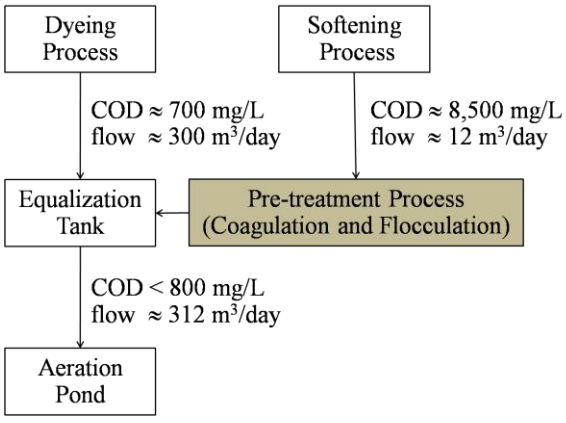

Fig.1. Wastewater from fishing net manufacturing process

Fig.2. Charecteristic of wastewater from fishing net softening process

There are various chemical that used as coagulant but the most popular is alum due to its cheap. The important process of coagulation and flocculation process is pre-testing or jar test to find out the optimum dose of chemical in precipitation processes: alum, lime, and polymer. [2-4]

The objective of this research was to examine the optimum dose for pre-treatment wastewater from fishing net softening process by using alum, lime, and polymer. The optimum should have a lowest cost of chemical usage and the final mixing of both wastewater sources (wastewater from dyeing process and supernatant form pre-treatment process) in equalization tank should have COD less than 800 mg/L.

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2. MATERIAL AND METHODS

Reagents

Aluminium Sulphate ($Al_2(SO_4)_3$) industrial grade (Fig 1.(a)), Hydrate lime ($Ca(OH)_2$) purity 90% calcium Hydroxide (Fig 1.(b)), and Anionic acrylamine copolymer (CLEARFLOC-2710) (Fig 1.(c)). All chemicals were used as received. Only polymer was dissolved with tap water before used with ratio 3 g. per liter.

Experimental procedure

Preliminary test in lab scale was conducted in beaker to find out the optimum dosage of coagulation and flocculation processes (Fig. 3.). The result from screen test, there are three types formula for testing in pilot scale (Table.1). Pilot scale testing was conducted in PE tank 1,000 liter with working volume 500 liter per batch testing. Rapid mixing (5 minute @ 100 rpm) and slow mixing (60 minute @ 20 rpm) with stainless steel paddle controlled speed with electric motor, then stop motor and left the floc settle for 1 hour (Fig. 4-5).

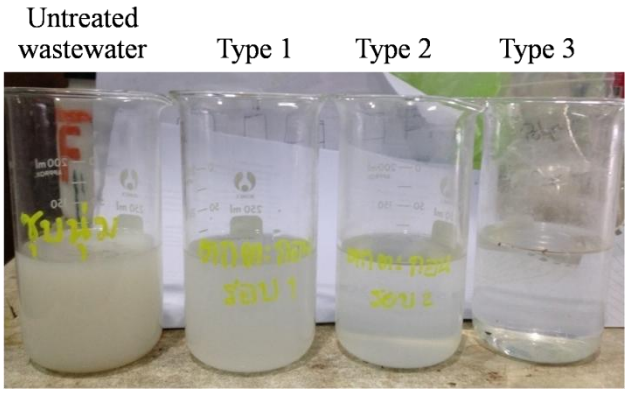

Fig. 3. Preliminary test in lab scale

Fig. 4. Rapid mixing and slow mixing with stainless steel paddle and control speed with electric motor.

Fig 5. Supernatant after settling for 1 hour

Table 1. Charecteristic of untreated wastewater and treated wastewater with three type formulas for wastewater 1000 liter

Parameters	Waste-water	Type 1	Type 2	Type 3
pH	7.48	5.43	5.42	5.56
TDS (mg/L)	1830	1450	1510	2040
COD (mg/L) (% removal)	8400	2820 (66%)	3040 (64%)	750 (91%)
Dosage of Coagulants and Flocculant				
Alum (kg)		2	4	5
Lime (kg)		2	4	4
Polymer (g)		6	12	16
Chemical Cost (Baht)		**30.6**	**61.2**	**65.6**

3. RESULTS AND DISCUSSION

Table 1. illustrate charecteristic of untreated wastewater and treated wastewater with three type formulas for wastewater 1000 liter. All three type formulas gave pH drop from 7.48 to acidic range of pH 5.42-5.56. Type 1 and Type 2 had shown a lower TDS than TDS of untreated wastewater, only Type 3 gave a higher TDS than original wastewater. COD removal efficieny for three type were 66%, 64%, and 91% respectively.

4. CONCLUSION

Consider on COD removal, Type 3 was the best condition with final COD of 91%, but it gave high chemical cost and also shown highest TDS which was higher than TDS of untreated wastewater acorrding to the highest alum uasge. Type 1 and Type 2 presented COD removal of 66% and 64% that was removal efficiency unsignificant different, thus Type 1 condition was the most interested formula. Inaddition mass balance of COD loading after mixing in equlization pond, should not exceed 800 mg/L due to the capability of the wastewater treatment plant and the operation control. The calculation of mass balance of COD loading, Type 1 presented a final mixing liquid in equlization pond of 781.54 mg/L that was less than the optimum COD loading of wastewater treatment plant. As a result, Type 1 was selected for pre-treatment process.

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Removal of Crystal Violet and Safranin by Fenton Reaction

Soraya Pimonporn, Panomchai Weerayutsil, and Kulyakorn Khuanmar

Abstract*—COD removal efficiency of Crystal violet solution and Safranin O solution with reaction time 50 minutes, the maximun efficiency of COD removal was 56.43% and 66.95 %, respectively. The efficiency trends to increase as reaction time increasing. The experiment result for the mixed solution of crystal violet solution and Safranin O solution illustrated that after the first 10 minute until 50 minute, the efficiency of COD removal was about 50%. The efficiency trends to still remain of 50% removal as reaction time increasing. This can summarize that to achieve a higher efficiency of wastewater treatment for single solution of Crystal violet and Safranin O, the reaction time should increase. The mixed solution of Crystal violet and Safranin O, to gain higher efficiency, the ratio between Fe^{2+} and H_2O_2 supposed to increase.*

***Keywords*— Crystal violet, Safranin O, Fenton Reaction**

1. INTRODUCTION

Wastewater from gram staining laboratory was contaminated with crystal violet and safranin which need to treatment before discharge the effluent to wastewater collection system. Crystal violet and safranin have carcinogenic properties, these chemicals may affect to aquatic life and also to human life.

Different techniques have been suggested to remove dyes from aqueous solution such as adsorption, biological degradation, coagulation, and advanced oxidation processes (AOP). One of simple approaches of AOP to remove dyes from wastewater is Fenton reaction, the reaction presents by Equation (1) - (2) [1-4].

$$H_2O_2\ (aq) + Fe^{2+}\ (aq) \rightarrow Fe^{3+}(aq) + OH^-(aq) + OH^- \quad (1)$$

$$OH^- + \text{Organic compounds} \rightarrow \text{Oxidized products} \quad (2)$$

The objectives of this research examine the optimum condition of Fenton reaction to treat individual wastewater of crystal violet and safranin and mixed wastewater of both crystal violet and safranin.

2. MATERIAL AND METHODS

Reagents

Crystal Violet (Fig 1.) was procured from Merck and Safranin O (Fig 2.) was procured from BHD, both of them were used as received and prepared as synthetic wastewater with concentration of 0.49, 0.09, and 0.05 mM for crystal violet, safranin O, and mixed solution, respectively. Deionized water was used for all dye solutions. Hydrogen peroxide (H_2O_2, 35% w/w) was obtained from Merck and used at a final concentration of 60 mM. Ferrous Heptahydrate ($FeSO_4.7H_2O$, purity 96%) was obtained from Merck and prepared at concentration of 0.72 mM for all experiments.

Experimental procedure

The experiments were carried out in closed reactor which has 500 ml of capacity and the volume of synthetic wastewater of dye solution was 50 ml. The solutions both of Fe^{2+} and H_2O_2 were added in to the reactor then were shaking by horizontal shaker at constant speed of 100 rpm for 50 minutes. All the experiments were carried out at room temperature. The samples were added with NaOH to stop reaction then filtered through 0.45 μm filter disk and were analyzed COD by closed reflux according to Standard Methods (2005)[5].

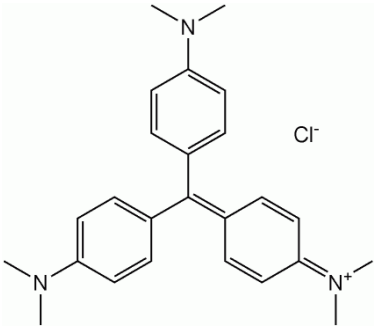

Fig 1. Crystal violet structure

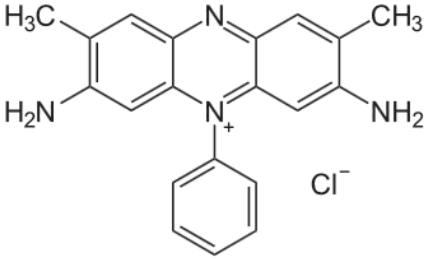

Fig 2. Safranin O structure

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3. RESULTS AND DISCUSSION

COD removal efficiency of crystal violet solution and Safranin O solution show on Fig.3 and Fig.4. The result shown that within 50 minutes the maximun efficiency of COD removal was 56.43% and 66.95 %, respectively. The efficiency trends to increase as reaction time increasing.

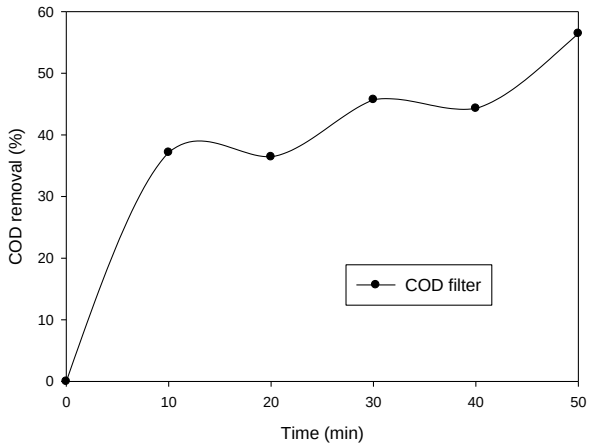

Fig.3. COD removal efficiency of Crystal violet solution

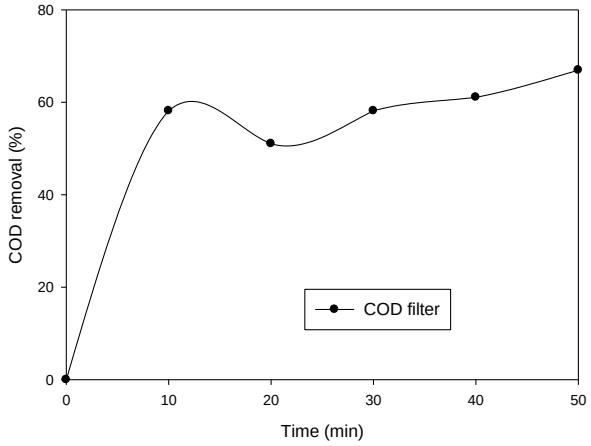

Fig.4. COD removal efficiency of Safranin O solution

The experiment result for the mixed solution of crystal violet solution and Safranin O solution show on Fig.5. The result illustrated that after the first 10 minute until the end of the experiment time which was at 50 minute, the efficiency of COD removal was about 50%. The efficiency trends to still remain of 50% removal as reaction time increasing.

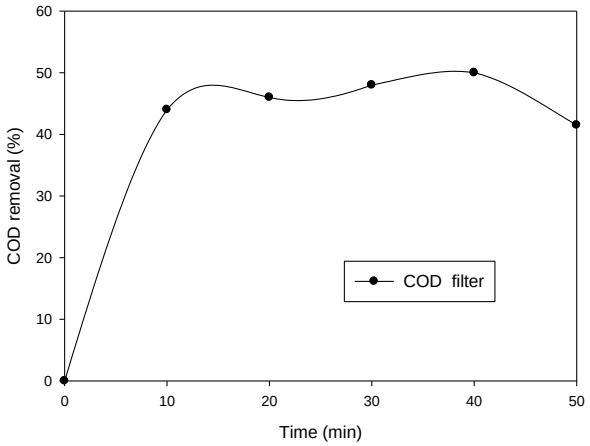

Fig.5. COD removal efficiency of mixed solution

4. CONCLUSION

Comparing the COD removal efficiency of Fenton reaction for single solution of Crystal violet and Safranin O, the result shown that Crystal violet presented a lower efficiency than Safranin O. However, both single solution trend to give a higher COD removal efficiency. For mixed solution of Crystal violet and Safranin O the maximum COD removal efficiency still remain about 50% even through reaction time was increased. This can summarize that to achieve a higher efficiency of wastewater treatment for single solution of Crystal violet and Safranin O, the reaction time should increase. The mixed solution of Crystal violet and Safranin O, to gain higher efficiency, the ratio between Fe^{2+} and H_2O_2 supposed to increase.

ACKNOWLEDGMENT

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Finite Point Method for Convection-Dominated Flow Problems

Chinapat Buachart and Worsak Kanok-Nukulchai

Abstract*— *In this paper, the new upwinding scheme incorporate to meshfree technique has been proposed to overcome the instability issues in convection-dominated flow problem. This techniques is then demonstrated in one and two-dimensional problems using meshfree point collocation method. Numerical results for example problems demonstrate the techniques developed in this paper are effective to solve convection dominated problems.

***Keywords*— Meshfree, point collocation, upwinding, convection-flow**.

1. INTRODUCTION

Many practical problems in engineering are governed by the so-called convection-diffusion equations, in which, there are both convective and diffusive terms. To analyze the convection-diffusion problems, the conventional finite element method (FEM), the finite difference method (FDM), or the finite volume method (FVM) has been widely used.

However, there is a well-known instability issue of convection-diffusion problem; the highly oscillatory solution will occurs when the convective term is dominated. Hence, the special treatment is required to stabilize the numerical solution. A lot of studies have been performed to solve the instability problem in conventional numerical schemes, and excellent documentation on stabilization techniques can be found in the book written by Zienkiewicz and Taylor [1].

In recent years, meshless or meshfree methods have attracted more and more attention from many researchers in computational mechanics field, especially in computational fluid mechanics. These meshfree methods do not required a mesh to discretize the problem domain, because the shape function is constructed entirely based on a set of scattered nodes. They are categorized to be two groups. First category is based on the collocation techniques, for example the finite point method (FPM) [2] and the *hp*-cloud method [3]. Other meshfree methods are based on weak form, e.g. the element-free Galerkin (EFG) method [4], the reproducing kernel particle (RKP) method [5], the meshless local Petrov-Galerkin (MLPG) method [6], and so on, this category of meshfree method require numerical integration to approximate the weak form. Hence, the first category is defined to be truly meshless, *i.e.* no mesh required to perform numerical integration.

Only very few works was reported to solve convection dominated problems using meshfree methods. Oñate *et al.* [2] applied the finite point method to the convection dominated problem with upwinding for the first derivative or with characteristics approximation. Atluri *et al.* [6] used the MLPG method with local upwinding weight to solve the convection-diffusion problems. Gu and Liu [7] proposed several adaptive support domain techniques incorporate with meshfree collocation method to solve convection-dominated problem successfully.

In this paper, techniques to stabilize the convection dominated problems will be developed and investigated for finite point method (FPM). These techniques based on edge stabilization with analytical solution of equivalent one-dimensional convection dominate equation. Numerical results demonstrate that using these techniques, the instability problem caused by convection term can be solved effectively using meshless method.

2. APPROXIMATION IN FPM

Weighted-Least Square Approximation

Let suppose Ω_i is an local approximation domain (cloud) of unknown function $u(\boldsymbol{x})$ consists of *star point* $\boldsymbol{x}_i$, and set of points $\boldsymbol{x}_j$, $j = 2,3,\ldots,np$ surrounding star point as shown in Figure 1.

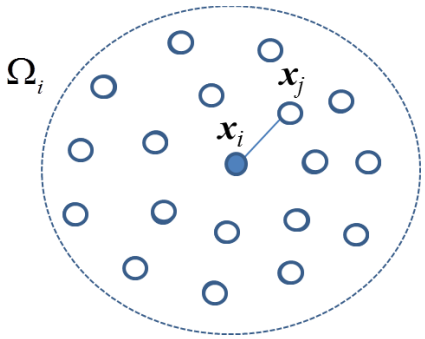

Fig.1. Local Approximation Domain in WLS

Then, the local approximation of u can be defined by

$$\hat{u} = \sum_{l=1}^{m} p_l(\boldsymbol{x})\alpha_l = \boldsymbol{p}^{\mathrm{T}}(\boldsymbol{x})\boldsymbol{\alpha} \qquad (1)$$

where $\boldsymbol{p}(\boldsymbol{x})$ is a vector whose m-components are the terms of a complete polynomial basis functions and $\boldsymbol{\alpha}$ is a vector of coefficients which must be determined. In this work, complete quadratic polynomial bases are employed, e.g. $\boldsymbol{p}^{\mathrm{T}}(\boldsymbol{x}) = [1, x, y, x^2, xy, y^2]$ in 2-dimensional domain. Note that the point's coordinates are relative to the star point position. For each region Ω_i the number of could nodes is

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larger than number of parameter $\boldsymbol{\alpha}$, $np > m$. To solve for approximation parameter $\boldsymbol{\alpha}$, we define the functional

$$J_i = \sum_{j=1}^{np} \varphi_i\left(\boldsymbol{x}_j\right)\left[\hat{u}_j - u_j\right]^2 \tag{2}$$

in which $\varphi_i(\boldsymbol{x}_j) = \varphi(\boldsymbol{x}_j - \boldsymbol{x}_i)$ is a compact support weighting function centered on the star point $\boldsymbol{x}_i$ and np is the number of points in the local cloud. This procedure, known as fixed Weighted Least-Squares (WLS), can be considered as a particular case of the Moving Least-Square (MLS) method proposed by Lancaster and Salkauskas in [8]. The minimization of Eq. (2) with respect to parameter $\boldsymbol{\alpha}$ leads to the following system of equations

$$\mathbf{A}\boldsymbol{\alpha} = \mathbf{B}\boldsymbol{u} \tag{3}$$

where $\mathbf{A} = \mathbf{P}^{\mathrm{T}}\boldsymbol{\Phi}(\boldsymbol{x})\mathbf{P}$, $\mathbf{B} = \mathbf{P}^{\mathrm{T}}\boldsymbol{\Phi}(\boldsymbol{x})$, $\boldsymbol{\Phi}(\boldsymbol{x}) = \mathrm{diag}[\varphi_i(\boldsymbol{x}_j)]$, and $\mathbf{P}^{\mathrm{T}} = [\boldsymbol{p}(\boldsymbol{x}_1), \boldsymbol{p}(\boldsymbol{x}_2), \ldots, \boldsymbol{p}(\boldsymbol{x}_{np})]$. Then, the vector of unknown coefficient can be obtained by inversion of matrix $\mathbf{A}$, *i.e.* $\boldsymbol{\alpha} = \mathbf{A}^{-1}\mathbf{B}\boldsymbol{u}$, and the approximation value of $u(\boldsymbol{x})$ at the star point of the cloud is computed by Eq. (1)

$$\hat{u}_i = \boldsymbol{p}^{\mathrm{T}}\left(\boldsymbol{x}_i\right)\mathbf{A}^{-1}\mathbf{B}\boldsymbol{u} = \sum_{j=1}^{np} a_{ij}u_j \tag{4}$$

where a_{ij} is the approximation coefficient or shape function at star point $\boldsymbol{x}_i$. Having adopted a fixed weighting function, matrices $\mathbf{A}$ and $\mathbf{B}$ become constant in Ω_i, thus fist-order derivatives of the unknown function at star point are approximated in the FPM by

$$\frac{\partial \hat{u}_i}{\partial x_k} = \frac{\partial \boldsymbol{p}^{\mathrm{T}}\left(\boldsymbol{x}_i\right)}{\partial x_k}\mathbf{A}^{-1}\mathbf{B}\boldsymbol{u} = \sum_{j=1}^{np} b_{ij}^k u_j \tag{5}$$

in which b^k_{ij} is the first partial derivative of shape function a_{ij} with respect to x_k and higher-order derivatives can be obtained by successive differentiation of basis function vector. Henceforth, the WLS approximation of Laplacian operator can be computed by

$$\nabla^2\hat{u}_i = \nabla^2\boldsymbol{p}^{\mathrm{T}}\left(\boldsymbol{x}_i\right)\mathbf{A}^{-1}\mathbf{B}\boldsymbol{u} = \sum_{j=1}^{np} c_{ij}u_j \tag{6}$$

where c_{ij} is the Laplacian of shape function, defined by $c_{ij} = \nabla^2 a_{ij}$.

The Weighting Function

There exits many possibilities for choosing the functional form of a weighting function. In this paper the following normalized Gaussian (exponential) weighting function is adopted

$$\varphi_i\left(\boldsymbol{x}_j\right) = \frac{e^{-\left(wd_j/\gamma d_{\max}\right)^2} - e^{-w^2}}{1 - e^{-w^2}} \tag{7}$$

where d_j = distance between star point $\boldsymbol{x}_i$ and surrounding point $\boldsymbol{x}_j$ in cloud. The parameters w and γ govern the shape of the weighting function. In this work, we will set the value of $\gamma = 1.01$. Next, to assign the admissible range of parameter w, the effect of parameter w on the shape of Gaussian weight function is illustrated in Figure 2.

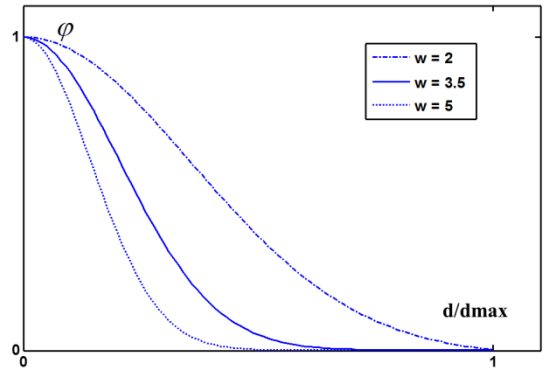

Fig.2. Effects of the parameter *w* on the weighting function.

For large values of w, the shape function a_{ij} tends to the Dirac delta function (see Figure 2) and the approximation procedure tends to interpolate nodal data. Larger value w causes the error in the approximation to decrease, while the condition number of matrix $\mathbf{A}$ increased [9]. As a result, the system Equation (3) becomes more and more ill-conditioned. Hence, this parameter should be properly set. The maximum value of parameter w is set to be 3.5 in a whole domain and then it is reduced for each cloud of points whenever necessary, in order to obtain a given accuracy in the approximation or until reach the minimum value of 2.0.

Consistency of Approximation

It is usual practice in meshless method to associate the ability of approximation coefficients to reproduce a given polynomial of order p and its derivatives in an exact way. A set of approximation coefficients a_{ij}, b_{ij}^k and c_{ij} from WLS approximation have to satisfy following conditions

$$\begin{aligned}
&\sum_{j=1}^{np} a_{ij}\boldsymbol{p}_j = \boldsymbol{p}\left(\boldsymbol{x}_i\right) \\
&\sum_{j=1}^{np} b_{ij}^k\boldsymbol{p}_j = \frac{\partial \boldsymbol{p}\left(\boldsymbol{x}_i\right)}{\partial x_k} \\
&\sum_{j=1}^{np} c_{ij}\boldsymbol{p}_j = \nabla^2\boldsymbol{p}\left(\boldsymbol{x}_i\right)
\end{aligned} \tag{8}$$

where $\boldsymbol{p}(\boldsymbol{x})$ is a complete polynomial base of order p and $\boldsymbol{p}_j = \boldsymbol{p}(\boldsymbol{x}_j)$. Due to the fact that the weight function use to construct WLS approximation is fixed, the shape function and its derivatives are discontinuous. It is *only* possible to satisfy the consistency requirements (8) at the star point where the center of weighting function is located.

3. MODEL GOVERNING EQUATIONS

Two-Dimensional Convection-Diffusion Problem

Consider the advection-diffusion equation in two-

dimensional space [10]:

$$\frac{\partial \phi}{\partial t} + \boldsymbol{u} \cdot \nabla \phi = \kappa \nabla^2 \phi + f \tag{9}$$

where $\phi(\boldsymbol{x},t)$ is the dependent variable, a scalar-valued function of the spatial coordinates $\boldsymbol{x}$ and time t. The advection velocity field is denoted by $\boldsymbol{u}(\boldsymbol{x})$ and the positive coefficient $\kappa(\boldsymbol{x})$ represent diffusivity. The body source term denoted by $f(\boldsymbol{x},t)$.

We allow the essential and natural boundary conditions (diffusive flux), respectively:

$$\phi(\boldsymbol{x},t) = g(\boldsymbol{x},t), \forall x \in \Gamma_g \tag{10}$$

$$\boldsymbol{n} \cdot \kappa \nabla \phi(\boldsymbol{x},t) = h(\boldsymbol{x},t), \forall x \in \Gamma_h \tag{11}$$

where $\boldsymbol{n}$ is the unit outward normal vector to the boundary $\Gamma = \Gamma_g \cup \Gamma_h$ and g and h are prescribed functions. The steady-state solution is defined by $\phi(\boldsymbol{x})$ when time derivative term in Equation (9) equals to zero.

4. THE MESHLESS FPM SOLVER

Spatial Discretization

The scalar variable ϕ and derivatives are approximated by the WLS scheme as described in section 2. Therefore, for each star point $\boldsymbol{x}_i$ we have the following numerical approximations

$$\begin{aligned}
\hat{\phi}(\boldsymbol{x}_i) &= \hat{\phi}_i = \sum_{j=1}^{np} a_{ij} \phi_j^h \\
\frac{\partial \hat{\phi}(\boldsymbol{x}_i)}{\partial x_k} &= \frac{\partial \hat{\phi}_i}{\partial x_k} = \sum_{j=1}^{np} b_{ij}^k \phi_j^h \\
\nabla^2 \hat{\phi}(\boldsymbol{x}_i) &= \sum_{j=1}^{np} c_{ij} \phi_j^h
\end{aligned} \tag{12}$$

It is importance to note that the nodal parameters ϕ^h do not coincide with the approximated ones $\hat{\phi}$ because in the WLS approximation the shape functions do not interpolate nodal data. These values are related by first line of Equation (12), which implies that a linear system have to be solved in order to obtain the nodal parameters ϕ^h. Experiment shows that this equation system can be solved by a few iterations of a Gauss-Seidel method or similar [11, 12]. Then, taking advantage of the partition of nullity (PN) property of the shape function derivatives, it is possible to infer

$$\sum_{j=1}^{np} b_{ij}^k = 0 \rightarrow b_{ii}^k = -\sum_{j \neq i} b_{ij}^k \tag{13}$$

and replacing Equation (13) into second line of Equation (12) the following expression for first derivative of scalar variable is obtained

$$\frac{\partial \hat{\phi}_i}{\partial x_k} = \sum_{j \neq i} b_{ij}^k \left(\phi_j^h - \phi_i^h \right) \tag{14}$$

However, Equation (14) is unstable and needs to be stabilized. For that purpose, a more suitable equivalent form is proposed [11, 12, 13], which is given by

$$\frac{\partial \hat{\phi}_i}{\partial x_k} = 2 \sum_{j \neq i} b_{ij}^k \left(\phi_{ij} - \phi_i^h \right) \tag{15}$$

where ϕ_{ij} is a mean value of scalar variable at the midpoint of the line segment connecting the star point $\boldsymbol{x}_i$ to another point $\boldsymbol{x}_j$ in cloud. This stabilized value ϕ_{ij} is calculated by concerning the equivalent one-dimensional exact solution of convection dominated equation. The stencil of points used in the calculation of Equation (15) is presented in Figure 3. The theoretical issue of stabilized variable will be described in the next section.

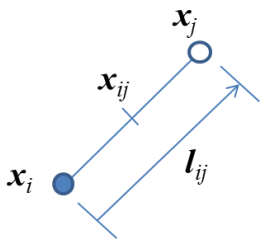

Fig.3. The one-dimensional stencil of points.

Upwind Computation of First Derivative

The general solution of the steady-state equivalent one-dimensional convection-diffusion equation with no source term is represented by the exponential form [14]:

$$\phi = A + Be^{\alpha \xi} \tag{16}$$

where $\alpha = \boldsymbol{u} \cdot \boldsymbol{l}_{ij} / 2\kappa$ is the stencil Peclet number and the normalized coordinate $-1 \le \xi \le 1$. Substituting the essential boundary conditions at both ends, namely $\phi(-1) = \phi_i$ and $\phi(1) = \phi_j$, we obtain

$$\begin{aligned}
2A &= \phi_i + \phi_j - (\phi_j - \phi_i) \coth \alpha \\
2B \sinh \alpha &= (\phi_j - \phi_i)
\end{aligned} \tag{17}$$

Hence, the mean value ϕ_{ij} can be expressed by average integral of solution in Equation (16) over the line segment as shown in Figure 3:

$$2\phi_{ij} = \phi_i + \phi_j - \zeta (\phi_j - \phi_i) \tag{17}$$

where ζ is the stencil *dissipation* coefficient, which its magnitude less than or equal to one. Using the value of coefficients *A* and *B* from Equation (17), we obtain the *optimal upwind scheme* (OU):

$$\zeta = \coth\alpha - \frac{1}{\alpha} \tag{18}$$

A simplified scheme which avoids the calculation of hyperbolic cotangents and maintains second-order accuracy [15] is given by

$$\begin{aligned} \zeta &= -1 - 1/\alpha, && \alpha < -1, \\ &= 0, && -1 \le \alpha \le 1, \\ &= 1 - 1/\alpha, && 1 < \alpha, \end{aligned} \tag{19}$$

We refer to Equation (19) as the *critical upwind* scheme (CU). Moreover, the most simple *full upwind scheme* (FU) defined by

$$\begin{aligned} \zeta &= -1, && \alpha < 0, \\ &= 0, && \alpha = 0, \\ &= 1, && \alpha > 0, \end{aligned} \tag{20}$$

which results in the first-order accuracy scheme. Thus, the approximation of convection term in governing equation (9) at star point *i* can be expressed as follow:

$$\boldsymbol{u}\cdot\nabla\hat{\phi}_i = u_1\frac{\partial\hat{\phi}_i}{\partial x_1} + u_2\frac{\partial\hat{\phi}_i}{\partial x_2} = 2\sum_{j\neq i} d_{ij}\left(\phi_{ij} - \phi_i^h\right) \tag{21}$$

In which $d_{ij} = u_1 b_j^1 + u_2 b_j^2$, the algebraic divergence operator. Further simplify of Equation (21) using the result from (17), obtain the stabilized convection flux (denoted by dF_i) as follow:

$$dF_i = -\boldsymbol{u}\cdot\nabla\hat{\phi}_i = \sum_{j\neq i} d_{ij}\left(\zeta - 1\right)\left(\phi_j^h - \phi_i^h\right) \tag{22}$$

The stabilized flux in expression (22) will be used to compute the convection term in next section

Discretization in Time

From the governing equation (9), expressions (12) of the WLS approximation procedure, and the discretization of the first derivatives (14), (15) and (22) we obtain the following semi-discretization form for the unknown at each star point *i*:

$$\sum_{j=1}^{np} a_{ij}\frac{\partial\phi_j^h}{\partial t} = r_i \tag{23}$$

In which $r_i = dF_i + \kappa\sum_{j=1}^{np} c_{ij}\phi_j^h + f_i$, represented the right-hand-side or residual term at current time. Integrate equation (23) in time using Euler scheme with critical time step size [11, 12] for each star point *i* leads to the incremental equation as follow

$$\sum_{j=1}^{np} a_{ij}\Delta\phi_j^h = \Delta t r_i \tag{24}$$

where $\Delta\phi_j^h = \phi_j^h\left(t+\Delta t\right) - \phi_j^h\left(t\right)$, the difference of nodal unknown parameter between current and next time step. Equation (24) can be solved iteratively by adding unknown parameters at star point *i* on both sides:

$$\Delta\phi_i^h = \Delta t r_i + \Delta\phi_i^h - \sum_{j=1}^{np} a_{ij}\Delta\phi_j^h \tag{25}$$

The iterative form (25) typically converges within few iteration steps [12, 13].

5. NUMERICAL EXAMPLES

Numerical solutions presented here onwards have been obtained with a FPM based on WLS approximation, taken from literature [2]. Half-size of critical time step is used in time integration process.

One-dimentional case

The one-dimensional convection-diffusion problem with *homogeneous boundary condition* at both ends is investigated. Twenty-one equally spaced points have been used to discretize unit length domain. Convective velocity u = 1 m/s and diffusivity parameter κ = 0.01 m^2/s.

Figure 4 shows the steady-state results for equation (9) with a sinusoidal source term f = sin πx using three-scheme, namely OU, CU and FU schemes as described in previous section. The values of unknown parameters ϕ_i^h solved by optimal and critical upwinding show no different and very close to analytical solution. A small over diffusion appears for FU scheme.

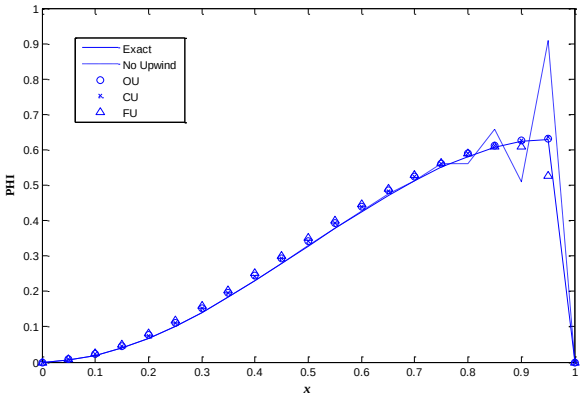

Fig.4. One-dimensional solution with various stabilized schemes.

Two-dimentional case

The next example is analysis of two-dimensional thermal convection-diffusion a square domain under a uniform heat source f = 10 using a regular square grid of 8

× 8 points with diagonal convective velocity $u_1 = u_2 = 1$ m/s and diffusive coefficient $\kappa = 0.005$ m^2/s. A prescribed zero value, *i.e.* homogeneous boundary condition, of the temperature at the boundary has been taken. Figure 5 and 6 show the results for the unknown parameters ϕ_i^h. The numerical solution is free of oscillations and coincides with the expected result [2] for all stabilized schemes.

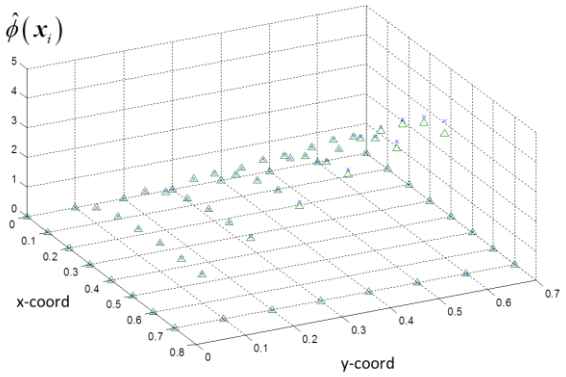

Fig.5. Two-dimensional solution with diagonal velocity field. Cross-point shows results from OU and CU schemes; Triangular marks represent FU result.

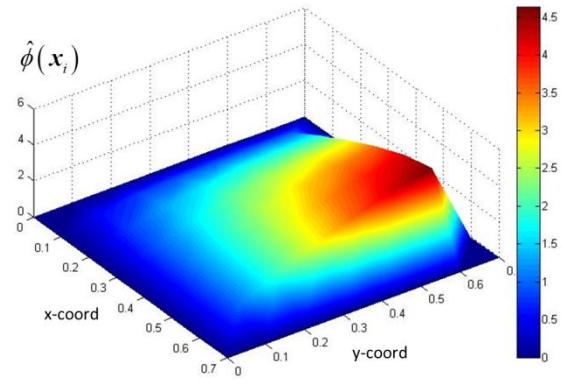

Fig.6. Contour of two-dimensional solution with diagonal velocity field, the optimal upwind (OU) scheme.

6. CONCLUSION

The finite point method (FPM) with upwind discretization of first derivatives to solve convection-dominated flow is presented. The advantage of the method compared with standard finite element method (FEM) is to avoid the necessity of mesh generation and compared with classical finite difference method (FDM) is the facility to handle the non-structured distribution of points.

The results from numerical examples show that present FPM seems to be sufficiently accurate. Extension of this method to solve other specific fluid mechanic problems should be further investigated.

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Environmental Protection and Conservation Best Practices for Waste Management of Small Sized Hotels in the Southern Gulf of Thailand

C. Choosri and Ann S. Ashton

***Abstract*—** *This study was designed to explore the management of waste in the small sized hotels (SSHs) in the Southern Gulf of Thailand. This study involves the policies of agencies that affect the management of waste within the hotel operations in various departments, for example food and beverage and kitchen It investigates environmental management systems (EMSs) to evaluate the position of the small sized hotels (SSHs) on environmental issues and to impart this knowledge to interested parties, including other scholars. However, to achieve the basic objectives of social responsibility and the environment it is essential for system development and integration between policies and practices relating to the management of waste in small hotels. Therefore, it is necessary to perform small hotel training related to waste management, and assessment of incident, training in accordance with local policy, and involve all staff in environmental protection and sustainable development together.*

***Keywords*—** Hotel industry, Waste management, Environmental policy, Environmental practices

1. INTRODUCTION

The World Tourism Organization [1] defines Small Hotels as typically supplying fewer than 50 bedrooms, employing fewer than ten people, and operating in the lower reaches of the market. Alongside such tangible measures are essential, largely intangible and qualitative, defining features inherent in small firm ownership and management, in general and at sector level. [2] Working from a rational economic business mind-set. [3] Reflect this stance in their definition of a Small hotel, it often has more than minimal capital invested in it, employs non-family labor and is perceived as a business by its owners. They have commonly up to twenty or thirty rooms and less than twice the number of beds, a restaurant or a dining room, and a bar, and sometimes also offer a few other guest facilities and services. Small hotels can be defined as hotels with a 3-star and below rating, with a 50-room and below accommodation, including budget hotels, motels, backpacker inns and home-stay businesses. [4] Anticipates that there will be growth in the hospitality business for one-to two-star and budget hotels because more tourists are expected to demand lower-star accommodations and budget hotels. Small hotels often have limited time and resources. [5] For that reason, the survival of a firm can be a combination of several factors, such as human resources, technologies, organization, culture, and marketing. [6]. The resource-based view of the firm theory, resources and capabilities can create a competitive advantage for hotels. [7] The most significant problem is that small firms generally are not as advantaged as the large firms, since their limited financial resources and liability do not allow them to innovate as easily as larger firms.

The International Hotel Environment Initiative (IHEI): [8] Each year guests of the hotel create waste of 1 kg resulting in the accumulation of billions of tons. However, several small hotel managers are less interested in waste management, for example reducing or recycling, because such activities would be costly and time consuming. [9] Reported with that the solid waste from the source, the entire economy would increase in the United Kingdom 3% per a year faster than GDP and also for most of other European countries in the hotel business, the cost of solid waste is not just the cost of disposal; but also other hidden costs such as staff resources and energy [10].

Many agencies are concerned about the environment in Thailand. For example, The committee in charge of environmental activities are to promote tourism. The environmental assessment has been prepared for the operation of the hotel [11] .The Green Leaf Foundation was founded in early 1998by a company with a vision for the development of the tourism and hotel business, which includes the Tourism Authority of Thailand Hotel Association of Thailand. United Nations Environment Programme for Asia Pacific. General office management.Electricity Generating Authority of Thailand The quality of the environment.The Metropolitan Water-works Authority. The Green Leaf Foundation works to improve the energy efficiency and environmental quality of tourism business and this hotel is the green leaves.

Small Hotels in the Southern Gulf of Thailand popularity of mutual care and protection of the environment is constantly increasing. In parts of the country the concept

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of environmental protection is to be taken as part of national policy, such as government agencies and the private sector. International organizations. All aspects of the industry. The hospitality industry and tourism industry, especially in Small hotels. In addition to the energy services industry is heavily used. The impact on the environment in many ways. Whether the resources. Discharges and Environmental impact in the community [11].

Based on this study and the basic theoretical assumption that the hospitality industry faces environmental issues similar to those of small hotels, the present study was designed to investigate the general nature of environmental protection programs, waste management of small hotels in the Southern Gulf of Thailand. The objectives of the research were:

How to create best model for a small hotel in terms of waste management within small hotels in the Southern Gulf of Thailand.

Key Definitions

Key terms may be defined in several ways depending on the theoretical approach adopted. The definition of key terms as presented below are based on prior literature and are used throughout this thesis.

Environmental management: defined as waste management in the environmental performance of small hotels in the Southern Gulf of Thailand.

Small Hotels: defined as typically supplying fewer than 50 bedrooms, employing fewer than ten people, and operating in the lower reaches of the market [1] in the Southern Gulf of Thailand.

2. LITERATURE REVIEW

The Conceptual Model of solid waste management in the Hospitality Industry

The International Hotel Environment Initiative (IHEI) [8] reported that solid waste is one of the most negative impacts on the environment of the Small Hotels. Several hoteliers get rid of their waste by landfill, but this is the least preferred option for solid waste management (SWM) and waste management is a major cause of environmental degradation. While some of the larger hotels have been developing habitat covered include Solid waste management)SWM), [12]. The Westin San Francisco Airport Hotel had a project to recycle waste from the hotel in 1994 as a reduction; how to buy recycled products to provide environmental education for employees and donating excess food to local food banks and recycling paper, aluminum and plastic. Small hotels often face a range of barriers to recycling of waste. Is the lack of space and time [13] needs to be concerned about the comfort [14], [15], said structure. Fundamental in influencing the waste management of Small Apotheker (1995) [16] it argues that there are many ways. Local authorities need to increase the recycling of Small Grouping, a collection of businesses that are concentrated geographically imposing costs for garbage collection. The development of markets for recycled materials and enhancing awareness of the benefits of the recycling program.

Industry Solid waste management conceptual has been investigated for several years, for instance a study carried by For example, a study carried out by Cummings [17] developed a hierarchy model of hospitality SWM. The model introduces five levels for waste minimization, first level commit to waste minimization, second level purchase with eco-intelligence, third level use efficiently to generate less waste, fourth level reuse waste materials and last level segregate and recycle waste. However, Cummings's model will not be applicable to hoteliers who have negative attitudes towards the implementation of more sustainable SWM practices because the model does not have any system of motivation and/or pressure to influence hoteliers' behavioural intentions in relation to SWM. It is essential to educate and train staff about waste minimisation practices, along with providing incentives to enhance their commitment to the programme [17] ,[18]. In addition, Cumming [17] suggested that customers can play an important role in a hotel's waste recycling management, such as not contaminating waste with food. A range of methods can be used to encourage customers to segregate their recyclable materials, for example providing another rubbish bin in the room or near lifts for recyclable materials, add more example. Hayward [19] indicated that customers' attitudes towards the environmental issues had changed positively, such as many hotels reported that customer participation rates in hotel waste recycling programmes has increased significantly, for example Disneyland resort in Anaheim and Disney World.

The waste hierarchy introduced by Waste [20] provides a range of options to handle different waste streams (prevention, minimisation, reuse, recycle, energy recovery and disposal) (see Figure 1). Prevention is the elimination of waste before it is actually created, while minimisation is the reduction of waste during the life cycle of the product. Re-use is a process of putting waste materials back into use so that they do not go into the waste stream. Recovery is the retrieval of a part of the value of the materials through recycling and energy recovery. Disposal, at the bottom of the hierarchy usually involves landfill and incineration of waste [21]. However, the waste hierarchy did not address composting, which was an essential SWM option for handling organic waste in a sustainable way [22].

This hierarchy can be used as a guiding principle of the potential options for small hotels to manage their solid waste effectively. For example, it has been modified to involve composting and incineration has been omitted from the potential range of options as it causes harmful impacts to the environment and human health, wastes valuable resources and hampers recycling and composting alternatives [23] .

Fig. 1. The SWM hierarchy

Taleb [24] developed a model for larger hotels in Egypt to assist them recycling hotel waste. It involves nine steps: (1) incorporating recycling into hotel policies, (2) performing a waste audit, (3) reusing waste materials, (4) identifying eligible materials for recycling, (5) working with the waste carrier at all stages, (6) developing a waste separation programme throughout the hotel, (7) purchasing recycled products, (8) making staff aware of the hotel's waste recycling programme and (9) involving customers. Nevertheless, Abu Taleb's model targets only recycling and thus pays more attention to dealing with the waste after production rather than preventing it at source or reducing it during the production and processing stages.

Many countries undertake the principle of "pay as you throw" to encourage waste reduction activities [25]. Some local authorities in the United States have enacted legislation to enforce commercial recycling but such laws are particularly targeting larger businesses [26] identified 13 ways for local government to enhance small businesses' recycling collection, among these are cluster collections from geographically concentrated businesses, imposing a charge for municipal waste collection, developing markets for recycled materials, making waste carriers and producers aware of the benefits of implementing recycling programmes and working in partnership with the private sector to encourage small businesses' recycling collection.

A range of barriers often face small businesses in recycling their waste, including lack of space, inconvenience and time constraints [13]. Small businesses often generate small quantities of waste which are unattractive to waste carriers. Most recycling companies typically require specific amounts of materials to be available before collection [27]. Operators of small tourism firms often lack the information, guidelines, time and motivation to implement environmental practices [28]. Composting is considered an effective way for disposing of waste with high organic content, i.e. food waste [29].

It is a process in which the organic waste is broken down biologically under controlled conditions so that the end product can be used for horticulture. The decomposition is carried out by bacteria in the presence of oxygen, and the food waste is broken down into water, carbon dioxide and humus which are returned to the soil to improve its structure and to add to the micronutrients in the soil [22].

Composting is a process, normally taking between three and six months, depending on how the materials are handled. The period can be reduced by turning over the composting materials regularly [30]. The composting process can be simply undertaken using a traditional compost heap at home or commercially via using open air windrows, covered windrows and specially designed composting vessels. Traditionally, food waste was fed to animals in the United Kingdom but this option is no longer used since the foot and mouth disease outbreak in the United Kingdom in 2001 [32].

Based on the results obtained from the case studies along with the reviewed literature, a best practice model of SWM is proposed below to help small hotels manage their solid waste effectively (see Figure 2). The model considers four main steps to reach zero waste.

3. METHOD

Data were analysed using a grounded theory approach so that themes emerged from the data analysis began with transcribing, reading through the text and coding the data Relevant text was then identified and categorised into different themes. Congruence and dissonance in the data and exploration of the relationships between theoretical constructs enabled the development of a best practice model for SWM in small hotels.

Model of solid waste management in the Small Hotels

*Step 1: D*etermination of the best small hotels in a good environment. The results showed that Small and showed great determination to tackle. Responsibility for their environment, which is related to SWM small hotels. A commitment to continue to build small hotels management eco-friendly is the most important communication that should first take place.

Implementation of practices to reduce and recycle waste in small hotels. There is also pressure from external customers and the environment. However, the training of employees can facilitate the correct use of the allocation of resources and procedures, for reducing and recycling waste .

Operators who hold a negative attitude toward the small hotel that is environmentally friendly. Operators who hold a negative attitude towards a small , eco-friendly . Government should consider the main punishment . How to find the implementation of environmental laws . However, the introduction of benefits such as reduced costs for SWM in Small hotels. General customers are demanding better environment . This is a way for small hotel operators with the government on the environmental management of the Small hotels.

Step 2: Undertake a waste audit. Previous researches, such as Taleb [24] indicated that the auditing process is an essential step to move towards better SWM best practices.

Although auditing was not a practice carried out by the hotels in our case study, it is known to be effective at identifying types, sources and quantities of waste streams produced by hotel businesses and then determining the best way to handle each waste stream. Hoteliers must maintain records for waste audits and disposal routes to measure the effectiveness of their SWM strategies and their control of disposal costs. Disposal costs are a key performance indicator in this respect.

Step 3: Implement an SWM programme based on the waste hierarchy. The hierarchy introduces five options to handle solid waste until the stage of zero waste is reached. It starts with prevention of waste at source through undertaking green purchasing practices. Second, operators should consider different ways to reduce waste during the processing and production stages, for example adopting new technology and changing production techniques. Third, once the waste has been produced, hoteliers have to make use of it through different means: re-using waste materials in-house and exploiting product takeback schemes, selling durable items and giving large/heavy items to charities. Fourth, hoteliers should segregate and recycle waste materials. Finally, operators should compost organic waste,food waste. Thus, careful SWM in small hotels could result in zero waste for disposal to landfill.

Step 4: Select a waste carrier. Hoteliers can contract with either the local authority or a private-sector contractor to get rid of the hotel waste. The decision should be based upon one key consideration, the environment. However, economic considerations are likely to drive decision-making and thus options should be costed to incentivise hoteliers to reduce environmental impact so that cost becomes a proxy for environmental impact. The model considers the significant role of the waste carrier in the hotel's SWM programme. A range of facilities and services should be provided by the waste carriers to ensure that all the options in the waste hierarchy can be implemented. Waste carriers should educate small hotels on how to reduce and/or cut waste at source, through the adoption of green purchasing practices. Moreover, carriers should have recycling and composting systems for commercial businesses and provide the tools needed to enable them recycle and compost their waste, bins or bags to separate their waste.

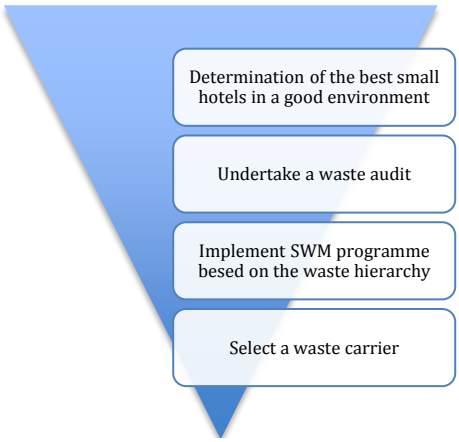

Fig. 2 Best practice model of SWM in small hotels

4. CONCLUSION

It is evident from the literature reviewed that the hotel industry all over the world is becoming increasingly environmentally responsible. The main forces exerting pressure on the hotel industry throughout the world are said to be government regulations, changing consumer demands, shifting professional ethics, and initiatives by professional associations, international organizations, and nongovernmental organizations. The prevailing recommendations, as well as the recommendations of this study, include almost all activities that have environmental issues.

IT is recommend that for the hotel industry in Thailand**,** it is necessary to perform small hotel training related to waste management, and assessment of incidents, training in accordance with local policy, and involve all staff in environmental protection and sustainable development together.

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The Development of Hotel Business in Lao PDR

Saynakhone INTHAVONG, Phanhpakit ONPHANHDALA, and Zhou ChangChun

Abstract— *Lao PDR is selected as the World Best Tourism Destination for 2013 by European Council on Tourism and Trade. Enriched with natural and cultural spots, Lao PDR attracted more than 3.2 million visitors in 2012 or a half of its population, which has increased by over 3-folds as compared to 2005. This achievement suggests that the boom in hotel industry will be continuing in the following years. Thus, the paper aims to review the development of hotel business in Lao PDR. The study finds that the recent development of hotel business in Lao PDR can be devided into three phases as of Prior to 1986, 1987 to 1999, and from 2000 until the present. About 40% of hotels in the country concentrates in the Vientiane Capital. The birth rate is especially high in recent years. Domestic private firms still dominate the majority of the total, whereas foreign investment and joint venture show a fast growing. In addition, the study also finds a continuous emphasis from the Lao government on the promissing supportive development policy on tourism and hotel industry.*

***Keywords*—Hotel Business, Tourism, Development Policy, Lao PDR**

1. INTRODUCTION

The economy of Lao People's Democratic Republic (hereafter refer to as Lao PDR or Laos) has been progressively developed since the country started to open its door to outside world in 1986. Over 2000-2012, the economy is emerging rapidly by an average growth of 7.2% [1]. The engine of economic growth is led by the investment in hydropower, mining exports and services sectors. As stated in the Seventh National Socio-Economic Development Plan (2011-2015), the government of Lao PDR recognises the tourism sector as one of the priority sources of economic growth [2]. Among the services sector, the hotel business has outstandingly developed and expanded over the time. Since hotel and tourism are two things connected to each other, the development of hotel business has tightly related to the growth of tourism sector.

In 1991, the numbers of tourism arrivals were only about 37,613 persons and the revenues from tourism sector were roughly 2.25 million USD. In 2012, the numbers of tourist arrivals reached more than 3.2 million persons and created revenues over 450 million USD [3]. These figures show that, over the past two decades, the number of visitors has increased by about 85 times and the revenues have increased by over 200 times. The strong growth of tourism sector has led to the increase of investments in hotel business accordingly in various sources including domestic private, state-owned, foreign direct investment and the joint venture. In early 1990s there was limited number of hotels available in Lao PDR, while now more than 435 hotels are provided in different grades or classes all over the country. Besides, more than 1,400 guesthouses are also running [3].

In parallel to the progress and development of the tourism industry and hotel business section, the Lao government has also improved relevant legislations to boost and administrate the industry properly and accordingly over decades.

The Lao Hotel and Restaurant Association was conceived in 1995 and have been fully active since 2000. The law on tourism was proclaimed in 2005. Moreover, the government has upgraded the Lao National Tourism Administration (LNTA) to be a part of Ministry of Information, Culture and Toursim in 2011. Along the similar line, the government agencies have also been rearranged to ensure the administration of the industry. These changes include restructuring National Tourism Authority to stretch out from central agency to province and district levels [4].

Despite the facts mentioned above, there is a lack of research to clearly identify the historical and recent development in hotel business in Lao PDR. The main objective of this paper is, thus, to review the development of hotel business in Lao PDR in various aspects. The scope of the study covers a broad view from the whole country, with an emphasis to the case of Vientiane Capital. The research content includes the development phases, values and forms of investment, growth measured by the birth rate, and related government policy. The authors employ both desk works of reviewing policies, regulations and statistics from relevant authority as well as interview survey to senior officials and hotel respondents to fulfill needed information.

The rest of the paper is structured as follows. Section 2 shows a brief literature review. Section 3 provides a short note on research methodology. Section 4 present the findings from the interview survey and data analysis. Section 5 concludes the paper with some

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remarks.

2. LITERATURE REVIEW

"Growth rates depend on both current economic conditions and how well or poorly the economy is expected to perform in the future". From the survey of Trip Advisor, the world's largest travel site, conducted from December 21, 2011-January 4, 2012. It implied that there was a growth prospects of the hotel and hospitality industry as shown in Table 1. From conclusion of the Hotel Manager Group, it claims that the hotel industry is generally doing well. The key elements in affecting the future growth rates of the hotels are the economy and political climate [5].

Table 1: Hotel Occupancy Rate in the Worldwide

Region	2011	2012
Asia Pacific	64.0%	65.5%
America	61.4%	63.4%
Europe	71.2%	70.5%
Middle East/Africa	53.3%	60.4%

Source: Hotel Manager Group, 2012.

What are the quantitative effects of various factors on the rates of entry and exit of firms? And what have been the effects on a firm's growth rate? These are two fundamental questions to review the development of a sector. Pioneer research in this area includes the outstanding works done by Mansfield (1962), Evans (1987), Dunne et al. (1988), Geroski (1995) [6-9]. Thereafter, a number of studies are followed and developed into many sectors both manufacturing and services, and areas/countries. Examples of Recent studies on the survival and growth of firms in services include Cheung and Lam (2009), Anyadike-Danes et al. (2009), and Kosova and Lafontaine (2010) [10-12]. To lesser extent, few studies have paid attention on hotel business [13]. Much of related surveys look at marketing, customer relationship management, service quality, strategic planning and so on.

Within the Lao context, so far, there has been a very limited study in Lao PDR regarding to the overview of developent and growth in hotel sector. Earlier studies have been made on tourism industry in Lao PDR. Yamauchi and Lee (1999) explores the mechanism of the Lao government to implement social and environmental policies and programmes, particularly in co-operation with various international organizations and nongovernmental organizations, in order to promote sustainable tourism development while facing a challenge to achieve sustainable tourism development [14]. Southiseng and Walsh (2011) studies on tourism and labour in Luang Prabang. The study focuses on the weak point or drawback of local labour which lacks of skills and qualification and that it could not provide adequate labour supply to booming tourist market of Luang Prabang. Both studies in general touch upon service industry in terms of tourism, but lack of focus or a deep investigation loyalty of service sector [15]. Moreover, Phommavong et al. (2008) attempts to apply SERVQUAL model from the customers' expectation and service providers' perception of hotels and guesthouses in Luang Prabang [16]. Thus, there is much room to further investigate the hotel industry in Laos such as the historial development process, using the models of SERVPER, CRM and other methods and to apply to many locations in the country including the Vientiane capital and other major cities.

3. RESEARCH METHODOLOGY

As far as observation has been made, there is very limited number of studies in the hotels or accommodation related topics in Lao PDR. Therefore, our research is designed to rely on (1) the interview survey to relavant senior government officers (former LNTA, now Ministry of Information, Culture and Tourism); and (2) the analysis from secondary data on hotel statistics, rather than desktop survey on exisiting research and/or report documentations.

The interview is based on the questionnaire form with free comments from the respondents. The interview focus on six main areas of: 1) Background of hotel industry in Lao PDR; 2) Changes of hotel industry in periods; 3) Models or forms of business operations; 4) Coherence and proximity between hotels and guesthouses; 5) Role and business models of foreign investments; and 6) Role and policy of government towards hotel industry in Lao PDR.

The analysis from hotel statistics focus on Vientiane capital, which has relatively completed data as compared to other provinces. With the limitation of growth in terms of sales, profit and employment generation according the avalibility of data, the analytical points are restricted to birth rate based the business registration, investment forms and value, to observe the overview and trends.

4. FINDINGS AND DISCUSSION

4.1. Historical Development of Hotels in Lao PDR

Hotel industry in Lao PDR started to appear since the country was established right after 1975 onwards. In the beginning, there was only a few hotels available. The hotels were merely seen at certain provinces such as Vientiane Municipality, Luang Prabang, Savannakhet and Champasack. Especially in the Vientiane Capital at that time, some of well-known hotels included Vientiane hotel, Apon Lao, Lane Xang, Dok Mai Deng, Apolo, Meuang Lao, Ekalath and Anou hotel.

The purpose of the hotels at very beginning period of the hotel industry was purely to provide a place of stay for formal and official foreigners and a small proportion of domestic customers. From then until now the industry has become more developed and more sophisticated. The industry now can be viewed as a big picture which encompasses hotels and guesthouses. There is also high involvement of foreign investment in high quality hotels and international hotel chain.

At first, accommodation form was only hotels until 1997 and then guesthouses began to serve as alternatives to hotels. In 2012, the statistics indicated 435 hotels and more than 1,400 guesthouses are running in the whole country. The guesthouses are different from hotels

because of their fewer number of rooms and smaller scale of facilities and some certain features may not be applicable. These differences are defined in the Tourism law proclaimed in 2005. In terms of customer attraction and occupants, hotels are in general more available in the downtown with higher price range where guesthouses scatter around the country. Customers for hotels tend to be ones that prefer more convenient to the center of town and demand substantial level of service and facility.

Changes in each period

From minimal and limited developed industry to the current fully competitive business environment, the hotel industry has faced tremendous differences and changes throughout its history. The industry sometimes get affected in negative way from regional disease such as SARS and Bird Flu and some uncertain political uncertainty of the surrounding countries which made the number of tourists to drop. Another outstanding phenomena in the industry is that some hotel runners are not professional but rather family own business style which only built business based on the trend or to grab the short opportunity and later failed to survive after sometime.

From the result of interview survey, we find that up to present, the hotel industry can be divided into 3 main periods of recent development.

- **Prior to 1986**
  (before the government's open door policy)

This period is the initial period of the development where the country was just established. There were no exact the number of hotels. However, it was estimated that there were no more than 50 hotels through out the country. There were obviously found in three main big provinces Vientiane capital, Savannakhet and Champasack. In that period there was purely one reason for hotel establishment which was to serve official visit of foreign delegates and visitors. Laos domestic officials during trips.

- **1986 to 1999**
  (after the open door policy but prior to the visit Laos year):

The country started to changed gradually since the government's open door policy in 1986. With the open policy, more international border crossing points were open. This period was when there were actual tourists, business people, investors entered the country. The number of foreign people increased year by year. For instance, in 1990, there were 14,400 tourists visited Laos while it was counted at 614,278 tourists in 1999.

Within this period, it was obviously seen that accommodation business or hotel industry had began to expand and more established especially a new type of accommodation business what was so called *Huen Pak* (guesthouses) began to appear in the late session of this period. This period marked real business of the hotel industry. Hotels and other accommodation types aimed at profits and expanded to serve the increase number of visitors both international and domestic.

- **2000 onwards:**

Right from 2000 when the government announce the Visit Lao Year, number of tourists confirmed to increase steadily. There were more both policy, regulations and advertisement made to support and boost the tourism industry. From 737,208 tourists in 1999 to 3,212,916 tourists in 2012. In apparel to the increase of the tourists, hotel industry also increased in its number [3].

In this period, hotels have been more developed towards professionalism and accessed to business models and competition environment. All over the country or every province have hotels with different types and grades to serve travelers.

Business models

Hotel businesses in Laos comprises of two obvious models of operations as follows:

- **Amateur/Family own type:**

From the observation, this type of business model is seen outstanding in Laos especially for most of private own hotels. This also mainly applies to those hotels that have no greater than 2 stars hotels. Some attributes of this model is depicted in Table 2 below:

Table 2: Family Hotel Business

Management	Owner/Investor
Board of directors	No
Structure	Simple and not permanant
Accounting System	Loosely accounting, simple
Number of Staff	Few number of staff
Facility	Mainly rooms
Marketing	Simple/No planned marketing

Source: Authors' Survey

- **Professional type**

From later period of the open door policy together with the period of tourism promotion onwards, the hotel industry of Laos has begun to access to a higher competition state and the provision of hotels need to be more selectable and flexible of choices. At this stage there were some establishments of bigger hotels which are invested and run in professional way. These type of hotels includes Lao Plaza hotel, Donchan Palace Hotel, Mercure hotel and so on. This type of business model has the following attributes in Table 3.

Table 3: Professional Hotel Business

Management	Through employment, not investors
Board of directors	Yes
Structure	Clear and structure
Accounting System	Proper accounting
Number of Staff	More staff and attach to each division of work
Facility	Rooms, conferences, fitness, etc
Marketing	Planned marketing

Source: Authors' Survey

Policies and Influences of the Government

Through the history of hotel business or industry it is very apparent that policies and influences of the government plays a great role to the growth of the industry. Some outstanding movements are described below:

- **Country open door policy:**

  The most impacting policy was the open door policy in 1986 which was the changing point of country economy including the hotel industry (from almost solely designed for domestic customers to widely open all kinds of customers).

- **Visit Laos Year Policy:**

  As described in the national social economic development plans in a few along its row that the government selected the potentials of tourism industry as one of its contributing source of country development. In 1999, the first promoting tourism industry was launched and called the Visit Laos Year 2000. The policy and implementation of this policy was actively try to make the world officially know the country better and try to draw world tourists into the country.

  As a routine machanism, lately in 2012, Laos also organized and implemented the Visit Laos Year to stimulate the tourism industry once again. In addition, the Lao government also got the opportunity to host the 32nd ASEAN Tourism Forum in late January 2013 which will bring the tourism as well as hotel industry to be more attractive for the years to come.

- **Tourism Law:**

  Application of Tourism Law in 2005 made the industry more secured. As a cascading pattern, relevant regulations and proper authority controls were in place. The law also indicates clearly types of accommodation such as hotels, guesthouses, room services and resorts.

- **Token host of international and regional events:**

  Since the establishment of the country until now, Laos has been honored to host many international and regional great events such as ASEAN Tourism Forum 2004, ASEAN Summit 2004, International Convention on Cluster Munitions 2010, ASEP7 2012, ASEM9 2012 and so on. All these special big events demand the hotel industry to be ready to serve the huge and privileged official travelers and tourists.

4.2 Findings from Data Analysis

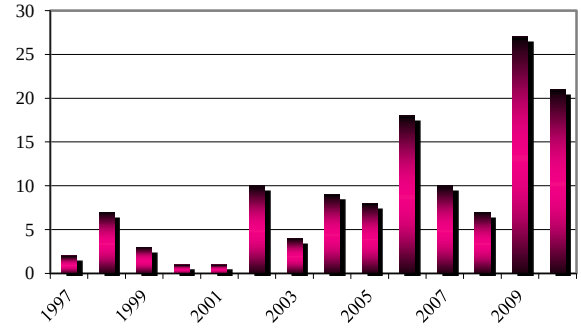
Investment forms

Nowadays hotel industry is getting to its high competition state. In relation to the growth of the social and economic state of the country, the hotel businesses follows the same trend. From the statistics, it is obviously seen that the most investment belongs to private ownership of local investors. Second highest is foreign ownership and very least proportion is occupied by state investment. More precisely, in the Vientiane capital, about 85% of hotels in Vientiane capital are owned by domestic private businessmen. Foreign investors own about 11% of the total, while the rest is in form of joint-venture.

Birth Rate of Hotels in Vientiane Captial

The figure 1 shows the birth rate of hotels in Vientiane.
From late 1990s to early 2000s, number of hotels newly received permission (registration) was very small.
In mid-2000s, the number had increased, roughly speaking, about 10 hotels are newly constructed.
The number is peak at 2009, which is the year that Lao PDR hosted ASEAN Games 25th.
From this historical event, birth rate of hotels have been sharply increasing in the past few years.
It is safe to say that now is hotel booming in Vientiane capital.

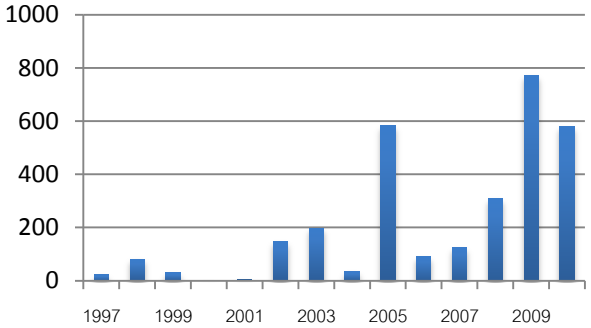
Figure 1: New Born Hotels by year in Vientiane capital



Investment Value

The figure 2 indicates the investment value of hotel business in Vientiane over 1997 to 2010.
It well reflects or consistent with the graph of the birth rate presented in the previous slide.
In late 1990s, the investment value was small and then it increased gradually in mid-2000s.
The peak of investment value is in 2009 as hotel owners were targeted to open new hotels relating to ASEAN games and business chance after the event.

Figure 2: Investment Value (unit: Billion Kips)



5. CONCLUSION

This study finds that the recent development of hotel business in Lao PDR can be devided into three phases as of Prior to 1986, 1987 to 1999, and from 2000 until the present. About 40% of hotels in the country concentrates in the Vientiane Capital. The birth rate is especially high in recent years. Domestic private firms still dominate the majority of the total, whereas foreign investment and joint venture show a fast growing. In addition, the study also finds a continuous emphasis from the Lao government on the promissing supportive development policy on tourism and hotel industry.

Lao PDR is selected as the World Best Tourism Destination for 2013 by European Council on Tourism and Trade. Enriched with natural and cultural spots, Lao PDR attracted more than 3.2 million visitors in 2012 or a half of its population, which has increased by over 3-folds as compared to 2005. This achievement suggests that the boom in hotel industry will be continuing in the following years.

This paper is an important short note to lay down the overview of hotel business in Lao PDR. However, more and more studies are needed to investigate and document other aspects such as service quality gap between expection and actual perception, customer relationship management, strategic plan and marketing and so on. Further studies on such topics would be very helpful for both private sector and the government to promote the development of hotel industry in Lao PDR.

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Street Food in Pattaya: Situation and Prospects

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Abstract— *Street food vending is considered important to employment and income generation, particularly for poor people. Besides, the street food vending is also the source of affordable food in town. This research examines the characteristics and attitudes of street food vendors and their consumers, including their street food In addition, business locations and relevant business factors, government policies, and relevant laws are also investigated. Finally, findings and conclusion lead to suggestions to development and management in vending areas and food sanitation in Pattaya City.*

Keywords— **Street food, Food hawker centers, Food sanitation, Pattaya.**

1. INTRODUCTION

The street food sector has become an important component of food distribution system in many cities in both developing and industrialized countries, particularly for midday meals (WHO, 1996). Moreover, Street food vendorsplay an important role in grassroot community, securing the source of income from the informal sector especially poor peoples. Moreover, it supplies low-cost meals for urban peoples. In this study, street food vendors and consumers‘ characteristics and their attitudes to cooking and preparing food were examined. Besides, this research threw light on on street food vendors location and its closely-connected determinants decision including public laws and rules . Finally, , the street food vendors sanitary solution policy was formulated policy-makers to promote street food vendors in Pattaya.

2. RESEARCH METHODOLOGY AND STUDY AREA

Research Methodology

Surveys were conducted in South Pattaya in 2010. Geographical spreading as well as time (morning, noon, evening) and type of business (ambulatory, stationary and residential) were taken into account to draw t a representative sample of the street food population both vendors and consumers. From vendors and consumers data collection, 132 and 315 persons respectively were selected by Simple Random Sampling technique during March – October 2010, a questionnaire and an in-depth interview were employed.

Meanwhile, WAI technique was introduced to analyze attitudes and determinant factors of street food operating and consuming patterns. In this research, the street food was dived into 5 categories; firstly, ready-meal with heating process such as roasted chiken and meat-ball fried; secondly, the ready-meal without heating process for example, papaya salad. Thirdly, cooked-to order such as fired-rice and noodle. Forthly, ready-to-eat fruits such as pine-apples, water melons and papayas. Last but not least, beverage with ice cubes.

For street food vender location pattern and its determinants, nearest-neighborhood index was employed, while street food vendors reconnaissance during March – October 2010, by geographical information systems (GIS) and global position systems (GPS). After that, the feasibility of food hawker centers location were developed by multi-criteria decision analysis.

Study Area

In this research, South Pattaya was chosen because almost all street food venders were located in this area, particularly in the South Pattaya market and Jomtien beach.

3. FINDINGS

It was found that, almost all of them were carts which can divided into 2 forms, firstly the traditional cart moved by pushing. Secondly, the modern type, a motor cart.. However, it was found that some of them are temporally stands located on the footpath or bare land.

According to the data as resulted of vendor and consumers data analyzed, the characteristics of street food venders in the study areas are shown in Table 1. It was found that, most vendors are not well-educated women migrants. They always locate their enterprise in commercial business district and high population density of urban area, moreover the place of tourism and their resident are factors influencing their location decision. Interestingly, street food vendors performed an important role to serve seasonal unemployment problem, however it does not promote their saving and remittance

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significantly. Almost all of vendor's location were good for their business, such as space, rent cost, infrastructure and number of customers.

Table 1. Characteristics of Street Food Venders

Category	Total	
	No.	%
Gender		
Male	55	41.7
Female	77	58.3
Age (Years)		
< 20	4	3.1
21 – 30	20	15.3
31 – 40	41	31.3
41 – 50	44	33.6
51 -60	21	16.0
> 60	1	0.8
Education		
Primary school	79	60.8
Junior high school	19	14.6
Senior high school or Vocational certificate	24	18.5
Diploma	1	0.7
Bachelor's degree or higher	7	5.4
Current address		
Pattaya	146	89.6
Other	17	10.4
Ownership of housing		
Householder	36	27.3
Rent	91	68.9
Living with relatives or friends	3	2.3
Other	2	1.5

Meanwhile, as shown in Table 2, almost all of street food consumers were middle-low income women who stay in Pattaya, including tourists both Thai and foreigners. Moreover, it was found that accessibility, diversity and cleanliness were decision factors for them. However, some of consumers got diarrhea from street food and food contamination tarnish reputation of Pattaya.

Table 2. Characteristics of Street Food Consumers

Category	Total	
	No.	%
Gender		
Male	136	46.9
Female	154	53.1
Age (Years)		
< 20	25	8.7
21 – 30	103	35.7
31 – 40	90	31.1
41 – 50	55	19.0
51 -60	14	4.8
> 60	2	0.7
Education		
Primary school	60	20.4
Junior high school	42	14.3
Senior high school or Vocational certificate	78	26.5
Diploma	24	8.2
Bachelor's degree or higher	90	30.6
Occupation		
Merchant or Shop keeper	104	35.3
Agriculturist	4	1.4
Government official	20	6.6
Business employee	53	18.0
Employee	56	19.0
Student	23	7.8
Other	35	11.9
Nationality		
Thai	289	99.1
Other	3	0.9
Purposive in Pattaya		
Travel	116	40.6
Work	170	59.4
Current address		
Pattaya	146	89.6
Other	17	10.4
Market boundary (Meter)		
0 - 100	41	44.1
100.1 - 500	18	19.4
500.1 – 1,000	14	15.0
> 1,000	20	21.5

For street food hawker location pattern and its determinants, nearest-neighborhood index by GPS and GIS were employed, while street food vendors reconnaissance during March – October 2010. Geographical spreading as well as time (morning, noon and evening).

Figure 1 has shown the location pattern of street food in pattaya. In this section, the areas studies were divided into 4 areas. Firstly, the central business districts (CBD) of the South Pattaya where occupy the walking street Chaimongkol temple as Zone A. Secondly, the middle density resident areas where the CBD vicinity as Zone B. Thirdly, the Pattaya view-point (Khao Phra Tamnak) area as Zone C. Meanwhile, the Fourthly is Jomtien beach area as Zone D.

It was found that almost all food hawkers location pattern in high density of resident and commercial areas were cluster pattern such as high-density resident area of the South of Pattaya including the Walking street and Chaimongkol temple, middle and low-density resident areas in Sukhumvit road. In addition, almost of them are concentrate distribution in the CBD as Zone A during 6.00 p.m. to 2 a.m. of everyday, particularly during 10.00 p.m. to 2 a.m. some of them was move from the footpath to on the road, about one-fourth of road surfaces, because many street food consumers are the Walking street worker and other enterprises such as hotel and shopping department servicers. Almost all of them live in Pattaya, then after their office hour was closed, these street food hawkers were supplied for their demand.

Meanwhile, the hawkers location pattern in Zone B was supplied to local community in the CBD fringe as the middle density resident areas. On the other hands, the hawkers location pattern in the Pattaya view-point (Khao Phra Tamnak) areas and Jomtien beach as Zone D were ribbon pattern its related with tourists behavior who concern accessibility and parking.

(Fig.1)

Fig.1. The Street Food Hawker Location Pattern

As resulted of reviewing street food vendors policies and law both national level and Pattaya office including stakeholder meeting and in-depth interview such Vice Mayer of Pattaya city and public health officer.

It was found that the Pattaya vision was developed and promoted to modern of tourism place. Therefore, food safety issue was selected in this mission. However, currently it was found that some laws and rules related to street food vendor are not effective. due to lack of budget and personal less. Therefore, some of them were not concentrate under the law such as road and footpath encroaching.

(Fig. 2)

Fig.2. The Food Hawker on the South Pattaya Road near Chaimongkol temple

However, after in-depth interview with many vendors, it was found that some of them do not understand the waiver area where the boundary still unclear, moreover many venders willing to food hygiene improving, they said that *"Food safety is good for health and Pattaya image"*, then it's good opportunity for sanitary training to develop them both vendor and cooking place.

4. DISSCUSSION

It can be concluded that, the street food vendors in Pattaya needed improvement. The strategies for street food vendors promotion should be done in two levels, areas and sanitation. . Firstly, the area and location optimization for street food vendors policies were divided into 2 strategies; the first is the space development and controlling for pervious street food vendors. The second is the optimum location for food hawkers center development. The geographical technology was employed and it was found that the hawker food center can be promoted at Jomtien beach. However, its location depends on existing land use and related laws and rules. Secondly, the street food vendors sanitation promotion policies should be formulated.. It focuses on street food vendors space, cooking and infrastructure which involves water supply, waste water and solid waste treatment system etc.

(Fig. 3)

Fig.3. The Food Hawker Center

(Fig. 4)

Fig.4. The Suitable of Food Hawker Center Location

Under this policy, the street food vendors were needed supporting form the local administrative and the ministry of public health. Therefore, street food vendors should be promote to food safety sources, moreover its was play important role on tourism industry promotion.

4. CONCLUSION

Hawker foods are an important cultural heritage, important source of nourishment/income for the public and significant contributor to the economy in Pattaya. Moreover, the industry is growing substantially in popularity and size. However, there have been concerns over the food safety of hawker foods, with studies showing poor hygiene and food safety practices of food hawkers in Pattaya. These concerns could potentially lead to a health issue for the Thai citizens and tourists, in regards to food-borne diseases.

The WHO has mentioned the popularity of street food stalls as a contributory factor to food-borne illness globally, and poor sanitation/attitudes of hawkers have been associated with reports of foodborne illness. Thus, to ensure food safety of hawker foods in Pattaya, government food safety strategies must be reinforced. This may include food safety distribution guidelines in training programmes, implementing strategies to encourage more customers to designated hawker sites and standardizing food safety polices. In addition, the importance of customer access/satisfaction to hawkers merits the need to encourage consumer participation in the improvement food safety of the hawker industry in Pattaya. Implementing an award/grading system for hawkers' stalls based on cleanliness/hygiene of the premise, could attract more customers to clean/hygienic stalls and thus compel hawkers to improve their food safety standards.

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APPENDIX

Table 4. Satifaction of Street Food Vendors

Category	Level of Satifaction		
	f	%	WAI
Income			
Very High	7	5.3	0.55
High	36	27.5	
Moderate	65	49.6	
Less	23	17.6	
Rent Cost			
Very High	62	48.1	0.73
High	18	14.0	
Moderate	28	21.7	
Less	21	16.3	
Location			
Very High	42	32.3	0.73
High	47	36.2	
Moderate	31	23.8	
Less	10	7.7	
Space			
Very High	32	25.0	0.72
High	53	41.4	
Moderate	39	30.5	
Less	4	3.1	
No. of Customer			
Very High	15	11.5	0.60
High	49	37.4	
Moderate	43	32.8	
Less	24	18.3	
Facilities			
Very High	17	13.9	0.57
High	33	27.0	
Moderate	40	32.9	
Less	32	26.2	

Table 5. Satifaction of Street Food Consumers

Category	Level of Satifaction		
	f	%	WAI
Table and chair available			
Very High	25	9.3	0.65
High	81	30.1	
Moderate	106	39.4	
Less	49	18.2	
Very Less	8	3.0	
Food cleanness			
Very High	24	8.8	0.62
High	55	20.1	
Moderate	139	50.9	
Less	36	13.2	
Very Less	19	7.0	
Food equipments cleanness			
Very High	30	10.9	0.63
High	49	17.9	
Moderate	143	52.2	
Less	38	13.9	
Very Less	14	5.1	
Place cleanness			
Very High	31	11.3	0.61
High	53	19.3	
Moderate	126	46.1	
Less	25	9.1	
Very Less	39	14.2	
Cook and vendors			
Very High	21	7.7	0.54
High	37	13.7	
Moderate	118	43.6	
Less	28	10.3	
Very Less	67	24.7	

Institutional Creativity in the Human Resource Management (HRM) System in Laos: Case of Ministry of Public Works and Transports

Thongchanh KIMANIVONG

Abstract *- Human resource management plays an important role in maximizing all professional employees to achieve organizational objectives. However, this should be done in accordance with employees' willingness and feeling as the part of organizational success. The Ministry of Public Works and Transports (MPWT) obtains a variety of professional competences from diversified job responsibilities. This paper firstly examined the perception of the MPWT personnel on the existing performance management system, performance appraisal, and induction; and secondly, identifying strengths and weaknesses of performance management system at the ministry.*

Both qualitative and quantitative research methodologies were deployed. Qualitatively, the in-depth interviews were conducted with stratified sampling of directors of personnel divisions and department while quantitatively; a survey questionnaire was employed in collecting primary data on perceptions, attitudes, and value of the employees and administrators regarding performance management system of the MPWT.

It was found that performance management system in the MPWT was mainly on system evaluation, and from top-down process rather than from multi-angled feedbacks. However, what was interesting was that performance management system in the MPWT significantly contributed to the improvement of strategies for managing or leading human resources and supported professional development of personnel in the MPWT, which in turn enhanced the performance of staff, and contributed to overall the organizational performance.

It was also found that the performance management activities were based upon the trusts and reliability of peers and colleagues voting for the popularity and professional knowledge and competence suitable for the position or should be promoted to another higher rank in the MPWT, which is difficult to measure the significance of staff performance and performance appraisal since the people providing feedbacks may not be acquaintance to the individual appraise.

The result highlighted the needs for performance management system of the MPWT to be generated to the concept from system evaluation to process; from appraisal to joint review; from outputs to outputs or inputs from reward oriented to more development oriented; from top-down to 360 degree feedbacks; from directive to more supportive; and from human resource manager's responsibilities to more individual employee's responsibilities.

Key words: *Performance management, Performance Appraisal*

1. INTRODUCTION

1.1. Rationale

Over the two decades, there has been a dramatic change in organisation's choices of human resource management (HRM) practices towards what are often called 'innovative practices'. These practices embrace greater teamwork, greater participation by employees in decision making, more information sharing among employees, greater training and education, and often new forms of incentive pay to complement the practices [Shaw, 2003]. Institutional creativity or innovation has its specific meaning. In this paper, the term 'innovation' is preferably used as it covers broader meanings. Farazmand [2004] succinctly defined 'innovation' as "novelty in ideas, approaches, methods, processes, structures, behaviors, attitudes, and cultures, as well as in technologies and skills. It is also referred to the knowledge base that is used to produce new products and deliver services, to govern and administer societies, and to manage organisations of all types" [p.8].

Institutional innovation in human resource management plays an important role in organisations. Shaw [2003] stresses that innovation practices enhance the opportunity for employees to undertake problem-solving, and raise the personal returns to problem-solving with new forms of incentive pay; whereas, Farazmand [2004] emphasises that institutional innovation is seen as a key to the legitimacy and support systems that innovative ideas can enjoy as a strategic instrument toward capacity building and enhancement in human resource development and management. Therefore, the organisations most likely to gain from innovative practices are those that produce high quality of performance or high complex products [Farazmand, 2004; Shaw, 2003]. It is further put forwards that necessary to national development and sound governance is urgent need to innovate in strategic human resource management that serves as capacity building. It is difficult for organisation to function without competent and cooperative people, and strategic HRM is central to the development and enhancement of sound governance and management [Farazmand , 2004].

Innovation in HRM involves three categories, according to Farazmand [2004], namely: human resource or personal area concerned with general management and leadership; technological and financial resources essential to sustain and promote HRM; and organisational area, including structure, process, and value system or culture. It is elaborated that the first category for innovation is a constant search for the needed personnel, for the right

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person for the right position, and for the right position or job for the right person. As asserted by Farazmand, this is a challenging job, which can be achieved through careful planning, recruitment, education, and training at all time. Technological innovation is essential to human resources development and capacity building; however, this can only be possible through availability of necessary financial resources that finance and support it. In addition, organisational settings provide structure that processes of innovations take shape [Farazmand, 2004]. Several researchers reveal that the key constituents of strategic innovation in human resource development and management are information technology, strategic motivation, strategic knowledge development and management, transparency, accountability, trust, and ethics [Davenport, 2002; Farazmand, 2004; Milner, 2000; Shaw, 2004].

In relation to institutional innovation, human resource management itself (HRM) is recognised as a top priority in many organisations with high performance, and as a top-level activity concerned with setting broad directions and strategies to achieve organisational goals [Campling, Poole, Wiesner, Schermerhorn, 2008]. As Bolman and Deal [2008] emphasise, HRM is associated the relationship between people and organisations since organisations need individual's energy, effort, and talent; whereas, individuals requires organisations for intrinsic and extrinsic rewards. it is noted by Macky and Johnson [2003] that HRM is seen as the process and activities focused on utilising all employees to achieve organisational goals [Macky & Johnson, 2003]. In addition, several authors such as Boxhall and Purcell [2003] and Rudman [2002] add that HRM is related to all the concepts, strategies, policies and practices which organisations use to manage and develop people who work for them. Rudman [2002] support that human resource management has four goals, namely: integration which means an organisation's strategic plans are more likely to be implemented successfully when those plans take human resource issues into account. Employee commitment is that employees must identify with the organisation, and be committed to helping the organisation to achieve its goals and objectives. Flexibilities and adaptability mean human resource management contributes to the development of organisational structures which are organic; while quality means that quality of staff, performance, standards and public image are important objectives for the organisation.

Diagnosing the human resource management system at Ministry of Public Works and Transports (MPWT) has been a continuous effort of the Lao government for the past three decades. The Lao government has recently focused on reducing the number of public servants in all levels, improving personnel development by providing continual training opportunities, creating fairer systems in recruiting people for appointment and promotion into public services, creating a new wages systems and other incentives such as health care cover and bonus, organizing and scheduling workloads and output, setting priorities, creating a system in monitoring staff's performance, and better handling conflict and grievance within departments or inter departments. In addition, ensuring efficient public service delivery through improved organizational structures and procedures, and creating a productive and motivated professional civil service adhering to high ethical standards is a top priority

1.2. Objectives

This study has the following objectives:

(1) To explore the perception of existing HRM system in terms of human resource development climate, performance appraisal, induction, and knowledge creation in MPWT.

(2) To identify the strengths and weaknesses of HRM system.

1.3. Scope of Research

The content of this research project covers the evaluation of perception of the existing leaders, managers and employees regarding the existing human resource development climate, performance appraisal (including compensation and benefits), and induction in MPWT. These management aspects are believed to be responsible for the institutional creativity leading to enhancing human capital in an organization.

1.4. Scope of Population and Sampling Size

The study aims at three different locations: Vientiane capital, Borlikhamxay and Champasack. The top management at each target location and the head of divisions will be approached for data collection. The study will be conducted in 2013.

2. LITERATURE REVIEWS

2.1. Overview of Human Resource Management (HRM)

Human resource management (HRM) in an organization involves the policies and practices needed to carry out the staffing (or people) function of management. HRM helps the management process avoid mistakes and to get results. Therefore, the HRM manager's job in management process involves planning, organizing, staffing (human resource management), leading, and controlling [Campling, Poole, Wiesner, Schermerhorn, 2008]. HRM includes conducting job analyses, planning labor needs and recruiting job candidates, selecting job candidates, orienting and training new employees, managing wages and salaries, providing incentives and benefits, appraising performance, communicating, training and developing managers, building employee commitment, being knowledgeable about equal opportunity, affirmative action, and employee health and safety; and

Theoretically, there are various ways to assess how well Human Resource Management System (HRMS) perform their roles. McKinsey & Co [2001] proposes organizational effectiveness and organizational capacity model as tool for measuring state management performance. Management is generalized as a process of managing the organization's internal elements for implementing a set of activities towards desired results under the changing and uncontrollable external environments for fulfilling the organizational objectives in line with its vision. The organization's ability to align its vision, goals, planning, activities and results is known as organizational effectiveness.

2.2. Key Human Resource Management in the past and present

Personnel administration or human resource management system has a long history, differing in each era of development. The human resource management system is usually called a theory, which has been discussed and studied in combination with organization culture. The central issues of the theory focus on the labour in each era. Through the observations of labor forces, researchers have learnt the objectives of human resources management, and the system has varied in each period of time.

Human resource management (HRM, or simply HR) (Wikipedia) is the management of an organization's workforce, or human resources. It is responsible for the attraction, selection, training, assessment, and rewarding of employees, while also overseeing organizational leadership and culture, and ensuring compliance with employment and labor laws. In circumstances where employees desire and are legally authorized to hold a collective bargaining agreement, HR will also serve as the company's primary liaison with the employees' representatives (usually a labor union). HR is a product of the human relations movement of the early 20th century, when researchers began documenting ways of creating business value through the strategic management of the workforce. Between 19th century and 20th century, United States of America created a science of human resource management. Labor is regarded as an economic asset, therefore, economic model has been used for human resource administration through training and development, using economic as incentive to reinforce the activities or action of the labor.

The development of human resources in 1920s regarded human as machinery; therefore workers have to work as machines. As such a worker has to explore the working method by himself/herself, which requires the capacity and the needs of personal development. The development of human resource management system, in the 1930s, experimentation of Pearson investigated the relationship of thoughts, ethic and dissatisfaction of labor, through employee ethic survey. In the 1950s, behavioral science theory specializes on incentives competency. The highest incentive was believed to be self-satisfaction. The theory states that when employees set their highest target by themselves, they will be highly satisfied and put utmost efforts to fulfill the objectives. In the 1980s, worker can choose their own job, therefore, has developed capacity called autonomous human model, equiped with the right of a citizen. It all depends on a person to choose a job and responsibility. This new ideology ignited the creation of various human resource management systems, for example, opportunity seeking through training and education for capacity enhancement and good employment.

Human models developed in the past have been through various stages. At present, there are varieties of systems, which have been influenced by human right. The human resource management system, in reality, depends on the hypothesis of humanity, with mysterious history. Nowadays, humanity or human right has been regarded as self-humane. The management of human resource management systems have, therefore, changed from managing slave, to managing work force, to managing personnel, to managing human resources, to managing human creativity, and currently, managing human capital in the knowledge economy.

According to wikipedia.org, a human resource management system (HRMS) or human resource information system (HRIS), refers to the systems and processes at the intersection between human resource management (HRM) and information technology. It merges HRM as a discipline and in particular its basic HR activities and processes with the information technology field, whereas the programming of data processing systems evolved into standardized routines and packages of enterprise resource planning (ERP) software. On the whole, these ERP systems have their origin on software that integrates information from different applications into one universal database. The linkage of its financial and human resource modules through one database is the most important distinction to the individually and proprietary developed predecessors, which makes this software application both rigid and flexible.

There are theoretical models that have been proposed to assist HRM specialists to develop organisational structures and systems that could achieve the system integration which is essential. That is, the 'hard' and the 'soft' model. The notion of 'hard' and 'soft' approaches is an integral component of all HRM practices. These two underlying themes of soft and hard HR practices can be seen in the Harvard and Michican Models. As pointed out by Clegg, Kornberger and Pitsis [2008], on the one hand, the 'soft' model of HRM, it is assumed that work is an integral part of life and should provide a fulfilling, empowering, and positive experience for people. People will be attracted to jobs that provide opportunity for growth and advancement; they will stay in jobs that invest in them as valuable assets. While on the other hand, the 'hard' model of HRM, it is assumed that people do not want empowerment, they simply want to be told what is required of them, given the resources and training to achieve these requirements, and the be remunerated if they go beyond those requirements. People will be attracted by good pay, clear objectives, and unambiguous job duties [Clegg, Kornberger, Pitsis, 2008].

2.3. Core Function of Human Resource Management Practices

The core HRM functions have the potential to influence significantly the performance and outcomes of organisations. Several authors point out that key functions of HRM include recruitment, selection, performance management, retention and development of personnel [Campling, Poole, Wiesner, Schermerhorn, 2008; Clegg, Kornberger, & Pitsis, 2008].

2.3.1. Recruitment

One of the critical aspects of effective HRM is the ability to design appropriate recruitment methodologies. Recruitment, according to Clegg, Kornberger and Pitsis [2008] and Macky and Johnson [2003], involve searching for and obtaining potential job applicants in sufficient numbers and quality so that the organisation can select the most appropriate people to fill its job needs. In addition, Campling et al. [2008] add that recruitment is a set of activities designed to attract a qualified job

candidates to an organisation. The focus is on the word 'qualified' as the importance.

These researchers stress that effective recruiting should bring employment opportunities to the attention of people whose abilities and skills meet job selection. It is noted that the process of recruitment needs the organisation and HR manager to know what they are looking for in terms of skills, knowledge, and capabilities and to know that these things match what is required for the job [Clegg et al., 2008]. Recruitment covers both external and internal strategies. External recruitment as Campling et al. [2008] reveal is that job candidates are sought from outside the hiring organisation, which involve local, city, national, and even international newspaper, Internet and e-recruitment websites, universities and employment agencies. Whereas, internal recruitment seeks applicants from inside the organisation, and most organisations have a procedure for announcing vacancies through newsletters and electronic bulletin boards. Both strategies for recruitment have their own advantages and drawbacks, however, what HR managers need to know in the recruiting stage is that the applicants is provided with a realistic job preview [Campling et al., 2008; Clegg et al., 2008].

2.3.2. Selection

It is noted that selecting applicants is not distinct from recruitment because both functions require high level of synthesis between the nature of the jobs being filled; the skills, qualification, capabilities and attributes required of the prospective employees; the skills, qualifications, capabilities, and attributes of the people available in the job market [Clegg et al., 2008]. They go on to note that where recruitment focuses on attracting the right person for the job, selection concentrates on choosing the right person based upon a range of selection techniques and methodologies [Campling et al., 2008; Clegg et al., 2008]. Clegg et al. [2008] and Campling et al. [2008] refer selection to the tools, methods, and criteria upon with people will be, and are selected fro a given position, and include job applications, interviews, tests, and measurement. These become the essential and integral selection tools for HR managers. Research suggests that the use of these selection tools (the job application, the job interview, test and measurement) is a good predictor of performance of staff, especially so when multiple tools are appropriately used [Mendoza et al., 2004].

2.3.3. Performance Management

Organisations require ever-improving performance to survive and prosper in today's competitive world. Individual and organisational performance improvements are the key to competitive advantage. Performance management is seen as "an interlocking set of policies and practices which have their focus the enhanced achievement of organisational objectives through a concentration on individual performance" [Stone, 2002, p.265]. Macky and Johnson [2003] support that "performance management is to ensure that employee actions are linked to and add value to organisational objectives, that a performance culture is developed and maintained, and that employees are rewarded for their contribution and developed so that they can perform" [p.7].

Performance management, as asserted by Stone [2002, p. 265], has the following key elements:

- The creation of a shared vision of the organisation's strategic objectives
- The establishment of performance objectives for each function, group and individual to ensure their performance is aligned with the needs of the business.
- The use of a formal review process to evaluate functional group and individual progress towards goal achievement
- The liking of performance evaluation and employee development and rewards to motivate and reinforce desired behaviour. Thus, performance management involves goal establishment, performance evaluation, employee development and reward. It provides the link between the organisation's strategic business objectives, employee performance, development and rewards and organisational results.

It is, therefore, important to note that performance management can have a significant impact on the success of an organisation through promoting cooperative effort towards common goals, encouraging teamwork and more open communications; increasing individual and group performance; and facilitating change [Stone, 2002].

2.3.4. Performance Appraisal

Performance appraisal can be viewed as an overall measure of organisational effectiveness since organisational objectives are achieved through the effort of individual employees. Performance appraisal of employees is a critical, dynamic and ongoing management activity because managers are continually observing and judging their employees. It is noted that performance appraisal involves evaluating performance, communicating that evaluation the employee and establishing a plan for improvement. This evaluation process, as asserted by Stone [2002], may be formal or informal which has a direct impact on the employees' salary increase, promotions, terminations, training and career development or professional development. Dynamic performance appraisal program has its characteristics of goal establishment, performance feedback, and performance improvement. It is stated that good performance measurement is a necessity for effective feedback, while feedback in turn is also essential for a quality goal-setting program because it allows staff to see how well they are performing and helps them to set new goals. Setting goals without creating a way of measuring achievement is useless. Goal setting, if they are designed well, can be the powerful tools for increasing staff motivation and performance [Stone, 2002].

2.3.5. Remaining and Developing People

It is argued that an important goal of HRM is to maintain a qualified workforce. There are two interrelated aspects to retention and development. The retaining refers to methods and approaches used to keep talented people in the organisation such as awards, promotions, and remuneration; the developing of staff concerns the methods and approaches used to enhance, transform, and better utilise staff knowledge, skills and capabilities—such as training and education that assists them in

entering and finding their way around the organisation and familiarizing them with the job, skills training that aids in learning and updating skills required for technical aspects of a job, and management or leadership development programs that help develop employees' managerial and leadership skills. These forms of development can be done via on-the job training which includes coaching, apprenticeship, and mentoring programs; and via off-the job training which includes formal courses and programs, delivered in-house or by independent training and education institutions, as well as other training and development methods [Clegg et al., 2008], [Campling et al., 2008].

Lawler [2005] believes that organisations should strive towards virtuous spirals in their HRM practices and processes: "organisations need to offer a skills and performance-based substitute for the loyalty contract that motivates selective retention and high performance. It needs to stress that continued employment is based on performance and having the right skill set for the organisations' business strategy. It also needs to stress that people are rewarded for performance and skill development. When this is translated into the right combination of rewards system practices, people will be motivated to excel and those who excel will be motivated to stay because they will be highly rewarded. This is the foundation of the virtuous spiral, in which both sides win and create success for each other" [pp.14-15]

Furthermore, the function of human resource management was initially dominated by transactional work such as payroll and benefits administration, but due to globalization, company consolidation, technological advancement, and further research, HR now focuses on strategic initiatives like mergers and acquisitions, talent management, succession planning, industrial and labor relations, and diversity and inclusion

3. RESEARCH METHODOLOGY

Quantitative and qualitative research approaches were employed in this dissertation. The survey questionnaires were used to collect data from 80 respondents within MPWT; and the in-depth interviews were conducted with stratified sampling of directors of personnel divisions and department in MPWT. The questionnaires used in this paper were to collect data concerned with perception, attitude, and value of the employees and administrators regarding performance management system in MPWT.

The completed questionnaires were analysed by SPSS software, version 19. The analysis looked into descriptive statistics, including mean.

4. RESEARCH FINDINGS

4.1. General Information about Respondents

The result of this study shown that there were male respondents more than female respondents which covered 62 persons and 18 persons respectively. It was indicated that most of the respondents were holding technical staff (62 persons), Deputy Head of Division (25 persons) and Head of Division (13 persons) respectively. Thirty respondents were holding Bachelor degree; whereas, twenty-one respondents had higher diploma, eighteen and eleven respondents were holding Master degree and diploma respectively. The result further revealed that most of the respondents had experiences and worked in MPWT over fifteen years. With respect to job responsibilities, most of the respondents in the survey had responsibilities for technical work (38 persons), then supervising or coaching (21 persons) while administrative (13 persons) and clerical work (8 persons)

4.2. Performance Management

Rating Scale: 1, strongly disagree; 2, disagree; 3, partly agree; 4, agree; and 5, strongly agree.

The result from the analysis of performance management rating from 1 to 5 or from strongly disagree to strongly agree and measured by means of 39 indicators or variables starting from: Mission is clear and energise employees; Strategic goals and objectives have focus and stretching; Owners defined for goals and objectives; Strategies are developed and resources allocated; Customers' needs are addressed; Output and outcomes are defined; Decision issues and decision process are used; Management culture is supportive; Measures flow from goals and objectives are developed by managers; Inventory of common measures is formalized resources provided; Responsibilities for data collection, reporting, analysis and posting are identified; Managers used measure to evaluate performance; Reward system are clear and consistent and reflective levels of success; Data resources are identified; Information systems are designed to support data collection and reporting; Pilot tests are conducted; Automatic or manual requests are used for periodic update; Data entry tabulation, summarization methods are documented for each measure; Data definition for common measure are followed; Reliability, timeless, accuracy, rapid access and confidentiality are addressed; Data are integrated; Analytical capabilities are developed; Results are analysed and validated; Management review results vs. expectations and make mid-course connections; Feedback is provided for continuous improvement; Activities of process owners used performance information for continuous improvement; Rewards and recognitions are based on results; Benchmarking and comparative analysis with best in class are done; Management feedback is provided; Performance is used to identify opportunities for reengineering and allocation of resources; Professional development of the staff is seen as an important aspect of management by the ministry; The personnel in this institution are very informal and do not hesitate to discuss their problems with superiors; The personnel are encouraged to take initiative and do things on their own without having to wait for instruction; The management of this institution make efforts to identify and utilise the special talents of the personnel; and Promotion decision of personnel are based on their suitability.

Quantitatively analysis of PM found that PM was generally from good to excellent since the majority of respondents agreed and strongly agreed with the statements mentioned in performance management at 3.49 and 4.70, specifically, management culture is supportive and mission was clear and energise employees respectively. Whereas, it was found that female respondents partly agreed with the statements that Inventory of common measures is explored and balance scorecard or similar tools are used at 2.94 and 2.83 respectively.

Performance Management (PM) by job title: head of division, deputy head of division and technical staff found that the deputy head of division partly agreed with the statement that management culture was supportive at 2.76. The statements that the management of this institution made efforts to identify and utilise the special talents of the personnel; and promotion decisions of personnel are based on their suitability were rated at 5.00 by heads of division while the deputy head of division only ranked 3.52 and 3.32 respectively.

It was found that PM by number of working years experienced strong disagreement by those under 1-5 years of working experience under the statements that strategic goals and objectives had focus and stretching; output and outcome were defined; inventory of common measures was explored; balance scorecard or similar tools were used; performance levels were reflective of resources; automatic or manual requests were used for periodic update; reliabilities, timeless, accuracy, rapid access and confidentiality were addressed; data are integrated; analytical capabilities were developed; promotion decision of personnel were based on their suitability, which were all rated at 1.00, which was contrary to those with more years of working experience as it could be seen that PM in the above statements were rated more and more according to the number of experience.

Qualitatively, the analysis of the performance management in the Ministry of Public Works and Transports (MPWT) was largely on system evaluation, and from top-down process rather than from multi-angled feedbacks which significantly contributed to the improvement of strategies for managing or leading human resources and supported professional development of personnel in MPWT.

4.3. Performance Appraisals

Based upon the performance appraisal on variable statements: The performance appraisal of personnel by the directors provides opportunities for staff to have clear understanding; the appraisal system provide the personnel effective feedback about their performance; the appraisal system helps directors to identify the needs of the personnel; the appraisal system provides opportunity for staff to communicate the support the needs from his/her senior to perform his/her job well; the appraisal system provides opportunity for self-review and reflection; the appraisal system encourages the directors and staff to have common understanding of the staff; the appraisal system has scope for reflection and assessment; the appraisal system encourages open communication between directors, staff and peers through performance review; the appraisal system aims at strengthening directors-personnel relationship through developing mutual trust; the appraisal system helps interested staffs to gain more insights into their strengths and weaknesses; the appraisal system has scope for communicating the institute plans and development goals to staff; the objectives of the appraisal system are clear to all staff; periodic orientation programmes are conducted to explain the objectives and other details of the appraisal system; the director generally spend time with their staff to discuss their performance; the director helps their staffs to plan their performance in the beginning of the year; discussion on key performance areas /key results/tasks between director and staffs is very educative; the director does a thorough join on self-appraisal in terms of reviewing reflecting and analysing the factors affecting their performance; the performance review discussions are taken seriously by directors and sufficient time is spent on these discussions; the performance review discussion are conducted with high quality and care; efforts are made by directors to see that staff are objective in their appraisal system; the appraisal data are used as inputs for recognition and encouragement of high performers; and the appraisal facilities growth and learning in the institute both for the staff and the directors.

Quantitatively, it was found that the majority of respondents considered performance appraisal from neutral to high since they seemed to strongly agreed with the statements mentioned in performance appraisal activities while it was seen that the female respondents strongly agreed with the statements that the appraisal system helped directors to identify the needs of the personnel; and the appraisal data were used as inputs for recognition and encouragement of high performers at the rate of 5.00 as well as male respondents rating from 4.23 to 4.65.

Based upon the number of year of working experience, it was found that the respondents with 1-5 years of experiences rated the lowest in the performance appraisal system had scope for reflection and assessment at 1.00; and PA of personnel by the directors provides opportunities for staff to have clear understanding at 3.00 whereas they strongly agreed with the rest of the statements. Similar to PM, PA rating increase depends on the respondents' number of years of experience.

Qualitatively, the content analysis revealed that PA depends on trusts and reliability of peers and colleagues voting for the popularity and professional knowledge and competence for rewards and punishment, which was difficult to measure in case of unfamiliarity of the appraisers.

4.4. Induction Training

Based upon the statements analyzed in this section: induction training is given adequate importance in this institute; induction training is well-planned; induction training is of sufficient duration; induction training provides excellent opportunity for new staffs to learn about the institute; norm and values of this institute are clearly explained to the new staffs during induction; the senior staff stake interest in and spend time with new staffs during induction training; new recruits find induction training very useful in this institute; our induction training is periodically evaluated and improved; the staffs are helped to acquire technical knowledge and skill through training; there is adequate emphasis on developing managerial capacities of colleagues through training; human relations competencies are adequately developed in this institute; training of staff is given due importance in this institute; the staff are sponsored for training programs on basis of carefully identified developmental needs; those who are sponsored for training programs take training seriously, the staffs sponsored for training programs take the training seriously; in-house training programs are

handled by competent senior staffs; the qualities of in-house training programs in this institute; the senior staffs are eager to help their junior develop their competencies through training; the staff returning from training are given adequate free time to reflect and plan improvements in the institute; the directors provide right kind of climate to implement new ideas and methods for juniors through training; external training programs are carefully chosen after collecting enough information about quality and suitability; and there is a well-designed and widely accepted training policy in this institute.

Quantitatively analysis of total induction training found that protocol of induction training were generally rated from high to highest levels, specifically there was a well-designed and widely accepted training policy in MPWT at 4.16 and induction training provided excellent opportunities for new staff to learn about MPWT.

The rating given by female respondents found that induction training was given adequate importance in MPWT at 5.00 while in-house training programs were handled by competent senior staffs were given 3.72. Male respondents strongly agreed with all induction training activities.

The rating scale given by job title of the respondents: head of division, deputy head of division and technical staff were all high to all activities as well as rating scales given by educational qualification and work experiences.

4.5. Strengths and Weaknesses

4.5.1. Strengths

Performance Management has been implemented high in clarifying and energizing its missions to employees, goal and objective definition, data management and identification, and information management.

Whereas, performance appraisal with clear objective and system emphasises on its implementation in terms of identifying needs of employees, providing opportunities for junior staff to communicate with senior ones and opportunity for self-review and reflection, encouraging the development of common understanding and communication between the top management and employees, correcting biases of directors to a review process, strengthening directors-personnel relationships through developing mutual trusts, assisting interested staff to gain more insights into his/her strengths and weaknesses, and having scope for communicating the MPWT plans and development goals to staff.

Moreover, there were periodic orientation programmes to explain the objectives and other details of PA, which includes the time the directors spent for discussion with staff, the plan they share at the beginning of the year, the indicative key performance areas, the high quality and care performance review discussion, the use of appraisal data as inputs for recognition and encouragement of high performance, and the training of subordinates to cope with their personal bias and favouriticism

Inductive training implementation was totally accepted by staff, specifically on providing excellent opportunities for new staff to learn about MPWT, and the opportunity to transfer knowledge from seniors to juniors.

4.5.2. Weaknesses

Although majority of PM activities have generally been well-implemented, they were not well applied to the junior staff with one to five year of work experience in terms of providing the insight on strategic goals and objectives, output and outcome definitions, exploration of common measures, the use of balance scorecard reflective of resource performance levels, the addressed reliability, timeless, accuracy, rapid access and confidentiality, integration of data and developed analytical capabilities. In addition to PM, the PA system did not have scope for reflection and assessment for the above mentioned juniors.

5. DISCUSSION

During the collection of data, the MPWT was in the process of restructuring the organisation, the respondents were worried about the changes in MPWT may lead to difficulties in carrying out PM and PA consideration as it was found in the junior staff.

The performance management and performance appraisal were usually conducted by the end of management term (every 4-5 years) by the team of inspectors from the MPWT which seemed to conduct PA rather than PM since the terms ‘PA’ and ‘PM’ are interpreted as interchangeable meaning among management people and staff, which evidenced that some activities were overlapped or interchangeable of one another.

6. CONCLUSION

Quantitatively, it can be concluded that performance management were significant from neutral to high performance since the majority of respondents rated from 3.69 to 4.70 except for junior staff with 1-5 year of work experience.

Whereas, it can qualitatively concluded that the performance management was considered as top-down system rather than individual feedbacks. Although in some practices of PA and PM were based upon trusts and reliability of peers and colleagues, there was a risk in the practice as the people providing feedbacks may not be acquaintance to the individual appraisee.

RECOMMENDATION

PM in MPWT in some cases need improvement, especially among the junior staff in PM and PA practices. The implementation of both PM and PA should be conducted by sector and individual responsibility rather than inspector teams since 360 degree evaluation is needed and to avoid the consequences from unfamiliar biases

The induction training shall be regularly organised for newly-appointed staff so that they can obtain sufficient information about MPWT.

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Society & Education: Lessons from Japan

Olivier Gervais and Masazumi Ao

***Abstract*— The Tohoku earthquake which struck Japan on March 11th, 2011 has been a turning point for Japan, in terms of energy policy, but from a social perspective as well. The main aim of this study is to analyze the trends in the wake of these events in a comprehensive social context. What do these tell us about the general mindset of the population with regards to sustainability issues central to the development of our societies? It is essential to examine the roots of the problems in order to improve the long-term outlook and ensure that the nation is able to make educated decisions regarding issues which are critical to the future sustainability of society. Based primarily on an analysis of secondary data, this study shows that this could be achieved through the development of lifelong learning, as a tool for the population to be able to participate more actively in society. While education is a central issue in this regard, it is also believed that social welfare measures, government transparency, as well as the implementation of better communication channels between experts and the general public are prerequisites to achieve this.**

***Keywords*— Sustainable Development, Education, Policy Development, Japan, Tohoku earthquake**

1. INTRODUCTION

Since the Tohoku earthquake and tsunami struck Japan on March 11th, 2011, many studies have been conducted by researchers and the government to analyze the effects and aftermath of the disaster. Many of these studies focus on concrete measurements of radioactivity and on the actual effects of nuclear radiation on soils or water resources, or on disaster mitigation and potential measures to be taken by citizens and the government in order to achieve significant energy savings or improve the efficiency of recovery efforts.

In contrast with this, it appears that relatively little research has been done to try and interpret these events from a broader social perspective, in order to assess the general state of mind of the country with respect to global issues such as climate change, or regional concerns like the necessity to secure a safe water supply for the years to come. Although these issues might seem unrelated at first glance, the debates and confusion that emerged when the accident started at Fukushima Daiichi nuclear power plant can be used as a reflection of other social concerns: the interest and attention that the population shows with respect to a broad issue like nuclear power and the direction that the country should follow in order to ensure a safe, stable, and clean energy supply for the future can indeed provide a good indicator of the general opinion regarding other ethical and/or societal concerns such as waste management, food security, or education.

Aim of this study

Based on this assumption, the main aim of this study is to analyze the trends in the wake of the events of March 11th, 2011, in a comprehensive social context. What do these tell us about the general mindset of the population with regards to sustainability issues central to the development of our societies? Most importantly, it is essential to examine the roots of the problems in order to be able to take effective counter-measures and find solutions to improve the long-term outlook, as well as the behavior of the population to ensure that the nation is able to make educated decisions regarding issues which are critical to the future sustainability of society.

Methods

The primary method used in order to achieve the objectives above is an analysis of secondary data, with particular focus on recent years, which have seen an evolution in mindset and behavior because of the Tohoku earthquake and tsunami. Focusing on this period of change also helps reveal how the population reacts to unforeseen events and understand better the reason why such changes occur. Policy development in general, and social policy in particular, must take these elements into account in order to make sure that the measures taken are effective.

Scope

In spite of the fact that this study pays close attention to the Japanese society, it is believed that the mindset and efforts needed to develop a sustainable society share universal characteristics, and therefore that the notions presented in this study apply to most industrializing societies as well.

Additionally, this paper is built on the implicit assumption that in order to achieve triple sustainability, i.e. durable prosperity from an environmental, social, and economic perspective, it is indispensable that all of the actors of society (from citizens, to voters, to consumers) be knowledgeable and actively participate to help solve sustainability issues in all aspects of their lives (in everyday life, when they vote, when they consume).

2. Results

A lack of knowledge?

The events of March 11th, 2011 have been a turning

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point for nuclear power in many parts of the world, and especially in Japan, where the accident at Fukushima Daiichi has caused much fear and anxiety, but also provoked a democratization of the debate about safety and energy. In spite of all the negative consequences of the earthquake, it is positive to see that the population seems to have gained interest for such issues which are central to our lives, and on which we almost entirely depend. Nevertheless, it is at the same time worth questioning the amount (and quality) of knowledge of the population as a whole, as it may have significant consequences when trying to move the discussions forward with regard to these issues.

Approximately a year and a half before the Tohoku earthquake occurred, the Public Relations Department of the Cabinet Office of the government of Japan conducted a survey about nuclear power, and the results are clear: nearly half of the population did not seem to have a general idea of the proportion of electricity generated from nuclear energy in Japan, nor to be aware of the fact that high-level radioactive waste is produced in the process (Figure 1) [1].

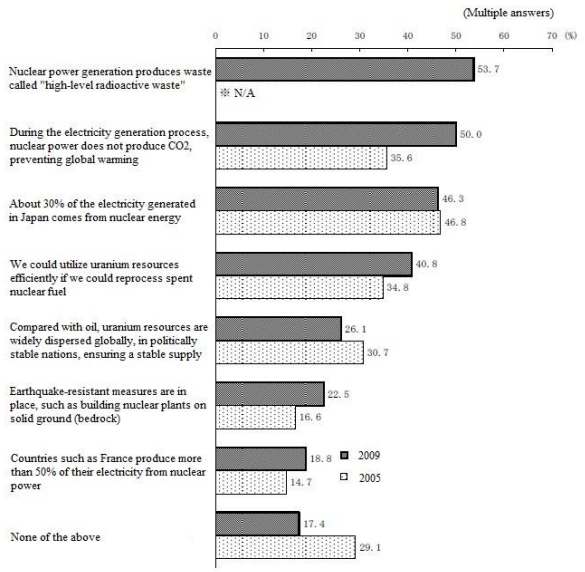

Fig.1. Nuclear power awareness (transl. by the author) [1]

These elements reveal the difficulty for the population as a whole to conduct a meaningful debate about the future of nuclear energy and therefore make proper decisions regarding that technology, as there seems to be a lack of basic knowledge in the field.

Furthermore, 50% of the respondents have indicated that they were not aware of the fact that nuclear power is known not to produce CO_2 during the electricity generation process, thereby contributing to the prevention of global warming. Concretely, this means that a vast proportion of the population appears to be unaware of the benefits of nuclear power. While the debate about nuclear power is extremely complex and deciding on whether or not it should be used as an energy source goes beyond the scope of a scientific paper, it is nonetheless essential to ensure that everyone who participates in the debate is aware of the pros and cons of each alternative to able to form an educated opinion.

Moreover, not only do these figures indicate that a large part of the adult population is in general not knowledgeable enough to form an idea and participate actively in a debate about nuclear power, but this also reveals that the issue of climate change is not clearly understood either. As a matter of fact, how could one have a solid opinion in this debate (and in turn act upon it) when basic, non-technical knowledge about the pros and cons of the different energy sources available to us is clearly not sufficient? It is extremely important that all citizens take part in the debate, as we live in an era where the scientific community agrees on anthropogenic climate change, which can be described as "[a threat to] the basic elements of life for people around the world – access to water, food, health, and use of land and the environment." [2]

Beyond the issue of nuclear power, the lack of knowledge about other issues of critical importance for the sustainability of our societies is conspicuous as well. This is the case for waste management policies for example; according to a survey of public opinion conducted in 2012 by the Cabinet Office with regard to environmental issues and awareness of recycling initiatives, only a third of the population indicated they knew what the words "3R" meant, despite the efforts made by the central and local governments to promote the concept. [3] This confirms the relative lack of awareness of the population regarding such problems. It is however to be noted that this is not necessarily related to a lack of interest about these issues, as the exact same study shows at the same time that more than 98% of the Japanese population considers the problem of waste to be serious. [3] Although it could be said that these surveys also show an improvement over the years[1], this trend is in general relatively slow, as it would be desirable that these numbers climb to levels close to the literacy rate of the country.

Expert knowledge

In spite of this apparent lack of awareness by the general public, however, much research is being conducted in the field of nuclear power in Japan, with a yearly budget of approximately 150 billion yen (about 1.5 billion USD) for research and development for 2012, on top of the budget devoted to recovery and decontamination efforts in relation with the nuclear disaster at the Fukushima Daiichi power plant [4]. While nuclear energy experts and involved parties came into the spotlight during the period following the Tohoku earthquake, it is interesting to notice that the level of trust from the population, which was already fairly low in September 2009 (approximately 35%), dropped significantly after the events, down to 16.8% by November 2011, and to 14.8% by November 2012, according to the Japan Atomic Energy Commission [5][2].

Although it appears that these results seem to come

[1] With regards to the issue of nuclear power, only about 35% of the Japanese population was aware of the fact that electricity generation does not produce CO_2 in a nuclear power plant in 2005, compared with 50% in 2009 [1], and regarding the recycling policies implemented by the government, knowledge about the meaning of the words "3R" has spread across the country, from 29.7% to 33.3% during the 3 year span from June 2009 to June 2012 [3].

[2] The same document by the Japan Atomic Energy Commission also points out the low level of trust for the central and local governments with respect to safety management for nuclear power, with only 32.7% (less than a third of the population) in September 2010, and as low as 10.1% in November 2012 being confident in the ability of the government to manage the issue [5].

substantially from the fact that the Japanese have been disappointed by the lack of transparency and public disclosure of information from the government with regards to the nuclear accident at Fukushima Daiichi [5], this does not explain the low level of trust before the events.

Similar studies, which have been conducted by the National Institute of Science and Technology Policy to assess the general level of trust of the population in scientists, but not specifically with regards to nuclear expert nor involved parties, show a slightly different trend. Before March 11th, 2011, the level of trust for scientists was as high as 85.7% (October 2010), but dropped down to 40.6% in April 2011, one month after the tsunami [6].

There are only two main factors which differ between these two public opinion surveys, and therefore can help bring an explanation for the discrepancy between the results obtained. Firstly, the first survey, conducted by the Japan Atomic Energy Commission, revolves specifically around nuclear power, while the other, conducted by the National Institute of Science and Technology Policy, simply used the word "scientist" in their questions, without defining or laying stress on any particular field. Although this could mean that the population was particularly distrustful about the nuclear sector even before March 2011, this seems unlikely as more than 75% of the population was convinced at the time (September 2010) of the necessity to develop nuclear energy in the future, according to the very same survey[3] [5].

The second factor which can explain this gap comes from the fact that in their study, the Japan Atomic Energy Commission inquires about the level of trust for experts *and* involved parties[4], therefore including a wide range of personnel, from power reactor operators to management-level businessmen at Tokyo Electric Power Company (Tepco). This may overall indicate a low level of trust for these so-called involved parties, and a relatively high level of support for experts; however, this support rests on a fragile foundation, as it appears in both cases that an unexpected event like the earthquake and nuclear disaster of 2011 can quickly halve the level of trust of the population.

In addition to these elements, this sudden drop in trust is also representative of the lack of transparency and publicly disclosed information; it is indeed because of the disaster that the world realized that the preventive measures taken were insufficient and not at all adapted to an earthquake of that magnitude, and there seems to be no sign that the population would have discovered such faults had nothing happened on that day.

Furthermore, it is concerning as well to think that the population might have put a great deal of trust in experts because of their own lack of knowledge, as if conveniently relying on them to avoid facing the ethical dilemma that nuclear power represents, and subsequently have felt that their trust had been misplaced, and anxious about the future as even experts seemed to be unable to find a solution when the events of March 11th, 2011 unfolded.

The positive effects of education

The discussion above helped identifying two elements of importance; firstly, the general public appears to lack knowledge about critical issues for the future of our societies, and secondly, although educated experts exist who can transfer at least some of their knowledge, the trust placed in them seems to be insufficient and/or fragile, meaning that there is at least an issue of understanding and communication which compromises the smooth flow of information between them and the general public.

Solving this problem, and therefore facilitating the knowledge acquisition process of the population, could offer numerous benefits, such as raising public participation and awareness about a given issue and improving the quality of the debate about this issue, ultimately improving the democratic process for better decision-making. Additionally, in the case of sensitive matters, like the discussion about the future of nuclear power and the energy sector, for which the degree of uncertainty and apprehension of the population is high when unforeseen events take place, it is expected that an increase in the awareness and abilities of the general public would lead to a decrease in the level of anxiety.

To illustrate this, a survey conducted in late 2011 (6 months after the tsunami) reveals that there is much variation in the degree of anxiety about the future effects of radiation depending on the amount of knowledge (Figure 2). The results are unequivocal when comparing for instance the level of anxiety of the citizens of Fukushima prefecture with medical doctors who reside in the same place: 72% of the citizens who were asked answered that they were "anxious" or "very anxious", whereas only 30% of the doctors gave the same answer [7]. This trend is also similar outside of the prefecture, albeit not as conspicuously. Conversely, even though only 2% of the citizens of Fukushima prefecture and 8% of those from outside the prefecture asserted that they were "not anxious", this rates goes up to 21% and 28% for doctors from Fukushima and from outside of the prefecture, respectively [7].

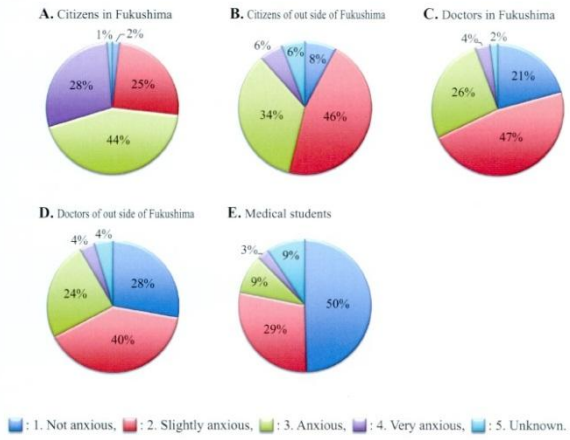

Fig.2. Anxiety level about future radiation effects after the Fukushima Daiichi nuclear power plant accident [7]

Furthermore, although it might seem natural to think that it would be the doctors who display the less anxiety following the nuclear accident, it is interesting to note that it is actually the medical students, who had just been

[3] As of November 2012, this number has dropped to 36% [5].
[4] Kankeisha, in Japanese.

taking a course in radiation hygiene, who seem to feel the less anxious: only 12% of them answered that they were "anxious" to "very anxious", while up to 50% of them declared that they were not.

These results tend to suggest that in spite of the fact that experts (here, the doctors) are more experienced and knowledgeable about a given topic, having a fresh recollection of scientific facts, and feeling informed and "up to date", helps in turn feeling more composed and clearheaded when dealing with specific circumstances. In other words, there appears to be a constant need for learning, above all with regards to issues which are central to our lives or that we take for granted.

Empowering the population

Given the elements examined above, it can be argued that lifelong learning is indispensable for any individual to forge a solid opinion about such important issues, especially as the world keeps on finding new technologies and innovations, and our politicians have to decide how to utilize them. These subjects should certainly be addressed within the framework of the school system, since it is an efficient way to reach the vast majority of the population, and at a young age, when it is particularly important for any individual to develop a strong value system as well as curiosity and interest for the challenges that lie ahead. Basic knowledge about sustainability issues (water, food, energy) is needed at an early stage in order to help children develop good habits before they become adults.

Nonetheless, continuous learning, throughout life, is a critical aspect of the issue as well, as the knowledge acquisition process may almost stop after one gets out of school to start working full-time and specialize in a given field. It is therefore necessary to ensure that the population has at its disposal adequate resources to achieve these objectives.

In Japan, according to a study conducted in 2012 by the Cabinet Office about the population's awareness and habits with regards to lifelong learning, approximately 58% of the respondents claimed to be involved and practicing an activity related to it, leaving about 42% who have not adopted the concept [8]. When pointing out the problems that they have with regards to implementing their activities, almost 30% of the respondents indicated that they were often too busy with work and therefore do not have enough time to devote to it; most of them are men between 20 and 49 years of age. Similarly, almost 45% of the respondents who do not devote any time to lifelong learning activities provided the same reason: work takes up too much of their time [8]. On a side note, only a small part (15.2%) of those who responded positively related their activity to a skill or ability that they may need at work.

Lifelong learning, as a process which is supposed to enhance participation in society and personal development, is somewhat time-consuming. In Japan, it is however so that the traditional gender roles place men at work, leaving them to provide for their family while women assume their responsibilities with their children and in the kitchen. These roles are still very much ingrained in the Japanese society; for instance, in 2011, the rate of fathers who took a paternity leave, only 2.63%, illustrates this situation well (although it was the highest rate ever achieved) [9]. This explains why Japanese men, who have to work long hours every day, can only afford to spend little time for other activities.

For all of the reasons mentioned above, the social issues discussed in this paper which are closely related to lifelong learning, are not simply a question of how to encourage citizen participation, but depend as well and to a great extent on other variables, which can be associated with social welfare.

3. Conclusion and recommendations

As it was discussed throughout this study, the Tohoku earthquake and tsunami of March11th, 2011 provide an indicator of the state of mind of the Japanese population in general, by exemplifying some of the dysfunctions still existing in society.

The most conspicuous issue is related to what could be defined as a lack of basic knowledge from the general public about matters essential to our lives, such as the country's production of energy or climate change. The interesting and somewhat paradoxical aspect of this topic, however, resides in the fact that this lack of knowledge does not seem to be related to a lack of interest from the population, as a vast majority actually shows curiosity and concern about these matters.

Instead, the reasons appear to be rooted in the modern lifestyle, as well as in an education system which does not provide this essential knowledge about sustainability issues, and therefore does not meet the needs of our societies to prepare the citizens for the challenges of the coming decades.

The suggestions achieved through this analysis therefore range from a broad spectrum of options, which can however be summarized into the following policy areas, which are thought to be the key to achieving social transformation.

Firstly, the education system is an extremely effective way to reach an important proportion of the population, especially at a young age. Nevertheless, learning must take place on a lifelong basis in order to ensure that the population is knowledgeable enough in a rapidly changing world.

Secondly, there is also a clear need for more transparency and better communication between informed experts and the general public; the population is reluctant to trust decision makers, especially after the earthquake and tsunami disaster of 2011, which also shook the level of trust for experts and scientists, whether they are in the field of nuclear power or not.

Thirdly, it appears that Japanese adults often stop learning the kind of general knowledge that is necessary to participate actively in society as they start working, since most Japanese men tend to have extremely long working hours; social welfare, which is often neglected in the workplace, is thus also thought to be an area which should be given priority. Achieving change towards an educated society requires with no doubts improvements in these fields, to ensure that each citizen has the possibility to develop the values and skills needed for progress towards a sustainable society.

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Using Experimental Design in Tourism Related Research

Thitikan Peace Satchabut

Abstract—While it is common to see correlational studies in social science research, this study offers another perspective on how to launch a study grounded in experimental design. This example study was part of the author's Phd Dissertation at Texas A&M University. The research inquiry was to assess whether outdoor recreation programs and/or park interpretation programs influence park visitors' environmental concern. Data were collected through an experimental design. Two hundred forth participants were randomly assigned to eight groups of activities (photography, photography with interpretation, birding, birding with interpretation, motorcycling, motorcycling with interpretation, motor boating, and motor boating with interpretation). While nature photography and birding were considered as appreciative recreation, motorcycling and motor boating were considered as consumptive recreation. Results suggest that participants' environmental concern is enhanced when recreation is joined with interpretation services.

***Keywords*—social science, tourism, recreation, experimental design**

1. INTRODUCTION

As housed in social sciences, we as tourism scholars, need to realize where tourism studies stand among other scientific studies. While Sciences value objectivity, tourism studies are often viewed as being less objective compared to those in natural sciences and not fit the criteria of 'scientific' study. As noted in [1], "The very nature of the subject matter…is often regarded as fun" (p. 14). To position ourselves as being objective given the popular notion of positivism, quantitative research may be a useful approach. For example, in order to assess whether ecotourism experience has an association with tourists' concern for nature, a researcher can just randomly go to any national parks and ask tourists to fill in surveys asking the frequency of park visitation and their concern for nature. This seems to be a feasible and convenient approach for data collection. After correlation analysis, the researcher then can conclude whether there is an association between those two variables.

However, if noticed, the researcher can only use the term "associated", "correlated" or alike. As correlation does not mean causation, this research does not show that ecotourism experience causes tourists to concern about nature. Then, the research's practical implications maybe limited. How can we offer a convincing statement i.e. for management or policy changes if the research itself cannot provide strong argument for the need for ecotourism? Another issue is that tourists under the study are mostly from various demographics, thus their concern for nature maybe stem from religion, education, age, income, etc. Also, each tourist experience ecotourism differently. Other factors such as the scenery of ecotourism site, activities engaged during that visit, relationship with other trip's members, etc. may as well influence that experience and their answers on surveys. As seen here, these factors are nuisances for the research's result.

In natural sciences, however, if we wonder whether amount of water affect plants' growth, we can launch an experiment to compare different results between the control group (plants with no water received) versus the experimental groups (i.e. plants that receive water possibly 1, 2, or 3 times per day, etc.). To avoid effects from other factors such as the surrounding environment, the researcher have to control nuisance factors, for example by using same species of plant and providing same amount of lighting and temperature. This research thus enables the researcher to assess the causal effect. Hence, if everything else is controlled, researchers can be confident to conclude that the change in growth's plant is from the treatment's effect. With this example, this paper aims to provoke readers the need to encourage and integrate experimental design into tourism studies.

2. LITERATURE REVIEW

This example study was launched to explore whether recreation participation can stimulate park visitors' environmental concern. Followings provide an overview of the literature on environmental concern and the review of studies assessing the relationship between recreation participation and environmental concern. Research addressing environmental concern primarily originated in the United States in the 1970s [2]. Gradually, research in this area expands to other countries, yet most are restricted to North America, South America, and Europe [2]. In the existing literature, a number of variables have been playing an important role in the formation of environmental attitudes. There are considerable theories and research suggesting that behaviors like recreation participation do influence environmental attitudes. The

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well-known one is the Dunlap and Heffernan (1975)'s first hypothesis which contends that involvement in outdoor recreation is positively correlated with environmental concern. However, their study, as well as many later studies in this topic, found a positive but weak relationship between recreation and environmental concern.

There is, however, more substantial support for the Dunlap-Heffernan's second hypothesis: environmental concern is more strongly associated with involvement in appreciative recreational activities than in consumptive activities. In this area, recreational activities are grouped into two main categories. The first is the "appreciative" type, which includes slight resource-utilization activities (e.g. nature photography, birding, biking, etc.) and is believed to leave little or no impact on the environment. The second category is the "consumptive" type, which includes intensive resource-utilization activities (e.g. hunting, fishing, mechanized or motorized activities, etc.) and is believed to yield more negative impacts on the natural environment compared to the first category [3].

While recreational activity may be somewhat predictive of pro-environmental attitudes or behaviors, the relationships found were relatively weak in most cases. In fact, other studies such as [4] and [3] revealed that socio-demographic factors are more predictive of environmental concern than levels and types of recreational activity. It is also noted that a positive relation between recreation and environmental concern can be a result from informational and educational programs offered during recreation experiences [5]. With inconclusive findings from existing correlational studies, we still cannot conclude whether recreation participation has an effect on people's environmental concern. To gain a complete picture of the causal relationship, this study offers a perspective from an experimental design. As recommended by [6],"Whether participation in and meaning of outdoor recreation contributes to the development of an environmental ethic or whether possession of an environmental ethic drives an interest in recreating outdoors is a question requiring more complex experimental designs" (p. 27). Also, as noted in [7], "The ideal of science is the controlled experiment" (p. 467).

3. METHODOLOGY

Based on the second hypothesis of Dunlap and Heffernan (1975): environmental concern is more strongly associated with involvement in appreciative recreation than in consumptive recreation. In addition, as discussed in many studies, interpretation might be a factor affecting environmental concern, this variable is therefore included in the study. The study design thus included eight groups of activities randomly assigned to participants. These are photography, photography with interpretation, birding, birding with interpretation, motorcycling, motorcycling with interpretation, motor boating, and motor boating with interpretation. Broadly, nature photography and birding are considered as appreciative recreation, motorcycling and motor boating are considered as consumptive recreation. Interpretation program used in this study was based on Tilden's principles of interpretation.

Sample included 240 participants: 30 participants in each group of activity. To eliminate nuisance factors that may affect the results of this study, sample was purposely selected. To control for socio-demographic factors (i.e. age, education, gender), students from a community college in Phattalung, Thailand were recruited as research participants with equal numbers of male and female and the first and second-year students.

Data collection started with randomly taking each group of participants (based on a random assignment of eight activities) to Thale Noi Waterfowl Park, Phattalung, Thailand. Each activity was about 8-hour experience, including travel time. All participants completed a measure of the quality of their experience immediately following participation. Participants' environmental concern was measured by the NEP. This scale was chosen due to its acceptance in various countries [2] with various age ranges including secondary school students and college students [8] and [9].

4. RESULTS

Results of the analysis of variance showed that the interaction effect of recreation type by interpretation was significant ($F_{1, 234} = 51.816$, $p < .05$, η^2partial = 0.181). When interpretation was included in recreation, participants' environmental concern became higher especially among those in consumptive form (see Figure 1). If noticed, recreation form (appreciative versus consumptive) itself did not have a significant effect on participant's environmental concern. However, variation among recreation activities (photography, birding, motorcycling, and motor boating) had a significant effect on participants' environmental concern. Group means for the recreation activity variable were .569, .477, -.651, and -.395 for nature photography, birding, motorcycling, and motor boating, respectively.

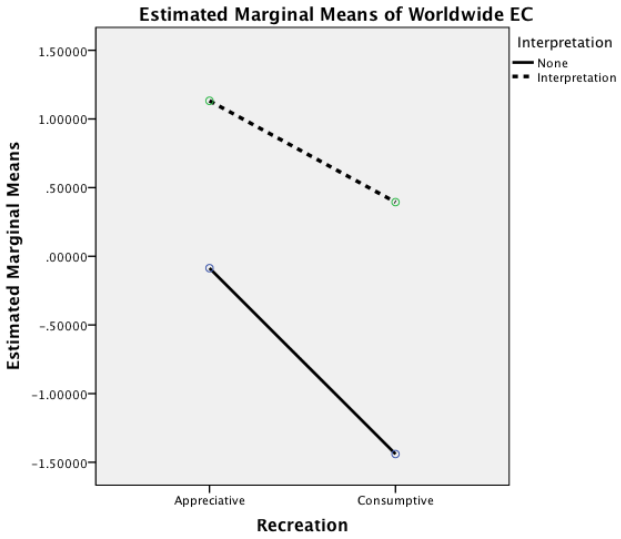

Fig. 1. Interaction Effect on Environmental Concern

5. DISCUSSION AND CONCLUSION

This paper aims at providing an example on how to conduct experimental-design study. The example study was launched to assess whether recreation participation (guided by the Dunlap-Heffernan hypothesis) and/or interpretation service influence park visitors' environmental concern. Results showed a significant effect of recreation participation when integrated with

interpretation service. Specifically, interpretation can enhance recreationists 'environmental concern with a larger effect on a consumptive form. Nevertheless, limitations to the study include the fact that recreation activities chosen in this study do not fully represent all activities offered at the park. Grouping recreation activities into appreciative-consumptive typology can limit an understanding about the diversity of recreation experiences. In addition, participants' environmental concern may not translate to their environment-friendly behaviors. Despite these weaknesses, the study offers various contributions. While most recreation literature is from North American, this study offers perspectives from a developing and non-Western county. Most importantly, being grounded in experimental design with a greater control on the study's intervention, results thus serve to increase confidence of cause-effect relationship, which is different from existing correlational research. It is important to acknowledge that this study is to showcase the possibility to integrate experimental design in social science research. Definitely, the motivation of this research is based on the ontology of positivism. Yet, it is not intended to show off that this value is superior to other competing paradigms. As concluded by [10], "There is no single philosophy of science, and so there can be no single method of science either" (p.30).

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Leaching Potential of Nanosilver from Commercial Products

Sandhya Babel and Pawena Limpiteeprakan

Abstract—*This study aimed to investigate the potential of leaching of nano-Ag from commercial products by using Toxicity Characteristic Leaching Procedure (TCLP) test according to USEPA method 1311. Nano-Ag fabrics in different concentrations were also prepared in laboratory scale with different concentration. Eight nano-Ag products were purchased from the market. Only the product that has potential to be disposed into the landfill after end use, were selected. The concentrations of nano-Ag were quantified by Inductively Coupled Plasma – Mass Spectroscopy (ICP-MS). The concentrations of silver in eight samples ranged from 0.946 to 6.348 µg/g of product. The silver concentration of nano-Ag fabrics were found in the same range with the commercial products between 1.949-2.315 µg/g of product. The silver concentrations of the TCLP leaching test for all samples ranged from 0.014 to 163 µg/L in the commercial products and ranged from 116 to 280 µg/L in the nano-Ag fabrics. All the concentration from leaching test under TCLP did not exceed the regulatory limit of 5.0 mg/L for TCLP silver. However, the increasing use of nano-Ag in many types of consumer products may lead to an increase level of silver in the environment while the regulatory control for the use and disposal is still lagging behind. The silver being used in products will somehow release into the environment through their life cycle. It is very important to assess the potential of nano-Ag and Ag^+ release during disposal phase and their release into the environment in long term since Ag is toxic to bacteria in the environment.*

Keywords— **Commercial products, Leaching potential, Nanosilver, Nanosilver fabric, TCLP.**

1. INTRODUCTION

Nanosilver (nano-Ag) is now used as antimicrobial agent in many kinds of products like cloths, plastic, toys, medical devices etc. Since it is a good antibacterial agent and non-toxic in low quantities, it is an interesting material to be used in different kind of textile fabrics [1]. The rapid growth of products containing nano-Ag increases the potential for their appearance in environment: in soil, plants, fish, and microorganisms [2]. Their toxicity effects to soil and aquatic organism under various environmental conditions have been reported [3]. These nanoparticles can enter the wastewater treatment plants (WWTPs) through daily washing from silver-containing plastics and textiles [4]. At the end, these nano-Ag products will be likely disposed into the landfills [5]. A greater understanding is needed to address the potential for nano-Ag to accumulate in the environment because these kinds of products will finally become part of waste which can be referred as nanowastes (NWs). There is limited data on the amount of NWs generated and the solution for a proper disposal. NWs can pose increased threats to the environment in two important ways. Firstly, materials often behave differently in nano-form in comparison to how they would behave in bulk, for example, they are likely to be more reactive with substances they come into contact with. Secondly, they may act as carriers for other pollutants, helping to disperse them widely in the environment. So when such wastes are disposed in the landfill, fate of these NMs under landfill condition is not known.. They may migrate from waste into leachate then pose risk to human and environment [2]. There is a little known about the ignitability, corrosivity, reactivity, and toxicity of nanomaterials. These four characteristics are used under the Resource Conservation and Recovery Act to determine whether solid waste must be handled as hazardous waste or whether it can go to the regular landfill. Not many studies have been reported on the impact and potential of nano-Ag release in leachate under landfill conditions during acidogenic phase. The information concerning the release of nano-Ag particles from consumer products are lagging behind, although there is rapid increase in number of such products in the market. Thus, it is important to study their potential of leaching under landfill conditions. TCLP test is designed to determine the mobility of both organic and inorganic substances present in liquid, solid, and multiphase wastes. This is normally used to determine if a waste may meet the definition of the United States Environmental Protection Agency (EPA) Toxicity, that is, carrying a hazardous waste code under RCRA (40 CFR Part 261) of D004 through D052. The Code of Federal Regulations (CFR) 40 CFR §261.24, are outlines the 40 contaminants the TCLP analysis tests [6].

The aim of this study is to investigate the potential of leaching of nano-Ag from commercial products and cotton fabrics prepared with different concentration of nano-Ag using Toxicity Characteristic Leaching Procedure (TCLP). The form of nano-Ag on fabrics and in the leaching solution were chracterized using scanning electron microscopy (SEM) and transmission electron microscopy (TEM).

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2. METHODOLOGY

Collecting nano-Ag products from the market

Products containing nano-Ag were purchased from the market via visiting different stores and buying from internet shop. Only products that claimed to contain nano-Ag were selected. The product itself must have a potential to dispose into the landfill after end use.

Nano-Ag Fabrication

Three concentrations of nano-Ag fabrics were prepared. Cotton fabric (100%) of size A4 (29 cm x 35 cm) were pretreated by immersing with enzyme amylase (LUNAZYME LTAA) 1 g/l then heated at 80°C for 1.30 h. The cotton fabrics were then cooled with water and allowed to dry at room temperature. For silver coating, these fabrics were treated with the silver suspension obtained from Private Company in Samutprakan, Thailand at concentration of 1000, 700 and 500 ppm by using a Laboratory Padder with 80% wet pick-up of the fabric weight. Samples were then dried at 100°C for 1 min in a Laboratory Stenter. Finally, the fabrics were cured at 120°C for 3 min in the same machine [7].

Quantification of silver in the products and nano-Ag fabrics

Eight nano-Ag products and fabrics prior to and after loading nano-Ag process were quantified for the amount of silver incorporation on the fabrics by microwave digestion and Inductively Coupled Plasma – Mass Spectrometry (ICP-MS).

Samples were shredded into small size and 0.2 $\pm$ 0.05 gram of each sample was weighted into a microwave vessel. 8 mL of HNO_3 (CARLO ERBA 65%) and 1 mL of H_2O_2 (CARLO ERBA 30%) were added to break down the sample and dissolve all the silver. The vessels were placed in microwave digestion system (Milestone ETHOS PRO Lab station) with irradiation cycles of 10 and 25 min at 210°C according to MILESTONE application notes for polyester digestion. After digestion, samples were filtered through a Whatman filter paper No.41 and volume was made with deionized water to 25 ml. Samples were then stored at $\pm$ 4 °C before further analysis. The product were analysed in duplicate and the final concentrations werecalculated from mean of two determinations.

Leaching test and analysis

The pH of the leaching solution is an important controlling factor for leaching test. There are two types of extraction fluid.

Extraction fluid # 1: Add 5.7 mL glacial CH_3CH_2OOH to 500 mL of deionized water, add 64.3 mL of 1N NaOH, and dilute to a volume of 1 liter. When correctly prepared, the pH of this fluid will be 4.93 ± 0.05.

Extraction fluid # 2: Dilute 5.7 mL glacial CH_3CH_2OOH with deionized water to a volume of 1 liter. When correctly prepared, the pH of this fluid will be 2.88 ± 0.05.

To determine the appropriate extraction fluid for the TCLP test, a preliminary test was performed to measure the pH of the samples (5 g of sample: 96.5 mL of reagent water). Since the pH of all commercial nano-Ag products samples was less than 5, TCLP extraction fluid #1 with a pH of 4.93 ± 0.05 was used. While the pH of nano-Ag prepared fabrics was higher than 5, and thus TCLP extraction fluid #2 with a pH of 2.88 ± 0.05 was used.

For the leaching test, nanofabrics and nanoproduct were cut into small size less than 1 cm. Twenty five to fifty grams of nanosilver products were loaded into an extractor bottle (high-density polyethylene (HDPE)). Extraction fluid was added to the extraction vessel. The weight of sample used in the leaching was the solid to liquid ratio (1:20 by mass). The sample was rotated end-over-end at 30 rpm and 23$\pm$ 2 °C for a period of 18$\pm$ 2 h. Then the extraction fluid was filtered. The pH of the extract was corrected to <2.0 with concentrated nitric acid. The extracts were stored at 4 °C for further analysis [6]. This TCLP analysis simulates landfill conditions. Over time, water and other liquids percolate through landfills. The percolating liquid often reacts with the solid waste in the landfill, and may pose public and environmental health risks because of the contaminants it absorbs. The TCLP analysis determines which of the contaminants identified by EPA are present in the leachate and their concentrations [6].

Characterization of nano-Ag

The morphologies of textiles were observed using Field Emission Scanning Electron Microscope (FE-SEM) (Model: Hitachi-S4700) with Energy Dispersive X-Ray (EDX) (Model: EDS2006 550i Analyzer). Firstly, fiber and fabric samples were pasted on the stub by double coated adhesive tape. Then, samples were coated by platinum before placing in the vacuum system for analysis.

Size characterization of nano-Ag in leaching solution from the products was also carried out using Trasmission Electron Microscopy (TEM) (JEOL 2010) equipped with EDX (Energy Dispersive X-Ray Spectroscopy). For TEM analysis, a drop of extract solution form leaching test were applied on carbon grid and was dried at room temperature.

3. RESULTS AND DISCUSSIONS

The concentrations of silver in eight samples ranged from 0.946 to 6.348 µg/g of product. The highest content was found in the body suit in which silver wires were visible. The silver concentration of nano-Ag fabrics were found in the same range with the commercial products between 1.949-2.315 µg/g of product as shown in Table 1.

Table 1. Quantity of silver in various commercial products

Sample name	Average Conc. From ICP-MS (µg Ag g product^{-1})
Body suit	6.348 $\pm$ 4.99
Car sheet	2.692 $\pm$ 0.77
Nursing cover	2.459 $\pm$ 0.77
Shoes	1.450 $\pm$ 3.85
Clear pet sheet	1.334 $\pm$ 0.72
Sock D	1.155 $\pm$ 0.23
Face Mask	1.045 $\pm$ 0.55
Shower cloths	0.946 $\pm$ 0.05
Untreated cotton	0.171 $\pm$ 0.002
Cotton 1000 ppm	2.315 $\pm$ 0.04

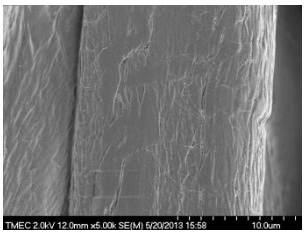
Cotton 700 ppm	2.001 ± 0.02
Cotton 500 ppm	1.949 ± 0.01

The low concentration may occur from inhomogeneous distribution of silver in the products itself [8]. Highly uniform blending of different kind of fibers cannot be obtained by sampling [9]. Benn and Westerhoff found the lowest concentration in commercial socks at 2 µg Ag/ g product [4]. Lorenz et al. also found low concentration in commercial textiles [10]. The measured ranged of Ag in a selection of Ag containing products was between 0.016 and 270,000 mg/kg [11]. Silver content of cotton fabrics was also determined as 1.488 - 2.022 µg/g of product. Test results of the each concentration of cotton fabrics are shown in Table 2.

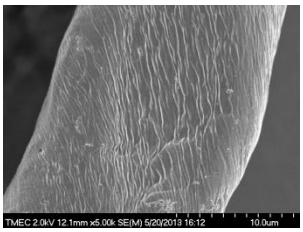
Table 2 Determined silver content of prepared cotton fabric

No.	Sample name	Silver Conc. (µg Ag g product^{-1})
1	Treated cotton with 1,000 ppm	1.488 ± 0.72
2	Treated cotton with 700 ppm	1.786 ± 0.75
3	Treated cotton with 500 ppm	2.022 ± 0.10

Silver content in prepared fabrics was quite in normal range with other studies. Thanh and Phong treated nano-Ag on the cotton fabrics in various concentrations and found that in 100 ppm treated fabrics, silver content was around 0.758 µg Ag per g of fabrics [12]. Figure 1 shows images with 5,000 times magnification between untreated cotton and treated cotton with 500 ppm. It can be seen from picture that the untreated cotton fibers show clean and smoother surface.



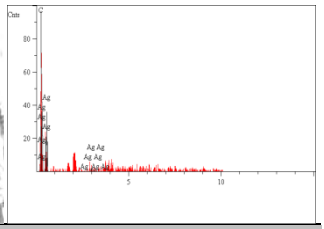
(a) Untreated cotton



(b) Treated cotton with 500 ppm

Fig 1 SEM images of nanosilver coated and uncoated fabric

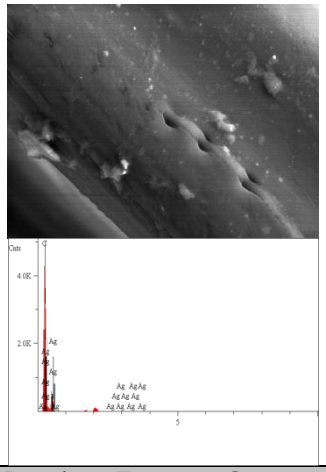
Figure 2 shows the nano-Ag impregnated fabrics along with the presence of the silver peak confirmed by EDS.



Elt.	Line	Intensity (c/s)	Error 2-sig	Conc	Units	
C	Ka	19.26	1.602	33.698	wt.%	
O	Ka	5.93	0.889	17.242	wt.%	
Ag	La	0.89	0.345	49.060	wt.%	
				100.000	wt.%	Total

Fig 2 SEM images of nanosilver coated fabric at 500 ppm

SEM analysis of body suit and car sheet was carried out in order to recheck for nano-Ag composition. SEM images and EDX line scan result of body suit is shown in Figure 3.



Elt.	Line	Intensity (c/s)	Error 2-sig	Conc	Units	
C	Ka	985.74	11.464	69.794	wt.%	
O	Ka	139.99	4.320	29.594	wt.%	
Ag	La	1.51	0.448	0.611	wt.%	
				100.000	wt.%	Total

Fig 3 SEM images of body suit at 10,000×and EDX composition

With EDX line scan, it showed that the surface of analysis area had silver particles, but this technique could not show the size of silver. It can be implied that the small particles on the surface are silver. At high magnification, the SEM images could not be obtained because high temperature from electron beam causes fabric to become unstable and sometimes it gets burned.

Leaching test and analysis results

Table 3 presents the silver concentrations of the TCLP leaching test for all samples tested. Generally, silver concentrations ranged from 0.014 to 163 µg/L in the commercial products and ranged from 116 to 280 µg/L in the nano-Ag fabrics. The highest concentrations of silver were obtained from shower cloths. Leaching solution from this sample had silver concentration of 163 µg/L. Concentration from leaching test under TCLP did not exceed the regulatory limit of 5.0 mg/L for TCLP silver.

Table 3. Silver released during toxicity characteristic leaching procedure (TCLP)

Sample name	TCLP silver content (µg L^{-1})
Body suit	27.7 ± 0.16
Car sheet	17.6 ± 1.33
Nursing cover	0.56 ± 0.74
Shoes	7.85 ± 0.77
Clear pet sheet	62.2 ± 1.34
Sock D	0.01 ± 18.5
Face Mask	0.19 ± 2.30
Shower cloths	163 ± 0.63
Cotton 1000 ppm	280 ± 0.32
Cotton 700 ppm	259 ± 0.62
Cotton 500 ppm	116 ± 0.65

Since leaching of nano-Ag products is below the required limit, they are not considered hazardous waste.

However, silver ions will slowly leach from nano-Ag over a prolonged time [13]. This behavior might cause accumulation of nano-Ag in bio-living thing. It has been shown that nano-Ag strongly affect the hatching rate, notochord, heartbeat, and tail development of Zebrafish [14]. In addition, Drinking Water Standards and Health Advisories issued by US.EPA is regulated at 100 µg/l, so the silver concentration released from prepared fabrics was higher than this standard [15].

A comparison of all samples based on the amount of silver leached relative to the silver content of the sample (Table 1) suggests that fundamental differences in the manufacturing processes of the products control the amount of silver that is released into the TCLP extracts. For example, body suit and car sheet contained relatively large amounts of silver (6.347 and 2.692 µg, respectively), release high concentration of the silver in TCLP extracts. Different nano-Ag textile designs may emit more or less nano-Ag. There is a variation in the incorporation of nano-Ag that correlates with the way silver was attached to the textile and the amount of silver emitted [16]. Silver can be added during the manufacturing of a material either directly or in the form of a liquid coating that contains silver and that may form a surface covering on fibers or fabrics [17].

Even they are not leachable under the TCLP test conditions and do not pose toxicity characteristic hazards, silver still pose toxicity via silver ion that continue to release in the long term if suitable condition occurs such as presence of sufficient amount of oxygen. This may lead to formation of reactive oxygen species (ROS) which can induce oxidative stress on cells, destroy important cell components and finally cause cell death [18]. Thus, the accumulation of nanosilver in landfill can cause effect to environment in the long term.

TEM analysis of leaching solution

A drop of leaching solution from body suit, shower cloths, car sheet, sock D, treated cotton with 500 and 1,000 ppm, were placed on carbon grid. These were then dried at room temperature before transferred for TEM analysis. None of samples showed nano-Ag particles on the grid, while on three samples (body suit, shower cloths and sock D), Titanium particle were found under TEM analysis along with EDX. A thick film on the carbon grid was found in leaching solution of prepared nano-Ag cotton under TEM analysis. This may result from the binder solution that are also released and dispersed in the TCLP extracts. Figure 4 shows the TEM analysis of body suit along with EDX.

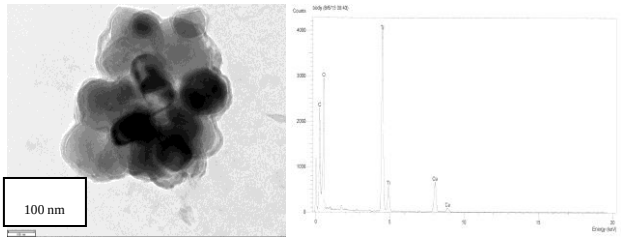


Fig 4 TEM images of Titanium particle from leaching solution of body suit

TiO_2 is one of the most applied inorganic nano-structured materials. It is used widely due to its properties such as self cleaning, anti-bacterial agent, UV protecting agent etc. Therefore, in some samples that were claimed to have nano-Ag, might also possibly contain TiO_2 and it can be released during the leaching process.When comparing cost, TiO_2 is cheaper than silver and some manufacturers may use them in the textiles for UV protection or whitening purpose.

4. CONCLUSIONS

Eight nano-Ag products and cotton fabrics treated with nano-Ag at various concentrations (500, 700 and 1,000 ppm were used for TCLP test. The silver content was found in range between 0.946 to 2.022 µg Ag per g product. After TCLP test, silver was released from the different samples to varying extents, ranging from 0.01µg/L to about 280 µg/L. The quantity of silver released from the samples was likely to be dependent on the amount of silver coated, the fabric quality and its pH.

Leaching test is performed to demonstrate release of nano-Ag in the environment. Even silver concentration of TCLP extract did not exceed the 5 mg/l regulatory level for characterization as hazardous waste, these products will end up in the landfill and may pose some risk to the environment. The increased use of nano-Ag in many types of consumer products may lead to an increase level of silver in the environment while the regulatory control for the use and disposal is still lagging behind. This study simulated the condition when nano-Ag containing products were subjected to acidogenic phase in landfill condition. The silver being used in products were somehow released into the environment through their life cycle. Products still contain some amount of nanosilver while they were disposed into the landfill, the Ag+ may be harmful to landfill environment. So the assessment for potential of nano-Ag and Ag^+ release during disposal phase and their release into the environment in long term needs to be investigated.

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Community's Benefits from the Tourism Growth and Tourism Site Development in Vangvieng District of Vientiane Province, Lao PDR

Khamtanh SALIANKHAM, Bounlouane Douangngeune, and ZhangBin

Abstract *- This study attempts to measure benefits of the local residents of Vangvieng from tourism growth and tourism site development. Here, community benefits involve not only economic benefits but including also social, cultural and environmental benefits. The data used in this analysis are primary data provided through a questionnaire by the residents of Vangvieng district, a famous tourist spot in Lao PDR. The results are mixed results. On the negative side, the community faces some risks as a result of tourism development. On the positive side, tourism growth and tourism site development bring about improvements in living conditions and conservations of residents' attitudes towards tourism improvement development.*

Keywords**: Tourism improvement management, tourism growth, communities' benefit, residents, visitor, public sectors, accommodation entrepreneur**

1. INTRODUCTION

The Vientiane Province is divided into 12 administrative districts, VangVieng is one district with a land area of 212.5 Km^2. The district is further divided into eight sub-districts and 75 villages, 809 units, which are home to 13,265 families or 64,918 people. (VangVieng interior office 2013)Vangvieng tourism is composite of many activities, industries and services organized towards deliverying a travel experience, including accommodations, restaurants, bars, entertainment, shops, transport, activity facilities and other hospitality services. Tourism in Vangvieng has greatly contributed to economic development as it is one of the major growth industries and a key part of the economy of Vangvieng. The advantage of Vangvieng tourism is a generic terms of which can be based on its natural landscape and highly cultivated farmland and rich cultural life. A survey conducted in 2012 by sector of culture, information and tourism of Vangvieng district involving 128,276 foreign visitors found that 50% of the visitors were from Europe, 30% from Asia and 20% from other continents *(VangVieng Tourism Office, 2012).* The survey also found that the main features attracting foreign visitors into Vang Vieng were natural environment mixed with unique customs of minorities. VangVieng, like other parts of Lao PDR has started to promote investment policy, focusing on promoting tourism related businesses such as hotels, guest houses, restaurants, tour services. Thus, tourism facilities in VangVieng have grown rapidly, and currently there are 9 hotels, 11 resorts, 111 guest houses , 82 restaurants and 3 entertainments, 1000 tubs services, 173 Kayakings, 1 balloon service, 110 bicycle services , 150 motorbikes, 6 textile souvenir shops , 17 massage centers and 11 internet cafes. The values of investment in hotels have reached about 267 billion Kip (about US$33.44 million) and in restaurants have reached about 3.67 billion Kip (or US$453,611 *(VangVieng Tourism Office, 2012).*

The above mentioned growth in tourism sector in Vang Vieng indicate that tourism brings significant benefits, particularly economics to the area. Nevertheless, it is not certain whether such tourism growth and tourism site development will bring significant benefits to local residents. The benefits do not only refer to economic benefits but also include social, cultural and environmental benefits as described in sustainable tourism management definition (Kishore Shah, Jan McHarry and Rosalie Gardiner, 2003). This study aims to examine the community benefits in these four dimensions based on primary data collected from Vang Vieng district local residents. Such benefits reflect the quality of state management and supervision over tourism sector.

2. LITERATURE REVIEW

Sustainable tourism management by definition includes eco-tourism, green travel, environmentally and culturally responsible tourism, fair trade and ethical travel (Kishore Shah, Jan McHarry and Rosalie Gardiner, 2003). The most widely accepted definition is that of the World Tourism Organization (WTO), which defines that sustainable tourism is "tourism which leads to management of all resources in such a way that economic, social and aesthetic needs can be fulfilled while maintaining cultural integrity, essential ecological processes, biological diversity and life support systems." In addition, WTO describes the

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development of sustainable tourism as a process which meets the needs of present tourists and host communities whilst protecting and enhancing needs in the future (World Tourism Organization 1996). In other words, community's benefits are a crucial component of sustainable tourism development.

The size of the tourism industry can be clearly seen from the World Travel and Tourism Council (WTTC) statistics 2002. The WTTC estimates that in the year 2002, travel, tourism and related activities contributed to approximately 10% of the world's GDP, growing to 10.6% by 2012. The industry is currently estimated to help generate 1 in every 12.8 jobs, or 7.8% of total employment. This will rise to 8.6% by 2012 (WTTC 2002).

For developing countries, tourism is also one of the biggest income generators. But the enormous infrastructural and resource demands of tourism can have severe impacts upon local communities and the environment if it is not properly managed. Referencing to words of Director, Uganda Community Tourism Association of January 23, 2002 saying that "you'll find community members make the best guides; they are the ones who really know the area and the local attractions. They need to be a part of the tourism enterprise to make it better." Usually the paths the tourists use are the ones the community used first. The purpose of communities encourage in a concept and there is the tool for employment in the area, and also a concept of keeping in view of positive impact of tourism sector development and economic growth in the area, finally the sustainable management seeks a balance of economic, social and environmental effects of tourism.

In the literature, discussions have been made about the residents' perceptions and support on tourism development, particularly tourism is increasingly seen as a key community tool, with the recognition of its economic contribution in bolstering stagnating economies and its ability to unify local community residents (Fennell, 2003). Bushell and Eagles (2007) says tourism plays a role in facilitating community development through business mentoring and educational opportunities that contribute to local communities in increasing skill and knowledge in local communities and local residents. The process of tourism development is important as an important tool in community development. Hence many local communities have turned to tourism development to provide economic, social, cultural and overall development of the community.

The previous tourism impact studies found that local communities' perceptions in terms of economic, environmental, social and cultural impacts have affected communities' support for community tourism development and business (Davis, Allen, &Consenza, 1988; Gee, Mackens, & Choy, 1989; Getz, 1986; Gunn, 1988; Fesenmaire, O'Leary, &Uysal, 1996; McIntosh &Goldner, 1986; Murphy, 1985; Perdue, Long, & Allen, 1990).

Crouch (1994) found that the communities' economic benefits from tourism invloves rising income of the local residents. Goeldner and Mclntosh (1984), Torres and Momsen (2005) and Hughes (2006) say that tourism growth provides employment opportunities for the local residents. Tourism growth and tourism site development can also bring business opportunities to local communities but such economic impacts of tourism will vary from one place/destination to another (Andrew and Withey, 1976).

The social benefits refer to the direction in which tourism contributes to wellbeing of society and tourists in the destination (Milman and Pizam, 1988). Murphy (1985: 133) explains that if tourism is to merit its pseudonym of being " the hospitality industry" it must look beyond its own doors and employees to consider the social impact it is having on host community at large. Sharpley (1994) explains social impact in the tourism has a significance. The three social impacts that were included in discussions include community pride, impact on the quality of life for host community and celebration of community values. These three impacts constitute a component of change in quality of life for host community (Peter Sherwood , 2007, P: 115). Employment, labor displacement and increased land price are also considered as social impacts of tourism growth and tourism site development (Gjerad, 2005).

Tourism can contribute to improving the cultural identity of destination, heritage value, natural feature, way of life, lifestyle values and multi-culture artistic. These refer to identity in local community and exchange with external for enhancing, preserve in term local tourism development. HO sauyingPamela (2006, P:49) says that this type of travel is distinctive from mass tourism for tourist travel to pursue a particular interest offered by as specific destination. Hall (1989) mentioned the motivation and decision- making process of traveler are determined in whole or in part by a special interest.

The studies of culture impact indicated by many researchers such as (Cohen, 1992) believe that excessive commercialization of traditional art, music and crafts might result in the distortion of the purity of those strong cultural elements. In contrast, Simpson and Wall (1999), Besculides et al (2002), and Boyd (2002) think that tourism contributes to endeavors to preserve traditional art, music and crafts. Similarly, Hall, Mitchell and Keelan (1992) indicated that tourism development in the Maori community in New Zealand provides financial support to the local people in preserving their cultural heritage as well as the ethnic groups from developed countries also benefit from the tourism development in the preserving their traditional arts, music and crafts. Hashimoto (2002) indicated the tourism businesses provide the opportunity for the woman to work in the tourism industry.

Environmental impacts of tourism refer to situation in which such development as infrastructures and tourism development towards providing facilities for local residents lead to pollution, solid waste, the destruction of natural resource, the degradation of vegetation and the depletion of wildlife (Andereck, 1995; Koenen, Chon and Christianson,

1995; Ahrmed and Krohn, 1992). However, some studies state that such negative impacts of tourism are often out weighted by such positive contributions of tourism as increased investments, created jobs, infrastructure improvement, and the government often concentrates on using the advantage of tourism in promoting balanced economic growth and rural development. Furthermore, Var and Kim (1990) mentioned that tourism helps create a greater awareness and appreciation for the need to preserve the environment to capture its natural beauty for tourism purposes and increased investments in the environmental infrastructure in the host country.,.

In the current study, the Vangvieng community's benefits from tourism growth and tourism site development in terms of economic, social, cultural and environmental benefits will be assessed. Only when these four aspects of community's benefits are met, tourism growth and tourism site development in Vangvieng will be on its sustainable path. Particularly, economic, social, cultural and environmental benefits will be measured as follows:

- Economic impacts include employment opportunity, revenue generation opportunity for local business and standard of living and cost of living.
- Social impacts include congestion, local service and crime.
- Culture impacts include preservation of local culture, cultural exchanges between residents and tourists
- Environmental impacts include pollution, wildlife decline and solid waste

3. METHODOLOGY

The resident model is a causal relationships between the direct variables (residents support for tourism growth and tourism site development) and indirect variables (economic, social, culture and environment). We try to apply this model in analyzing the Vang Vieng residents' benefits from tourism growth and tourism site developments in this world famous tourism site based on a questionnaire survey. Two hundred local community members were randomly chosen as survey respondents. As a result, 155 questionnaires were returned, among which 148 questionnaires contained complete data necessary for the analyses in this study.

Two types of data were collected through the questionnaire such as basic data about the residents as well as their subjective economic, social, cultural and environmental benefits from tourism growth and tourism site development in Vang Vieng. The benefits are measured in a 5-point Likert scale from one = Strongly disagree – five = Strongly agree. The interpretations of the benefits follow the following rules: 5.00 – 4.20 = highest benefits, 4.19-3.60 = high benefits, 3.59-2.80 = moderate benefits, 2.79-2.00= low benefits, 1.99-1.20=lowest benefits.

The analyses in this study are mainly based on descriptive statistics although quantitative statistics such as F-statistics arealso used to supplement the analyses.

4. FINDINGS

The objective of this study is to subjectively quantify Vang Vieng local residents' benefits from tourism boom in Vang Vieng. This section will present the findings which are divided into three sub-sections. The first sub-section describes basic characteristics of the sample in terms of their income, job,birthplace and others. The second sub-section presents benefits of the sample from tourism growth and tourism site development. The third sub-section compares the benefits of the sampled local residents with different jobs and income levels.

4.1 Sample profile

Among the 148 community members joining this survey, 58.8 percent were males and 41.2 percent were females. A majority of the survey participants were born and live in Vang Vieng while about 23 percent were not born in elsewhere and have moved to live in Vang Vieng. In terms of their education qualification, the junior high school and senior high school completers account for about 60 percent, 22.3 percent have completed higher diploma and about 10 percent have obtained a bachelor degree. This data shows that the survey participants somewhat have a quite high level of education. Due to their high educational level, as high as 48 percent of them are entrepreneurs involving in trading businesses, 27.7 percent are civil servants and 21 percent are employees of private companies or non-governmental organizations. Due to their relatively high educational levels and sound occupation, as high as 64.7 percent of the survey participants earn more than one million eight hundred thousand Kip per month, among which 26.4 percent earn more than two million two hundred thousand Kip per month. About one thirds earn less than one million eight hundred thousand Kip per month.

4.2 Measures of community benefits and supports

As described earlier, this paper seeks to measure the local residents' benefits from tourism growth and tourism site development in Vang Vieng based on a belief community's benefits are crucial to sustainable tourism development. The argument follows that if the community members receive significant benefits from tourism growth and tourism site development in their community, they will provide their supports to promote tourism growth and tourism site development.

Table 1 Benefits of Vang Vieng Residents from and supports on tourism growth and tourism site development

Benefit components and community's supports	**Sample size (n)**	**Mean score**
Environmental benefits	148	3.67
Economic benefits	148	4.16
Social benefits	148	3.56
Cultural benefits	148	3.67
Community support to tourism site development	148	4.13
Community support to tourism growth	148	4.03

Notice : (5 - 4.2 =highest benefits/strongest supports, 4.19 - 340 = high benefits/strong supports, 3.39 - 2.60 = moderate benefits/support, 2.59 - 1.80 = low benefits/weak support, and 1.79 - 1 = lowest benefits/weakest supports).

Table 1 shows the data on the benefits and supports of the Vang Vieng residents who participated in this survey in terms of the mean score of their perceptions towards environmental, economic, social and cultural benefits, as well as their supports provided towards tourism site development and tourism growth. As can be observed in the table, the community residents receive high environmental, economic and cultural benefits and moderate social benefits. Such results may be reasonable because due to tourism growth and tourism site development, both natural and built environments in the community are improved in order to attract more tourists into the community. Such changes make local residents feel environmental benefits. Tourism growth and tourism site development surely bring economic benefits to local communities as tourism brings about employment and business opportunities to the local residents. With more tourism, local residents can show their indigenous cultures to tourists, adding more value to their cultures. On the other hand, with tourism growth, society becomes more complex and some social drawbacks such as crimes and thieves may increase. Therefore, the local residents feel that they receive only moderate social benefits from tourism growth and tourism site development.

Nevertheless, the above results show that in overall the local residents in Vang Vieng receive high benefits from tourism growth and tourism site development. As a result, they show high supports to both tourism growth and tourism site development, which can also be seen in Table 1 above.

4.3 Comparisons of local residents' benefits and supports across occupations and income levels

In Section 4.2 we found that the local residents of Vang Vieng get high environmental, economic and cultural benefits, and moderate social benefits from tourism growth and tourism site development in Vang Vieng; and therefore, they provide high supports to promote tourism growth and tourism site development. However, development experiences in many countries show that certain development activities differently bring benefits to different groups of people in society. In some emerging economies, rapid economic growth in their early development stage has brought about great disparity among members of society, and such huge disparity can bring about social distresses and consequently hamper further economic growth. In this sub-section, we attempt to test whether there are any disparities in benefits the community members with different characteristics receive from tourism growth and tourism site development in Vang Vieng.

Based on the discussion in the previous paragraph, we show comparisons of benefits of local residents in six different occupations (such as civil servants, private company employees, non-governmental organization employees, entrepreneurs and others) and in ten differentmonthly income categories (such as (1) <600,000 Kip, (2) 600,001 Kip – 800,000 Kip, (3) 800,001 Kip - 1,000,000 Kip, (4) 1,000,001 Kip –1,200,000 Kip, (5) 1,200,001 Kip – 1,400,000 Kip, (6) 1,400,001 Kip – 1,600,000 Kip, (7) 1,600,001 Kip – 1,800,000 Kip, (8) 1,800,001 Kip – 2,000,000 Kip, (9) 2,000,001 Kip – 2,200,000 Kip,(10) >2,00,000 Kip). The one-way ANOVA test is applied to detect the disparities. That is, if the test shows statistical differences at least at the 5-percent significance level, we can infer that we cannot reject possibility of disparate benefits among the people of different occupation groups or different income groups. The results of such statistical tests are shown in Table 2 and Table 3 for comparisons across occupational groups and income groups, respectively. In Table 2, we found that there are statistically significant differences in the environmental benefits among six occupational groups. The community members with different occupations also provide statistically different supports to tourism growth. The statistical results for the economic benefits, social benefits and cultural benefits, and that for the community supports on tourism site developments do not allow us to reject the null hypothesis that the community members of the six occupational groups have the same economic, social and cultural benefits, and that they have the same level of supports on tourism site development.

Table 2 Comparisons of local residents' benefits and supports across occupations

Job variation	d.f	F-statistics	p-value
Environmental benefits	5	2.465	.036
Economic benefits	5	.615	.689
Social benefits	5	1.397	.229
Cultural benefits	5	2.214	.056
Supports on tourism site development	5	2.099	.069
Supports on tourism growth	5	3.079	.011

The results in Table 3 show only one significant difference in cultural benefits across the community members of 10 different income groups, while the statistics for the environmental benefits, economic benefits and social benefits, and those for the community supports on tourism site development and tourism growth are not significant; indicating that there are no disparities in these three benefits and supports the community members of different income groups receive from and support on tourism site development and tourism growth in Vang Vieng.

Table 3 Comparisons of local residents' benefits and supports across income levels

Income Variation	d.f	F-statistics	p-value
Environmental benefits	9	1.394	.196
Economic benefits	9	1.313	.235
Social benefits	9	.763	.650
Cultural benefits	9	2.013	.042
Supports on tourism site development	9	.984	.456
Supports on tourism growth	9	1.228	.283

5. CONCLUSION

Previous literatures show that tourism growth and tourism site development is an important driving force of socio-economic development in developing countries because tourism creates opportunities for local communities in improving their economic status based on environmental improvements, social issues and cultural values. Therefore, policy makers in developing countries try to promote tourism growth in their economy, and the host communities also provide strong supports to tourism development. The results of this study support these arguments. That is, the local residents of Vang Vieng, a world famous tourism site in Lao PDR receive great benefits in terms of environmental, economic, social and cultural benefits and they show strong supports to tourism growth and tourism site development in their town. The benefits seem to spread quite evenly among the community members. The community members also provide somewhat even supports to tourism growth and tourism site development in Vang Vieng.

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Tourist Satisfaction on Tourism Growth and Tourism Site Development in Vangvieng District of Vientiane Province, Lao PDR

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Abstract-*This study attempts to understand tourist satisfaction on their visit for recreation and leisure purposes inVangvieng of Lao PDR. Here, tourist satisfaction is measured in tourists' perceptions and opinions on tourism site development and services they receive during their stay in Vangvieng. The data collected for purposes of this study were provided by tourists through the use of questionnaire where the tourists were asked to express their opinions and perceptions on economic, social and cultural benefits received from their stay in Vangvieng. Tourist statisfaction is one condition for achieving sustainable tourism development. In recent decades, Lao PDR has been a very attractive tourist destination, indicating that the satisfaction levels of the tourists would be high. This study will show results for this hypothesis. It is found that tourists are generally satisfied in their visits to VangVieng although personal characteristics of the tourists cause significant variations in the satisfaction levels*

Keywords: **Tourism improvement management, tourism growth, communities' benefit, residents, visitor, public sectors, accommodation entrepreneur**

1. INTRODUCTION

VangVieng is one destination for visiting in Laos.Vangvieng tourism is composed of many activities, industries and services organized towardsdeliverying travel experiences. Vangvieng tourism facilities involve accommodations, restaurants, bars, entertainment, local product shopping areas, transports, activity facilities and other hospitality services.

Tourism in Vangvienghas made significant contributions to economic development and has become one of the major growth industries in Vangvieng. The advantage of Vangvieng tourism is generally referred to a good combination of its magnificent natural landscape and highly cultivated farmland mixed with rich cultural and traditional values of the local residents.

A survey conducted in 2012 by sector of culture, information and tourism of Vangvieng district involving 128,276 foreign visitors found that 50% of the visitors were from Europe, 30% from Asia and 20% from other continents *(VangViengTourism Office, 2012).* The survey also found that the main features attracting foreign visitors into VangVieng were natural environment mixed with unique customs of minorities. VangVieng, like other parts of Lao PDR has started to promote investment policy, focusing on promoting tourism related businesses such as hotels, guest houses, restaurants, tour services. Thus, tourism facilities in VangVieng have grown rapidly, and currently there are 9 hotels, 11 resorts, 111 guest houses, 82 restaurants and 3 entertainments, 1000 tubs services, 173 Kayakings, 1 balloon service, 110 bicycle services, 150 motorbikes, 6 textile souvenir shops, 17 massagecenters and 11 internet cafes. The values of investment in hotels have reachedabout 267 billion Kip (aboutUS$33.44 million) and inrestaurants have reachedabout 3.67 billion Kip (or US$453,611 *(VangViengTourism Office, 2012).*

Theoretically, the growth of tourism sector in VangVieng described above should bring benefits to all concerned people including local community members, business people, public sector and tourists. The benefits are measured in four facets such as economic, social, cultural and environmental benefits as described in Kishore Shah, Jan McHarry and Rosalie Gardiner (2003). This paper focuses only on

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measuring benefits of the tourists, particularly foreign tourists. Benefits are measured by subjective perceptions and opinions of foreign visitors in VangVieng, which are referred in this paper as tourists' satisfactions. The study finds that tourists are generally satisfied in their visits to VangVieng although personal characteristics of the tourists cause significant variations in the satisfaction levels.

2. LITERATURE REVIEW

Increased access to travel was accompanied by other developments in society, and this contributed to the growth in demand for and provision of tourism. A variety of important factors contributed to the development of tourism during the nineteenth and early part of the twentieth century. Mason (1990) suggested five major reasons for the growth of tourism. These are as follows: (1) A rise in industrial output associated with the industrial revolution that in turn led to an increase in the standard of living.(2) Improvements in transport technology, which led to cheaper and more accessible travel. Railways and ocean liners appeared in the nineteenth century and cars and aircraft in the first half of the twentieth century. (3) The introduction of annual holidays towards the end of the nineteenth century.(4) Changing perceptions of the environment. Locations that were once viewed as hostile were now seen as attractive. (5) An increasing desire to travel. This was related partly to improvements in education and also to greater overseas travel, which was mainly the result of war. This created interest in foreign locations and also overseas business travel.

Responsible tourism is not a brand or type of tourism. Rather, the term refers to a "tourism management strategy embracing planning, management, product development and marketing to bring about positive economic, social, cultural, and environmental impacts" (DEAT 2003). More specifically, Husbands and Harrison (1996) define responsible tourism as "a framework and a set of practices that chart a sensible course between the fuzziness of ecotourism and the well-known negative externalities associated with conventional mass tourism." To them, the idea of responsible tourism provides an effective approach to conceive social and eco-cultural tourism products in the real world.

The visual and understanding of visitor perspective are different point of view, Thus, while the term of quality tourism experience is commonly used in the sustainable tourism literature (Boyd, 2002; Moscardo, 1996; Ross & Wall, 1999; Ryan, 1998).The concept has not been explicitly defined. Generically, these studies associate quality tourism experiences with tourism based on cultural, historic and natural attractions, which involves extensive interaction between tourists and local residents and results in high satisfaction and enrichment to tourists. A key indicator of a high quality visitor experience is visitors' level of satisfaction with their experience.

Natural environment ; According to Jones and Sasser(1995) mentioned of satisfaction: there are four basic elements affect tourists (customers) satisfaction for basic of product or service, basic support services, a recovery process for counteracting bad experience and extraordinary service. The importance of delight has additionally been recognized in the area of quality by Deming (1986) The studies have show: Swarbrooke,(1999) mentioned tourism also benefited the natural environment by providing motivation for its environment, Mathieson and wall,(1982) Tourism extends an appreciation for the natural world and heightens environment knowledge for both the host communities and visiting tourists.

Economic impact, Matarrita- Casante and Luloff. (2008) indicated the economic restructuring results from the changing direct, indirect and induced employment generated from changing conditions and often newcomers have different socioeconomic status as evidenced by their higher levels of education and income than those of long-term residents. The relationship between the tourism impact (tourists support economic) and communities they refer to the tourism growth and tourism arrival for visiting to lead the development of many things to have new version. Var&Kim,(1990) mentioned services of all kinds

are established and offered to tourist, which in turn also serve local residents and tourism the impetus to improve and further development communities infrastructure and communities service.

Many words of social impact and many rural developments were attracting destinations, the tourism growth and tourism arrival. According to many studies indicated that: the social impacts of tourism fall into three different categories. It is concerned with tourist, the host and tourist-host interrelations (Affeld, 1975, P.109). Burdge, (1998:47) mentioned the socioeconomic characteristics may result in the perceptual changes among different resident types, different socioeconomic characteristic affect how newcomers perceive the community and how the community perceives the newcomers. The relationship between the tourism impact and local \

resident in term of social support by tourism growth and tourists arrival which led to change the communities which will be the reducing poverty and contribution to sustainable development into rural area.

The tourism growth in term of cultural resident impact which was led to the positive and negative points for the patterning of development as well as Sustainable tourism development, According to the meaning of cultural tourism there are many thing to many people and herein lies its strengths and its weaknesses(ICOMOS 1996: 17). The defining cultural tourism, it can mean different things to different people such as cultural attraction/objects mean different things and have other meanings than for other people(Understanding the Behavior of cultural tourists, (Rami Isaac,2008 P: 16).Sethna&Richmond (1978) indicated The Virgin Islanders exhibited consensus that tourists seem to respect local traditions and cultures and want to know more about them.

The tourism growth is characterized by a sort of 'Baume's disease', since the 'productivity' of natural and cultural capital hardly increases over time (Baume and Baume, 1985).Buckley (1993) identifies a systemic scenario in which tourist sector linkages with environmental and cultural capital assets and linkages between consumption(number of foreigner visitors) and investment ((Number of Hotels, Guesthouses, Resorts, Restaurants and Entertainment) as they arise in the Environment of tourism development.

3. Study approach

In order to capture tourist satisfactions on tourism growth and tourism site development in VangVieng, we developed a questionnaire for collecting two types of data such as the data on personal characteristics of foreign tourists in VangVieng and the data on their satisfactions of tourism growth and development there in terms of economic, social, cultural and environmental benefits. The latter are measured in a Likert scale ranging from 1 through 5; where 1= strongly dissatisfied and 5= strongly satisfied. The data were collected during July 2013 involving a sample size of 200 foreign tourists. The analyses in this study are mainly based on descriptive statistics. Quantitative statistics such as t-statistics and F-statistics are used to supplement the analyses.

4. RESULT

4.1 Sample profile

VangVieng is a world most famous tourism destination receiving many domestic and foreign tourists every year. A majority of the tourists are young people as they are in the age of seeking new experiences. In this current study, we also found that 67.4 percent of our sample are in the age of lower than 31 years. The oldest stratum of tourists (60 years old and older) accounted for only 4.4 percent.In terms of their income levels, about one half of the sampled tourists fall in the lowest income group (up to US$3000 per month) and one quarter of the sampled tourists earn between US$3000-US$6000 per month. These results show that a majority of the tourists fall in the two low income groups, with the remaining 25 percent earn more than US$6000 per month. Such income distribution is reasonable as about two-thirds of the sample tourists are young. In terms of their education qualification, we found that about 33 percent have completed higher diploma and 32

percent have a bachelor degree. These people are most likely in young ages and earn low incomes. About 45 percent of the sampled tourists are from Europe, 35.4 percent are from the Asia-Pacific region, about 17 percent are from America and less than 3 percent are from Africa and the Middle East. Among the tourists from each continent, we also found that a majority of the tourists are in their young ages and earn low incomes per month. For example, 41 out of 43 Asian-Pacific tourists of the up to 30 year-old group earn not more than US$6000 per month. Likewise, such 41 persons account for about 79 percent of all Asian-Pacific tourists in the first two income groups (the up to US$3000 group and the US$3001-US$6000 group). For the European tourists, 41 out of 44 tourists in the up to 30 year-old group earn not more than US$6000 per month, or such 41 persons account for about 67 percent of all European tourists in the first two income groups (the up to US$3000 group and the US$3001-US$6000 group).

4.2 Tourists' benefits from their visit to VangVieng

It is difficult to quantify the benefits each tourist receive from a particular tourist destination. In this study, we follow the literature reviewed in Section 2 in equating the tourists' benefits from visiting VangVieng to their satisfaction in terms of economic, social, cultural and environmental satisfactions. The satisfaction on the environment includessatisfaction in both natural and built environments. Here, we also attempt to compare tourists' benefits or satisfactions by age group; 30 years old and younger, 31 – 40 years old, 41 – 50 years old, 51 – 60 years old, and 60years old and older. We also compare the benefits across different income groups such as below or equal to US$3000, US$3001-US$6000, US$6001-US$9000, US$9001-US$12000, and >US$12000.. The results are shown in Table 1..

Table 1 Mean satisfactions and statistical tests for differences in satisfaction by age and income groups

Satisfaction factors	Sample size	Mean score	p-value for age	p-value for income
1	Total1: Naturalenvironment satisfaction	181	3.58	.218	.890
2	Total2 : Builtenvironment satisfaction	181	3.42	.092	.814
3	Total3: Economic satisfaction	181	3.80	.707	.683
4	Total4 : social satisfaction	181	3.43	.374	.425
5	Total5: Culture satisfaction	181	3.57	.342	.644

As can be observed in Table 1 above, it can be stated that although VangVieng is one most popular world tourist destination, the tourists under study were only moderately satisfied to highly satisfied with their visits to VangVieng. Specifically, they are moderately satisfied with their natural environment benefits, built environment benefits, social benefits and cultural benefits. They showed high satisfaction only for the economic benefits, which may be due to cheap prices compared with the prices at other tourist destinations in other parts of the world. When we compare the benefits in each of the five components in the table above across tourists in different age groups and in different income groups, (based on the one-way ANOVA test for comparing more than two means) we cannot reject the null hypothesis that the tourists of different age groups or the tourists of different income groups have the same level of benefits for each of the five components.

These results suggest that local authorities concerned and local communities have to improve their tourism

sites and services in order to provide more environmental, cultural and social benefits to the tourists. Such improvements are important for sustainable tourism growth and tourism site development in VangVieng. On the other hand, if the tourists continue to receive moderate benefits from their visits to VangVieng, tourism in VangVieng may decline in the future. As described in the introductory part of this paper, tourism is one main contributing factor to socio-economic development in VangVieng. Therefore, if tourism declines due to a decline in the tourist number, living conditions of local residents of VangVieng will be disturbed unless alternative livelihoods are developed.

5. CONCLUSION

Tourism is a very important sector contributing to socio-economic development in VangVieng, one world famous tourism site in Laos. Particularly, in recent decades, after the announcement of Lao Tourism Year in 2000, tourism in VangVieng has grown steadily. Foreign tourists make up a majority of visitors and bringing most of the tourism-related benefits to the local community and public authorities in VangVieng. Therefore, in order to ensure sustainable tourism growth and tourism site development in VangVieng, it is important to understand and maintain high benefits or satisfactions of the tourists who visit that town. This current study attempts to quantify such tourists' benefits by collecting the data on tourists' satisfactions on tourism growth and tourism site development in VangVieng. The results show that the tourists in VangVieng are mainly young people in low income groups and most of them are from Europe, Asia-Pacific and America. The tourists are moderately satisfied with both natural and built environments, cultural and social landscape of VangVieng. They show high satisfaction only for the economic aspects which may be due to low costs. Such results show some risks of tourism decline in VangVieng. In order to prevent such risks to materialize, local communities, tourism-related entrepreneurs and local authorities need to seek ways to improve tourism services and attractions in VangVieng. Such improved services and attractions will be necessary for maintaining VangVieng as a world tourism site and ensuring that local communities and entrepreneurs continue to gain benefits from tourism development.

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Integrated Job Analysis of Civil Servant in Lao PDR: Ministry of Public Works and Transport

Souvanny Rattanavong

Abstract—*Job analysis is a key effectiveness in building a strong foundation to enhance staff and organisational performances since it focuses attention on what staff are anticipated to do, and determines employees' tasks, duties, responsibilities and their relationships to the job, the conditions under which the job is performed, and the personal capabilities needed for satisfied performance. This paper aims at firstly analyzing the current situation in preparing and implementing the job analysis in Ministry of Public Works and Transports (MPWT) by identifying key obstacles and challenges in implementing the job analysis; secondly investigating the steps, procedures and best practice of the organisation. Both quantitative and qualitative research methodologies were employed. Questionnaire and in-depth interviews were deployed. It was found that the current practice of job analysis in the MPWT faced with difficulties and challenges since many of employees were not recruited according to their field of expertise. As a result, the work implemented did not seem to be well functioned as it should be since the job description has been designed from top-down, no detailed tasks has been described, as well as job specification was not in detailed and not effectively reinforced. Although the job description was broad, it was officially appointed and has been monitored and evaluated consistently, thus strengthening human resource management in MPWT. It was recommended that MPWT needed human resource management tools for job analysis, detailed job descriptions in the foundation or at grass-root level by designing workload for each position appropriately; improving job description in accordance with knowledge specification, educational qualification, experience and capabilities.*

Keyword: **Job description, job analysis**

1. INTRODUCTION

The concept of human resource management (HRM) took the management world by storm during the1980s and has represented a significant change of direction. The difference needs to be explored, even though the nature and degree of the difference remain largely matters of opinion rather than fact, and the similarities are much greater than differences.

Over the last decade or so, there has been considerable discussion about Human Resource Management (HRM) as a distinctive approach to the management of people [1]; [2]; [3]; [4]. It is generally accepted that HRM is a United States (US) export [5] with its focus on individual (as opposed to collective) management of people and the application of human resource (HR) methods intended to win employee commitment to organizational goals [6]. There has been a strongly prescriptive slant to the HRM literature, which has associated HRM with business success. Legge describes this ''project'' as ''the search for the Holy Grail of establishing a causal link between HRM and performance.''[4]. In practice, there have been several empirical studies that have found some support for the relationship between job analysis and job performance.

The notion that HRM impacts organizational performance has generated much research attention during the past fifteen years. In fact, three leading journals *(Academy of Management Journal, Industrial Relations,* and *Journal of Accounting and Economics)* have been recently published special research forums focused on the performance impact of people and human resource management. Underlying this stream of research is the assumption that people create value in organizations by helping them achieve their strategic objectives [7].

Over the past 5 years, the use of technology in human resources has increased dramatically and is now a vital aspect of many personnel-related decisions such as collecting job information, recruitment, employee selection, training, and performance management [8].

An organization structure is developed through the planning process [9] by the identification of position to be staffed to support implementation of the organization's strategy. It notes that organizational structure, the knowledge, skills and abilities that employees require to enable the organization to achieve its objectives can be identifies. The process of job analysis includes the analysis of job to determine the tasks being performed and the skills, knowledge and abilities required to perform them. There are many types of information to be collected via job analysis such as work activities, human behaviors, machines and equipments performance standards, job context and human requirement [9]. Well conducted and regular job analyses which results in updated and accurate job descriptions can help to avoid disputes over performance standards and remuneration levels.

It is argued that the quality of HR activities in an organization depends on the quality of the job analysis process [9].

Job analysis may be viewed as the hub of virtually all human resource management activities necessary for the successful functioning of organizations [10]; [11]; [12]; [13]. At the heart of almost every human resources

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management program or activity is the need for accurate and thorough job information. Job analysis is thus a prerequisite activity for the effective management of human resources. However, many important assumptions that underlie such fundamental uses of job analysis in management are becoming questionable in today's business environment. Job analysis focuses on the collection of work-related information for the job as it currently exists and/or has existed in the past [14]; [15]. Further, the procedures are related more to the situation of a one person-one job situation.

Yet, as competition and technological innovations increase, jobs are becoming not only less static, but also less individually-based. Consequently, the tasks to be performed, and the knowledge, skills and abilities (KSAs) required for effective job performance are also becoming more volatile, and sometimes more team-based. Furthermore, and in all likelihood, organizations may perceive the creation of jobs that do not currently exist, the analysis of which is beyond the scope of traditional job analysis.

Job analysis involves the collection of various types of job data and worker requirements in an organization [16]; [17]. The information obtained from a job analysis serves as a foundation for most, if not all, human resource (HR) related activities and issues [18]; [19]; [20]. In fact, job analysis is important to an organization because it serves as a strategic human resource management (HRM) practice through which organizations gain a better understanding of their jobs and their workers [15]; [21].

Every organization, both public and private sector, acknowledges the importance of Human Resource management which play a vital role in an organization especially in a high business competitive environment. Having adequate number of employees in an organization does not always mean that it is an effective organization. One factor that seems to be receiving more attention than any other is the people who work for organization [22]. As a rapid change of global business environment, organizations need to develop and adapt themselves into an innovative structure and work design which lead to effective organizational performance. Job analysis plays an important role in contributing to organization success.

2. BACKGROUND AND PROBLEM STATEMENT

The Human Resource Management, in the last decade, had taken into account in strengthening the employee's performance and work system in the particular organization. In the Lao P.D.R., job analysis has been introduced since 2004 nationwide by the ministry of Interior. Many organizations, especially in the government body, have faced challenges in implementing the job analysis while others were more successful in practical implementation.

The present Decree determinates the position, roles, rights, organization chart and method of working of the Ministry of Public Work and Transport. It serves as a basic document for the civil servant to follow as guidance in order to perform their job assignment.

The Ministry of Public Work and Transport in short so called "MPWT" is a Government's mechanism, whose roles are to assist the Government and to manage the communication, land route, waterway, aerial, railway transportation, housing and urban planning and water supply within the country. [PrimeMinister's Office No.373/PM; Vientiane, date 22 October 2007]. Even though all rules and regulation related to the civil servant are in place but the enforcement are likely to be weak in term of implementation.

The administrative mechanism of MPWT at the national level consists of (1) Cabinet Office, (2) Department of Organization and Personnel, (3) Department of Planning and Cooperation, (4) Department of Inspection, (5) Department of Road and Bridges, (6) Department of Transportation, (7) Department of Housing and Urban Planning, (8) Department of Civil Aviation, (9) Department of Waterway Public Work, (10) Railway Project, (11) Public Work and Transportation Institute (PWYI).

It is interesting to note that from 2006 to 2010, the government, the Ministry of Home Affairs had allocated 403 new employees to MPWT to be recruited, 309 for provincial offices (77%), and 94 for the Ministry Office (23%). The Ministry's direction is to strengthen the provincial capacity through the decentralization which in line with the government policy. In the fiscal year 2010, the total number of employees was 2,357; among these 356 people are females. At the ministry level, there are 739 staffs (151 females), while 1,618 staff in provincial level (PPWTs), including district offices (DPWTs). In the provincial offices, there are 1,058 staffs, and 560 people in district offices.

The department of personnel conducted a job analysis assessment in 2007 both at central and provincial level. The result from the assessment indicated that among 503 employees who hold a middle management position, such as head and deputy head of the division and equivalent, 181 employees were not meet job requirement. The information gaining from the job analysis assessment report illustrated the black spot in the Human resource management which related to the implementation of the job analysis. This issue has driven the author to investigate the gap between the job analysis system and the job analysis implementation in the ministry, and then lay out the pattern to fill the gap the job analysis.

3. RESEARCH AIM AND OBJECTIVES

An important area of civil service management reform, currently being implemented by the Government of Lao PDR, is to strengthen the limited capabilities of managerial and technical personnel in civil service, especially in the local administration. One of the main activities is writing job analysis and performance management.

The main objective of this study is to identify the challenges and issues relating to job analysis at MPWT, generate lessons to improve understanding of an importance of job analysis and roles towards organization which contributes to the organizational effectiveness. Therefore this proposed research attempts to explore the reasonable solutions to the following issues:

1. Analyze the current situation in preparing and implementing the job analysis in the Lao PDR
2. Identifying key obstacles and challenges in implementing the job analysis

4. LITERATURE REVIEW

4.1. Job Content

Recently, there seems to be a growing trend in studying job descriptions in the literature of business and psychology [23], selection and assessment [24]; and advertising [25]. Due to the diverse areas of study, the presentation of job related information in an attempt to advertise the job position has been given many names in the literature. Some examples include job description [26] recruitment advertisement [27], job advertisement [25]; [24], and recruitment message [24]; [23]..

Yüce and Highhouse investigated the effects of multi-level attributes in job descriptions on job candidates [28]. They performed an experimental study using 104 introductory psychology students from a university in the United States. The experiment probed the effects of attribute set size (different attribute or information in job descriptions such as work shifts and benefits), attribute relevance, and pay ambiguity to applicants' perception of job descriptions. The results showed that job descriptions that contained more attributes increased their attractiveness. At the same time, they discovered that students in the study paid attention to the missing information and viewed the missing information as a negative quality of the organization.

In another empirical study, Reeve and Schultz studied "to what extent individuals utilize selection process information contained in job ads in making evaluations of organizational attractiveness and decisions to apply." [24]. The study was performed with 207 undergraduate introductory psychology students at a university. Each student was instructed to read a list of job descriptions and to answer questionnaires. These questionnaires probe the relationship between the attributes of the selection process information and the reactions of the applicants. The results indicate that job seekers attend to the information contained in job descriptions to make "initial job-pursuit evaluations".

Smith et al. performed a study to analyze the impact of job description on job evaluation [26]. They performed three experiments using students from a university to test two hypotheses. The first hypothesis stated that "job descriptions presented with positive information first and negative information last will be evaluated more highly than the same descriptions with the information presented in reverse order." The second hypothesis stated that "moderately scaled job-descriptive information will lower the evaluation of highly scaled job-descriptive information and raise the evaluation of lowly scaled job descriptive information." One of their research objectives was to determine if the scale of job description complied with the additive model or the averaging model. The additive and the averaging models indicate the reaction of candidates to job descriptions as a sum and an average of the content values respectively. The results showed evidence supporting the averaging model. They also found that the sequence of the information presented affected applicants' judgment. Furthermore, job titles proved to have a very high influence on job evaluations. Finally, they commented that there were no clear guidelines for constructing job descriptions. Subsequently, evaluations of job descriptions can be inconsistent and may be influenced by the way the job descriptions are written.

In reviewing a number of scholarly studies that related to the content of recruitment materials, Barber[1998] comments that job descriptions should be informative in order to provide value to job seekers. Although many studies reveal that there is a positive correlation between the amount of information and the probability of applying for a job, he also suggests that information overload may be a concern and should be studied. Job applicants can only retain or understand a certain level of information; beyond that, there is a possibility that any additional information will have a negative impact. Furthermore, he comments that many scholarly studies on job content use fictitious companies as subjects. Hence, it could be beneficial to conduct additional studies using real applications to provide more realistic results.

4.2. Job Analysis

According to the United States Department of Labor Employment and Training Administration a job analysis is a systematic study of a specific job in terms of the worker's relationship to data, people and things, the methodologies and techniques employed, the machines, tools, equipment and work aids used, the materials, products, subject matter or services which result and the worker attributes that contribute to successful job performance. Worker's traits such as the physical demands of the job, working conditions, general educational development level, specific vocational preparation, aptitudes, interests and temperaments were also included. Physical demands should include the exertional and non-exertional requirements. Lifting, pushing, pulling, reaching, handling, stooping, climbing and many other factors incorporate the physical components. Job analyses usually include aptitudes such as verbal, numerical and spatial requirements or temperaments such as directing others, dealing with others or making judgments and decisions.

Job analysis comes in many forms, such as written reports, video analyses, pictorial analysis and others. Job analysis can be performed using electronic data, and the purpose of the analyses can vary. As a physician's concern is primarily with protecting against exceeding the physical limitations imposed by the injury, job analyses performed for a physician's review usually have a specific emphasis on the physical demands of the job. They can be used to identify the essential functions of a job and also the reasonable accommodations that would allow the individual with an impairment or disability to continue working.

4.2.1. Significance of Job Analysis

In order to understand why a job analysis is done, one might benefit from first knowing what a job is. A job position is better understood when it is broken into its component parts. The job can be broken down into "units" such as "duties, tasks, activities, or elements" [29]. Often in a job analysis the position is broken down into smaller parts so the company and the person in the position know every aspect of the job.

The breakdown of the units might be easiest to describe from smallest to largest. First, the smallest unit is the element. An element is something that has "a clear

beginning, middle, and end" [29]. Brannick et al. give dialing a phone as an example of an element [29]. This is something that has a clear beginning, middle, and end. Second, an activity is considered a cluster "of elements directed at fulfilling a work requirement" [29]. Third, a task is a group "of activities" [Brannick et al. give talking "to conflicting parties to settle disturbances" as an example of a task [29]. One is required to do several activities in order to complete this task. Finally, a duty is "a collection of task all directed at general goals of a job" [29]. One would most likely use activities or tasks when creating a job analysis questionnaire. The job analysis helps a company understand the importance and frequency of each of the tasks that are involved in a job.

A job analysis is carried out in order to better understand a job position. Brannick et al. describe a job analysis as the "discovery of the nature of a job" [29]. After a job analysis is done a company is better able to know the exact tasks, duties, and many of the knowledge, skills, abilities, and other personal characteristics (KSAOs] that are involved in a job position. Also, an organization gains a broader knowledge of which tasks and duties are most critical. When hunting for job applicants a company is able to use a job analysis in order to tell whether the potential employee will be able to fulfill the duties expected of them [30]. Also, the potential hire is able to know if they meet the minimum qualifications for the job position and they are able to know whether the job position sounds like a position of interest.

Beyond giving a solid job description, a job analysis benefits a company in the following areas: recruitment and selection; criterion development and training; and performance appraisals and job evaluations [31]. The job analysis also helps a company avoid "exposure to litigation based on allegations of discriminatory hiring" [31].

In the recruitment and selection process the recruiter, as well as the individual seeking employment, needs to have an in depth knowledge about what tasks are related to a job [31]. By having an extensive knowledge base about the job the recruiter is able to choose the best candidate. Another benefit of a job analysis in the recruitment and selection process is that the recruiter and the company are able to know any changes a job has undergone over time [31], which enables an organisation to focus on selecting candidates who have the most relevant qualifications.

Most job analyses are centered on the selection process [31]. It is highly important that an organisation chooses proficient candidates for the job positions. Therefore, one can see the value of a job analysis in the selection process, because an organisation's success or failure depends on whether the right candidates are selected. By knowing the essential functions of a job one is able to select the best qualified candidates for the job.

Many times a job analysis is done on a job which exists and the job has people in the position. There are many aspects of the job which are deemed to be crucial. When the tasks and duties are found to be crucial, it often becomes apparent that certain individuals may not be sufficiently trained [31]. Those who do not fit the qualifications may need to be further educated in order to increase their productivity in a job. After identifying the criticality of the tasks an organisation is better equipped in the training process.

There are many companies which understand that candidates will not have certain qualifications when entering a job. A job analysis will help a company understand which qualifications a candidate needs to have when entering the job and which qualifications can be taught on the job. A job analysis is also used to set a pay range for the job and it gives one a reference for job evaluations. In setting a pay range a job analysis identifies the amount of education, training, and experience that are needed to enter a job and the complexity or degree of difficulty of a job. Job evaluations are also aided by the job analysis. The job analysis identifies what are known as critical tasks, which are the most important tasks involved in a job (explained in greater detail below). These tasks can help guide a company in creating a job evaluation [31]. If individuals do well in the critical tasks areas they are often given raises or promotions. If they are doing poorly they often do not receive a raise or promotion and it may be determined that they require additional training.

By doing a job analysis a company has an outline of what is expected of an individual in a specified position. If the company does not use what is defined as being part of the job to determine whether an individual should be hired, promoted, etc., they may face legal problems. Basically, the job analysis helps companies avoid litigation. By using a job analysis when one is hiring, giving pay raises, giving promotions, etc., a company is basing their decisions on qualifications and performance and not the individual's race, sex, or any other factor that is unrelated to the job. If they do this they are complying with the law, which states that individuals cannot be discriminated against and they have protections which allow them to receive equal opportunities for employment and equal opportunities for pay. By having an outline of a job a company has a way of ensuring that their hiring and pay structure is performance based [31].

When testing for a job position it is very important that the test coincides with the job analysis. If one is testing for things that are not related to the job they run the risk of violating the law. Bemis, Belenky, and Soder give an example of a landmark case [32] (U.S. v. State of New York) which helped to define the importance of linking performance and job tasks. The case emphasized that the Job Element approach (the individual having the characteristics/experience to be in a job) was not a sufficient approach on which to base decisions. Decision making (e.g., raises, promotions, etc.) had to be based on the performance of the individual in job related tasks.

4.2.2. Job Analysis Techniques

There are a number of sources used in order to complete a job analysis. Some of the main sources that are used include past job analyses, the Occupational Information Network (O*NET), and subject matter experts (SMEs). Many times a past job analysis has already been carried out by a company. As companies grow or change the job analysis becomes outdated, because the job position requires a different set of knowledge, skills and attitudes , or because job duties may have changed due to advances in technology.

However, the past job analysis can often be used in order to guide an individual in creating questions or task statements that are rated by SMEs.

The O*NET is another source which provides good, basic, information on many different job positions. Before the O*NET came into existence the Dictionary of Occupational Titles (DOT; United States Department of Labor, 1939) was used. The DOT was originally put together by the United States Employment Service (USES) . The DOT was put together by conducting observations and interviews of individuals in many different job positions. The information obtained from the observations and interviews were transformed into descriptions of the job positions. The information in the DOT centered on the tasks that the individual needed to do on the job. This was not enough to describe a job position. Also, the descriptions of jobs in the DOT tended to be outdated in a short amount of time [29]. Due to the problems encountered with the DOT it was necessary to create a better source describing job positions. As technology grew, and the internet came into existence, the O*NET was created so that individuals could know what was involved in a job position at a faster rate and could have the most up-to-date information available.

The contents of the O*NET can be understood by looking at the O*NET content model. The model contains the following information:

1. Worker requirements: basic skills, cross-functional skills, knowledge, and education.
2. Experience requirements: training, experience, and licensure.
3. Worker characteristics: abilities, occupational values and interests, and work styles.
4. Occupational requirements: generalized work activities, work context, and organizational context.
5. Occupation-specific requirements: occupational knowledge; occupational skills; tasks; and duties; machines, tools and equipment.
6. Occupation characteristics: labor market information; occupational outlook; and wages [33].

Basically, the O*NET centers around the knowledge, skills, ability, and other characteristics that are required in order to complete the tasks and duties of a job. If a person is knowledgeable about things involved in a job they are able to navigate the technical aspects of the job [29]. If an individual possesses the skills required for the position they are capable of performing the tasks of the job. Ability involves the physical and mental aspects of the individual [29]. In other words, a qualified person is physically (e.g., lift 50 kilos) and mentally (e.g., deal with multiple job stressors) able to deal with the tasks required of them when they are in a job position.

Past job analyses and the O*NET are often used to gain an early understanding of the job, which is generally followed up with an interview with SMEs to understand the details of a job and to guide an individual when they are creating the tasks statements, which are compiled into a questionnaire. These questionnaires are used to rate the frequency and importance of each task that is involved in a job.

4.2.3. Methods of Collecting Data for Creating Job Analysis Questionnaires

There are several methods one can use in order to create a job analysis questionnaire. Wei and Salvendy discuss the following methods for collecting data: “observations and interviews”, “process tracing”, and “conceptual techniques” [34]. They explain that the observations and interviews approach is the most direct approach. One is directly observing the individuals who are in the job and asking them questions based on information gathered about the job. Wei and Salvendy warn that this approach is sometimes “unwieldy and difficult to interpret” [34]. Ultimately, data are interpreted based on numbers. When interviewing an individual one is asking questions about the job and not assigning numbers (e.g., level of importance) to the questions. Therefore, it is difficult to rate the questions because they are not initially assigned a number.

Even though there are certain interpretation problems with interviewing, this method may be preferred over other methods. In fact, Prien et al. emphasizes the benefit of an interview over a self-report [31]. When an individual is interviewed they are often interviewed by a trained professional. However, Prien et al. explains that when individuals are told to write a description about their job there is a greater probability that they will inflate the importance of the tasks involved in their job [31]. Similar to interviewing, the process tracing technique is also verbally based. However, with process tracing one is looking at a specified group of tasks. In a job analysis, there may be certain tasks which require a more in depth analysis. By using process tracing one is able to get detailed information about those tasks [34]. Again, due to the fact that the data are verbal it is hard to interpret. However, it is a useful way to obtain information on tasks and duties, which require a greater amount of detail.

With conceptual techniques one is focused on “domain concepts” [34]. The benefit of conceptual techniques is that it asks about specific tasks and can be rated [e.g., questionnaire; [34]. A drawback is that it does not provide the detail which is often obtained through an interview. The questionnaire is a highly used conceptual technique. [31] discusses two types of questionnaires which are used. First, one can use a “custom-designed questionnaire” [31]. The questionnaire is specifically designed for the job being analyzed. One could also use a more general questionnaire, “the commercially available questionnaire”, to analyze the job [31]. Prien et al. explains that the drawback to the commercially available questionnaire is that it is often created for a broad range of jobs [31]. Therefore, there may be questions which are not directly applicable to the job. Also, it may be missing questions that should be asked.

As was mentioned above, past job analyses and the O*NET give individuals who are creating the questionnaire a guide for making the tasks statements. The O*NET gives a general guide and past job analyses gives a more detailed guide. Even though one might gain a lot of insight into the job based on these sources, these sources alone may not be sufficient to create a detailed questionnaire based on the position in its current form. One of the best sources for creating a questionnaire is the current SMEs who occupy the position of interest. One can observe (if circumstances allow) the SMEs in their

work environment and ask them questions either on the job or in an interview.

The interview questions can be made by using the O*NET or a past job analysis. However, since jobs tend to evolve over time one might come up with some questions while doing the interview. In other words, one might notice that certain questions need to be asked that may not have been thought of based on the past job analysis or based on the information obtained on the O*NET. Brannick et al., explain that one can use paper and pencil or a video or audio recorder to write out or tape the interview [29]. They further explain that if you are going to tape the interview it would be a good idea to ask the person first, since recording devices tend to make people nervous. After the information is obtained from these sources it is then turned into a job analysis questionnaire.

When creating a job analysis questionnaire it is important to collect demographic information (e.g., age, gender, ethnicity, job position, etc.). This information is very useful when analyzing certain aspects of the data. The questionnaire should also be divided into several subcategories in order to better organize the different duties of the job. For instance, a task that is clerical would not go in a security category. Questionnaires are often lengthy and organizing the tasks into groups helps to clarify what is being asked and helps to avoid confusion.

As has been mentioned before, the task statements are rated on the level of importance and frequency. For instance, the questionnaire can ask, on a Likert type scale, the level of importance (0 = not applicable to job, 1 = not very important, 2 = somewhat important, 3 = important, 4 = very important) and the frequency (0 = not applicable to job, 1 = infrequent, 2 = somewhat frequent, 3 = frequent, 4 = very frequent).

There are several types of rating scales that one can choose from. The rating scales can be made based on the type of job that one is asking about. Also, the number of data points for the scale can vary. For instance, a rating scale used by Baranowski and Anderson gives the following prompt "How important is this knowledge, skill, or ability for performing this work behavior?" [35]. The prompt is followed by a five point rating scale: "1 = Not important", "2 = Slightly important", "3 = Moderately important", "4 = Very important", and "5 = Extremely important" [35]. However, the amount of ratings does not have to be limited to five points. Typically, one would see ratings between three and seven points. One could also use a two point rating scale if he or she is simply interested in knowing whether the tasks are relevant to the job (e.g., has some degree of frequency and/or importance).

Harvey gives a couple of common examples of scales that are used in a job analysis [36]. In the first example the SME indicates that the tasks are part of the job prior to filling out the scale. When filling out the scale, the SME gives an estimate of time given to each task. The scale has eight ratings, which range from "0 = I spend no time on this task" to " 7 = I spend a very large amount of time on this task as compared with most other tasks I perform." [Harvey, 1991, p. 90]. The second example gives a scale which tells the reader to consider importance, frequency, and difficulty when rating the task statements and it explains that not all the statements will apply to the job. The ratings range from 0 = definitely not part of my job; I never do it" to "7 = Of most significance to my job" [36]. A significant difference on the ratings is that the only ratings that are defined are 0, 1, 4, and 7. In other words, on the previous scale 1, 2, 3, 4, 5, 6, and 7 are defined, while this scale only has definitions for 0, 1, 4, and 7. On this scale, the SME may decide that the task does not quite fit under the 4 definition, therefore, they may choose to rate the task as an undefined 3.

The third example gives a frequency scale with time related ratings. The ratings range from " 0 = I do not perform this task on my current job" and "1 = about once every year" to "7 = about once each hour or more often." [10]. The fourth example gives a scale that is known as a Behaviorally Anchored Rating Scale (BARS). This scale is rated on a continuum and the data points are defined in sentence form [36].

Finally, the fifth example shows the Job Element Inventory (JEI), which, as the name implies, breaks the job down into elements. The inventory uses a simple five point rating scale and tells the person to fill in the rating that best fits with the element [36]. As can be seen ratings can take many forms. Harvey explains that using a limited number of rating scales may be beneficial to one's analysis [36]. He also explains that if two scales are highly correlated then one of the scales can be dropped from the analysis. Harvey explains that when the rating scales appear to ask similar questions, and the correlation is high, one is often asking redundant information [36].

In deciding on how many data points to use one might consider a study done by Wilson and Harvey [36]. In their study they compared the difference between relative time spent (RTS) scales and simply asking whether the tasks were or were not part of the job. They found a correlation of .90 between the two types of ratings. In other words, dichotomously and polytomously scored variables gave approximately the same amount of information. Also, a study done by Hernandez, Drasgow, and Gonzalez-Roma found that when rating personality many individuals do not use the "?, not sure, or undecided" category [37]. They explain that there is a commonly held belief that having a middle category is beneficial because it does not force the individual to answer a question that they are actually unsure of [37]. Hernandez et al. found that those with certain personality characteristics (e.g., reserved) tended to use the middle category more often [37]. Based on their findings they recommended that the middle category should be used with caution, because it may lead to interpretation problems.

4.2.4. Typical Task Inventory Data Analyzes

There are several ways in which the task inventory data are analyzed. The descriptive statistics may tell you something about how much the individuals agree on the task statements. Brannick et al. emphasizes that at a minimum one should report descriptive statistics such as the "mean, standard deviation, and N" [29]. The mean of each task statement tells you how the average rater scored the statement. The overall mean of the task statements tells you how the average rater scored all of the items. The standard deviation of the task statements tells you how much the ratings differed in the statements. A large

standard deviation would indicate that the individuals differed a lot when it came to rating a certain statement. There may be reasons why the ratings for individual task statements differ substantially among the SMEs (e.g., poorly written task statements). N is simply the number of individuals (e.g., SMEs) who rated the task. There are tests which can help one to learn more about how the items are functioning. Some of these tests include tests of interrater reliability and interrater agreement.

Brannick et al. explain that there is a difference between interrater reliability and interrater agreement [29]. They explain that "[r]eliability refers to two sources of variance: variance due to random errors and variance due to systematic differences among the items of interest" and "[a]greement simply refers to a function of those judgments that are identical and different" [29].

One can understand reliability a bit more clearly through the following equation given by Meyers: Reliability= VTVO [38]

VT is the true variance and it is divided by VO which is the observed variance. The true score would be a score that does not contain any error. The observed score is the score obtained from the individual or subject and it does contain error. When a study, test, questionnaire, etc. controls for error (e.g., testing at the same time of day) the observed score increases thereby increasing the reliability. However, there will always be a certain amount of error that cannot be controlled for (e.g., individuals not getting good sleep the night before the test takes place).

Interrater agreement can be understood by its name. It is simply the amount of times the judges/raters agree on how the item is scored. For instance, if three judges rated a task statement and all of the judges rated the statement as a two (highly important) then it would indicate that there is one hundred percent agreement among the judges. Brannick et al. explain that interrater agreement ("interjudge agreement") "is simply the number of ratings for which the judges agree divided by the total number of judgments" [29].

Meyers explains that the level of agreement can be found by using Cohen's Kappa [38]. He explains that the procedure is available in SPSS and it can be interpreted using the chi square statistic. Meyers also explains that if there are more than two raters then an alternate form of Kappa created by Fleiss [38] can be used. Kaplan and Saccuzzo explain the common way to interpret Kappa [39]. They explain that if the value is ".75" then one would have ""excellent" agreement, a value between .40 and .75 indicates "fair to good" ... agreement, a value less than .40 indicate poor agreement" [39].

Meyers also explains that rater reliability can be found by finding the Pearson correlation [40]. With this statistic one is finding the "correlation between pairs of raters" [40]. In other words, one is finding the degree to which there ratings trend in the same direction. Meyers explains that correlations above are good, but correlations "in the .7s" may also be strong enough in many cases [40]. The correlation coefficient (r) can be used in order to estimate interrater reliability. Brannick et al. explains that a large correlation indicates that there is a small amount of error in the problem and it indicates that the problem has good reliability [29]. In other words, it indicates that there is a low amount of random error in the items. Besides making estimates of how well the items are working and how accurately the judges are rating the items, one can also estimate how critical each task is to the job.

4.2.5. Understanding the Criticality of the Tasks

After the task statements are rated by multiple SMEs the means of the frequency and importance scales are multiplied for each of the task in order to find which tasks had the highest criticality. This is used to find the critical tasks, which are then organized into a criticality index. The criticality index shows the tasks from the highest criticality to the lowest criticality. The following equation is often used to calculate the criticality of each of the tasks:

Criticality Index = Importance (M) x Frequency (M)

For instance, if organizations rate tasks on an importance scale (5 = very important, 4 = important, 3 = somewhat important, 2 = somewhat unimportant, 1 = unimportant) and a frequency scale (5 = highly frequent, 4 = frequent, 3 = somewhat frequent, 2 = somewhat infrequent, 1 = not frequent) one would use the mean rating from each of these scales to calculate the criticality index. If the mean of the organizations' scores is 3 for importance and 3 for frequency then the score on the criticality index would be 9. One would decide how high the score should be in order for the task to be considered critical. This helps one to understand a bit about the combination of importance and frequency. If one of these ratings is low then the task may not be considered to be critical to the job. By finding the most critical aspects of a job a company or organization is better able to understand the type of employee they need to be searching for to fill a position. If the potential employee does not possess the KSAs needed to perform the critical tasks of a job then they may not be a qualified candidate.

There are several ways in which the statements and questions for a job analysis questionnaire can be analyzed. Some have been mentioned above (e.g., mean ratings, standard deviation). Another way to look at the items is through IRT. In a job analysis one is looking at the educated opinion of individuals rating the items. The mean and standard deviation are a good starting point in gathering information about each of the items. While the mean gives an indication of the average level at which the raters are rating the tasks, IRT gives an indication of how individuals are rating the item from lowest to highest ratings for each task. IRT potentially allows one to gather more detail about the items and allows one to understand whether the items are functioning properly.

5. METHODOLOGY

5.1. Research Design

The design of the research is case study combined with survey research that integrates both qualitative and quantitative information. It is an empirical study. In order to develop and define a practical solution to the stated objectives, the following procedures was followed.

5.1.1. Literature survey

- Papers delivered and received at workshops and training session
- Document concerning law, rules and regulation, decree, and etc.
- Report of personnel office at MPWT.

5.1.2. Empirical Study

- Questionnaires were sent to management position ranging from deputy head of division up to Director General of department
- Interviews were conducted with the above mentioned positions.

5.2. Data Sources

5.2.1. Type of Data

There are two sources of data for the research, primary and secondary data. Primary data include a job analysis questionnaire. The questionnaire is used to clarify job duties and equipment that would be used by managers and employees in MPWT. The tasks were rated for the jobs from the individuals in the position and those supervising the individuals in the position.The following areas are covered in the questionnaire: tasks, duties, responsibility, tools and utilities used, communication, ability required, academic qualification required, and experience required. Individuals was given task statements and were asked to rate the frequency and degree of consequence for not performing each of the task statements. Individuals was given a column for the frequency of the task and for the importance of the task. In addition to the surveyed questionnaires, in-depth interview was used, based on semi-structured questionnaires.

The content of the questionnaires includes current employees' capacity assessment, covering: personal drive (achievement motivation), impact on results, analytical power, strategic thinking, creative thinking (ability to innovate), decisiveness, commercial judgment, team management and leadership, interpersonal relationships, ability to communicate, ability to adapt and cope with change and pressure, ability to plan and control projects.

The secondary data include decree on position assignment, rules and regulation in relation to job assignment, labor law, government official rules, and etc.

5.2.2. Source of Data

Primary data was collected from the administrators and employees of MPWT. Secondary data was collected from the offices concerned, namely the Personnel Department, Government Offices, library, and perhaps internet sources.

5.3. Population and Sampling

The population of the research is the people in the main office of MPWT, including *managerial people from Deputy Head of Division up to Director General of Department.* The samplings for this research covered only the population at MPWT headquarters.

5.4. Data Collection Techniques

Questionnaires were distributed to all staff members at MPWT headquarters. In-depth interviews were conducted with the management positions.

5.5. Data Analysis and Reporting

Data analysis includes:

1. Review related existing literature as well as decrees issued by the organization concerned, Lao civil servant law, policies, and other reports related to the job analysis implementation from various organizations both public international organizations.
2. Surveyed data was statistically analyzed, by using SPSS Software, in terms of mean, percentage, and standard deviation.
3. Descriptive report was the main reporting method.

6. Academic contribution

Job analysis is one of the most important elements of human resource management. So far, there has been no research in this area in Lao context. Thus the result of this research contributes to the academic side in the following ways: (1) uncover the practices of job analysis in the Lao PDR context; (2) reveal the history of Job Description policy and practice, which can be used as a reference in human resource management education; and (3) enrich the localized academic resources in the area of HRM.

7. RESEARCH FINDINGS

7.1. General information

Quantitatively, the study was conducted among the staff, directors of departments, heads and deputy heads of divisions, totally of 35 respondents, i.e. 14 staff, 40%, 3 directors of departments, 8.6%, 13 heads of divisions, 37.1%, and 5 deputy heads of divisions, 14.3% in the Ministry of Public Works and Transports (MPWT). The majority of respondents, 37.1% obtained bachelor degree while 17.1% of the respondents hold higher diploma. The respondents with master's degree were about 25.7% and those with diploma were 20%.

Whereas qualitatively, it was conducted with 1 director of personnel department, 1 director of Lao Airline department, 2 heads of divisions and 3 staff in the MPWT.

7.2. Current Situation in Preparing and Implementing the Job Analysis

There has basically been fundamental job analysis within the MPWT. There is a unit under the MPWT whose responsibility is to prepare general guidelines and forms for job analysis for each position. The form is then sent to each Department for execution. Each department assigns each division under their responsibility to write job description. In this process, the division lists tasks required under their division, then divide the tasks into groups. Each group is then transcribed into a job position. Then basic job description is prepared. Currently, basic job description is written for deputy head of division up to Director General of Departments. Throughout this process, job analysis has been carried out as desk review rather than empirical investigation.

Job appointment was not necessary based on the Job Description and Specification as a result of the job analysis. Based upon the job responsibility, it was found that heads of divisions graduated at Diploma covers 14.3%, Higher Diploma 8.6% and Bachelor Degree 14.3% while 14.3% of deputy heads of divisions hold Master's Degree and 11.4% of the staff obtained Master's Degree. The directors of departments somehow graduated at Bachelor's Degree. It implied that the educational level were more likely to be opposite to communicative level of operation. This would lead to difficulty in communication practice. This included 2.9% of the respondents did not

need any educational qualified certification, especially the persons responsible for accounting.

It was also found that the major of personnel responsible for higher positions were administration (40%), and business administration (14.3%) while the administrative persons with high position comprised only 5.7%. The recruitment of personnel did not seem to put the right persons to the right job since it required the persons with qualified knowledge about their jobs.

It was further found that the deputy heads of divisions worked fewer hours per week, around 35 hours per week, than the directors of departments, heads of divisions, and the staff, 40 hours per week. This result indicated that there were no standard numbers of working hours.

The analysis of knowledge requirement for the future improvement, specifically computer utilization, the large proportion of informants, 48.6% required knowledge of data entry, which required a simple use of Microsoft Word up to 60% of the total informants. Some 8.6% of the respondents needed to have the data access in Microsoft Excel, and 8.6% would prefer to update their knowledge of the Internet. This included the comprehension of command and instructions (60%), shorthand (11.4%), the skills of reading, drafting and giving instruction (5.7%), and the skills of planning and time management (22.9%).

It was finally found that a large proportion of the informants, 34.3%, would not like to upgrade their knowledge reasoning that it was a bit late for them to do so since they were about to retire while it could be seen that 17.1% of informants would prefer to pursue their professional knowledge and competences for 3-4 years. Around 28.6% wanted to continue their further education for 1-3 years, and somewhat 14.3% wanted to take short-term training courses.

The result of this quantitative analysis shows that the administrators currently in position need to enhance their technical capacities to be utilized in their duties. Perhaps the fact that educational varies greatly may contribute to the needs of training. Aging population at administrative level also shows reluctant to their professional development. Therefore, it can be concluded that there has been a lack of job analysis, inappropriate recruitment, and insufficient qualified personnel.

In quantitative analysis, the educational qualification showed that the personnel with high position were at diploma and higher diploma reasoning that by the time they were in the position, the only available courses in Lao PDR were higher diploma. The bachelor degree courses have been available after 1995, the establishment of the National University of Laos, while the Master's Degree Courses were available in 2006. It was believed that personnel with Master's Degree were new to the organisation while personnel with lower level of education gained a lot of experiences.

For those working for under 40 hours per week, the informant mentioned that it was not clear for them since it was based upon the provision of Ministry of Labour and Social Welfare, which was not widely disseminated among staff in the MPWT. However, the staff knew that official hours start at 8:00 and finished 4:00 with no overtime hours although they worked late in their sectors, except for airline.

The number of personnel would like to continue their further education but it seemed that many were unable to do so as they were shortage of time to pursue higher education, they lived distance from education institutes, no financial support since they had to pay the tuition fee themselves and they were too busy with their work and found no time to pin down.

Since there were no clear job descriptions and specification in the informants' workplace, the staff had to follow the general missions established in their work sector. Many of the informants needed to upgrade the knowledge in no specific area; therefore, they wanted to upgrade themselves according to the change of information and technology, which was inappropriate to the tasks and duties needed by the sector.

7.3. Key Obstacles and Challenges in Implementing the Job Analysis

Requirement of strong leadership in both political and technical capacity, with higher weight on the former, for the high position resulted in job analysis for higher position as not obligatory. Nevertheless, it is acknowledged that job description for deputy head of division through general director of department is necessary, a process for writing job description and job specification has been outlined in the manual for government official HRM. The form, however, does not consist of the roles and responsibilities of the division or department concerned. The job analysis, nevertheless, has not been fully conducted.

Government directives on government employee administration system does not necessarily require lower position job to be analyzed. In addition, job description and specification was not a requirement.

Budget and time allocation for conducting job analysis has never been taken into account.

Inadequate knowledge, knowhow, and skills of staffs in personnel divisions contributes to the difficulties in conducting proper job analysis.

8. DISCUSSION

Despite there is a manual for government official management with guidelines on job analysis, writing job description and specification, the practicality of job description is yet to be fully employed. The job analysis techniques discussed in literature section, namely past job analysis, occupational information network, and subject matter expert were not used. Data collection method such as questionnaires, observation and interview, process tracing, conceptual techniques were not employed. Nevertheless, there is special internal system that has continuously been improved to administer government official used as a guideline. The use of technical aspects in job analysis may enhance the quality of job description and specification.

The appointment of higher ranking position comes with relatively clear job description (roles and responsibility), technical staff do not have clear job description and specification. Thus, it is difficult to justify

the appropriateness of recruitment, training, and evaluation.

The performance management and performance appraisal for job analysis and assessment were not task oriented Thus, the number of working hours was not agreed with one another, which leads to confusions in practice. The over-time working hours were only practiced in airline sector.

The opportunity for further education for staff had been difficult since firstly there were no bachelor degree courses available until late 1990s, master's degree courses until 2006. The choices for persons with high positions were only working experiences and short-training courses; secondly, the staff wishing to pursue their education had their own financial responsibility for tuition fees; and finally were too busy and unmotivated to continue further education since they live distance from higher education institutions. Therefore, the large number of senior staff with high positions was only at diploma and higher diploma.

9. CONCLUSION

It can be concluded that the difficulties and challenges faced by the MPWT is that the job analysis has not been conducted thoroughly. It is top-down, rather than bottom up, focusing only in middle management and higher level management. There is no linkage between job analysis and the mandate of the concerned divisions or departments. The content of the job analysis does not cover all necessary information; which leads to unclear job description and specification. Obstacles include policy, guidelines, implementation requirement, and limitation of skilled personnel conducting job analysis.

10. POLICY RECOMMENDATION

Since the job descriptions and specifications have not been clear and available for all personnel, it is recommended that proper job analysis are conducted, using appropriate tools, procedure, and method. Through appropriate method and process, the tasks and duties of each staff should be identified as to find the right persons with certain expertise to the right job.

The result of job analysis may be seriously taken into account in designing job description and specification so that recruitment, training and development, evaluation, performance appraisal can be carried out effectively. Before having staff recruited, it is important to identify what kind of professional knowledge and competence needed for the positions required by the MPWT. As a result, it could recruit more relevant staff to the relevant tasks and duties, including certain kind of educational qualifications. Recruitment shall refers to job description and specification of the position strictly.

Policy may allow rooms for institutional innovation, enhancing both top-down and bottom up coordination regarding the job analysis preparation and execution. The enforcement of recruitment policy should be seriously implemented at all level.

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Socio-Economic Impact and the Adaptation of Boten People Under Chinese Transnationality

Sivarin Lertpusit

Abstract*: -This research paper is about Socio-Economic Impact and the Adaptation of Boten people under Chinese Transnational influences. Its aims are 1.) To find out the transnational issues and the influences of Chinese capital in Laos: Boten 2.) To study the socio-economic impact on Boten people. This paper uses quantitative research methodology by gathering information from documents and field research, analyzing the information with Transnational Enclosure theory, Territorialization and Periphery framework.*

The research finds that the transnational enclosure and territorialization were acting and processing in parallel. Chinese capital power spread its influences on economics and politics in Lao which is the strategic country that China can connect itself to South East Asia. The influences slowly enclosed Lao local people's authority on their own spaces. Meanwhile, Lao government did not act against these Chinese investments, in contrary, it set up regulations to support and facilitate these Chinese capitals.

Both procedures directly impacted Boten people and pushed them to margin. They moved out of their hometown and adapted themselves to the new environment. They were suffered by the unfair compensation that is non-negotiable. Lastly, they were victims of the development and were forced to surrender to the government and the capitalism.

Keywords **- Boten, Chinese transnationality, development impact, Lao's socio economic**

1. INTRODUCTION

Lao's development strategy since the 2nd National Economic and Social development plan (1986-1990) to the 7th National Economic and Social development plan (2011-2015) emphasized on Economic Development by promoting Foreign Direct Investment: FDI. Land-linked strategy and Battery of Asia strategy are important development strategies that attract huge amount of FDI such as Hydro power dam projects and Developing Logistic and Economic Corridors.

Until now, Chinese people are the majority of foreign investors in Lao. It has dramatically increased the investment projects since 1990s as Chinese investors have been investing around 800 projects, valued 3,900 million USD in Lao. The increasing number of Chinese investors in Southeast Asia was the effect from "Go West Strategy", "Go Out Policy" and "Go South policy". These policies aim to develop the periphery and indigent regions of China, especially, the West and the Southern part of China. Therefore, Yunnan and Guangxi are the strategic areas for those policies in order to connect China to Southeast Asia.

Chinese Investments in Lao are mainly in service sector, logistic, mines industry, hydro power and agro-industry. For example, R3A road, which connected Yunnan and Lao, has a benefit on China in logistic strategy. China investors also invested in hydro power dam to produce electric and export to China to solve the electric deficiency of South China. In service sector, Chinese private investors invested in hotels, entertainment complex including Casinos such as Royal Jinlun in Boten, King Roman in Bokeo and Savan Vegas in Savanakhet. Moreover, they invested in agro-industrial in the model of contract farming. To conclude, China's "Go Out Policy" has been conformed with Lao development strategy in achieving the Lao's vision 2020, a promising year that Lao will be unnamed from Least Develop Countries. According to both countries' development strategies, Lao state and China state gained advantages from the investments of Chinese investors in Lao. Lao GDP indicators are rising, while China's investment abroad policy is reaching its target.

Nevertheless, those areas and lands that were invested by foreigners are not useless or wasted. It was once a living area for Lao people. Until Lao government allowed transnational capital to increase Lao economic development indicators, Lao government has allocated land, both useful and useless, to facilitate these foreign investors. For Boten case, the area was a living area and paddy rice field of Tai Lue people. However, Lao government allowed Boten Dankham Co.,Ltd. by Chinese investors to invest an entertainment complex in Boten in Special Economic Zone model. Boten SEZ will be rented by China developers for 30 years and can be extended to 90 years. Therefore, Tai Lue people in Boten were forced by their government to move the village to resettle in a new area, located 10 kilometers from their own land.

Former Boten village was just a periphery area which was far from state power and modernization. It was

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recognized when Lao government has identified a SEZ and a strategic area for trans-border trade and logistic. It is now a stop point of R3A road and the high speed train which will value up the SEZ. Boten then may gain its potential in being the center for trade and product distribution center. The changes are what Boten people have to face with either nowadays or in the future. How Boten people adapt themselves and what their disadvantage in development projects are the main questions for the aim of development in Lao.

2. PURPOSES

2.1 To explain the trans-boundery procedure and the expanding of Chinese influences in Lao: Boten village as the case study.

2.2 To explain the impacts on socio-economic activities of Boten people.

3. RESEARCH METHODOLOGY

This research applied quantitative research method by gathering information from literature review. Sources of information are from primary and secondary data in Thai and English. Collect field information by interviewing Lao officials and local people in Boten. Data has been analyzed to prove the theory and research to find a new conclusion from the area study.

4. THEORY

This article applied 3 theories: transnational enclosure, Reterritorialization and Marginalization.

5. Transnational enclosure and reterritorialization in the development discourse

5.1 Lao government and development

Lao main stream development vision is to upgrade Lao from LDCs list. Its aim is modernization. Lao economy was once depressed in 1960s from the socialist strategy which has a pressure on Lao government in order to open the country and revise its economic policy. New Economic Mechanism (NEMs) was launched in 1986; it turned Lao economy to follow capitalism. Private and Foreign capitals became the main income for Lao economy. Of course, the development after 1986 focused less on economic and social equality which are the cores of socialism, but it gave more attention on the growth and progressivity in Economic Indicators.

"Development" is the main principle for Lao government before NEMs, though the meaning is difference from "development" after NEMs. The former development focused on creating modern and equal society; shorten the differences between social classes by central-planned economy. Private ownership was posed by state as it was criticized in being the source of social classes and privileges. Lastly, socialist way could not reach its aim in economic and social sector because it was in an immediate process and lack of socialist fundamental. For "development" after NEMs, it was defined as modernization under capitalism. This time, private ownership and market-oriented system are the principle of development. This is the effect of development discourse which identified Lao as an underdeveloped country. It was reproduced the definition by the categorization of International organization. For example, UN declared Lao as a Least Developed Country (LDCs), ADB cited in 1986 that Lao was one of the poorest countries in the world. By that definition, Lao was donated over 1.11 billion USD in between 1986-2004 by ADB. Lao's income depended on Foreign Aid over 85%. As the definition of an underdeveloped country in development discourse, Lao government changed its strategy to increase modernization indicators and economic development indicators. The discourse also acted in enclosing the opponent knowledge such as local wisdom. Local wisdom is community's holistic perspective which does not categorize daily life from ecology as a part of community's relations. It is the opponent of modernism because wisdom defines ecology as a part of community that people can get advantages from ecology only under the belief (animism) conditions and community's regulations. While modern economy defines ecology as natural resource that should be exploit its usefulness, the development discourse encloses the value of wisdom and redefines the traditional behavior as a useless and demolished activity, such as the slash and burn agriculture. With these internal and external procedures, capitalism development in Lao has been expanded to stand and hegemonize the meaning of "development" in Lao.

New Economic Machanism was the turning point of economic strategy. Market-oriented system was implied to provoke the slow-down economy. Lao government promoted Foreign Direct Investment and Foreign trade by modern investment laws and regulations. In 1989, Lao state accelerated the country reform which resulted in the increasing amount of FDI and trade. However, the majority of trade and investment in Lao are in natural resources sector which are forestry, mines, and hydro power. Another strategy for Lao economic development is "Land Linked Strategy". R3A road, R9 route, and high speed train are logistics channels of distribution between Lao-China and Lao-ASEAN. Moreover, mega projects for development, such as contract farming and Land concession in the model of Special Economic Zone and Specific Economic Zone are the latest development projects.

"Development" in capitalism does not only increase the economic indicators, it also supports and ligitimizes the state authority expansion. As Lao was suffered from war period for a long time and, historically, the country was never been united. In the past, Lancang was separately governed in three kingdoms; Luangprabang, Vientian, and Champasak. They were assembled when France occupied all Lao into French Indochina. After the independence, Lao was in the proxy war period and had to face with the conflict between Liberalists and Communists until 1975 when communist could control the country. However, Lao government still could not use its absolute power in some areas and some groups of people such as border area and high land area. The socialism ideology in nation state

building period emphasized on the conflict among minorities. Though, when the government initiated capitalism development in 1986, "Development" became the tool of the government in strengthening state authority among minorities and periphery areas. Constructing a road was modernization and it was also a tool to spread state power to access the remote area. Dam building did legitimize the state to take possession on natural resources management in the name of state resources. Boten village is a case study for the state authority legitimization. Declaring Boten Special Economic Zone is an excuse for Lao government to ligitimize the government authority in order to manage Boten area.

The development of capitalism in Lao is the specific model as in other socialist countries, such as China and Vietnam. These countries use market-oriented system in economy while they are also insisting rules in socialism regime. Therefore, Lao economic development model is liberal capitalism under state control or half centralized – liberalized economy. Nevertheless, state interference does not cause any anxious to foreign investors because they are protected by investment laws. In controversy, one party government gains more benefit in facilitating private investors. As the government is in an absolute power to allocate natural resources, those democratic countries have a pro-long public hearing process. To sum up, "Development" in Lao is benefit those foreign investors and to Lao state in legitimizing its power.

5.2 Lao's economic growth and the influence of Chinese capital

China is one of the most rapid economic growth countries in these 2 decades. 4 modernization policies and liberal capitalism were launched in late 1970s. Chinese economy drastically increased from two hundred billion USD in 1978 to 5.7 trillion USD in 2010. China became the second largest amount of import-export value country. Moreover, Chinese government changed the economic strategy to export investments instead of import foreign investors. As a result, China claimed as ranking up to the 9th investment country of exporting in 2011 with 6.5 ten billion USD.

Yunnan and Guangxi are assigned to act like a linkage between western and southern part of China with Greater Mekong Sub-region and Southeast Asia. Conforming to "Go South policy" that Chinese government promotes Chinese investors to invest abroad with low-rate interest loan, China is splendidly positioned in the high rank of foreign investors in Southeast Asia, including Lao. Until now Chinese Investors have invested in Lao around 3,300 million USD or 800 projects in mines industry, agro-industry, forestry, electric industry, garment industry and other service sectors.

5.3 Chinese capital's influences in Boten: Transnational enclosure and reterritorialization

There are two national interests for Chinese capital in Boten; the interest in Boten Special Economic Zone and the interest in logistic sector. The second interest is in developing process. These logistic projects will upgrade Boten to be a strategic connecting point between China and Lao. Moreover, China local government had defined Xisuangbanna to be Xishuangbanna Border Free Economic Cooperation Area, thus, Boten is now a valuable area for Chinese developers. Golden City Group Co.,Ltd is the developer and investor who receives the concession in developing Boten Special Economic Zone. It is approved by the National Planning and Cooperation Committee on 9th December, 2003. It has been specified that the company is allowed to manage and develop on a 1,640 hectares under the contract of 30 years which can be renewed to 90 years. The developer company has the authorities in managing and developing the area. Boten SEZ is planned to be the center of entertainment complex, casinos and hotels which are the main income for the first phase. Boten SEZ is rapidly well known by Chinese, Thai, and Lao gamblers.

However, the Special Economic model raised some issues about national sovereignty and the legitimacy of Lao government in approving foreign investors to develop the concession zone and drive out local Lao people. The distinctly sovereignty of Lao government was reduced by SEZ and replaced by Transnational Chinese capital. The state sovereignty, once the sacred principle of nation, has been ambiguous in some parts under this development discourse.

The Chinese private investors promoted by Central China Government were the result of the transnational enclosure procedure, compromising between private sector, state, and local people. On the other hand, Chinese private investors invest correctly under the Lao investment law and regulation. With the positive bilateral relations between China-Lao, the investors smoothly start to develop real estates and business in Boten SEZ. Meanwhile, the western and the southern region of China gain the advantage from this relationship and the border development.

As quoted before that both states gain advantage from the Chinese investments, for Lao, it is invaded under some particular conditions. Lao referred the ADB's development discourse to reterritorialize the space. It is the process on defining a space, whether it is utilitarian or not. If not, reterritorialization will follow its process, starting with re-drawing a new territory line, called Special Economic Zone, then defining the aim to conform development strategy. Therefore, the reterritorialization process of Lao government is properly fixed with the Chinese capital's requirement. The benefit for China is the chance to spread its economic and politic influence to Lao and Greater Mekong Sub-region. Besides, the SEZ in Lao can be the channel for Casino business which is not allowed in the main land of China. Lao government also gains some benefit from the concession's income, tax revenue and cash flow from business in SEZ. To conclude, the reterritorialzation is the process that eases Chinese investors by referring national and local economic development, meanwhile, it drove out those local people to a new village. The transnational enclosure process therefore can be introduced as a cooperation activity between Lao government and Chinese government, enclosed the local people authority on their former land and push them to be the absolute marginal people.

Even the hotels and casinos had been closed down in 2011 by Lao government. Lao government announced that casino in Boten broke the regulation by allowing Lao people to gamble. Moreover, there are a lot of violence and drugs reports in the area. Central Chinese government also agreed with Lao government to close down casinos. The other reasons are the reports on deceiving Chinese tourists to become indebted and because the casino location is close to Chinese border. As a result, those casinos had closed down immediately and it affected the effort to develop Boten for a while. Later on, Golden City Group had sold its shareholder to Yunnan Haicheng Industrial Group Stock Co,.Ltd which is proficient in developing tourist attraction and trading area. However, from the former problems, Lao government gave more attention to security issue. The Special Economic Zone model was changed to Specific Economic Zone and Namtha local government had to take part in Boten Specific Economic Zone administration in term of security issue. For economic issue, the developer still has fully right to administrate.

In conclusion, Boten case reflected the expansion of Chinese capital influence that rapidly has accessed to Lao. The growth of economic indicators is increasing, but the economic and social equality issue are decreasing. Local people as stake holders of the development were forced and were pressed from state authority to become a periphery group. Therefore, it can be concluded that Boten development is run by state and capitalist in the model of reterritorialization and transnational enclosure process.

6. MARGINALIZATION IN LAO'S DEVELOPMENT PROCESS

6.1 Problems from development

The mega-investment projects and the concessions are a model for Lao's economic development. Social and economic problem defined in the 5th national social and economic development plan (2001-2005) are tended to terminate shifting cultivation, decreasing opium agriculture and decreasing poverty to 50% in 2005. Continuingly to 7th national plan (2011-2015), the plan aims to distribute fundamental infrastructure such as electricity, roads, and telecommunication. These national development plans take part in increasing Lao people's quantity of life, including their opportunities in general.

Though Lao economy development is precisely growing, long term problems are also discussed repeatedly. For example, environmental issues, inequitable problems among minorities and the foreigner's migration. Environmental issue in Lao is an international problem, such as Sayaburi dam project or the contract farming in agro-industry which are questioned about the losses in ecology in long term. Another important issue is the inequitable problems among minorities which last for a while and reflected in the unequal indicators. For example, the number of educational opportunity of Lao Lum is higher than those from highland and the great proportion of poverty people are Lao Teung and Lao Sung. Moreover, a new problem which is the result of promoting FDI is the migrating of foreigners in Lao.

These immigrants who came to work in Lao under Lao investment law have also settled down their business. In many cases, they pushed local people to a second class labor, though these local people are Lao citizen. For example, Tonphung Special Economic Zone where local people had been moved out to another location while most of the employees in the SEZ are Chinese people. Chinese investors earn a lot of money and the employees are hired in a high rate salary, while Lao local people are still suffered from the lack of occupation.

For Boten case, the transnational enclosure is a continuous procedure which relate to legitimacy in development. The government relies on state authority to negotiate and compromise with local people who have to move out. The migrant was preceded under a condition that Lao government will pay for rice field, house and moving cost compensations. The fact is local people receive an opportunity to negotiate, however, it is a discussion on a restricted condition that Boten community must move out. Furthermore, the following problem is that some villagers do not receive the compensation as agreed upon, and they cannot request a call for further discussion with state regarding any responsibility. It is because they already moved out and because the protest and requirement are not being responded. Boten SEZ still kept its progressive and earned a lot of money. Lao government reached its aim in increasing economic indicator. It is just former Boten villagers who are duplicated suffering from the negative impacts. They moved out from their familiar and fertility land and ended up with a limited land in the new location. They lost their agricultural life because they are not capable to buy any paddy field in the new village. Moreover, they are not properly reckoned by the government. This power structure reflects the government's aspect in separations of people from consideration process, development process, and land management process. It is a sample of a phenomenon that Lao government and Chinese capital occupied the authority while pushing local people to be marginal people in their homeland.

6.2 New Boten community: Marginalization

Special Economic Zone development strategy has its influence on local people. Kamyod Chaiyawong, vice Boten village headman, referred that Lao government has already notified villagers that the land would be developed and managed in SEZ model. The government would deal with the developer to compensate Boten villagers for house, paddy field, and moving cost. In 2005 and 2008, Boten people which comprised of 3 communities; merchandise community, farmer community, and salt pit community, moved out from their former homeland. Lao government and Golden City Group, the developer and investor, agreed to compensate for families who owned paddy field for 50 million Kip per hectare. However, the price was bargained. It was lower than the expected value at around 100 million Kip. Families who have no paddy field did not receive any compensation, just a proportion of land for habitation. Nevertheless, some villagers practically did not receive any compensation or not in full amount. At this point, the

government failed to compensate and to act in regard of its promise.

The second issue is that Boten villagers lost their occupations because of the lack of paddy field. The new village is not a vacant land but it is occupied by Panna, Lao Sung, who have been settled down there for a while. The land left in the new village is considered inefficient for a new agriculturist community. Families who want to own paddy field have to buy land at Namtha city. Some houses spent the compensation on a rubber plantation at Natoey village. Some adapted themselves and became a merchandise or worker at tariff barrier port. Some bought a truck or a cab for transportation employment. Even though Chinese developer has promised the community that they will employ Boten people in casinos, in practice, Boten people cannot speak Chinese and have no skill in service sector. As a result, they frequently failed the probation. Thus, most of the workers in casinos are Chinese or Lao workers who graduated from Vientien.

The effect from development projects in Boten SEZ thus has its influence on Boten people to face the changes and instability in lives. Even though Lao government had paid the compensation, it was not enough for a new settlement. To shortly interpret this phenomenon, "Development" in Boten turns to have a negative effect on local people.

6.3 The adaptation and change of Boten people

Boten development process is stimulated by the reterritorialization and transnational enclosure by Chinese capital. It is proceeding without a proper attention to local people who are negatively affected. Not only losing their paddy fields, Boten people also lost their socio-cultural practices which related to the losses of their agricultural lives. Some Boten people can adapt themselves by changing their occupations from agriculturist to other occupations because most of Boten people do not own paddy field anymore. However, some local people, especially elderly, cannot face the rapid change. They are familiar with their circular lives. They spent most of their money in building a new house in a new place. Now, they live on collecting wild products which is not enough to support themselves. Meanwhile, groups of younger generation learn to take advantage from Boten location. They set up a logistic service company. Some own a restaurant, a garage, and a shipping company.

Basically, socio-culture and community relations are declining because Boten people pay more attention to economic issue. Cultural system and its meaning are slowly being diminished. For example, animism is tended to be a marginal belief, only Buddhism remains. Interdependence relationship in community has also been changed. Those middle-age people often show their concern on individualism among community members. The spirit of unity and helpful are faded away. Likewise, social behavior is rapidly changed along with the new way of life. Youth have to work in a big city. Their work progressive depends on their personal abilities and their personal costs such as labor, education, potential, and skill. Stability and certainty have been lost in the way of life.

The adaptation of community reflects the effort in managing lives instead of waiting for government aid. It is because Boten people surrendered to government power that they could not fight or negotiate with. The strength of single party government thus does not come from only government, but also from the weakness of Lao civil society which rarely stand to fight in political activities. Boten is just a case study for the civil society that Lao people have denied their willing to surrender, however, their strength is less to fight against their government.

The future of Boten people are still faced with uncertainty from any upcoming projects. In the near future, Lao government will construct the High Speed Train which will pass through the new Boten. It is certain that Boten people have to move their community again. Villagers have the same opinion that they will confront with the situation if they have to relocate again. Their saving in building new houses is limited and they will not surrender to government power without a proper discussion. However, the strength of Boten people is less to fight against the government. It is possible that the High Speed Train will affect those people again. This time, the compensation will be decided and paid by the government, unlike the last migration which was paid by Chinese developer. So, it may be equal or less compared to the last migration. The future of Boten people seems to be in a difficult condition, both economics and politics. Though development brings a lot of advantages and progressive, for Boten people, it is not worth the stable life they have lost. Most of Boten people prefer their farmer lives than modern life style and civilization.

7. CONCLUSION

Boten district is a Tai Lue community located on border zone between Northern Lao and Southern part of China. Before 1980, Boten was just a local border where both states allowed local ethnic traders to trade and exchange under limited regulations. It was until the end of 1980s when Lao activated its open policy and promote the diplomatic relations between Lao and China. Under this circumstance, Lao authoritarian used capitalization as the main strategic to develop the country such as land concession, mining and hydro-power production. According to the intimate relationship between China and Lao, Chinese capital gained the high rank in investment statistic in Laos. Boten district was considered to become more important in the country's development strategic. Being a border economic zone and a connecting location are strategies for this space.

Lao government allowed Chinese developer's company to manage Boten Special Economic Zone since 2003. The contract lasts for 30 years and can be extended twice. This 1,640 hectar space was introduced to be a new tourist attraction with luxury hotels, golf club and casinos. Moreover, under Chinese developer and investors, the usual language used in Boten SEZ is Chinese, Renminbi is the major money and the time there is known as Beijing time. It seems to be a part of China, but it is not.

With this development plan, Lao government expanded its power over Boten community. Luangnamta province sent a number of officials to deal with Boten people. They had no choice, but to move their community to a new village

where it is 10 kilometers apart from the former village. The former land then was an economic zone, not an agricultural land anymore. The territorialization for Boten district was to redefine the value of the location that it could be developed to be a significant economic zone which was better than leaving it unworthy as a paddy field.

Both transnational enclosure and territorialization procedures directly impact Boten people and push them to the periphery of power. Boten people had to move out of their hometown where they located for more than 200 years. They were forced to move to a new place and they had to adapt themselves with the new environment. They were suffered by the unfair compensation that they did not have power to bargain with the government. They had to adapt their customs and lives because there were limited spaces in the new village for them to cultivate. Some grew up and earned themselves on paddy field, thus, they have no other expertise to afford themselves. Without paddy field, Tai Lue people had to work out of agricultural sector which caused changes in community relations. Although some families could adapt to the new circumstances, they moved from agricultural sector to service sector, but most of the community members felt of the uncertain lives. They wanted a secure and stable life as they used to when they were farmers.

For farmers, migrating is not something simple and acceptable, they rely on land. The first move for Tai Lue Boten was started in 2005-2008 for "National development". They lived with changes along eight years in the new place, and in the near future, they have to move for the second time. This time it is the high speed train project which will first stop in Boten station. Lao government banned every unfinished construction in new Boten because the train railway will pass through the center of the new village. This time Boten villagers will actively fight for themselves, at least fight for the proper compensation. However, lastly they are still victims of the development and will be forced to surrender to the government and capital power.

What happened in Boten district is just a case study in Lao that reflects the question from periphery people about the disadvantages of development that those with less-power have to face with. With this question, it leads to another suspicion that does development deserve its value as it is praise or not.

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Interview

Kamyod Chaiyawong, vice Boten village headman, 12th February 2012

Nang Ping, 30 years old, villager, 6th November 2012

Pu Saeng Noon, Boten villager, 12th February 2012

Pa Tong Kam, 40 years old, villager, 6th November 2012

Pa Bua Jan, 87 years old, villager, 6th November 2012

Pa Saeng Noon, 89 years old, villager, 6th November 2012

Hom, 29 years old, villager, 5th November 2012

Mae Kan Kham Kaewwongpetch, villager, 6th November 2013

Mae In Kaew and Mae Am Pai, villager, 12th February 2012

Yai Oun, villager, 12th February 2012.

Kam Khan, 42 years old, 6th November 2012

Kam Tun, 50 years old, 6th November 2012

Mai Kam, 65 years old, 6th November 2012

Kam Lar, Tai Dam ethnic in Boten village, 12th February 2012

Tong Sri, head of Luangnamtha investment promotion department, 5th November 2012

Lao PDR Primary Health Care Expansion Project: A Case Study of Development Project Implementation Efficiency and Effectiveness

Anousone Rassavong, Mana Southichack, and Saykhong Saynasine

***Abstract*— *This paper examines the effectiveness and efficiency of the Primary Health Care Expansion Project in eight provinces in northern part of Lao PDR to draw lessons for improving levels of efficiency and effectiveness of future project coordination and management. This case study provides lessons, from a management perspective, to larger questions concerning effective and efficient use of scarce financial resources, especially those of foreign loans, on development projects beyond the health sector. Our analysis finds that the implementation of the PHCEP was effective but inefficient, due to cost overrun and abnormally large miscellaneous spending. To improve implementation efficiency, we recommend that project fund from each partner, especially from government's share of financial commitment, should be in place prior to issuing contracts to avoid rising costs due to delays, and keep miscellaneous spending at a minimum. In addition, to improve allocation efficiency, more funding should be allocated for expansion of village-based health service centers, where responses to health care service expansion were highest and the poor benefited most.*

***Keywords*— Effectiveness, efficiency, project management, project evaluation.**

1. INTRODUCTION

Effective and efficient use of Official Development Assistance (ODA) has constantly been an issue of concern for both the donor and recipient countries, and it is the core issue in this paper. How efficient and effective have government development projects been managed and how can improvement be made? This is a larger, dual-question this case study of the Primary Health Care Expansion Project (PHCEP—the Project) seeks to answer. The Project covers eight provinces in northern Lao PDR (hereafter, Laos, for convenience), focusing on the *effectiveness* and *efficiency* issues of project implementation and outcomes of the civil work component of the project. Improving health care is an integral part of government's strategy towards sustainable socioeconomic development, as better health care helps reduce poverty and promotes equity, which tends to further promote a more sustainable development path. Knowledge gained from this case study is hoped to be applicable to improving future management of development project implementation with cooperative agreement between Laos and foreign/international aid agencies in order to raise effectiveness and efficiency, leading towards a more sustainable socioeconomic development.

Laos' economic reforms, which formally began in 1986, from a centrally-planned economy to a market-oriented one, have resulted in relatively high economic growth with increasing personal incomes and improving wellbeing. Between 2000 and 2011, per capita gross national income grew four folds, from $280 to $1,130, elevating the country from low-income to the lower-middle income countries group. Poverty declined from 38.6% in 1997 to 27.6% in 2008; and the Human Development Index (HDI), which measures wellbeing more broadly than just income by combining income, health and education, has increased from 0.453 in 2000 to 0.538 in 2011 [1]. Between 1995 and 2010, life expectancy at birth rose from 59.5 years to 68.5 years for female and, for male, from 57 years to 65.7 years. Infant mortality rate per 1,000 live births also nearly halved over the same period, dropping from 80.1 in 1995 to 42.1 by 2010 [1].

Despite initial economic success and improvement in social indicators as described, Laos remains one of the poorest and least developed countries in the world and in Southeast Asian region. Between 1995 and 2011, Laos received a total cumulative amount of $5,841 million in ODA, accounting for 53% of total government expenditure of $10,975 million over this period [2]. In 2002, ODA accounted for as much as 84.8% of government's total expenditure. Since then, ODA share in government expenditure budget has substantially reduced, dropping to 49.9% in 2008 and to 25.3% by 2010[2]. Despite a drastic drop in its share, the actual amount of ODA has actually increased 1.5 times over this period, from $278.5 million in 2002 to $413.8 million in 2010 [2]. ODA, thus, remains a crucial source for financing the country's development and maintaining economic growth momentum as total government spending has rapidly expanded to meet the growing demand of an expanding economy. Therefore the country's international cooperation remains a critical component of the country's development work.

Cooperation with the Asian Development Bank (ADB), a regional development bank for Asia and the Pacific, is particularly important as it has been Laos' largest multilateral source of ODA. Laos joined the ADB at its founding in 1966 and, as of December 2010, has

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cumulatively received $1.60 billion in total of approved loans and grants, with technical assistance projects worth $133.1 million [3]. Over the period of 2000-09 alone, ADB has provided Laos $643 million of loans (60.8%), grants (31.6%) and technical assistance (7.6%) combined. ADB's assistance over this 10-year period was channeled to finance development projects in agriculture ($109 million), energy ($106 million), transport ($103 million), water supply and other municipal services ($78 million), education ($70 million), health ($66 million), and others. As of December of 2010, ADB holds 41.2% of Laos' total public and publicly guaranteed (PPG) foreign debts of $2,938.8 million [3].

With this very large amount of foreign PPG debt, effective and efficient management of loans is critical. Effective use of loans means loans are used productively, resulting in high rates of utilization, which in turns leading to improved loan repayment capability while efficient use of loans means better results of loan utilization, leading to lower loan cost and more benefits reaching the intended beneficiaries.

An efficient development project is a project that attains a certain set of outputs with less resources used, or a project that produces more outputs of high quality with a given amount of resources used. That is, if Laos is more efficient in using scarce foreign financial resources, the country would either need to borrow less, thus lowering debt costs, or achieve more development outputs (more hospitals, more schools, etc.) with existing foreign debts. As an example, if there was an efficiency gain of just 1% for all development projects implemented and financed with public debts with aggregate value of $2,938.8 million (as of December 2010), the country would have saved $29.4 million, excluding interest cost. This amount of saving can be translated into improvement of many schools, health care centers, clean water facilities, roads or agricultural extension services in many villages around the country. This would result in lower poverty and, with better health and education, more productive population, raising the country's ability to clear foreign debts.

Beyond the question of how much resource is used to produce a given set of output at a certain quality standard, efficiency in development projects applies to project outcomes and impacts. Thus, there are a number of important post-project questions that require answers to. On outcomes, these questions concern quality standard and utilization. On impacts, these questions concern cost savings associated with getting local healthcare services and economic gains associated with increased access to and improved health care services. What could Lao government and international development partners do to ensure high efficiency of project implementation and outcomes? The answers to these questions are central to the concern over how much do development projects benefit the intended population and whether they will raise the country's financial solvency over time through economic benefits they are to create, directly or indirectly, or whether they will simply worsen the country's external debt burden.

The Project is an ideal case study because it involved multiple locations, multiple contract packages, and multiple levels of management and oversights. Other than on the ADB side, on the Lao side, it involved the central and local government bodies across eight provinces. Also, the project has been concluded, thus allowing for a conclusive assessment of project performance. The Project civil work primarily involved new construction, upgrade and renovation of provincial and district hospitals and village health care centers. Although the project also has institutional capacity building component, our focus is on civil work, a required step prior to institutional capacity building. Under the Project, six provincial hospitals, 14 district hospitals, 136 health centers, five training facilities (nurse schools and health training centers), and 12 health offices were either constructed new, upgraded or renovated, altogether at a cost of $6.48 million [4]. It is a cooperative agreement between Lao government and ADB, with the latter as major financial sponsor. The project implementation covered a span of six years (July 2001 – June 2007), financed by a loan from ADB, signed on November 9, 2000 (ADB Loan Number: 1749(SF)). This was part of a much larger assistance programs the ADB has provided to Laos over 2000-2009 as pointed out earlier.

2. LITERATURE REVIEW

Chianca (2008) provides a global perspective of aid evaluation, pointing out to common problems involving inadequate care and quality of the evaluation, too much emphasis on project outputs and less on outcomes and impacts, among others [5]. We examine effectiveness and efficiency issues for both of project outputs and outcomes, as well as impacts.

A project performance evaluation report for the Primary Health Care Project (PHCP) in Oudomxay and Xiengkhouang provinces (ADB loan 1348-LAO(SF)) indicates that the project would result in economic benefits through reduced health care costs and increased income for the population in the project area [6]. The PHCP, which was a pilot project preceding the PHCEP being examined herein, built 73 primary health care centers and three district hospitals, renovated five hospitals in the two provinces and supported an educational program in Oudomxay that trained nearly 6,000 health workers and staff. With increased service coverage, making medicine and treatment more accessible, not only costs associated with travel had decreased, diagnosis and treatment cost also reduced. Increased service coverage also led to better health awareness, which in turns reduced illness and income loss as a result of illness and of time adults used to care for ill children. This effectively resulted in an increase in income. In addition, a healthier population, as a result of improved access to health care and of better health care services quality, is more productive than the less healthy one, leading to income gain through productivity improvement. It was estimated that a 10% reduction in the under-5 mortality rate (U5MR) as a result of the project would result in 12% economic rate of return [6]. Between 1990 and 2000, Laos experienced approximately 40% reduction in U5MR. A cost-benefit analysis with a projection over 1995-2014 indicates that the project could save more than 0.5 million workdays that would have been lost to illness. The economic benefits of the project comprise of 60% cost savings and 40% of labor productivity gain [6].

The PHCP has been judged as effective and efficient. Efficiency evaluation in the performance evaluation report was based only on the difference between the planned budget and actual cost of project implementation. That is,

the PHCP was judged to be efficient because there was no cost overrun. This view of efficiency is relevant for cost control of project implementation, but not necessarily from the country level development management perspective. That is, it does not convey whether the project has allocated budget optimally. For example, while the project may have been implemented efficiently, right on the budget, it may have allocated too much resource towards provincial hospitals and too little towards village health service centers where a marginal impact may be much larger. The cost-benefit analysis of the whole project produced a positive result with 12.2% economic internal rate of return, justifying the economic feasibility of the project as a whole. However, while the cost-benefit analysis provides a basis for judgment concerning the entire project, it does not provide micro level information needed to channel the scarce resource towards areas that would generate greater benefits. Micro information would be useful for determining whether more resources should be allocated to provincial level, district level or village level health care facility, or to certain geographical areas. Our analysis addresses these short-comings by going in depth analyzing micro data.

3. METHOD AND DATA

The method of analysis employs in this study is qualitative. Strauss and Corbin, (1990) explain that qualitative analysis can be used to better understand many issues or problems where little is known [7]. In fact, it would be the only appropriate approach if relevant quantitative data is lacking. Palenberg (2011) describes how efficiency can be analyzed as a qualitative concept using comparative rating [8]. However, this study does not get into qualitative rating of efficiency in the sense of efficiency as a qualitative concept. Rather, we employ qualitative analysis mainly to gain a deeper understanding of the quantitative efficiency measure of project outcomes.

Both quantitative and qualitative data are used as complements to inquire a more in-depth understanding. Weaknesses in project implementation and management will be identified in order to provide appropriate recommendations for improvement of future development projects where applicable. To assess efficiency and effectiveness, in addition to financial data, survey data on health care facility, professional medical staff, outpatient visit, inpatient admission, and other relevant indicators after the project completion are evaluated against baseline data. Data used in our analysis are mainly from two sources, including Project's Building and Civil Works Component Final Report [4] and Health Facility Survey 2006 [9].

4. MAIN FINDING

Our assessment focuses on effectiveness and efficiency in selected provinces with significant investments in Provincial Hospitals (PH), District Hospitals (DH) and village Health Service Centers (HC). Here, as project investments in certain facilities in some provinces involved minor renovation, only investments that involved new construction or major renovation (deemed as an upgrade) of facilities are considered significant.

Civil works on health facilities in the provinces started in 2003 and nearly all completed in mid-2006. Thus, a few sites weren't captured in the survey which took place in 2006. Table 1 provides a summary of Project's provincial investment distribution, showing types of facility invested and total investment cost in US dollar as reported in Project's Building and Civil Works Component Final Report [4]. The per capita investment cost of the Project was added into the table to provide a cross-province comparison of project investment in per capita term.

Table 1. PHCEP's Major Areas of Investment

	Types of Facility Invested	Total Cost (USD)	USD / Capita (2004)
Phongsaly	PH, DH, HC, TF/NS	758,911	4.67
Luang Namtha	PH, DH, HC, TF/NS	1,449,525	10.19
Oudomxay	PH, TF/NS	841,713	3.24
Bokeo	PH, DH, HC	936,865	6.59
Luang Prabang	HO	13,845	0.03
Houaphanh	DH, HC, TF/NS	1,418,326	5.16
Sayaboury	DH	243,144	0.73
Xiengkhouang	TF/NS	194,812	0.87
Sub-Total		**5,857,141**	**3.02**
Offices & Misc.		626,075	
TOTAL		**6,483,216**	

Notes: PH - Provincial Hospital; DH - District Hospital; HC - (village) Health Centers; TF/NS - Training Facility/Nursing School; HO - Health Office; Offices & Misc. - project management office, health offices in southern provinces and miscellaneous.

Table 2 shows levels of project penetration on the three types of public health service facilities in project area. Project's civil works had the greatest penetration on PH, accounting for 50% of the total number of PH. Civil works on DH and HC had relatively small penetration rates of 15.8% and 16.7%, respectively, as DH and HC had relatively large initial units. Thus, it can be said that intervention at the PH level had created the greatest impact to health service capacity in the region in term of physical change to the facilities.

Table 2. PHCEP's Civil Works Penetration

	Units of Facility (2004)	Significant Investment		Level of Penetration	Spending Share of Total
		Units Build New	Units Upgrade		
PH	8	2	2	50.0%	32.1%
DH	57	3	6	15.8%	25.7%
HC	275	46		16.7%	32.2%

Effectiveness

We examined the effectiveness of the Project by analyzing its impact on various areas, including the direct impact of civil works on service space availability; on equipment, supplies and drugs; on staffing; and on service delivery. If, after completion of project implementation, these indicators increased as expected, the Project implementation is considered effective. Our assessment finds that, overall, the Project implementation is considered effective.

On service space availability, it is clearly noticeable that all provinces with significant investments in civil works experienced significant increases in service space availability, except for DH in Luang Namtha which remained constant. Four provinces (Phongsaly, Luang Namtha, Oudomxay and Bokeo) with significant investment in PH experienced an increase in service space availability between 6 and 30 percentage points (Table 3).

All five provinces with significant investments in DH (Phongsaly, Luang Namtha, Bokeo, Huaphan, Sayaboury) experienced an increase in service space availability between 7 and 16 percentage points, except for Luang Namtha, which remained constant. Similarly, all four provinces with significant investments in HC (Phongsalay, Luang Namtha, Bokeo, Huaphanh) experienced an increase in service space availability between 4 and 20 percentage points. Other provinces without significant investment in HC experienced decrease in service space availability, except for Oudomxay.

Though civil works would only directly impact the health care facility space availability, they are prerequisite for hospitals and health service centers to install new equipment and supplies and hire more staff in order to care for more patients. How much has investment in the physical structure affected other measureable indicators of the Project's effectiveness is thus examined.

Table 3. PHCEP Impact on Service Space Availability

Province (significant investments)	Change in % Space Availability for All Services Over 2004 - 2006		
	PH	DH	HC
Phongsaly (PH, DH, HC)	30	16	4
Luang Namtha (PH, DH, HC)	15	0	20
Oudomxay (PH)	6	-3	12
Bokeo (PH, DH, HC)	17	16	11
Luang Prabang	-7	-6	-3
Houaphanh (DH, HC)	4	7	4
Sayaboury (DH)	-6	9	-2
Xiengkhouang	-5	-3	-7
Overall	**8**	**4**	**12**

We start with changes in equipment and supplies and staffing. The survey shows that equipment installment in provincial hospital and district hospital type A (DH-A) increased considerably, especially for high and middle range equipment, with between 24% and 38% percentage point increases as illustrated in Table 4. However, civil works do not seem to have any impact on supplies and drugs neither at provincial hospital nor district hospitals of both type A and type B.

The situation at the village health service center, summarized in Table 5, is less clear. It should be noticed that all eight provinces in the Project area are shown in Table 5 and others through Table 8 with indicators specifying which province had significant investment in PH, DH, or HC in parentheses for convenient of making comparison. That is, for example, even if the focus is on PH, provinces without significant investment in PH are included. Four provinces with significant investments in HC (Phongsaly, Luang Namtha, Bokeo and Huaphanh) all experienced declines in equipment availability between 5 and 12 percentage points, except for Luang Namtha with no change over 2004 – 2006. Supplies also show a similar pattern as that of equipment. Nonetheless, drugs availability increased in all other provinces with significant investments in HC, except for Luang Namtha. In fact, other provinces either with insignificant or no investment in HC, except for Oudomxay, experienced improvements in availability of equipment, supplies and drugs. This could be a result of survey timing and site selection. The survey could have taken place before installments of equipment, supplies and drugs, causing the survey results for provinces with significant investments in HC to show availability deterioration. At the mean time, the Project most likely had selected appropriate provinces to intervene—those that needed additional investment. Thus, provinces without significant investments did not suffer equipment, supplies and drugs availability deterioration.

Table 4. PHCEP Impact on Equipment & Supplies at PH and DH

	Change in % of Availability Over 2004 - 2006		
	PH	DH-A	DH-B
Basic Range Equipment	8	8	1
Medium Range Equipment	30	24	-3
High Range Equipment	38	33	0
All Equipment Av.	25.3	21.7	-0.7
Supplies	0	-4	6
Drugs	-7	2	1

Table 5. PHCEP Impact on Equipment & Supplies at HC

Province (significant investments)	Change in % of Availability Over 2004 - 2006		
	Equip't	Supplies	Drugs
Phongsaly (PH, DH, HC)	-7	-8	11
Luang Namtha (PH, DH, HC)	0	1	-3
Oudomxay (PH)	-12	19	19
Bokeo (PH, DH, HC)	-5	-2	4
Luang Prabang	3	11	9
Houaphanh (DH, HC)	-11	3	12
Sayaboury (DH)	2	0	2
Xiengkhouang	2	11	4
Overall	-3.5	4.4	7.3

On staffing, the survey in general shows improvements for at all three types of health care facility. At provincial hospitals, Table 6, the share of high level staff increased (4 - 12 percentage points) while the share of low level staff declined (2 - 16 percentage points) in all four provinces with significant investments in PH (Phongsaly, Luang Namtha, Oudomxay, Bokeo). It is noteworthy to point out that, while Luang Namtha PH's total number of staff decreased over 2004 - 2006, the province's PH had the highest gain in the share of high level staff (12 percentage points), relative to other provinces with significant investments in PH, and the biggest lost in the share of low level staff (16 percentage points) compared to all eight provinces in the Project area. This can be interpreted as a significant quality improvement. At district hospitals, Table 7, all five provinces with significant investments in DH (Phongsaly, Luang Namtha, Bokeo, Huaphanh and Sayaboury) experienced an increase in total number of staff and the share of high level staff, Except in Luang Namtha which lost 1% of high level staff. In general, district hospitals in all eight provinces lost the share of low level staff, including those without significant investment in DH. At the village health service centers, the survey clearly reveals that staffing was growing rapidly in all provinces with and without significant investment in HC over 2004 – 2006. The increased was contributed mainly by growth in the number of public health care workers (PHC Worker) as illustrated in Table 8. In 2004 one HC had a doctor. By 2006, none of the HC had any doctor, as

staffing at HCs was dominated by nurses/midwives and PHC workers.

Table 6. Impact on PH Staffing, Change in Number and Composition Over 2004 - 2006

Province (significant investments)	Total No.	% High Level	% Mid. Level	% Low Level
Phongsaly (PH, DH, HC)	7	5	-2	-2
Luang Namtha (PH, DH, HC)	-10	12	4	-16
Oudomxay (PH)	17	8	1	-9
Bokeo (PH, DH, HC)	9	4	11	-15
Luang Prabang	-62	5	4	-9
Houaphanh (DH, HC)	-7	13	-10	-3
Sayaboury (DH)	19	-1	-8	8
Xiengkhouang	16	1	4	-4
Overall	-11	6	1	-6

Table 7. Impact on DH Staffing, Change in Number and Composition Over 2004 - 2006

Province (significant investments)	Total No.	% High Level	% Mid. Level	% Low Level
Phongsaly (PH, DH, HC)	55	1	7	-10
Luang Namtha (PH, DH, HC)	40	-1	9	-10
Oudomxay (PH)	-7	1	-1	-3
Bokeo (PH, DH, HC)	6	2	6	-11
Luang Prabang	-10	-1	1	-3
Houaphanh (DH, HC)	20	12	8	-6
Sayaboury (DH)	12	1	2	-4
Xiengkhouang	61	1	-2	-1
Overall	177	2	3	-5

Table 8. Impact on HC Staffing, Change in Number and Composition Over 2004 - 2006

Province (significant investments)	Total No.	Doctor	Nurse / Midwife	PHC Worker	Auxil. Nurse
Phongsaly (PH, DH, HC)	10	0	6	7	-2
Luang Namtha (PH, DH, HC)	38	0	9	22	4
Oudomxay (PH)	27	0	0	34	-11
Bokeo (PH, DH, HC)	25	0	6	19	0
Luang Prabang	24	0	7	24	-7
Houaphanh (DH, HC)	32	-1	3	23	1
Sayaboury (DH)	31	0	1	24	-6
Xiengkhouang	17	-1	7	11	-1
Overall	204	-2	39	164	-22

As has been discussed, the Project civil works had considerably contributed to improvement in service capacity for all three types of health care facility over 2004 - 2006. Health facilities gained more service space, installed new and better equipment, hired more staff, and the share of more skilled staff had increased. Next, we examined impacts on health service facility utilization. We selected three types of services outcomes as indicators for Project's impact on service capacity. Other important services delivery indicators reported in the health facility survey 2006 that were not discussed includes cases for X-Ray examination, surgical intervention, ultrasound examination, pre- and postnatal care, blood transfusion, immunization of women and children, etc.

Table 9 – Table 11 summarize project impact on services delivery of the three health facility types across provinces. To isolate project impact from other factors, only those with significant investment are included. As a whole, the numbers of outpatient visit, inpatient admission and birth delivery had all significantly increased across three types of health facility, except for inpatient admission at district hospitals, which increased just 0.1%. The numbers of inpatient admission and birth delivery in HC increased the most, compared with DH and PH, indicating that village-based health service facility was in high demand.

Services outcomes, however, varied across provinces. Among the four provinces with significant investments in PH, Phongsaly's provincial hospital was the only one experiencing substantial declines in all three selected services delivery indicators—outpatient visit, inpatient admission and birth delivery—while Luang Namtha's was the only one that had substantial increases in all three indicators. While Bokeo's provincial hospital experienced a considerable decline in the number of inpatient admission (22.7%), it had considerable increases in the numbers of outpatient visit (13.4%) and birth delivery (87.4%). Oudomxay's provincial hospital had a slight decline in the number of birth delivery (-0.2%), but the province had significant rises in the number of outpatient visit (74.5%) and inpatient admission (51.8%).

Table 9. Impact on Outpatient Visit: Percent Change over 2004 - 2006

Province (significant investments)	PH	DH	HC
Phongsaly (PH, DH, HC)	-35.5	6.2	28.1
Luang Namtha (PH, DH, HC)	64.2	-24.8	49.1
Oudomxay (PH)	74.5		
Bokeo (PH, DH, HC)	13.4	-12.1	49.0
Luang Prabang			
Houaphanh (DH, HC)		98.5	1.5
Sayaboury (DH)		59.2	
Xiengkhouang			
Overall	39.3	34.5	19.9

Table 10. Impact Inpatient Admission: Percent Change over 2004 - 2006

Province (significant investments)	PH	DH	HC
Phongsaly (PH, DH, HC)	-66.5	-49.8	121.6
Luang Namtha (PH, DH, HC)	113.5	-0.7	96.4
Oudomxay (PH)	51.8		
Bokeo (PH, DH, HC)	-22.7	49.3	-23.0
Luang Prabang			
Houaphanh (DH, HC)		-16.9	81.9
Sayaboury (DH)		33.4	
Xiengkhouang			
Overall	13.4	0.1	22.9

Table 11. Impact on Birth Delivery: Percent Change over 2004 - 2006

Province (significant investments)	PH	DH	HC
Phongsaly (PH, DH, HC)	-28.2	30.0	130.5
Luang Namtha (PH, DH, HC)	63.7	-10.4	132.1
Oudomxay (PH)	-0.2		
Bokeo (PH, DH, HC)	87.4	43.9	20.8
Luang Prabang			
Houaphanh (DH, HC)		7.9	26.1
Sayaboury (DH)		82.6	
Xiengkhouang			
Overall	34.6	30.0	48.6

The service delivery outcomes in Phongsaly may suggest that there was a shift in utilization from provincial and district hospitals to village health centers, as the number of patients at PH declined for all of the three selected types of services and the number of inpatient admission at DH also declined while those at HC increased phenomenally, 28.1% for outpatient visit,

121.6% for inpatient admission and 130.5% for birth delivery. As a whole, Project impact on services delivery outcomes was most dramatic at the village health centers. All provinces with significant investments in HC had substantial increases in the number of outpatient visit, except for Huaphanh, with only 1.5% increase, in the number of inpatient admission, except for Bokeo which experienced a decrease of 23%, and in the number of birth delivery, ranging from 20.8% to 132.1%.

Efficiency

We examined two types of efficiency. The first type of efficiency is project implementation efficiency, which focuses on cost control. The second type of efficiency involves resource allocation. Beyond examining the total financial cost of project implementation, efficiency can be examined in more depth by focusing on cost per unit of benefit created by the Project. How much did it cost to add a percentage of service space availability in provincial and district hospitals and village health service centers? How much per outpatient visit did it cost the project in each of the three types of the health care facilities and at different provinces? How much did it cost to allow one more patient to obtain health care in each of the three types of health care facilities and at different provinces? The answers to these questions provide essential knowledge for efficient resource allocation. That is, they can guide future development project preparation to decide whether more resource should be allocated to provincial hospitals, district hospitals or village health centers, and in which province.

Implementation Efficiency: The Project's civil works component was completed at a cost of $6.483 million, 14.3% above the total contract signed (Table 12). The civil works final report [3] explains that this cost overrun was contributed by rising domestic costs as the civil works covered a span of several years. Civil works started with Project Management Office in April 2002, followed by the provinces in early 2003, and nearly all were completed by mid-2006, with Huaphanh completed last in October of the same year. Over 2002 and 2006, inflation, measured by the Consumer Price Index (CPI), rose 10.1% annually on average. Another factor contributing to cost overrun involved delays in some construction projects caused by late payments to contractors whose work plans and schedules included expected payments from the Project. This led to upward cost adjustments as contractors must continue to pay certain cost commitments such as salaries to essential workers and interest cost of loans. The delay also further exacerbated the inflation effect. The loan agreement includes a condition that payments to contractors would be 12% from Lao government's contribution and 88% from ADB loan funds. The problem was originated from government's contribution commitment, according to the civil works final report [3].

Another area requiring attention, which the report did not point out, is miscellaneous spending of $359,320, which accounts for 5.5% of the total project expenditure. This miscellaneous spending is an exclusive category from other miscellaneous that would be included in all construction contracts. Thus, Project's cost that was bunched into the "miscellaneous" cost category was certainly higher than 5.5%. Since this miscellaneous spending does not have a clear record of what the spending was for, much of that may have been leakages and a lost for the Project.

Table 12. Cost Overrun

	Original Plan	Contract as Signed	Final Cost	% Cost Overrun from Contract
Phongsaly	569,000	679,285	758,911	11.7
Luang Namtha	1,077,500	1,158,097	1,449,525	25.2
Oudomxay	589,000	650,737	841,713	29.3
Bokeo	865,500	845,599	936,865	10.8
Luang Prabang	823,500	13,845	13,845	0.0
Houaphanh	730,000	1,287,241	1,418,326	10.2
Sayaboury	352,500	213,356	243,144	14.0
Xiengkhouang	158,000	176,812	194,812	10.2
PMO	100,000	174,939	177,298	1.3
Other-South	80,000	89,457	89,457	
Supplementary	360,000			
Miscellaneous		384,320	359,320	
TOTAL	5,705,000	5,673,688	6,483,216	14.3

Allocation efficiency: Four indicators were selected for benefit-based efficiency analysis. They include change in space availability for all services, outpatient visit, inpatient admission and birth delivery. The service space indicator measures the direct impact of the Project's civil works, while the other three indicators assess indirect impacts made possible by the completion of the civil works. While outpatient visit gauges change in the service space capacity for all patients that visited the health care facility and received services, the inpatient admission measures the facility's capacity to provide services to patients that needed to stay overnight for more attentive care by medical professionals. Birth delivery in a modern health care facility is an important indicator as it has a significant impact on the health and chance of survival of both the mother and child. Birth delivery at a modern health care facility equipped with qualified staff, medical equipment and drugs would not only significantly reduce infant and maternal mortality rate, compared to traditional rural birth delivery without proper medical care. The mother would receive basic but critical knowledge from professional medical staff, important for the health of both the mother and child throughout their lives beyond the postnatal recovery period. This would have a long term positive impact on the general health of the population, increasing labor productivity in a broad sense. That is, more healthy population tends to be more productive than less healthy population.

First, we compare across the three health facility types—PH, DH, and HC—cost per percentage change and per unit increase of the four selected indicators, and the results are summarized in Table 13. For each type of facility, only provinces with significant investments in that type of facilities, not from all 8 provinces, are included in the analysis. For instant, for PH, only four provinces (Phongsaly, Luang Namtha, Oudomxay and Bokeo) with significant investments in PH are included. Analysis for DH and HC was done in a similar fashion. The health facility survey [9] reported change in service space of the health facility only in percentage term. Thus, we compare across facility types—PH, DH and HC—the cost of a percentage increase in service space, and it

reveals that increasing service space at the provincial hospital was most efficient, as it cost the least per percentage point increase, followed by district hospital and village health service center. In term of cost per percent and per person increase in the number of outpatient visit, the district hospital was the most efficient, followed by provincial hospital and village health center. This suggests that investing in DH is most efficient, relative to PH and HC, as both per percent increase and per each additional outpatient cost of investment was the lowest.

The investment cost per percent increase in inpatient admission and in birth delivery was the lowest at HC, as provinces with significant investments in HC experienced the highest percent increase in the number of inpatient admission and birth delivery in HC over 2004 – 2006 (Table 13). The percent increase in the number of inpatient admission at HC, at 22.9%, was far exceeding the 13.4% increase at PH and 0.1% at DH. As well, the 48.6% increase in birth delivery at HC was far exceeding the 34.6% increase at PH and 30% at DH. In contrast, investment cost per each additional inpatient admission and birth delivery at HC was not the lowest. This suggests that although it cost more per each additional inpatient admission at the HC than at the PH and it cost the most at the HC per each additional birth delivery, investing more in HC would be relevant because demand for village-based basic health services was the highest, as response to improved basic health care in the villages was highest.

Table 13. PHCEP Efficiency Across Health Care Institutional Types

Category	PH	DH	HC
$ per % Change in Space	122,434	173,454	268,041
$ per % Change in OP Visit	52,928	48,214	105,268
$ per % Change in IP Admission	155,465	14,856,334	91,233
$ per % Change in Birth Delivery	60,185	55,543	49
$ per Additional OP Visit	106	67	204
$ per Additional IP Admission	1,374	104,072	1,815
$ per Additional Birth Delivery	4,179	3,750	11,301

While the overall investment cost per percent increase in service space availability was lowest for PH and highest for HC, the results vary across provinces (see Table 14). For Phongsaly and Bokeo, increasing space of PH was the most efficient and increasing service space in HC was the least efficient. In Luang Namtha, however, increasing HC service space was most efficient, and despite that 16% of the $1.4 million allocated to the province was spent on DH civil works, there was no change in service space availability. Across provinces, investment in PH had the highest impact on increasing service space availability per cost unit in Phonsaly, with Oudomxay having the lowest impact, while investment in DH had the highest impact on service space availability per unit cost in Sayaboury. Investment in HC had the highest impact on service space availability per unit cost in Kuang Namtha. While measuring per unit cost of increasing service space is important for comparing efficiency, the unit cost per percent change in the service space may not convey efficiency comparison properly if the service space in each of the province's PH varied. The same amount of space increase at the same cost would cause the percent increase in space higher for the PH with less space than the PH with more space before the civil works began. However, the comparison offers a broader picture of the Project's impact.

Table 14. Investment Cost in USD per Percent Increase in Space Availability for All Services

Province (significant investments)	PH	DH	HC
Phongsaly (PH, DH, HC)	7,023	20,430	
Luang Namtha (PH, DH, HC)	44,775		25,012
Oudomxay (PH)	129,511		
Bokeo (PH, DH, HC)	14,922	18,657	34,971
Luang Prabang			
Houaphanh (DH, HC)		96,874	170,844
Sayaboury (DH)		14,728	
Xiengkhouang			

5. CONCLUSION AND RECOMMENDATIONS

Our examination of civil works direct impact on service space availability and indirect impact on equipment, supplies and drugs; on staffing; and on service delivery finds that the Project was implemented effectively overall. Service space availability increased in all three types of health care facility—provincial hospital (PH), district hospital (DH), and village health service center (HC)—in all provinces with significant investments in any of the three types, except for DH in Luang Namtha, which remained unchanged. The availability of equipment clearly increased in PH and DH, especially for medium and high range equipment, but not in HC. The total number of staffing at all three types of the health care facility increased, with rising percentage of high and middle level staff in PH and DH. In HC, there was a substantial increase in the numbers of nurses/midwives and trained public health care workers. The Project has resulted in considerable increases in the number of outpatient visit, inpatient admission and birth delivery in all of the three types of health care facility, except for inpatient admission in DH, which increased by just 0.1%.

***Point of recommendation 1*:** The civil works implementation with an overall 14.3% cost overrun compared to the total amount of contracts signed (but 13.6% if compared to the original budget) is not considered to be efficient. Although the cost overrun was largely contributed by domestic price increases, as CPI was rising at an average rate of 10.1% annually over 2002 – 2006, the cost overrun was exacerbated by delays of some construction sites caused by delays of payments to contractors which originated from government's 12% share of financial commitment for all contracted works. Thus, it is recommendable that delays caused by financial mismanagement must be avoided by ensuring that committed funding from all project partners, especially from government, must be in place prior to any contract is signed. Also, a strong committee to oversee the bidding process and approval for all contracts is critical to ensure quality job outputs at a competitive cost.

***Point of recommendation 2*:** In addition to cost overrun, an exclusive category of miscellaneous spending in addition to miscellaneous normally included in every contract, which lacks a clear spending record and accounts for 5.5% of the total Project cost, suggests that a considerable amount of Project's financial resource could have been leaked. At 5.5% of the total cost is considered to be under the norm. However, since every contract of construction work already has miscellaneous expenses, which can be anywhere between 2% and 5%, an additional miscellaneous expense of 5.5% of Project's total cost with unclear spending record and purpose that

can be directly linked to project outputs require a close attention. This can be translated into 7-8 additional village health centers. Miscellaneous expenses must be controlled and kept at a minimum, as expenses in this category do not have a clear record of what the expenses are for and how they contribute to project outputs. In association with miscellaneous spending, funding for minor, unessential renovation that does not contribute to improving service capacity should not be allowed. Funding for this category should be coming from regular maintenance budget.

***Point of recommendation 3*:** A more detailed analysis finds that investment cost per percent increase in service space availability was lowest for PH, meaning increasing service space availability at PH was most efficient. However, responses to expanded service space in terms of inpatient admission and birth delivery were most robust at HC, indicating that demand for health care services at HC was high. Due to high responses, investment cost per percent increase in inpatient admission and birth delivery was the lowest at HC. Thus, it is recommendable that increasing investment in HC, a village-based health care facility, would better serve the needs of the population and would be economically more cost effective, as financial cost of investing in health care facility is only part of the entire economic cost to the country. Total economic cost of health care to the country is one that involves both health care service providers and users. Going to a hospital located in the capital city of the province or to a district hospital from many villages could be a matter of an entire day, and returning home would be another day. Thus, time alone can be a factor discouraging villagers from getting proper health services both for basic and more serious care. The transport cost between home and the hospital and overnight cost are out-of-reach for many poor villagers. Thus, the village-based HC would substantially reduce transport cost and the opportunity cost of time for villagers who need health services. A more convenient and affordable basic health services by HC would encourage villagers to obtain basic health care services, leading to better health and higher productivity. A statistical analysis finds evidence that, over 2002/03 – 2007/08, expanding HC services greatly benefit the poor while expanding PH services favors the better off [10].

There are several weaknesses and limitations to this paper. First of all, the analysis relied heavily on two sources of data, both of which are project reports. Although data in these two sources are considered reliable, without a third party, independent source of data, some biases may exist in the report. Secondly, the analysis does not include the post-project impact on measureable health conditions of the population in the Project area, such as changes in infant and maternal mortality rate, under-5 mortality rate, and a loss of time due to sickness. Thirdly, the paper does not include an analysis of the Project's impact on cost associated with travel and other costs involved in obtaining health care services. These data would allow an economic impact analysis of the Project, which would be useful information.

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Consumer Perception and Attitude Study for Market Development of Hommali Organic Rice Products from Thung Kula, Thailand

Pensri Jaroenwanit and Pornpirat Kantatasiri

Abstract— This research aims to study consumers' perceptions and attitudes toward Hommali Organic Rice Products for the purposes of market development in Thailand. Hommali Organic Rice Products from Thung Kula, Roi-Et Province were used for the case study in this quantitative research. Field survey research was conducted using questionnaires to collect data from 440 test subjects who were Thai Hommali Organic Rice Product consumers; 240 people were surveyed in Bangkok, 100 people in Khon Kaen, and another 100 people were in Roi-Et. Test subjects were selected using purposive sampling. Descriptive statistics and inferential statistics were used in the data analysis. The research found that all research subjects knew of and had consumed Hommali Organic Rice Products; however, only 56.8% knew of Hommali Organic Rice Products specifically from Thung Kula. They had a low level of awareness in terms of differences between Hommali Organic Rice Products from Thung Kula and from other areas and knew little about the distribution of such products from Thung Kula. This study suggests that marketing communication should be developed in order to build positive perceptions and attitudes towards Hommali Organic Rice Products from Thung Kula. As consumers pay a lot of attention to their health, the selling points of these products should focus more on the benefits of consumption, lack of poisonous substances,and relatively aromatic and soft qualities when compared to Hommali Rice from other areas. Development of product distribution, marketing, and the domestic market are needed in order to expand the product's reach and to be accessible for the target group.

***Keywords*—** Attitude, Market Development, Organic Rice, Perception.

1. INTRODUCTION

Consumer behavior in terms of willingness to pay or purchase organic products depends on consumers' perceptions and attitudes [1], [2], [3], and [4]. Specially, at present consumers are interested in the relationship between diet, food and health [5] and have concerns about the risks of illness and disease from food [6] because today many countries are spreading information about risks from the chemical synthesis on food products [4] and [7]. In addition, many research studies have revealed that consumers are increasingly aware and protect their health by consuming organic products instead the conventional food products [2], [3], [4], [6], [8], [9], [10]. These changes in consumer perceptions and attitudes about organic products are correspondingly important for companies to be aware of and employ in their marketing strategies.

Organic agriculture products are a popular choice for many consumers who are aware of their health [11]. Organic products are not associated with chemical synthesis in contrast to typical, agro-chemical products [12]. The International Federation of Organic Agriculture Movement (IFOAM) [13] and USDA Organic [14] determined the definition of organic agriculture to be:

"Organic Agriculture is a production system that sustains the health of soils, ecosystems and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects. Organic Agriculture combines tradition, innovation and science to benefit the shared environment and promote fair relationships and a good quality of life for all involved [13]*."*

In Thailand organized organic production began in the early 1980s when a group of farmers and local Non-Governmental Organizations (NGOs) came together to establish the Alternative Agriculture Network (AAN) (Anderson, Lonmo, Schaan, & Schenk) [15], [16], and [17]. The network aimed to foster sustainable agriculture activism in Thailand [17]. In Thailand, the main sources of agriculture are rice, vegetables, and fruits [15], [16].

The expansion of organic rice production in Thailand is supported by The Ministry of Agriculture and cooporatives, especially Hommali Organic Rice, which is famous around the world [15]. Hommali Organic Rice is grown in the Thung Kula Rong Hai area that contains five provinces: Roi-Et, Mahasarakham, Surin, Bureerum, and Yasothon. Government policy has increased the volume of Hommali Organic Rice production by two hundred and five tons from the Thung Kula Rong Hai area, distrubuted amongst the five provinces (i.e. a rice yield of 75,000 tons from the Surin area and 15,000 tons from the Yasothon area) [18].

Although Hommali Rice is a famous kind of rice in Thailand, Hommali Organic Rice is a new product in the market [18]. This distinction raised the research question of how consumers perceive and feel towards Hommali Organic Rice. Therefore, the objective of this paper is to study consumers' perceptions and attitudes about Hommali Organic Rice for the development of informed

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marketing strategies. Following the introduction, this paper contains a literature review, description of methodology, findings, conclusions, and further discussion.

2. LITERATURE REVIEW

2.1 Organic Rice Definitions

Organic rice is a natural growing rice that is minimally processed and free of synthetic preservatives, artificial sweeteners, colors, flavors and other artificial additives, growth hormones, antibiotics, hydrogenated oils, stabilizers, and emulsifiers while grown [14] and [19]. Specially, this rice is grown without the use of synthetic fertilizers or pesticides for at least three years prior to harvest [13], [14], [16], [17], [19] and [20]. Furthermore, cover rice seed, compost and other natural fertilizers are used for maintaining soil fertility, while biological control and natural pesticides are used for pest control [14], [15], and [17]. Organic livestock production requires that animals are fed organic feed, have access to a pasture or the outdoors, and prohibits the use of antibiotics and hormones [14] and [21]. Moreover, most organic rice products have an organic label to ensure consumer confidence in their origin [14], [17], [22], [23] and [24]. Therefore, organic rice definition refers to the process and product of organic rice production.

2.2 Hommali Organic Rice from Thung Kula

Khao Hom Mali Thung Kula Rong-Hai is the rice produced in the Thung Kula Rong-Hai area, extending across five provinces of north-east Thailand. It is grown from Khao Dawk Mali (KDML 105) and RD in15 varieties and is a light-sensitive paddy rice. It can be brown or white (milled rice) [15] and [16]. Thung Kula Rong-Hai is an area that used to be an expansive, harsh, and dry place in the middle of the region. It covers 5 provinces, which are Roi Et, Surin, Buri Ram, Yasothon, and Maha Sarakham. One-third of the area is in Roi Et [18] and [25]. There is a legend that says the Kula people were traders in ancient times who were also great fighters with excellent stamina. However, they cried when they got to Thung Kula Rong Hai because it was such a desolate place without water and big trees. Presently the area is fertile due to the efforts of the government to develop it and it is suitable for agriculture [25].

2.3 Consumer Perception

Consumer behavior is a dynamic phenomenon that depends heavily on consumers' perceptions. This is the most important psychological factor in the marketing field because consumers must have a perception or attitudes about a product before they are interested in purchasing it [26], [27], and [28]. Organic products in Asian markets are less recognized than in the EU market [7] and knowledge about such products has a slow rate of diffusion. For example, in Bangkok people who had bought organic products knew only about organic fresh vegetables [29] and were aware of a little market selling these organic products [30]. Thus, consumer's perception affects to marketing strategy [31] that can be induced the consumers' needs, especially, after consumer perceives the risk from food, they are always try to find the better [32] and [33].

Culture's influence consumption

Hofstede's culture definition refers to the dynamic process that can drive human social beliefs, create attitudes, perceptions, thoughts, and responses[13]. Hofstede discussed one dimension of culture that is particularly relevant here: individualism and collectivism. These play a key role in consumer perceptions and attitudes [34]. Western cultures (e.g. England, Australia) and Eastern cultures (e.g. Thailand, China) differ in ways that can be classified following Hofstede's cultural dimensions. Western cultures tend more towards individualism than those in the East, so a consumer in Eastern cultures who is part of a collectivistic society has more impetus to follow social trends [35] in the terms of consuming organic food [36]. In this way many researchers reveal that culture is an important factor which affects consumers' perceptions, attitudes, and consumption of a new product in the market [36] and [37].

Cognitive consumption behavior

Many research studies have found that not only gender and age, but consumer perception and attitude have an effect on food consumption behavior [38]. In particular, consumers who purchase organic products are often cognitive of the relationship between food and health [39]. Different opinions about this affect consumer perceptions [40], and statistically women are more likely than men to use information about how to be healthy to changing their behavior[39] and [41]. Generally speaking, women make the decision to purchase products while comparing the benefits from different choices [5] and [42]. Overall people who are aware of their health will pay extra to get food products with higher and safer standards than conventional products [5]. Consumers who regularly purchase healthy products have personal tendencies and cognitive reasoning that lead them to choose healthy food brand products [43] and [44]. On the other hand, this group of people is only one segment of the initial market for new food products [45]. In this way, consumers' perception is related to their cognitive reasoning, which in turn affects their behavior to consume the organic products [46] and [47].

2.4 Consumer Attitude

An attitude is a psychological tendency that is expressed by evaluating a particular entity with some degree of favor or disfavor [2]. In addition, it involves an overall evaluation that expresses how much we like or dislike an object, issue, person, or action. Attitudes are learned, and they tend to persist over time [48]. In other words, attitudes reflect the consumers' overall evaluation of something based on associations linked to it [49] and [48]. However, attitude is important because it guides our thoughts (the cognitive function), it influences our feelings (the affective function, or emotion), and it affects our behavior (the cognative function) [50] and [51].

Furthermore, attitude can be described in terms of five main characteristics: favorability, attitude accessibility, attitude confidence, persistence, and resistance [52] and [53]. This research emphasizes the consumers' attitude as it results in behavior. Attitude is understood as a rational, choice-based evaluation of the consequences of a behavior or a behavior's subjective

utility, as well as an estimate of the likelihood of expected outcomes [54] , [55] and [56]. Hence, an attitude includes affective (e.g. enjoyable or unenjoyable) and instrumental (e.g. benefit or harmful) evaluation toward a behavior that have contributed to the level a person possesses a desirable or non-desirable estimation or behaviour-based appraisal in question [56], [57], [58], [59] and [60].

2.5 Market Development

The body of consumers willing to purchase or actively seeking organic products is a new market, which is developing to suit consumers' needs [61], and [59]. Moreover, it has been found that more information about the organic food market, which increases consumers' organic food knowledge, is important because it positively influences consumers' attitudes towards organic food products [2] – [62], and [63].

3. METHODOLOGY

Field survey research was conducted using questionnaires to collect data from 440 test subjects who were Thai Hommali Organic Rice Product consumers; 240 people were surveyed in Bangkok(the capital city), 100 people in Khon Kaen (the biggest city in the Northeast region of Thailand), and another 100 people were in Roi-Et (the land of Thung Kula). Test subjects were selected using purposive sampling. The data obtained from the survey is analyzed using fundamental descriptive and inferential statistical methods.

4. FINDING

A. Personal Data of Test Subjects

74.5% of test subjects were female and 86.6% of these were married. Each household consisted of 3-4 members on average, with 55.7% of households meeting the average. 39.3% had an income around 10,000-20,000 Baht per month. 21.8% had been educated up to a high school or vocational level. Also, 28.6% were running their own business and 45.7% were loyal and sincere.

B. Consumers' Perception of Hommali Organic Rice Products from Thung Kula

All test subjects knew of and had consumed Hommali Organic Rice Products; however, only 56.8% knew of Hommali Organic Rice Products from Thung Kula. Most test subjects that didn't know of Hommali Organic Rice Products from Thung Kula were young and single with low income and their education was at a high school or vocational level or lower.

The areas which consumers were familiar with as cultivated areas were Roi-Et Province, Surin Province, and Burirum Province respectively.

It was most common that consumers had received information about Hommali Organic Rice Products from Thung Kula at exhibitions, followed by seeing the products themselves. Learning about the products through media advertisements, such as brochures, internet and television was less common.

Most consumers could not recognize the Hommali Organic Rice brand. For those who did, the brand of Hommali Organic Rice Product from Thung Kula that was most recognized was Sue Sat, followed by Moral Rice, and then by Rakbankerd brand. The product brands they had bought is shown in Table 1.

TABLE 1: Number and Percentage of test subjects that purchased various Hommali Organic Product Brands from Roi-et Province

Product brand \ Provinces	Bangkok		Khon Kaen		Roi-et		Total	
	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
Sue Sat brand	21	14.1	1	0.7	0	0.0	22	14.8
Rakbankerd brand	15	10.1	2	1.3	0	0.0	17	11.4
Khoa Phen Ya brand	21	14.1	11	7.4	6	4.0	38	25.5
Unrecognized	32	21.5	24	16.1	16	10.7	72	48.3
Total	89	59.7	38	25.5	22	14.8	149	100.0

Note: Subjects could choose more than 1 answer

When buying Hommali Organic Rice Products, consumers normally look at the label to ensure that the rice they buy is Hommali Organic Rice. Sometimes they receive information from retailers and advertisements. The majority of consumers buy Hommali Organic Rice from the supermarket, followed by grocery stores and then by Hommali Organic Rice Product Shops.

Customers had a high level of awareness about Hommali Organic Rice, but they paid little attention to the origin of the product. Consumers had confidence in the quality and price of Hommali Organic Rice Products from Thung Kula. However, they had a low level of awareness in terms of differences between Hommali Organic Rice Products from Thung Kula and Hommali Organic Rice from other areas and knew little about the distribution of Hommali Organic Rice Products from Thung Kula. The results are shown in Table 2

TABLE 2: Mean and Standard Deviation of Consumers' Perceptions of Hommali Organic Rice from Roi-et Province

No.	Consumers' perceptions	Mean	SD	Level of Consumers' perceptions
1.	I know Hommali Organic Rice, but I didn't pay attention to its origin.	3.44	1.171	High
2.	I know Hommali Organic Rice from Roi-et Province.	3.37	1.085	Moderate
3.	I know Hommali Organic Rice from Thung Kula.	3.35	1.040	Moderate
4.	I often receive information about Hommali Organic Rice from Roi-et Province.	3.04	0.920	Moderate
5.	Information about Hommali Organic Rice from Roi-et Province is interesting and attracts consumers' attention.	3.24	0.897	Moderate
6.	I saw Hommali Organic Rice Products from Roi-et Province in shops and supermarkets.	3.07	1.076	Moderate
7.	I'm confident about the quality and price of Hommali Organic Rice from Roi-et Province.	3.48	0.846	High
8.	I can differentiate Hommali Organic Rice from Roi-et Province and Hommali Organic Rice from other provinces.	2.87	1.216	Moderate
9.	I can easily find Hommali Organic Rice from Roi-et Province.	3.11	1.174	Moderate
10.	I tend to buy Hommali Organic Rice from Roi-et Province.	3.18	1.087	Moderate

C. Consumers' Attitude of Hommali Organic Rice Products from Thung Kula

Customers had a positive attitude toward Hommali Organic Rice because it was produced without chemical fertilizers, plant growth regulators, herbicides, insecticides, or additional hormones, and was not genetically modified (GMOs).

The production process of Hommali Organic Rice was considered environmentally friendly and helpful in

reducing pollution. Hommali Organic Rice Products do not contain poisonous substances and are good for consumers' and producers' health. Most consumers tended to buy Hommali Organic Rice Products from Thung Kula and would recommend it to other people.

Customers were highly satisfied with the widespread and wide range of products (as shown in Table 3).

TABLE 3 Mean and Standard Deviation of Consumers' Attitudes towards Hommali Organic Rice from Roi-et Province

No.	Consumers' Attitudes	Mean	SD	Level of Consumers' Attitudes
1.	I am satisfied with the widespread availability of Hommali Organic Rice from Roi-et Province.	3.85	0.808	High
2.	I satisfied with the Channel of Distribution of Hommali Organic Rice from Roi-et Province and these products are easy to find.	3.79	0.848	High
3.	I satisfied with the variety of brands of Hommali Organic Rice from Roi-et Province.	3.31	0.746	Moderate
4.	I satisfied with the price of Hommali Organic Rice from Roi-et Province. (about 60-80 Baht per kilogram)	3.17	0.909	Moderate
5.	I satisfied with the taste and smell of Hommali Organic Rice from Roi-et Province. (only for those who had it before)	3.90	0.670	High
6.	I satisfied with the packaging of Hommali Organic Rice from Roi-et Province.	3.77	0.761	High
7.	I satisfied with the information and details on the label of Hommali Organic Rice from Roi-et Province.	3.62	0.901	High

Moreover, they expressed that the products were tasty and smelled good with nice packaging and labels that provided information and details about the product.

The features of Hommali Organic Rice that customers prefer include its health benefits, that it is environmentally friendly and that it is safe to eat (as shown in Table 4)

TABLE 4 Mean and Standard Deviation of Customers' Decision-making Factors

No.	Customers' Decision-making Factor	Mean	SD	Level of Significance
1.	I pay attention to my health.	3.75	0.720	High
2.	I decide to buy products that are good for my health.	3.65	0.913	High
3.	I decide to buy good quality products regardless of price.	3.26	1.227	Moderate
4.	I decide to buy familiar brand products regardless of safety.	2.87	1.224	Moderate
5.	Good products are products that aware of environmental effects.	3.72	0.850	High
6.	I decide to buy products which are considered environmental friendly.	3.32	1.023	Moderate
7.	I decide to buy products which are considered to use animal friendly processes.	3.29	1.181	Moderate
8.	I will buy products whose quality I have confidence in regardless of environmental effect.	2.72	1.238	Moderate

5. CONCLUSIONS

The following can be concluded from the results of the field survey research:

1) The characteristics that set Hommali Organic Rice from Thung Kula apart include that fact that the products were certified as organic both domestically and internationally, and Thung Kula is the best location for growing Hommali Organic Rice in Thailand and has been well-known in rice production for a long time.

2) Hommali Organic Rice from Thung Kula has a more aromatic smell and is softer than Hommali Organic Rice from other areas.

3) The products have also been processed into a variety of products, including a rice germ drink powder, germinated rice milk, and rice facial scrub powder.

4) Product distribution, marketing, and selling Hommali Organic Rice Products from Thung Kula is still in an unstable position. Most consumers could not recognize the Hommali Organic Rice brand. Moreover, most consumers bought a small amount of Hommali Organic Rice Products, 1 Kilogram on average, and bought one package with each purchase; however; they tended to buy it more than once a month. The information above shows that the rate of popularity for buying Hommali Organic Rice is still low.

5) Customers had a positive attitude toward Hommali Organic Rice. They tended to buy Hommali Organic Rice Products from Thung Kula and would recommend it to other people. It can be seen that consumers pay attention to their health. Therefore, showing its health benefits would be essential for presenting the benefits of Hommali Organic Rice Products from Thung Kula.

6. RECOMMENDATIONS

Recommendations are drawn from this research study to sustainably increase competitiveness of Hommali Organic Rice Products from Thung Kula as follows:

1) Appropriate marketing communication should be developed in order to build positive perceptions and attitudes toward Hommali Organic Rice Products from Thung Kula, as consumers currently cannot recognize these products' brands accurately. Consumers can't recognize the differences between Hommali Organic Rice Products from Thung Kula and Hommali Organic Rice Products from other areas.

2) Development of product distribution, marketing, and the domestic market are needed in order to expand the product's reach and to be accessible for the target group. This could sustainably increase the competitiveness of Hommali Organic Rice Products from Thung Kula.

3) As consumers pay a lot of attention to their health, they need safe products. The selling points of Hommali Organic Rice Products from Thung Kula that should be developed include the benefits of consuming it, confidence that it has no poisonous substances and its relatively aromatic and soft qualities when compared to Hommali Rice from other areas.

4) A variety of products should be available in order to meet consumers' demands. Packaging and attractive labeling should also be taken into account.

5) The above market development could sustainably

increase competitiveness of Hommali Organic Rice Products from Thung Kula.

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Low Carbon Hotels towards Sustainable Tourism in Koh Chang and Neighbouring Islands, Thailand

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***Abstract*— *Tourism is considered as one of the most growing economic sectors, and also one of the emerging concerns faced by policy makers and stakeholders due to its potential implications to environment and climate change. Efforts should therefore be made to balance the economic benefits of the tourism industry and protection of the environmental values. This paper presents the results of a project, which developed guidelines for low carbon hotels in Koh Chang and its neighboring islands, under the Designated Areas for Sustainable Tourism Administration (DASTA), Thailand. The aim of the project is to develop criteria and indicators for measuring resource use and carbon emissions of hotels and related enterprises, with participation of local stakeholders. Primary data were collected through field surveys and unstructured interviews with key stakeholders. In addition, secondary data were gathered from review of related literature and existing supporting documents used in developing the guidelines. The analysis revealed nine categories ranging from policy and administration to carbon emissions, with each having several supporting indicators and criteria in the proposed guidelines. The results of the project suggest that the success of implementing the low carbon guidelines depends primarily on management support and development of supporting systems such as monitoring and auditing, documentation and database, and capacity strengthening for staff and related personnel. Real experiences from on-going pilot applications of the guidelines are expected to improve effectiveness and efficiency of actual implementation of the guidelines, before it can be adapted as a formal low carbon standards for Koh Chang, and other tourism areas.*

***Keywords*— Carbon Emission, Criteria, Guidelines, Indicators, Low Carbon Tourism**

1. INTRODUCTION

Nowadays, tourism sector is growing at a rate that potentially makes it a significant source of carbon emissions and environmental degradation due to its high demand on energy and other natural resources. Hotels as a part of tourism sector are major energy end-users [1]. Therefore, the concept of Low Carbon Hotels (LCH) is guided for solving problems which is broadly accepted as a significant implementation to reduce carbon emission.

An LCH is a hotel based on low energy consumption, low pollution, and low CO_2 emission. Its core principle is to use energy efficiently, use clean energy technology and pollute less [2]. This low carbon hotel project can be implemented through the collaboration of different stakeholders and decion-makers including relevant government ministries and their line agencies , monitoring and evaluation experts, hotel owners and customers, and communities dependent on the hotel and tourism industry. The cooperation formed by these stakeholders would aim to achieve energy saving, conservation of natural resources and environments, community income, community development and sustainable tourism.

The Designated Areas for Sustainable Tourism Administration or DASTA [3] was established as a public organization mandated to serve as a coordinator of sustainable tourism operation and integrated administration of valued tourism areas. DASTA provides mechanism that enables flexibility and promptness in joint-operations of government agencies or state enterprises. There are 6 designated areas in Thailand under DASTA: Koh Chang and its neighboring islands, Pattaya City and neighboring areas, Sukhothai – Kamphaengphet Historical Parks, Loei Province, Nan Old City, and U-Thong Ancient City. Koh Chang and its surrounding areas are regarded as the jewel of the Gulf of Thailand. This group of islands, which comprises of Koh Chang, Koh Mak, Koh Kood and other smaller islands near the coast, is located in Trat Province, Eastern Thailand, which is expected to become a world-class ecotourism destination. As of 2011, there were 147, 18, and 23 hotels in Koh Chang, Koh Mak, and Koh Kood, respectively.

To qualify as an LCH, the hotel needs to be assessed using an evaluation guideline that makes use of selected indicators and criteria such as, carbon footprint, energy consumption, total green area, building design, policy, administration management, pollution control, transportation, carbon emission, water consumption, and purchasing. This paper aims to present the process of developing the guidelines for evaluation of LCH. It also covers the process of setting up the cooperation among key stakeholders involved in energy and environmental management, local culture, and international sustainable tourism. The LCH program was developed as a pilot initiative for Koh Chang and its neighboring islands in Trat Province, Thailand, under DASTA.

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2. LITERATURE REVIEW

Hotel operations are one of the major carbon dioxide emitting industry through its large consumption of energy, water and non-renewable resources. Many studies posit that sustainable development and management can help reduce CO_2 emissions through effective energy and environmental management policies [4].

A green hotel indicates an eco-friendly hotel operation, which includes good practices in water and energy use conservation, environmentally purchasing policies, and waste minimization. On the other hand, low-carbon activity is defined as a smallest output of greenhouse gas (GHG) emissions into the ecosphere, especially CO_2 [1].

Low-carbon tourism, an offspring of low-carbon economy, is a form of eco-tourism based on low pollution, low power consumption, and low emission. Its aims are to improve the quality of tourism services, to protect local nature and cultures, and to make positive contributions to local population [2].

Related Guidelines and Standards

There are several international and national studies related to the development of sustainable hotel guidelines.

The Energy Conservation and Carbon Reduction (ECCR) was developed and adapted for the hotel industry in Taiwan by Teng, et al. [4]. The development of ECCR involved interviews with the senior hotel managers, environmental specialists and governmental officials to identify the framework, structures and determine weights of criteria through a questionnaire survey. The ECCR consists of 7 categories: (i) communication and participation; (ii) top management commitment; (iii) energy; (iv) water; (v) waste; (vi) building; and (vii) purchasing. Thirty-two (32) indicators were used to identify and prioritize ECCR contributions. The results revealed that top management commitment is the most significant factor in determining the success of ECCR implementation.

EarthCheck [5] is conducted mainly for benchmarking environmental and social performance. Using its own set of indicators, it compares whether these indicators are lower, equal or better than baseline level. Indicators can be divided into eight categories: (i) policy; (ii) energy; (iii) water; (iv) waste; (v) community; (vi) paper; (vii) cleaning; and (viii) pesticides.

The Green Key Eco-Rating Program [6] was designed to recognize hotels, motels, and resorts that have outstanding sustainable initiative improvement. The full online assessment contains 160 questions divided into five main areas: (i) corporate environmental management; (ii) housekeeping; (iii) conference and meeting services; (iv) food and beverage services; and (v) engineering and maintenance.

The Green Seal Environmental Standard [7] is a guidance process for lodging properties seeking Green Seal certification. Some requirements are needed to meet its initial certification level, such as organization and regular compliance. Other requirements are listed to pass bronze level, silver level and gold level, respectively, using the following major indicators: waste minimization, reuse and recycling; energy efficiency, conservation and management; management of freshwater resources; wastewater management; hazardous substances; environmentally and socially sensitive purchasing policy; continuous improvement plan; and any three (3) of the following: energy reduction; sustainable building; renewable energy; greenhouse gas reduction; zero waste; green cleaning; water conservation.

The Green Building Initiative [7] consists of many categories, which cover for major scopes such as energy; water; resources; emissions, effluents and pollution controls; indoor environment, and environmental management system.

The Oregon Economic and Community Development Department [8] developed benchmarks and criteria for green hotels certification in Thailand. The initial phase of its project identified and compared existing certification programs in Thailand and other international certification programs, including the Green Leaf Program (from Thailand); Green Tourism Business Scheme (from Scotland); Certification for Sustainable Tourism (from Costa Rica); Energy Star (from U.S.); LEED for Existing Buildings (from U.S.); Green Leaf Eco-Rating Program (from Canada); Nordic Swan Label (from Nordic Group of Country); ECOTEL; Green Globe 21; and International Hotels Environment Initiative. Each program consists of different categories and indicators.

The Green Leaf Standard [8], [9] was established as a guidance to protect and conserve the environment for hotel tourism in Thailand. The criteria are classified into 18 categories: policy and communications; human resource development; committee; target and plan; waste management; efficiency and energy consumption; water consumption; kitchen and restaurant; laundry; purchasing; indoor air quality, air and noise pollution; water and its quality; spa and healthy massage; fitness center, swimming pool and outdoor activities; security; environmental impact; corporate social responsibilities within the community; and cultural support.

The Green Tourism Business Scheme (GTBS) [8] includes the criteria of management; communication; hydro energy; waste; purchasing; transportation; wild life; and landscape. On the other hand, the Certification for Sustainable Tourism (CST) [8] covers for 4 categories: physical-biological environment; hotel facility; customers; and socio-economic environment.

The Leadership in Energy & Environmental Design (LEED) for Existing Buildings [8] includes 5 categories: sustainability; water; energy; materials and resources; and indoor environment. The Nordic Swan Label [8] is a unique of eco-labeling used by Nordic Countries, which covers the areas of energy, water; chemicals; consumables and raw materials; finishing and fixtures; waste management; and transportation.

Green Globe 21 [8] is a global certification, which is based on the following international standards and agreements: Global sustainable tourism criteria; Global partnership for sustainable tourism criteria; Baseline criteria of the sustainable tourism certification network of the Americas, Agenda 21 and principles for sustainable development endorsed by 182 governments at the United Nations Rio de Janeiro Earth Summit in 1992, ISO 9001/14001/19011 (International Standard Organization)..

Green Building [8] under Thailand Energy Award 2011 is a campaign to promote energy conservation in buildings. The scoring criteria used are energy efficiency; renewable energy; water efficiency; environmental

protection; indoor environmental quality; other green features and innovation.

Certification and Auditing Process

Each certification/program has different processes of auditing and weighting to judge a case.

The Green Seal Environmental Standard [7] is divided into 3 levels: bronze; silver; and gold. It requires applicants to at least meet some basic requirements to qualify for the initial certification level. More challenging requirements are set to qualify for the higher certification level.

GTBS [8] has 3 levels of certification: bronze, silver, and gold, and each level requires for significantly higher reduction of environmental impacts. Certification for Sustainable Tourism (CST) [8] is divided into 6 sustainability levels (from 0 to 5 by weight percentage), evaluated through a checklist questionnaire consisting of 153 questions. The range of weight percentage starts from less than 20 to more than 94.

LEED [8] certification levels are separated into 4 levels based on 100 possible base points: certified, silver, gold, and platinum. The scoring range varies from 40-49, 50-59, 60-79, and above 80, respectively.

The environmental auditing process of Green Leaf Hotels Standard [9] consists of 3 key steps: (1) the screening process in which 13 questions related to environmental restrictions are paneled; (2) the qualifying process through which environmental activities in hotels are identified; and (3) the grading process, which the environmental auditing in operational process of hotel are divided into 11 sections as mentioned earlier. There are 2 scoring standards. The first standard scores range from less than 45.34% to more than 77.99% and can receives from 1 leaf to 5 leaf certification. The second standard scores range from less than 52% to more than 66.5% and can receive from 1 leaf to 5 leaf certification.

ECOTEL Certification [10] consists of five areas or spheres: sustainability commitment; waste management; energy management; water management; employee education and community development. These areas encompass the processes, systems, and practices to ensure the sustainable operation in hotel through an audit under each of these globes based on checklist survey.

The ISO:19011 certification process [11] involves collecting data by appropriate sampling and verifying (audit evidence), evaluating against audit indicator (audit findings); reviewing; audit conclusion; preparing, approving and distributing the audit report; completing the audit; and conducting audit follow-up.

There are 3 processes of ECOTEL certification [10]: (1) property assessment, which is conducted through interviews, physical inspection, and data collection; (2) roadmap for certification, which is considered through targets, technology, and workshop trainings; (3) and audit, which is the final process to conduct and award the certification.

The assessment process of ISO:14015 [12] involves planning the assessment, collecting and validating information, evaluating the information, and reporting on the assessment.

3. METHODOLOGY

The overall methodology of developing the guidelines are organized into 4 phases as follows:

Phase 1 consisted of literature reviews related to LCH guidelines and standards including the survey on-site observations of project study areas and interviews with selected key stakeholder-representatives. This phase is the initial step in studying all related international and national literatures related to tourism, environment, low carbon, and energy. On-site observations of the study areas and interviews with selected key stakeholders, which included owners of tourism businesses and its related enterprises, policy makers and relevant local government officers were carried out in April and July 2012. Eight small and medium hotels in Koh Chang and Koh Mak were visited during those periods. The main objective of this phase is to acquire the baseline information about the study area, and the business owners' opinions about the future LCH project, the nature of their business, their knowledge and understanding about low carbon economy, and business constraints. The expected output from this phase is to obtain a preliminary draft of the LCH guidelines.

Phase 2 involved of the development of categories, indicators and criteria for the draft guidelines, with more detailed survey and interviews. This phase continues the process of data gathering started in phase 1, with literature reviews, and additional surveys adjusted to each study area, actual application, economic competitiveness, and other related concerns. The number of each category, indicators and criteria was taken into account in their scoring and weighing of indicators and criteria. The expected output from this phase is to obtain a detailed draft of the guidelines based on scoring and weighing of indicators and criteria.

Phase 3 was a pilot test of the developed guidelines. Adjustments were also made based on lessons learned and inputs from implementers and stakeholders. The guidelines developed from phase 2 was pilot tested on medium and small hotels. There are 12 selected cases in Koh Chang and 6 selected cases in Koh Mak that were conducted in September 2012. The selected hotels are either small-sized hotels (less than 30 rooms) or medium-sized hotels (more than 30 rooms), must possess working knowledge energy consumption and conservation, having readiness and efficacy for continuous improvement, having interest and good understanding on energy planning for the organization, experienced in energy management, willing to network and exchange knowledge and experiences related to energy and environmental management. The pilot tests were conducted through a causal method shown on Figure 1.

Phase 4 focused on the dissemination of the LCH guidelines and implementation plan and procedure for LCH certification. The purpose of this phase is to present the final draft of the LCH guidelines from phase 3, and to get feedback/suggestions from the key stakeholders such as DASTA, the provincial government agencies, hotel owners/representatives, local governments to further improve the guidelines. A seminar was arranged in Koh Chang in November 2012, where to gather feedback and suggestions from key stakeholder-participants to improve the final draft of the LCH guidelines. The agenda of the seminar focused on two main topics: (1) the appropriateness of the LCH guidelines in terms of indicators and criteria by case of Koh Chang and its

neighboring islands; (2) the implementation plan and procedure for LCH certification. Moreover, the LCH project was also promoted and disseminated to all related key stakeholders during the seminar, and also through its project website (www.lowcarbonhotel.webs.com) that provides some basic information about the project and updates for the project participants.

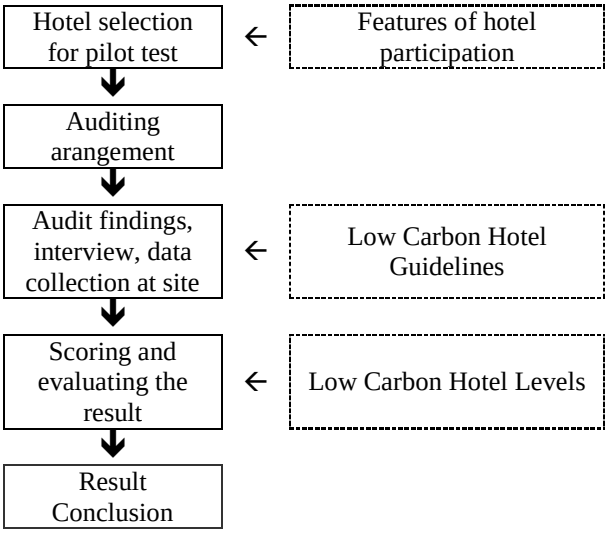

Fig.1. Causal Method for Testing the LCH Guidelines

4. RESULTS

Phase 1 - Literature reviews related to LCH guidelines and standards including survey the areas and interview selected key stakeholders.

A summary of different certifications and standards were reviewed based on existing literature can be found on Table 1. This summary helped shaped the primary draft guidelines used for the area survey. It consisted of the following categories: policy and administration, energy management; transportation; tourism activities and participation; building and nearby area; procurement and inventory management; waste management; water management; and CO_2 emission. The area survey and stakeholder interviews revealed that the guidelines should be universally acceptable and can also promote the image of participating hotels as supporters of sustainable tourism. It also revealed that the guidelines' process should not be complicated in view of hotel operation. Furthermore, the costs of certification should be reasonable and can be afforded and achieved by different sizes of hotels. Lastly, the guidelines should benefit all related stakeholders, including tourists, hotel owners, and communities dependent on the hotel and tourism industry, and the environment.

The characteristics of the hotels in Koh Chang and Koh Mak were revealed to be different. The hotel businesses in Koh Chang are mainly focused on tourism business operation, while the hotels in Koh Mak are focused on alternative energy technology and its application, and family business operation.

Phase 2 - Development of categories, indicators and criteria for a draft of the guidelines, with more detailed survey and interviews

The development categories, indicators, and criteria for the LCH guidelines were carried out through the second phase by adjusting them through scoring and weighing. Eight categories were developed for the guidelines: policy and administration, energy management; transportation; tourism activities and participation; building and nearby area; procurement and inventory management; waste management; and water management. The last category is CO_2 emission, which necessitates further data collection and analysis. The results of scoring and weighing of categories, indicators, and criteria before survey and after survey are shown on Table 2.

Table 1. Certifications/Standards/Projects Summary versus Categories from the Literature

Category	Certifications / Standards/ Projects										
	ECCR	Earth Check	Green Key	Green Seal	Green Bldg.	GTBS	Nordic	Green Globe	GTZ	Thai Energy	Green Leaf
Administration-Management	✓			✓		✓					
Policy-Developing Plan		✓		✓							
Communication-Participation-Society	✓	✓				✓		✓			✓
Purchasing	✓			✓		✓					✓
Environment-Nature-Animals			✓		✓	✓		✓		✓	✓
Energy	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Water	✓	✓		✓	✓	✓	✓			✓	✓
Waste-Waste Water	✓	✓		✓		✓	✓	✓	✓		✓
Building-Indoor Environment	✓			✓	✓					✓	✓
Chemicals-Hazardous Substances-Flammable		✓		✓			✓				✓
Pollution (Air, Sound)					✓			✓			✓
Transportation						✓	✓		✓		
Resources		✓			✓		✓				
Cleaning-Household		✓	✓	✓							
Services			✓								
Indicator Calculation		✓		✓					✓	✓	

Table 2. Developing categories, indicators and criteria for a draft of the guidelines

Categories	Before survey		After survey	
	Indicator	Criteria	Indicator	Criteria
Policy and Administration	5	5/5/5/4/5	2	5/8
Energy Management	4	11/9/9/6	4	7/6/5/6
Transportation	1	5	2	6/5
Tourism Activities and Participation	3	3/4/5	2	1/5
Building and Nearby Area	1	9	3	5/7/7
Procurement and Inventory Management	3	4/3/3	2	5/5
Waste Management	1	10	4	10/5/6/5
Water Management	1	7	2	8/1
CO_2 Emission	4	1/1/1/1	3	1/1/1
Total	23	116	24	128

Category 1 Policy and Administration

Policy and administration of the hotel are important factors that help communicate policies developed from top management or hotel owners to its supervisors and personnel on ground that implement or observe the hotels' policy on low carbon hotel and environmental sustainability. Since some hotels do not have the official written policy (due to having staff from different countries, which may or may not be legally documented), policies are often communicated verbally. However, poor or miscommunication can easily lead their personnel's poor or wrong understaning and interpretation of the rules. Officially written policies in Thai, English and the migrant workers' own languages should be published by the hotel to ensure staff's correct attitude and approach on running and maintainig a low carbon hotel. Meanwhile, many small and medium-sized hotels that are family businesses have simple administration and management systems,. Thus, these type of businesses tend to avoid complicated actions, complex systems, and documentation.

Policy and administration is required in 2 indicators: (1) policies towards low carbon and environmental & social sustainability; and (2) personnel and organization development.

Category 2 Energy Management

Energy consumption is a major concern for establishing low carbon hotels. Electricity expenses remain as one of the largest costs in running a hotel business. Hence, energy management is a key knowledge and skill for hotel operators to effectively and efficiently manage their hotel, in terms of energy expenses, energy consumption control, energy efficiency improvement, energy technology, operation and maintenance, energy policy, and use of renewable energy. Some of the hotels the project visited were still using energy inefficient equipment. Installation of power meters in different areas of the hotels can save, monitor, control and manage energy consumption, and thereby also curb the hotels' CO_2 emission. Energy efficient policies and renewable energy technology should be promoted and campaigned to entice more establishments to follow the principles of a low carbon hotel.

Energy management can be identified into 4 indicators: (1) energy efficiencies; (2) energy consumption for air conditioning system; (3) energy consumption for electrical lighting system; and (4) energy consumption for other systems and use of renewable energy.

Category 3 Transportation

Transportation is directly related on how much carbon is emitted into the environment through vehicular consumption of oil and gas. Alternative fuels such as biofuel or gasohol can help reduce CO_2 emission. However, access to alterative fuel is limited to hotels operating in Koh Chang area since the islands are 8 to 82 kilometers away from the nearest coast. Some hotel operators are also concerned by quality of engine run by biofuels. In the meantime, mass transportation, walking, bicycling, and carpooling can help the hotel being LCH.

According to the guidelines, transportation requires 2 indicators: (1) transportation management; and (2) supporting and persuading measure for an optional reasonable transportation.

Category 4 Tourism Activities and Participation

Supporting tourism activities and participation depends on site area, landscape, and group of tourists. Initiating environmental conservation activities can encourage the growth of eco-tourists, and also may help reduce carbon dioxide emission. Such activities can be in the form of low carbon menu, mountain biking tours, kayaking, among others.

Tourism activities and participation category includes 2 indicators: (1) number of sustainable tourism activities; and (2) participation and support for implementation.

Category 5 Building and Nearby Area

The hotel building and its surrounding landscape are factors related to energy consumption inside building when it is occupied after construction. If the site area and landscape, including green area, are taken into account for building design, then, CO_2 emission can be reduced. Moreover, building management, material construction and technology application also affect energy consumption significantly through more effective and efficient heat insulation, proper window orientation and ventilation, building orientation, and building color and reflectiveness.

Building and nearby area consists of 3 indicators: (1) building design and technology applied for reducing energy consumption; (2) area and landscape; and (3) building management.

Category 6 Procurement and Inventory Management

Procurement and inventory management need a good logistics operation practices to reduce the environmental

impact. More so since all of the goods and, most of the personnel, needed to run the hotel in Koh Chang are taken from the mainland. Sustainable purchasing and inventory or green procurement practices are necessary to take into account in achieving low carbon hotel status. This leads stakeholders to also realize how a sustainable hotel can help in maintaining low carbon emission.

Procurement and inventory management includes 2 indicators: (1) purchasing, materials and inventory management; and (2) reducing procurement and local procurement.

Category 7 Waste Management

Waste management is very important to relieve and reduce the environmental impact caused by wastes. Presently, there are many methods and solutions adapting to reduce the amount of waste, as like as, biogas, bio fertilizer, animal food, reduce, reuse, and recycle method.

Waste management is composed of 4 indicators: (1) Waste management efficiencies, (2) Waste reduction inside the room and bathroom, (3) Waste reduction in service center: kitchen, meeting room, conference room, outdoor activities), (4) Waste reduction inside the office and lobby.

Category 8 Water Management

Proper water management is required to address concern on metered water consumption and data collection, and water use efficiency. This helps hotels to manage and control water consumption of ground water resources in the island.

Water management indicator comprises of (1) water use efficiency; and (2) water consumption per tourist per day.

Category 9 CO_2 Emission

The eight (8) categories as aforementioned are the checklist questionnaire, however, category 9 on CO_2 emission, needs calculation and analysis of historical data from hotel (answerable via detailed questionnaire). CO_2 emission is calculated in accordance with: (1) Power and heat (electricity and fuel usages); (2) transportation (fuel consumption); and (3) waste management based on disposal methods.

Weighting Distribution

After scoring and weighing the criteria and indicators adjustment in according to area survey and stakeholder interviews, the distribution of weight among categories are shown as a bar graph in Fig.2.

The highest weight was given to Category 2: energy management (20%), and Category 7: waste management (20%). Next is Category 9: CO_2 emission which has 15% distribution compared to other categories. Category 1: policy and administration, Category 4: tourism activities and participation, and Category 8: water management were weighted for 10% each. The remaining 3 categories have less significant weights to the total scores of all categories as 5% weight distribution that are transportation, building and nearby area, and procurement and inventory management.

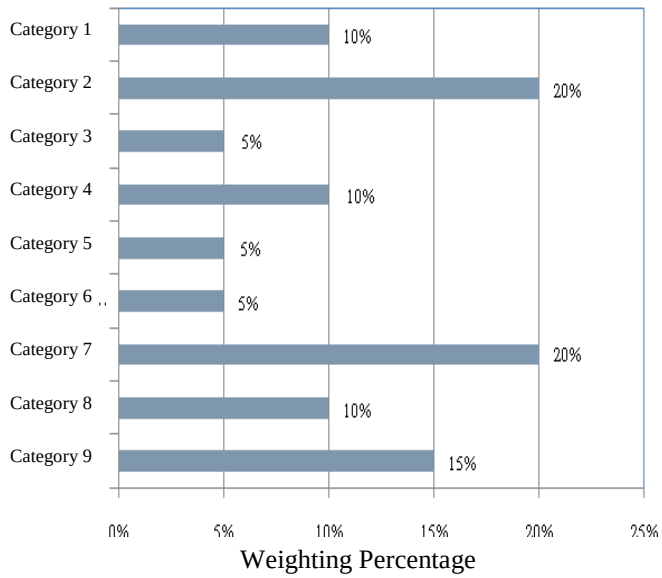

Fig.2. Weight Distribution among the Categories

Phase 3 - Pilot test the developed Guidelines and adjustment per lessons learned

This is a pilot stage of the draft LCH guidelines. Twelve (12) hotels in Koh Chang island and 6 hotels in Koh Mak island were considered for the pilot tests in September 2012. In this study, the LCH was divided into possible 4 levels: Platinum, Gold, Silver and Bronze, and via 2 types of scoring.

Type 1 is based on the overall scores earned from categories 1-8 counting from each score of indicators as presented in Table 3. Indicator 9 was excluded from consideration because of the incomplete data during analysis so that a fare evaluation could be obtained for all participating hotels.

Table 3. Scoring Type 1

Level	Definition	Total Score (%) Of Category 1-8
4 - Platinum	Excellent Low Carbon Hotel	>90
3 – Gold	Good Low Carbon Hotel	80-90
2 – Silver	Medium Low Carbon Hotel	70-80
1 - Bronze	Beginning Low Carbon Hotel	60-70
0-Underweight	Need to improve	<60

Result of pilot test and scoring based on Type 1 is shown by bar chart in Fig.3.

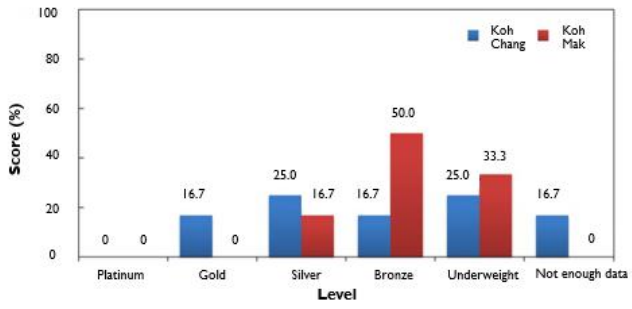

Fig.3. Result of Pilot Test based on Type 1

Based on scoring Type 1, the result showed that there is a normal distribution among the 18 pilot cases. None of the hotels can achieve the platinum level. The total score of hotels in Koh Chang that can achieve the gold level is

16.7%, but none of the hotels in Koh Mak can reach to this level. For silver level, there are 25% and 16.7% scores that the hotels in Koh Chang and Koh Mak can achieve, respectively. The highest score that the hotels in Koh Mak can achieve is 50% for bronze level, while hotels in Koh Chang achieved 16.7% score of hotels in the same level. However, there are some 25% and 33.3% scores of the underweight level of hotels in Koh Chang and Koh Mak, respectively.

Type 2 is based on selected categories for classification with a score of more than 75%, and a minimum score at 50% of each category (see Table 4). It should be noted that category 9 was again excluded based on the same reason. The result of the pilot test and scoring based on Type 2 is shown by bar chart in Fig.4.

Table 4. Scoring Type 2

Level	4 Platinum	3 Gold	2 Silver	1 Bronze	0 Underweight
Definition	Excellent Low Carbon Hotel	Good Low Carbon Hotel	Medium Low Carbon Hotel	Beginning Low Carbon Hotel	Need to improve
Category 1	++	++	++	+	+/-
Category 2	++	+	+	+	+/-
Category 3	++	++	+	+	+/-
Category 4	++	++	+	+	+/-
Category 5	++	++	+	+	+/-
Category 6	++	++	+	+	+/-
Category 7	++	+	+	+	+/-
Category 8	++	+	+	+	+/-
Category 9	++	++	++	+	+/-

++ more than or equal to 75%
+ more than or equal to 50%
+/- less than 50%

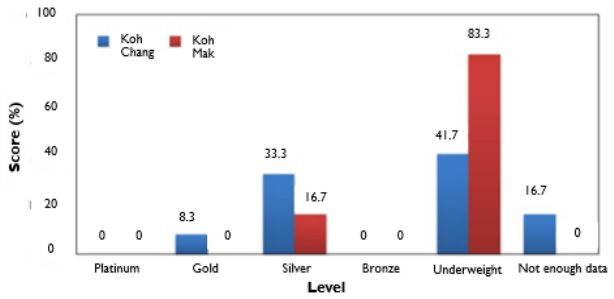

Fig.4. Result of Pilot Test based on Type 2

No hotel in Koh Chang and Koh Mak was able to reach Platinum level and Bronze level. The highest scores are in underweight level - 41.7% for hotels in Koh Chang and 83.3% for Koh Mak. None of the hotels in Koh Mak was also able to achieve the Gold level while the hotels in Koh Chang were able to achieve Gold level up to 8.3%. For Silver level, the total hotels in Koh Chang and Koh Mak gained the scores of 33.3% and 16.7%, respectively.

Phase 4 - Dissemination of the LCH guidelines and implementation plan & procedure for LCH certification

The purpose of this phase is to present the final draft of the guidelines and to get feedback and suggestions from key stakeholders. The seminar had participants comprising of 28 key stakeholders represented by hotel owners or representatives, DASTA, local government, and other agencies. The comments and suggestions can be generally aggregated into two main points:

(1) Appropriateness of indicators and criteria towards low carbon hotels. The feedbacks and suggestions are mainly about energy management concern on how to differentiate the break even point of efficient/saving appliances to electricity saving costs. Suggestions were also raised to consider not using any appliances which emit low carbon according to categories of accomodation. Secondly, the guidelines should also be developed to be able to cover other business sectors such as restaurants. Lastly, in calculating the category of CO_2 emission, the benchmark used as reference for calculation shall be referred universally in the country which the results are able to be compared among each other without any bias.

(2) The implementation plan and procedure for LCH certification. Some organization should be established to handle, promote, and sustain this project in order to persuade parties who are interested in achieving LCH status. As of now, the LCH project is promoted through www.lowcarbonhotel.webs.com. The benefits of participating in the certification process should also be promoted and identified, especially, in terms of global marketing. The project should have a trial that runs for at least 1 year before starting to formally apply and implement it on more hotels, on larger scale (i.e., national and international). DASTA can monitor the feedback and results continuously. When the project starts running, DASTA's responsibities would cover assigning commitee for different sectors and roles that the hotel owners can also attend. The goverment sector should issue supporting policies and lend assistance in some activities related to the LCH concept, together with a training course or seminar.

5. RECOMMENDED IMPLEMENTATION PLAN FOR LCH CERTIFICATION

After getting feedback and suggestions on guidelines, the recommended implementation plan and procedures were divided into 2 main terms:

(1) Overall implementation plan and procedure for LCH as shown in Fig.5. It is divided into 3 steps as follows:

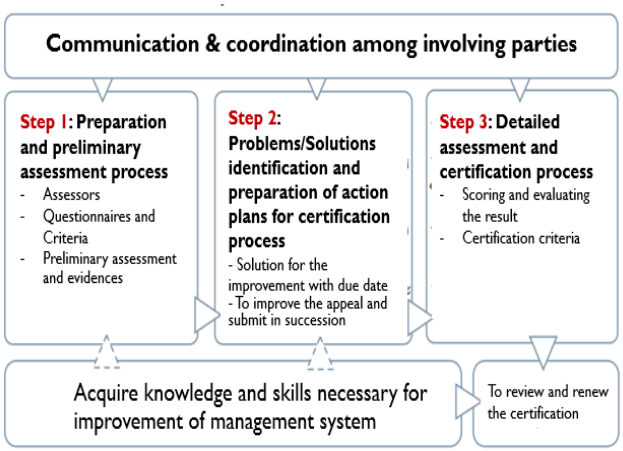

Fig.5. Proposed Overall Implementation Procedure for LCH

Step 1. Preparation and preliminary assessment process is a preliminary stage for the hotel owner to handle the

assessment process by themselves. This can be done by appointing staff to take responsibility towards LCH to prepare documents needed by the questionnaires, and to have an internal evaluation of the hotel based on the questionnaires.

Step 2. Problem/solution identification and preparation of action plans for certification process is according to step 1. Regarding to the internal preparation and assessment, the hotel owner or hotel representatives can find the problems, faults, and solutions through the guidance of the questionnaires and also put up recommendations at the same time when all evidences and documents are submitted to the LCH committee before having a detailed auditing.

Step 3. Detailed assessment and certification process is implemented by an external committee who handle the LCH project to audit and assess the hotel participant, and then, scoring and evaluating the results for certification. Monitoring system will be taken regularly after certifying the hotel with LCH degree.

(2) The supporting certification process requires 4 main elements: format and supporting system; auditor; evidences, data and documents; and certifying and monitoring.

In addition, Fig.6 provides key steps to be taken for certification, according to the suggestions from the dissemination seminar.

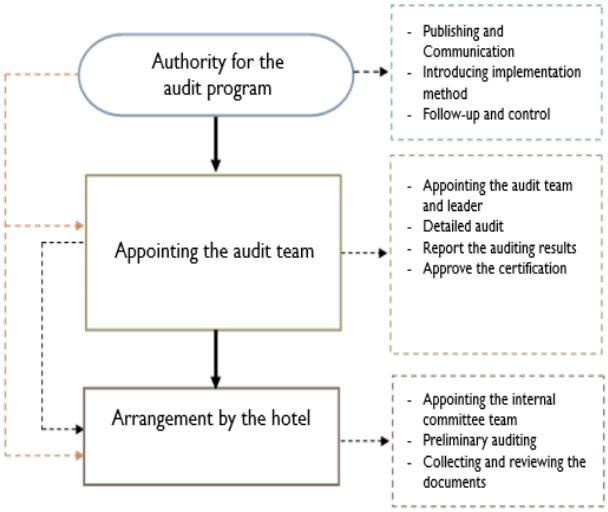

Fig.6. Recommended LCH Certification Steps

6. CONCLUSION AND RECOMMENDATION

The development of LCH guidelines for tourism business in Koh Chang and its neighboring islands lead to a total of 9 categories, with 24 indicators, and 128 criteria, covering policy and administration to CO_2 emission calculation. The guidelines are based on those key factors, and also on good practices indicating low carbon emission within hotel operations and management, such as corporate commitment towards sustainability of tourism industry, energy management, water & waste management, and CO_2 emission to the environment. It is a simple yet effective set of guidelines that will benefit not only to the hotel owners, in terms of cost saving for business promotion and marketing, increase competitiveness and earned recognition, but also to the environment.

The aim of developing the LCH guidelines for the future implementation is to reduce operation expenses, increase hotel competitiveness, and improve environmental quality. These aims need the participation of key stakeholders, in combination if adequate support in terms of legal and institutional frameworks for LCH. DASTA should be the main authority to announce and publicize the LCH project as a trial run project for a period (say 1 year) with potential and willing hotels, so improving indicators and criteria according to the practical use that can be achieved.

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Low Cost Paper-Based and Capillary Tube-Based Microfluidic Systems

Bundit Boonkhao, Pairoh Sohsomboon and Saowanaporn Choksakulporn

Abstract— *Microfluidic systems have advantages on many fields however the cost of fabrication is quite expensive. This paper describes the low cost fabrication of paper-based microfluidic system (PMS) and capillary tube-based microfluidic system (CMS). Both of the systems have been tested with the organic reaction between rose extracted solution (red colour) and bromophenol blue (yellow colour) to obtain blue color solution.*

Keywords— **Microfluidic system, paper based, capillary tube, chemical education.**

1. INTRODUCTION

Microfluidic systems are the study and application of fluid flow inside the narrow channels. Due to the narrow channel (e.g. in micrometer), characteristics of fluid flow represents potential application in many fields. At the present, the microfluidic systems have been widely applied for chemical, biochemical, clinical and medical analyzing equipment. For examples, blood group test kit [1], micromixers/microreactors [2], biosensors [3], and point-of-care device [4]. There are two types of microfluidic systems which are most popular, (1) glass or poly-di-methyl-siloxane (PDMS) based and (2) paper-based materials. For the first type of microfluidic system, the fabrication process is developed from the electronic fabrication process such as lithography and etching processes. These processes are quite expensive in instruments. Therefore, the fabrication on paper is an alternative fabrication process which is cheaper process. However, the applications of paper-based cannot cover all of applications of the first type of microfluidic systems. Hence, in some cases, it is avoidable to use glass- or PDMS-based microfluidic systems.

Due to the limitations of fabrication costs of microfluidic systems, low cost fabrication processes will be proposed in this article. Although there are many applications of microfluidic systems, applying microfluidic equipment in health promotions is limited due to the cost of fabrication. Hence if it is possible to develop microfluidic systems from materials that can be found in common laboratory, it will be advantage for research in these fields. In this article, two types of microfluidic systems, most popular types in microfluidic system, have been developed based on the materials which can be found in the common chemistry laboratory. Paper-based microfluidic system (PMS) and Capillary tube-based microfluidic system (CMS) have been fabricated. The PMS fabrication was adapted from Dungchai et al. [5] fabrication technique. In case of CMS, it was fabricated from capillary tube and resin solutions, which was proposed to use instead of glass- and PDMS-based. The next section will be briefly described fabrication processes and experimental tests of both PMS and CMS. Results and discussions of fabrications and tests are presented in Section 3 and the conclusion will be drawn in Section 4.

2. MATERIALS AND METHODS

Paper-based Microfluidic System

The fabrication of PMS was adapted from Dungchai et al. [5] fabrication technique. While in this work used hot air and sticker instead of hot plate and printed screen pattern, respectively, as a result the fabrication is much cheaper and easier. Fig. 1 illustrates the fabrication procedure of PMS which can be described as follow. A pattern of microfluidic system was drawn on and cut off from sticker. The sticker pattern was placed on a filter paper (Gammaco, Thailand) and then candle wax (candle was brought from local shop) was rub on the paper until it filled all the space. Hot air from hair dryer was blown on to melt the wax through the paper as the channel. Finally, taking the sticker off, PMS was obtained (Fig. 2)

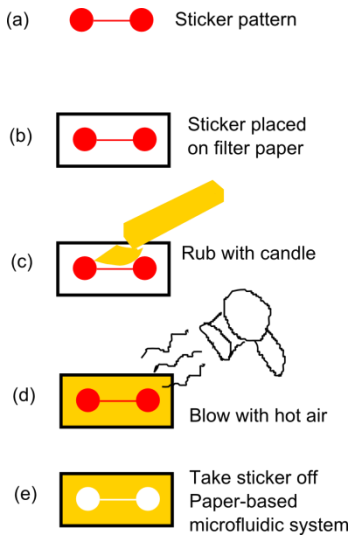

Figure 1 Fabrication process of PMS.

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Figure 2 Paper-based microfluidic systems.

Capillary tube-based Microfluidic System

CMS was fabricated following the procedure as presented in Fig. 3. The capillary tubes were connected to each other as T-type using small rubber tube then at the end of each tube was bended using alcohol burner. The T-type capillary tube was put inside the glass box and filled with the resin solution (unsaturated polyester resin and methyl ethyl ketone peroxide (MEKP) in the ratio 3:1 v/v). Wait until the resin settling (about 1 hr) then take the glass box off, the CMS prototype was obtained (Fig. 4a). Finally, installing input devices (syringes) into the end of the tubes, CMS was ready to use (Fig. 4b).

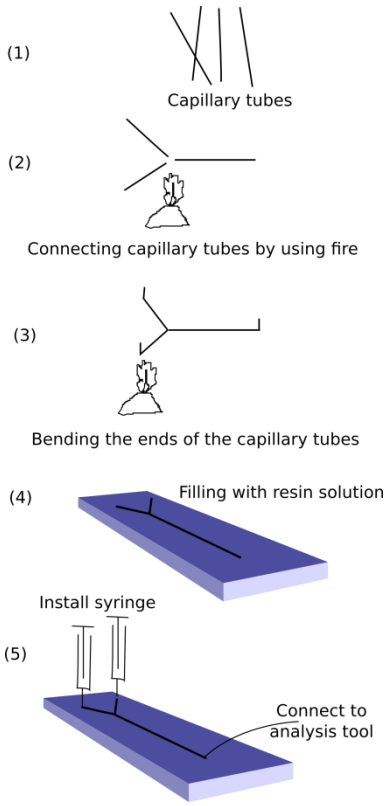


Figure 3 Fabrication process for CMS.

Experimental Tests

Experimental testing of both PMS and CMS were tested by running organic reaction between rose extracted solution (red colour) and bromophenol blue (yellow colour) to obtain blue colour solution. The extracted solution was prepared by collecting rose 10 g. Mincing by using mortar and extracting the rose with distillation water 100 ml. The indicator solution was prepared by dissolving bromophenol blue 0.1 g in distillation water 100 ml.

(a)

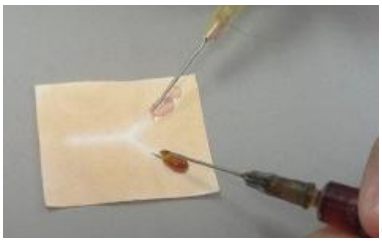
(b)

Figure 4 (a) CMS prototype (b) CMS prototype installing with syringes for injection.

3. RESULTS AND DISCUSSTIONS

Paper-based Microfluidic System

Experimental test of PMS was done by organic reaction between rose extracted solution (red) and bromophenol blue (yellow). Y-type of PMS was prepared following the step as presented in Fig. 1. Then small drops of rose extracted solution and bromophenol blue were dropped on the sample zones. The detection of reaction is observed by colour changing when both solutions are mixed together. As can be seen that the reaction was occurred in Y-type PMS where the colour was changed to blue colour.



(a)

(b)

Figure 5 Organic reaction between extracted rose solution and bromophenol blue.

Capillary tube-based Microfluidic System

For the case of CMS, the experimental test was done similar to PMS. The solutions were injected into the CMS via syringes. The reaction was occurred while both solutions meet each other and the colour was changed to blue colour.

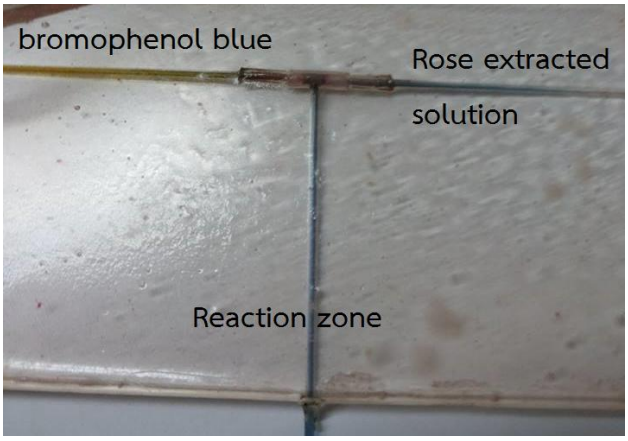


Figure 6 Reaction observation between extracted rose solution and bromophenol blue.

4. CONCLUSION

Low cost paper-based and capillary tube-based microfluidic systems have been developed. These systems can be fabricated from the simple materials that can be found in common laboratory. These are just only prototype of PMS and CMS. For the future research, they will be extended for the applications in health promotions.

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Ram Mamuat: A Reconfirmation of Thai-Khmer Cultural Identity in the Healing Ritual Context

Poonnatree Jiaviriyaboonya

Abstract— *Ram Mamuat, is a healing ritual performance in Northeastern Thailand, which largely exists in the Thai-Khmer border provinces including Sisaket, Surin, and Buriram. This paper applies theoretical discussions on ritual analysis including ritual symbols and ritual actions, to study the larger context of the Ram Mamuat ritual, including ritual functionaries, ritual structure, and ritual offerings. The researcher combines two research methods, including formal and informal interviews, plus participant observations, which took place at a Thai-Khmer village of Sisaket Province, and the city of Surin. The ethnographic data indicates that the Thai-Khmer ethnic group who calling itself Khamen Sung (Northern Khmer) practice Ram Mamuat for the veneration of their ancestral spirits, called Phi Puta. Additionally, the concept of Khru and Mamuat plays a major role in the local religious cosmology of the Khamen Sung group. A previous ethnography studied the Mamuat ritual as a way of alternative health management for the Khamen Sung group. This paper, however, will approach the Mamuat ritual as a system of symbolic action for conceptualizing the local religious worldview, as well as for constructing the ethnic identity.*

Keywords— **Healing Ritual, Thai-Khmer, Mamuat, Ethnic Identity**

1. INTRODUCTION

The religious cosmology and practice of villagers in northeastern Thailand has been studied in-depth by many scholars; however, healing ritual performances, particularly in Thai-Khmer communities, have not been examined in their contemporary contexts. The *Ram Mamuat* ritual has been studied by scholars who approached *Ram Mamuat* as an alternative health management of the Thai-Khmer ethnic group. However, this paper focuses on the larger context of the *Ram Mamuat* healing ritual, which includes ritual symbols, ritual actions, and ritual offerings.

The following research questions will guide this research project: first, how does the Thai-Khmer ethnic group in northeastern Thailand construct its identity through ritual practice? Second, how do the important aspects of ritual performance, such as ritual structure, ritual functionaries, and ritual offerings symbolize the local religious worldview of the Thai-Khmer group?

2. RESEARCH METHODS

This research is based on two methodologies that include library research and fieldwork during summer 2011. The fieldwork research took place in two settings: Ban Samrong Phlan village, Phraibeung sub-district of Sisaket Province, and the city of Surin Province as the second place. The two month fieldwork research is based on participant observations, as well as formal and informal interviews. Ethnographic data were derived from interview 35 key informants who are native to Sisaket and Surin, speak Northern Khmer dialect, and have experiences with the *Ram Mamuat* ritual. Additionally, the participant observed the ritual event and conducted in-depth interviews with the ritual functionaries, such as mediums, musicians, and ritual participants in a Thai-Khmer village of Sisaket Province.

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3. REVIEW of LITERATURE

3.1 Religious Cosmology in northeastern Thailand

Tambiah (1970) describes village religion in traditional Southeast Asian society, particularly in northeastern Thailand. Such village cosmology relies on aspects of Theravada Buddhist ideology and on the indigenous belief in guardian spirits. Keyes (1977: 115) agrees with Tambiah that Buddhism and animism belong to a single religious system according to the northeastern villagers' understanding. Keyes (1977: 114) explained, in detail that Theravada Buddhists focus their religious practice on spiritual rites rather than reaching the ultimate goal of Buddhism.[1] Nirvana, however, is "a remote goal" and not realistic for villagers, monks, or laity due to the difficult path to achieve purity (1977: 86). Buddhism provides for an alternative goal called *Bun* (merit), which is related to the Law of Karma; this goal allows individuals to reduce their life's suffering through realistic acts of *Tam Bun* (merit making).

In addition, Tambiah (1970: 338) discussed the structure of the local religious worldview of Isan villagers of northeastern Thailand. The primary religious concepts of the Isan villagers include *Bun* (merit), *Bap* (demerit/sin), *Khwan* (spiritual essence or vital essence), and *Winyan* (spirit) (Tambiah 1970: 339). As previously stated, the concepts of *Khwan* and *Winyan* are particularly significant in local conceptions of illness. The Buddhist

[1] This ultimate goal of orthodox Buddhism is Nirvana, which means that the individual can reach absolute purity and escape suffering and Karmic rebirth by the extinction of self (Keyes 1977: 86).

rites, such as the calendrical rites and rites of passage, are arranged by Buddhist monks and *Phram* or *Mo Khwan (*village elder or ex-monk), and are associated with *Bun* (merit) (Tambiah 1970: 339).[2]

However, the rites for perpetuating the guardian spirits and malevolent spirits, such as the collective agricultural rites (*Sukhwan* rites), rites of affliction, and exorcism are associated with *Bap* (demerit) and require ritual specialists including *Mosong* (diviner), *Motham* (exorcist), *Thiam* (medium), and *Cham* (intermediary) (Tambiah 1970: 338-339). Tambiah (1970) further suggested that most guardian ritual spirit offerings are associated with the Buddhist concepts of collective merit making (*Tham Bun*), the law of Karma, merit and demerit (*Bun* and *Bap),* and the practice of the five precepts (*Sin Ha*), which are the key components of the Isan ritual offerings.

The belief in guardian spirits is found in every village throughout the region (Vallibhotama 1999; Tambiah 1970). According to Tambiah, there are two different guardian spirits, the guardian spirit of the village (*Phi Ban*) and the guardian spirit of the Buddhist temple *(Phi Wat*). *Tapuban*, or *Phi Ban,* is the guardian spirit who protects the cultural norms and property of the village. [3] In contrast, *Chao Pho Phra Khao,* or *Phi Wat,* is a guardian spirit who protects the Buddhist temple's property. [4] The concept of the guardian spirit is an important core value of the founders' cult ideology in Southeast Asia. Tannenbaum and Kammerer (2003) contributed to the examination of the crucial concept of founders' cult ideology. This work is significant for a comparative examination of the Thai-Khmer founders' cult ideology.

3.2 Previous Ethnographic Studies on the Ram Mamuat ritual

Phratheep Khaeram (1992) and Theeraporn Namthong (2008) signify to understand the common features of *Ram Mamuat* ritual. Khaeram (1992) studies *Ram Mamuat* in the city of Burirum and conceptualizes *Ram Mamuat* as a traditional healing ritual which plays a major role on both individual and the societal levels. Khaeram (1992: 3) further emphasizes that individuals can get sick if they forget to redeem their vows to ancestral spirits. On the other hand, ancestral spirits have spiritual power to cure individuals from illness when the *Ram Mamuat* ritual is performed (Khaeram 1992: 3). Last but not least, Khaeram (1992) points out that the veneration for ancestral spirit during the ritual helps sustain social solidarity among the Thai-Khmer ethnic group.

Furthermore, Theeraporn Namthong (2008) studied the *Mamuat* ritual as kind of alternative health management, and as cultural reproduction for the Thai-Khmer ethnic group. Namthong (2008: 184) goes further than Khaeram's ethnography (1992) in order to approach the *Mamuat* ritual as "a tool of Thai-Khmer villagers" for formulating identity. According to Namthong (2008: 189), *Ram Mamuat* is a cultural reproduction of the local belief system of the Thai-Khmer ethnic group, which is based on Buddhism, Brahmanism, and spirit-worship. Additionally, the *Ram Mamuat* ritual strengthens the relationship between patients, families, and relatives, as well as reconciling the conflict between humans and ancestral spirits (Namthong 2008: 189). The Thai-Khmer villagers believe that super natural powers can cause illnesses, which can be seen as the quarrels and fights between patients and their ancestral spirits (Namthong 2008: 189). The conflict between humans and ancestral spirits, however, can be solved by the ritual, which leads by *Mae Khru* and *Mamuat*, the ritual functionaries who play major roles in conducting the ritual. Last but not least, Namthong (2009: 189) proposes that *Ram Mamuat* helps establish the identity of patients, because the ritual contains the process of illness diagnosis which associates with the background and circumstances of patients. The process of diagnosis also allows family members and relatives help patients recognize their life histories which are associated with their "roots" (their ancestral lines). In other words, the Thai-Khmer villagers identify themselves as the grandchild, who originated from the same ancestors, which helps formulate the collective identity (Namthong 2009: 189).

The previous ethnographies studied the *Ram Mamuat* ritual primarily focusing on the structure and function of the ritual that help to establish social solidarity as well as to symbolize social organization of the Thai-Khmer ethnic group. Namthong (2008) goes further than Khaeram (1992) in order to suggest that the *Ram Mamuat* ritual can be seen as alternative health management, and as a symbolic tool for building collective identity. This paper, however, focuses on the confirmation of the Thai-Khmer ethnic identity through the ritual context.

3.3 Theoretical Frameworks

Ritual Structure and Ritual Symbol

Van Gennep's *The Rites of Passage* (1960) suggests that transition rites have three phases: separation, liminal, and aggregation (1960: 7). Transition rites bring about a transformation in state, status, and condition. Van Gennep (1960: 9-11) also argued that life cycle rituals, agricultural rites, and annual rites are examples of the rites of passage that bring about transformation in the state, status, and condition of individuals and communities.

Van Gennep defines the separation phase as the first state in which there is a separation from the previous state, status, and condition (1960: 9-11). A common characteristic of the separation phase is that it is often symbolized by a change in physical space, clothing and purification rites (1960: 8). According to van Gennep (1960: 8), the liminal phase represents a state that is between and betwixt the previous and the new states, statuses, and conditions. The liminal phase is associated with notions of boundaries between the human and spiritual realms, the danger from spirits, the reversal of normal behavior, and special privileges (1960: 8-9). Van Gennep (1960: 8-9) further argues that the transformation to the new state, status, and condition occurs during the

[2] *Phram* or *Mo Khwan* is a village elder or ex-monk who performs the *Khwan* rite.

[3] *Tapuban* is combined with different kinship terms and meanings. In Thai, *Pu* means the grandfather from the Father's Father side while *Ta* means the grandfather from the Mother's Mother side. *Ban* means a house or a village. In the local cosmological belief system, *Tapuban* refers to the spirit of grandparent, ancestor, or the founder of the village. Vallibhotama (1997: 63) further explains that the *Tapuban* is a *Phi* of a layman who prefers secular food such as meat, chicken, and liquor.

[4] *Chao Pho Phra Khao* means a monk or a holy man who dresses in white. *Chao Pho Phra Khao* has a special link with Buddhism as a Buddhist follower. *Chao Pho Phra Khao* prefers a special food called *Pawan* (a mixture of sticky rice and sugar) along with sweet beverages such as commercially produced, colored, sweetened water and soft drinks (Vallibhotama 1997: 63).

liminal phase. Aggregation is the last phase of the ritual process, when the community reintegrates in their new state, status, and condition (van Gennep 1960: 8-9).

Bloch (1992: 6) agrees with van Gennep (1960: 7-9) that all rituals have a three-phase structure. However, Bloch (1992: 6-13) argues that the liminal phase is a significant component of the ritual, because the transformation of the entire community occurs in the liminal phase through the direct interaction with the ancestral spirits. Bloch (1992: 6-16) explaines that the transformation and spiritual revitalization of the whole community occurs not only through the transfer of spiritual potency from the ancestral spirits to the community, but also through the reunification of the community with their deceased kin. Bloch (1992: 6-16) emphasizes that these transformative actions are completed in the liminal phase. Bloch (1996: 15-16) argued that the entire community is involved in the process of transferring spiritual and life potencies through the direct interaction with spirits in the liminal phase, and the entire community will aggregate in the last phase of the ritual as a new community. Based on van Gennep's *The Rites of Passage* (1960: 7-11), I argue that there are three phases in the *Ram Mamuat* healing ritual, and my analysis will focus mainly on the significance of the liminal phase. I will emphasize Bloch's (1992: 15-16) arguments on the importance of the liminal phase in the *Ram Mamuat* ritual.

The Thai-Khmer Ethnic Identity in a Theoretical Context

Stuart Hall's (1990: 223) discussion of "Cultural Identity and Diaspora" suggestes two approaches for examining the formation of identity. First, he argues that one must understand cultural identity as being "one's true self," which is evident in the cultural markers of the people in society, including common elements such as shared history and ancestry (Hall 1990: 223). Second, cultural identity refers to the process of "becoming as well as being" and understanding "who they are" from the perspective of differences and similarities among the people in society (Hall 1990: 225). Hall's approach to cultural identity helps answer the question "Who are the Thai-Khmer?" Hall suggests that cultural identity shifts in the way indigenous people identify themselves as an ethnic group and in relation to the nation-state. The notion of cultural identity is a product of the specific history, language, and culture that shapes worldviews and the actions of individuals (Hall and du Gay 1996: 4). Therefore, the formation of ethnic identity is historically and culturally constructed through the interaction between agents (Hall and du Gay 1996: 15).

The concept of ethnicity is situational and can be defined as regional or national identity, in accordance with a common language, religion, and cultural heritage (Smith and Young 2005: 163). Additionally, ethnicity as a relational concept refers to a relational action between the "dominant" (the nation-state) and the "subordinated" (Wilmsen and McAllister 1996: 8). Thus, ethnic identity can be formulated based on its relation to the national identity. The Thai state defines the Khmer people as a vassal state who "lost territories" to the French and labels the Thai-Khmer people as a "non-Thai ethnic group" (Denes 2006:4). In order to foster a Thai national identity, the Thai government tries to impose a large number of assimilation projects such as teaching the Thai national language (Kammerer 1988: 278).

People who self identify as "Thai-Khmer" do so based on local ethnic markers, including racial background, historical and cultural heritage, and language (e.g., the Northern Khmer dialect) (Tambiah 1996). Ethnic identity is associated with specific local worldviews and sentiments that are expressed through ethnic cultural practices, such as religious rituals, cuisine, costume, commensality, and food sharing (Tambiah 1996: 140-141). Following this argument, the *Ram Mamuat* healing ritual as an "ethnic ritual" may reveal the Thai-Khmer ethnic identity through language, ritual actions, ritual offerings, and the performance of ritual functionaries.

4. ETHNOGRAPHIC DATA

Ram Mamuat is a traditional healing ritual which exists in the three Thai-Khmer bordered provinces: Surin, Sisaket, and Buriram. These three provinces reveal a variety of multi-ethnic groups, including Khmer, Kui, Suay, and Lao-Isan people. The people who identify themselves as *Khamen Sung*[5], are also identified as "Thai-Khmer ethnic" by the scholars—these all refer to indigenous people who speak the Northern Khmer dialect. Most of the Thai-Khmer believe in Theravada Buddhism; however, the belief in ancestral spirits also takes a key role in their religious belief system.

The *Ram Mamuat* ritual will be held by a community or a family, depending on a time and occasion. The first occasion of *Ram Mamuat* is held once a year during the harvest season (March-April), which allows the whole community to be involved. The second yearly occasion of the *Ram Mamuat* ritual is arranged by the *Khamen Sung* for the healing of illness.[6] In mid-June 2011, the *Ram Mamuat* ritual was arranged during the rainy season, which was "out of the season" for arranging the ritual. Miss Phon[7] became the host of the ritual, because her son was sick from headache and had not recovered from modern medical treatment. *Phon* asked the *Mo Song* (diviner) to diagnosis the cause of illness. The *Mo Song* explained that her son got sick because she used to ask for help from *Phi Puta* when she was young but had neglected to fulfill her vow. The *Khamen Sung* people call the process of diagnosis by the *Mo Song* as *Pai Bol* in Khmer or *Sieng Thai* in Thai which both mean the process of predicting the cause and outcome of any situation. The *Mo Song* determines the diagnosis by using eggs, or a portion of rice which are kept in the small tube called *Ok Kamon*, which the *Khamen Sung* people use as a tool for investigating the cause of illness. After reading the form of eggs or a small portion of rice, the *Mo Song* insisted that *Phon* had neglected to redeem her vow for *Phi Puta* which brought the illness to her son. *Phon* considered

[5] The villagers who stay in the Thai-Khmer bordered provinces include Sisaket, Surin, and Buriram, and speak the northern Khmer dialect call themselves as *Khamen Sung* and call Khmers in Cambodia as *Khmen Tam* because of the geographical circumstance. In Thai meaning, *Khamen Sung* means Khmer people who stay in the upper land while *Khamen Tam* means the Khmer who stay in the lower land. According to the geographical condition with comparing Thailand and Cambodia, Thailand remains as an upper land while Cambodia remains as lower land.

[6] Besides recovering from the illness, the ancestral spirits; however, brings a good luck for decedents in order to bless descendants to get the winner from the lottery.

[7] All key informants' names are replaced by pseudonyms to maintain anonymity.

arranging the *Ram Mamuat* ritual in which she dedicated herself as being *Mamuat* or the spiritual medium in the ritual. *Phon* continues the conversation:

"…I held the *Ram Mamuat* ritual because my son was sick from headache and couldn't recover from the medical treatment from the hospital. I recognized that I was to make a vow with *Phi Puta* asking for help which I couldn't remember what it was…but I haven't redeemed the vow to *Phi Puta* yet, and this could be the reason why my son was sick…"

The ritual event started in the evening of the first day and finished at noon of the second day. A key ritual functionary called *Mae Khru* (mother teacher) is a master of the *Ram Mamuat* ritual, who led the ritual host in conducting the *Wai Khru*, or *Ang Tuang Khru*[8] ceremony that is an important step before the spiritual possession of the medium. *Mae Khru* and *Mamuat* conducted the *Wai Khru* ceremony in order to invite the spirit to possess them, and to send the spirits back to the spiritual realm. The spiritual medium offered *Khan Ha Khan Paet* for venerating the spirits. *Khan Ha Khan Paet* consists of a small metal bowl with a small portion of rice, flower, banana leafs, money, and a candle. *Khan Ha Khan Pad* functions as an intermediary between the human and spiritual realms. The *Wai Khru* ceremony begins when the spiritual mediums touch the edge of *Khan Ha Khan Paet* with two hands, and they concentrate the candle inside the metal bowl. During that time, the musicians and the singers called *Charieng* perform the music with *Khaen*, *Krap*, and *Ching*[9]. The *Charieng* will sing a song in northern Khmer dialect. The spiritual mediums conduct the *Wai Khru* ceremony, which act the same pattern in order to let the participants know that the spirits of *Khru Kam Neut* and *Phi Puta* already possess them. The spiritual mediums press and rub the metal bowl on the floor while their bodies begin to tremble. When the spiritual mediums are possessed by spirits, they throw the *Khan Ha Khan Paet* away and start dancing.

4.1 The Conceptualizations of the Phi Puta and Khru Kamneot from a mystic narrative of the Mamuat

The Khamen Sung villagers conceptualize the *Phi Puta*[10] as the ancestral spirit who was the founder of the whole village. The Khamen Sung believe that *Phi Puta* will transfer life potency in order to protect them from the malevolent spirits. Moreover, the Khamen Sung believe that the *Phi Puta* can bless the agricultural potencies, especially the rice fields. For instance, the *Phi Puta*'s shrine was settled at the center of Ban Samrong Phlan village that was surrounded by the rice field. Looking from the outside, the *Phi Puta*'s shrine is similar to the villagers' houses but smaller. The shrine is connected by four concrete posts, which temporarily roofed with a natural colored of unbleached white cloth. Inside the shrine, there are the cement statutes of *Phi Puta*, which are separated by gender, male and female.[11]

The figure of the *Phi Puta* spirit is; however, ambiguous in terms of origins, name, and gender. Miss *Bua*, being a *Mamuat,* who narrated her dream which was associated with *Phi Puta*. *Bua* said:

"I have been the *Mae Khru Mamuat* since I was 60 years old. I was possessed by the *Khru* of *Phi Puta* spirit, which is a regular spirit for the house and the village. *Khru* of *Phi Puta* will come to the patients' houses and help them recover from illness. The *Khru* of *Puta* spirit appeared in my dream and revealed a big figure, dressed in a black shirt. His name is "Ta Kamhaeng Chatien"[12]

According to Bua, the *Khru* is used as the cosmological term, to refer to the spirit, which belongs to individuals. Based on Bua's statement, the *Khru* not only belongs to humans but also to the *Phi Puta* spirit. Another *Mamuat* named *Somchit* told about another interesting occurrence, she was possessed by the *Khru* of a baby. As *Somchit* expressed it:

"The *Khru* of a baby who I recognized as son of my neighbor." When the *Khru* of that baby possessed me, I was acting like a baby (smile), I spoke like a baby, and asked for the toy car, which is exactly what my neighbor's son likes to do."

4.2 Pan Choul Mamuat13: When Mamuat was possessed by spirits

The *Khamen Sung* villagers conceptualize the term *Pan Chon Mamuat* , which means the spirit possess the spiritual medium called *Mamuat*. The *Pan Chon Mamuat* started with *Mae Khru*, who is the first ritual functionary to contact with the spiritual world, then is followed by other mediums *(Mamuat)*. During the dancing with spirits, all spiritual mediums will change their clothing in many different colors. When *Mamuats* change their clothing, it means that they are already possessed by the spirits. The ritual functionaries explained that they were possessed by different spirits. One of the the *Mamuat* said:

"There are many different *Winyan* [spirit] to possess me. I have had the spirit of *Khru* [*Khru Kamnoet*], ancestral spirits, even the malevolent spirit who doesn't have any family."

During the dancing period, I further observed that the female spiritual mediums acted differently from their ordinary selves. A 70 year-old *Mamaut* spoke and urinated like a man, and preferred to wear the black clothing which implies masculinity. One of the ritual participants made the observation*:*

"Have you seen a *Mamuat* who was in black shirt (pointed at her)? We [ritual participants] know that she was possessed by a man spirit who was a member family

[8] *Wai Khru* is a Thai term and *Ang Tuang Khru* is a Khmer term, which both indicate the ceremony in which Khamen Sung people offer respect for the ancestral spirits. This paper; however, will use the term *Wai Khru* for the entire paper.

[9] *Khaen* is a mouth organ which is used in the Isan region (northeastern) Thailand. *Krap* is a clapper. *Ching* is a part of small thick cymbals joined by a cord which is mostly used to mark time.

[10] *Puta* has different kinship terms and meanings. In Thai, *pu* means the grandfather from the father's side while *Ta* means the grandfather from the mother's side (Vallibhotama 1999). In Khmer, *pu* means "uncle" and *ta* means "grandfather" from either the father's or mother's side. http://sealang.net/khmer/dictionary.htm (Apil 24, 2011).

[11] I should note that the *Khamen Sung* villagers also decorate the Phi Puta's shrine with the other sacred objects, such as the small Buddhist statue, Luang Pho Khun (the well-known Isan monk), Nang Guak (the woman spirit who helps increase the financial potency), and Som Det Ya statue (Somdet Phrasinakharinthra Borommaratcha Chonnani, or the Queen Mom of the King Rama IX) that can represent the local religious cosmology.

[12] The word "chatien" in the Northern Khmer dialect means the big India rubber tree.

[13] The *Khamen Sung* villagers sometimes call the *Ram Mamuat* ritual "*Pan Choul Mamuat*." The Khmer dictionary defines "Choul Mamuat" (ចូលមមាត់) the same as "Choul Ruup" (ចូលរូប), which means spirit possession. http://sealang.net/khmer/dictionary.htm (April 23, 2011).

of Phon's neighbor [the ritual host]. You can see that her [the black shirt *Mamuat*] has a male voice and she can tell the inside story about the origin of the neighbors' house and property. I mean the house which is next to the ritual altar's house. That spirit [the men spirit from the neighbor house] was passed away a long time ago, but we still recognize him because we can guess from his actions."

At this point, symbolic actions such as changing clothing, voice, and urinating like a man that symbolizes the gender differentiations that occur during the spiritual possession. One can see the spiritual mediums identified themselves differently from the distinct identifications depending on gender and kinship relations.

At midnight, the ritual host, the ritual functionaries, and ritual participants had the communal meal called *Sibai Palom Pali*. After the communal meal, the ritual functionaries returned to dance until 7 a.m. The *Pho Khru* and *Mae Khru* will negotiate with the *Charieng* or the ritual singer and the musical band about the rent for musical instruments such as Khan, Krab, and Ching. Next, the *Mae Khru* will arrange the *La Khru* ceremony again for sending the ancestral spirits and other spirits back to the spiritual ream. After conducting the *La Khru* ceremony, the ritual functionaries and ritual participants will have the second meal together. The next step, *Pho Khru* will generate the ritual offerings such as meat (chicken or beef), *Gaeng Hua Pli* (banana blossom soup), and *Khao Tom Sabong* (sticky rice with coconut milk and sugar).

5. ANALYSIS of RITUAL STRUCTURE

The *Ram Mamuat* ritual reveals a specific ritual structure. After the process of diagnosis, the host of the ritual will contact the ritual functionaries who are the master of the *Ram* Mamuat ritual, including *Mae Khru* and *Pho Khru* or *Song Meung*. Both *Mae Khru* and *Pho Khru* are the master in *Ram Mamuat* ritual, but are responsible for different functions. *Mae Khru* can contact with *Phi Puta* and *Khru Kam Neut* spirits directly. Mae Khru will lead other spiritual mediums in performing the *Wai Khru* ceremony in order to invite spirits to possess the medium as well as send them back to the spiritual realm. *Mae Khru* is not only a master of spiritual mediums (*Mamuat*) but also plays a key role in recruiting other spiritual mediums from the village. *Pho Khru* or the father teacher, also called *Song Meung*, is responsible for preparing the ritual altar, ritual pavilion, ritual offerings, and generating the offerings to other villagers.

At this point, I would like to emphasize the important findings that *RAM MAMUAT* defines the concept of healing in two instances. First, the Thai-Khmer villagers ask for healing the illnesses because they transgress the basic values and norms of the village. If the villagers fail to express gratitude toward their ancestral spirit called *Phi Puta* and the guardian spirit called *Khru Gamned*, they will become sick. Second, the *Ram Mamuat* ritual allows the whole community to become involved in the ritual. I argue that their involvement might help reconfirm the Thai-Khmer ethnic identity. In addition to the aspect of healing, Thai-Khmer villagers sometimes ask the spirits to bless them success in winning the lottery.

5.1 The Analysis of Ritual Symbol

Chuam Khru: A Ritual Symbol of the Ram Mamuat healing ritual

There are multiple meanings of the ritual offerings, but a certain offering can be a dominant ritual symbol. In this paper I apply the theoretical concept "the dominant ritual symbol" proposed by Victor Turner (1967) to explain how the *Khmen Sung* villagers conceptualize the religious worldview through the ritual symbol.

Victor Turner (1982; 1967) suggests that the meaning of ritual is derived from the analysis of ritual symbols. Turner defines a ritual symbol as the smallest unit of ritual, which stands for the specific properties of a ritual behavior (Turner 1982: 19; 1967). Additionally, Turner argues that ritual performances make social symbols "visible," which allow indigenous people to interpret symbolic abstraction in their own religious worldview (Turner 1999:184; Turner 1965). While the ritual symbol involves social action or social processes, the dominant symbol of ritual associates with the interaction within a group (Turner 1982: 22).

This paper proposes that *Chuam Khru* is a ritual symbol of the *Ram Mamuat* ritual because of its meanings, which are interpreted by the Thai-Khmer people. They believe that individuals have different types of *Chuam Khru*, depending on the form of birth and the age range of each individual. The Thai-Khmer villagers have to invent *Chuam Khru* and put it on the top of the pole house which stands in the middle of the ritual altar.

The *Chuam Khru* symbolizes ancestral spirits who protect newborn babies from illness caused by malevolent spirits. Individuals have different types of *Chuam Khru* depending on the form of birth and the age range. A special *Chuam Khru* will be made for special people who were born with the placenta or *Sai Rok*. The Thai-Khmer people believe that the babies who born with placentas have a spiritual power. *Chuam Khru*, for instance, symbolizes the mystical power of individuals born to have with a special talent. Furthermore, individuals possess different *Chuam Khru* depending on the age range. *Chuam Khru* for the young generation has a form distinct from that of the senior generation. The parents put the *Chuam Khru* of the new baby in front of the house to announce that they have the new born baby. The *Chuam Khru* for the newborn baby is made from a coconut shell which is painted with turmeric essence, decorated with *Bai Phlu* (Betel leaf), and including some cigarettes, palm, joss sticks, and candles. This is made to be kept permanently, because the parents will make a new one when they have the new baby. Additionally, the Thai-Khmer people believe that *Chuam Khru* can be used for blessing the new baby. The parents will put the *Chuam Khru* on the top of the bed for making an offering to ancestral spirit on the Buddhist Sabbath day, in order to help the child recover from illness caused by malevolent spirits.

At this point, this paper proposes that the multiple symbolic meanings of *Chuam Khru* can be categorized as natural and cultural symbols. The *Chuam Khru* is associated with the human nature of birth as well as with the social organization of the *Khamen Sung* community. The junior-senior relationship is significant in order to understand the social relationships in both human and spiritual realms. Lastly, *Chuam Khru*, which is represented in a bird figure called "*Chuam Nok*," symbolizes the arrival of a new member in society, and also symbolizes the rebirth of the whole society.

5.2 The Discourse of Ethnic Identification in Ram Mamuat

In addition to the analysis of ritual symbols, I will also elaborate how the Thai-Khmer villagers conceptualize their identity through the ritual practice. At this point, I apply the theoretical concept of "Cultural Identity" proposed by Stuart Hall (1990), in order to explain the formulation of the Thai-Khmer ethnic identity.

Hall (1990) suggests that the cultural identity shifts in the way indigenous people identify themselves as an ethnic group and as a part of a nation-state. The notion of cultural identity is a product of the specific history, language, and culture that shape worldviews and actions of individuals (Hall and du Gay 1996: 4).

As the "outsider" who can speak Khmer at basic conversational level, I also spoke central Thai and Lao-Isan dialect to aid in lessening the confusion of translation. The *Khamen Sung* villagers had to correct and clarify the conversation during the interview sessions. I observed that the Thai-Khmer villagers speak Northern Khmer dialect during their daily lives, at both public and private settings, and of course at the ritual event. Based on the ethnographic data, the Thai-Khmer villagers in Surin and Sisaket provinces speak the Northern Khmer dialect over the ritual process.

As observing the *Khamen Sung* villagers in Surin and Sisaket, they mostly spoke the Northern Khmer dialect at homes, at market, and at the office. However, the *Khmen Sung* villagers have to speak Thai at schools and workplaces due to the assimilation policy towards minority groups, administered by the Thai government (Denes 2006: 4). Teaching the Thai national language is an example of the assimilation projects. Thus, all ritual functionaries and participants identified themselves as part of the Thai nation state, called themselves "Thai" and refused to be the Khmer or the Thai-Khmer.

I am a hundred percent Thai [smile]. You can prove it because I have the Thai ID card and hold the Thai passport. As a Thai citizen, I know that I have the right to vote. And as a Thai, we [Thai] have to vote for good politicians who will develop our country [Thailand] and community [Surin]. And as Thai, of course, we [Thai] have to love, respect, and be grateful to the King [King Rama IX].

Furthermore, the Thai-Khmer villagers define the root of ancestral spirits as "native Thai" and they are "Thai citizens"

Yes, I'm Thai. I'm not Khmer or Thai-Khmer as you called [smile]. All people in the village [Ban Khlannak] are Thai. We have a lot of Khmer migrant workers [Cambodian migrants] here: they are Khmer. The founding ancestor of my family [Suban] was Thai. His name is "Nai Prapda Suban." We [the Suban family] started using Suban as our family name during the reign of King Rama V.

Moreover, the discourse of ethnic identification is formulated at the local level. I observed that the Thai-Khmer at Surin identify themselves as Thai; however, in the ritual context, the Thai-Khmers in Surin claimed that they are the real Khmer or "Khaman Thae" and label the Thai-Khmer at Sisaket as Lao. A Surin villager siad:

"Hey, I think you were cheated by the "Lao" people who called themselves "Khmer" but you know what? Khmer people at Surin province, they are Khmen Thae [real Khmer] not like the *Khamen thiam* [fake Khmer] in Sisaket" and you see…Khamen Thae [real Khmer] will not use the *Khaen* as a main musical instrument in *Ram Mamuat* ritual. The Khamen thae [real Khmer] will use the *Klong*, *So*, *Pi*, *Ching*, and *Chap* instead of the *Khaen* like Lao people. So, I think people in Sisaket are likely to be Lao instead of *Khmen* [Khmer]"

The discourse of ethnic identification is not only formulated at the local level, but also at the national level. Most of ritual functionaries in Sisaket claimed that *Ram Mamuat* only belongs to the Thai-Khmer people and not to the Khmer in Cambodia. Somchai, a *Khamen Sung* ritual functionary expressed:

"You can see *Ram Mamuat* only in Surin, Sisaket, and Buriram, but it does not exist in Cambodia."

The *Khamen Sung* people claimed the uniqueness of the *Ram Mamuat* ritual and insist that one cannot see *Ram Mamuat* in Cambodia, but that it only exists in the Thai-Khmer bordered provinces: Sisaket, Surin, and Buriram. However, a Khmer migrant of Surin Province, namely Phon, who migrated from Banteay Meanchey province in Cambodia argues that Khmer in Cambodia also practice *Ram Mamut*. Miss Phon, insisted that Cambodians also practice *Ram Mamuat*, and the pattern of ritual is the same except the different language dialect speaking in the ritual. *Phorn* stated:

"I saw the *Ram Mamuat* in Khamen [Cambodia] and here in Surin, I think it's the same…I mean the pattern of the ritual likes the offerings, the melody of the ritual song that we have are the same, but the accent of language is different, because we use different language dialects."

6. CONCLUSION

The Ram Mamuat ritual reveals a system of symbolic action which conceptualizes the local religious worldview of the Thai-Khmer people. This is divided into two realms, including the belief in guardian spirits (*Khru Gamned*) , and ancestral spirits (*Phi Puta*) that plays a key role in the conception of illness. Local belief in supernatural beings, the Karmic Law of Buddhism, and fate are all integrated aspects of Thai-Khmer notions of illness and healing practices. The ritual offering, *Chuam Khru*, is a significant ritual symbol that symbolizes the religious cosmology of the *Khamen Sung* or the Thai-Khmer ethnic group, in relation to the belief in ancestral spirit(s).

Additionally, the Ram Mamuat ritual defines the meaning of healing as individual illness treatment and the reconfirmation of the Thai-Khmer ethnic group. Furthermore, the idea of ethnic identity is formulated through the ritual practice at the local level between the indigenous Thai-Khmer groups (*Khamen Surin* versus *Khamen Sisaket*), and at the national level between the indigenous Thai-Khmer and the Khmer group in Cambodia (*Khamen Sung* versus *Khamen Tam* or the Khmer in Cambodia). Finally, the research findings support the assumption that the *Ram Mamuat* ritual is a cultural marker, which helps reconfirm the cultural identity of the Thai-Khmer ethnic group.

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Streamflow Drought Events and Severity Analysis of Chi Basin in Thailand

Homdee Tipaporn and Pongput Kobkiat

Abstract—*It has been projected that climate change will extremely increase water scarcity in the future ,so drought forecasting is an essential concern for water resources planning and management, to mitigate the severity of drought damages. The objective of this study is an application of a hydrological model to analyzestreamflow drought events in the Chi river basin, northeastern Thailand. A Soil and Water Assessment Tool (SWAT) model is firstly employed to simulate streamflow. The model calibration and validationwere carried out. Then, streamflow drought analysis was conducted using the threshold level approach as a fixed 95 percentile of the flow duration curve in order to classify dry conditions. The results show that the SWAT model performs sufficient is well in simulatingflows with relatively high values of coefficient of determination and Nash-Sutcliffe coefficient. The drought analysis indicates that trends of water scarcity on river have occurred noticeably since early 1980s and there has been a shift toward even dryer conditions during the mid and late 1990s. Moreover, drought events computed by threshold method show similar trends corresponding to the atmospheric phenomena, "El Niño".*

Keywords— **SWAT model, hydrological drought, threshold level, Chi river.**

1. INTRODUCTION

Drought is a complex natural phenomenon initially resulting from less than normal precipitation and in some cases also with enhanced evapotranspiration [1]. Long terms periods of recurring droughts can relatively affect other hydrological parameters (e.g., soil moisture, stream flow or groundwater) making it somewhat difficult to characterize their onset and terminations [2]. Mostly studies have described the concept of drought through its impacts into four types including; meteorological drought, agricultural drought, hydrological drought and socio-economic drought [e.g. 3]. Drought can be differently defined depending on what kind of drought, the region interested, perspectives, objectives and the stakeholders involved [e.g. 4].

As a convention, precipitation is the dominant aspect leading to the origin of drought but local feedbacks such as land use change and increased evaporation may enhance and prolong drought, leading to serious damage to the economy, society and environment [5]. Within this study, we present a concise concept of hydrological drought, characterized by the reduction in river streamflow, water storage in aquifers, lakes or reservoirs [6]. The fundamental statistical parameters needed to characterize changes in drought are in terms of frequency, duration, severity and spatial extent [e.g. 7].

To understand hydrological drought characteristics, most studies consider the threshold level approach for distinguishing flows, using annual, monthly or daily series of river discharge [8]. There are several ways to define flow quantity, such as percentile flows, or mean, median flows. Some studies have used drought indices to describe changes in droughts, e.g. the Palmer Hydrological Drought Index (PHDI) or the Surface Water Supply Index (SWSI). Nevertheless, these indices required relatively much data and intensive computation, which is a great obstruction in regions lacking data. Other simple and effective indices, the Standardized Streamflow Drought Index (SDI) or threshold level method, have been used to evaluate streamflow deficits in India, and it clearly illustrated changes in drought conditions [9]. Thus, not only complex methods are applicable in detecting droughts, but simple methods also.

The purpose of this study is an application of a semi-distributed hydrological model as the SWAT model, to simulate flows at basin scale, and propose the criterion for quantitative water scarcity in river by using the threshold level method. This study has been done regarding the Chi river basin, Thailand, which has experienced repeated deficits of river discharges. Also, there has been little research conducted for hydrological drought analysis in the basin. A suitable evaluation will be useful to predict and monitor drought events in the future, leading to disaster risk reduction through early warning.

2. DATA AND METHODS

Study area

In order to monitor changes in the monsoon climate caused by droughts, Thailand is an interesting choice. Especially, northeastern Thailand is located in a tropical monsoon climate zone, which has repeatedly experienced drought events, but where monitoring and early warning systems are not always available.

The Chi basin is located across the central part of the northeast region of Thailand within latitude-longituderange of15.3-17.3°N and 101.3-104.3°W. The total catchment area of the basin is about 49,476 km^2,

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and more than 60 percent of the basin is rain-fed agricultural area with paddy rice as the major crop. The basin is surrounded by mountain and high plateau ranges from the north to west that makes the river basin shape as of a flat bowl at the lower part, as shown in figure1.

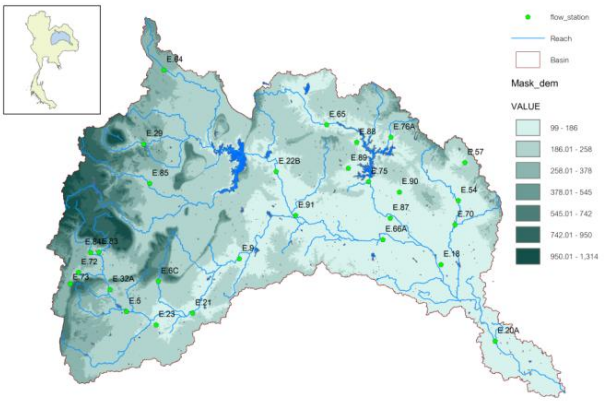

Figure1. The Chi basin in the Northeastern, Thailand

3. METEOROLOGICAL DATA

The weather over the basin is characterized by a monsoon tropical climate. Rainfall distribution is highly inconsistent and unevenly distributed in space and time, contributing to a large monthly variation of streamflow. Figure 2 shows average monthly precipitation over the basin.

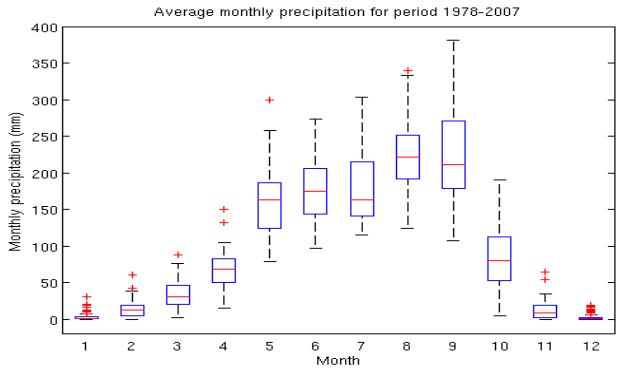

Figure2. Box plot of average monthly precipitation

The range of precipitation varies between 900-1,700 mm annual with an approximately annual average of 1,150 mm. The wet season usually occurs in mid-May to October, but its intensity increases from June to August and subsides in mid-September. The dry season occurs from November to April. Generally, drought events can occur in both the wet and dry seasons, especially dry spells have commonly occurred in June –July and the end of September, which are important periods for agriculture. Also, there are relatively critical periods for the sowing of crops in July and for the growth of different crops in August. The dry season always occur dry up in a river and problems are even more serious for the people during severe drought. Evidence has demonstrated that the frequency, severity and duration of droughts in Northeastern Thailand are higher than in other regions [10].

4. HYDROLOGICAL MODEL DESCRIPTIONS

SWAT is aspatially semi-distributedhydrologic modeloperating on a daily time step. The model is developed to predict the impact of land managementpractices on water, sediment andagriculturalchemical yield in large watersheds [11]. In the SWAT model, a digital elevation model (DEM) is imported into the model to delineate the watershed and then it is divided into multi sub-basins by overlaying land use and soil map and slope classes. Then it is further sub-divided into lumped units called hydrologic response units (HRUs), having unique land use and soil combinations. HRUs represent percentages of the sub-watershed area and are not identified spatially within a SWAT simulation. Further descriptions of the model are given by [12].The basic water balance equation was calculated on the following formula.

$$SW_t = SW_o + \sum_{i=1}^{t} (R_{day} - Q_{surf} - E_a - W_{seep} - Q_{gw})$$

Where

$SW_t$is the final soil water content

SW_o is the initial soil water content on day i

tis the time (days)

R_{day} is the amount of precipitation on day i

$Q_{surf}$is the amount of surface runoff on day i

E_a is the amount of evapotranspiration on day i

$W_{seep}$is the amount of water entering the vadose zone from the soil profile on day i

$Q_{gw}$is the amount of return flow on day i

5. HYDROLOGICAL DROUGHT APPROACH

Actually, a defined drought event is characterized by main parameters: duration, frequency, severity and areal extent of the drought conditions. For hydrological drought, however, water managers are interested only in a small number of points in space, such as a basin outlet that provides an integrated measure of spatially distributed runoff [9]. Thus, in this study, drought conditions would be conducted based on a single site at E20A, located at the basin outlet.

According to the region located in a monsoon climate zone, inconsistent rainfall distribution causes high runoff variability; thus a constant annual threshold level is not suitable for describing the complex nature of streamflow drought events [8]. The magnitude of threshold level should be designed by fluctuating on a monthly basis. To identify changes in hydrological drought the threshold level methodhas been proposed.

The threshold level method is either a constant or a variable threshold which can be chosen in several ways: the mean or median over a long period of flows. It can be defined depending on basic time units of data such as a daily, monthly, seasonal, or annual basis. As shown in figure 3, the drought events are defined whenever discharge is below a certain threshold level, which can then characterize their duration, severity and time of occurrence [13].

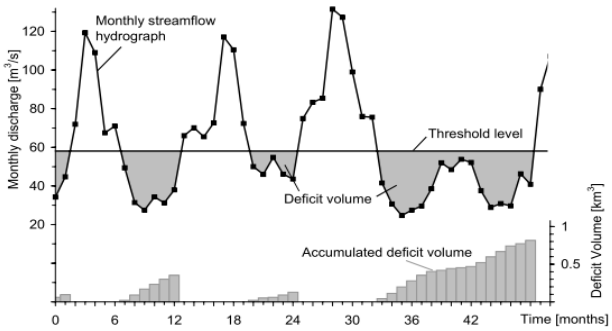

Figure 3.Definition of drought event and deficit volume[13]

The defined threshold level relatively relies on the type of river flow being studied. There are three types of flows: perennial, intermittent, or ephemeral flow [8]. In this study, the threshold level as a probability percentile of flow on a monthly basis was selected. Initially, the flow duration curves for each month were developed by plotting the probability of exceedance of flows. Then we determined the quantity flows at 95 percentile for each month to define as the threshold level.

6. Results and discussion

Sensitivity analysis, calibration and validation

A sensitivity analysis method was done with the details of sensitivity parameters areexplained in [14].Figure 4 shows a comparison of monthly observed and simulated streamflow at the basin outlet.The performance of the model was evaluated at several sub-watersheds by usingthe correlation coefficient (R^2) and the Nash-Sutcliffe coefficient in the range of 0.5 to 0.87 and 0.48 to 0.86, respectively. It can be pointed out that overall results generally indicated that the model performs sufficiently well in simulatingflow.

Assessment of drought duration and severity

For drought assessment, both topographic location and time in the basin are significant factors influenced by change in droughts. Therefore, we highlight here is drought at the basin outlet located on the main flow river which is kind of a perennial stream.

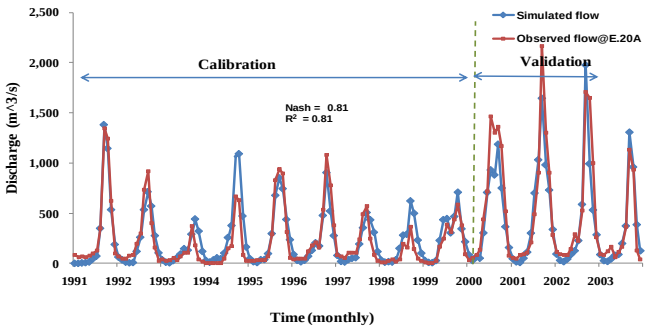

Figure 4.Comparison of monthly observed and simulated streamflow at E.20A station.

The choices of methods employed for characterizing drought conditions are quite subjective. The type of the flow regime is of dominant importance for a choice of threshold value. Smakthin (2001) suggested a threshold level for a perennial river may be in the range of discharge with 70- 90 % exceedance while that might be unreasonable for ephemeral rivers. Corresponding with Lehner B. et al (2001), stating that the most important factor for the results of a drought study is the choice of type and magnitude of the threshold level.

At this point, a drought event is identified by using the threshold level method which can be characterized by: onset and termination time of the drought event, severity, and frequency. Here, the threshold levels were derived as a constant 95 percentile of FDC for each month as shown in figure 5. Flow time series obtained by the SWAT model during the period of 1975-2004 were employed.

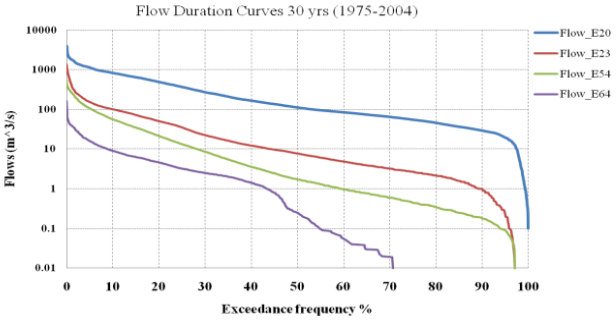

Figure 5. Example of monthly flow duration curve for Chi river basin at several flow stations.

Table 1 summarizes the results of the statistical characteristics of drought conditions achieved by setting the threshold levels as a monthly constant of 95 percentile of flows for each month. The period between the onset and termination dates is the duration for which streamflow is below the threshold level. The severe drought events as the cumulative water deficiency can be recognized in 1982, 1987, 1993-1994 and 1997-1999. Notably, the most severe drought events occurred during monsoon months. It seems thatthe selected threshold value is reasonable to detect droughts compared to realistic drought events recorded by Thai Meteorological Department as shown in figure 6. The results accompanied with El Niño Southern Oscillation (ENSO) occurred in 1982/83, 1993/1994 and 1997/98. Corresponding to some studies efforts to relate droughts to the El Niño event also [e.g. 15]. These have been accepted that forecasting of drought conditions remains an extremely difficult task. Certainly, a proper selection of the threshold stage is important. Too high a threshold level might lead to an overestimation of the severity and frequency of droughts while too low a value might underestimate the same [16].

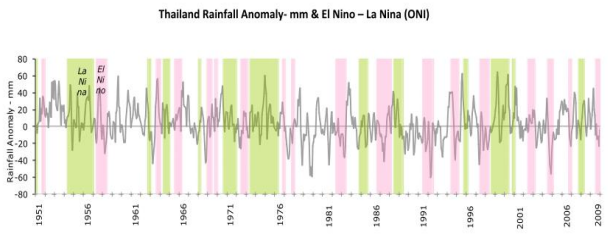

Figure6. Anomaly of 3 month moving average precipitation (average precipitation 1971-2000) El Niño (Ping) and La Niña (green) events based on the Niño 3.4 Index (longitude: 120°W-170°W, latitude: 5°S - 5°N)

Table 1 Streamflow drought events and their severity for the Chi River basin at outlet basin E20A (1975- 2004)

No.	Year of event	Onset date	Termination date	Durations (days)	Severity (MCM)
1	1982	1-Jul	28-Jul	28	-1053.91
2		3-Aug	20-Aug	18	-251.37
3	1987	2-Jun	18-Jun	17	-240.45
4		12-Jul	22-Jul	11	-200.92
5		20-Sep	8-Oct	20	-586.31
6	1992	12-Feb	28-Feb	22	-7.99
7		14-Sep	18-Sep	5	-252.36
8		29-Nov	10-Dec	14	-121.33
9	1993	2-Apr	27-May	56	-452.57
10		12-Jun	21-Jun	10	-102.69
11		19-Oct	30-Oct	12	-248.67
12		14-Dec	30-Dec	17	-54.18
13	1994	10-Jan	31-Jan	22	-55.97
14		8-Mar	21-Mar	14	-2.13
15		1-May	26-May	26	-166.93
16		22-Jun	16-Jun	6	-18.33
17	1997	4-Feb	26-Feb	23	-21.91
18		24-Jun	30-Jun	8	-66.06
19		26-Nov	31-Nov	6	-36.56
20	1998	24-Jan	31-Jan	8	-6.65
21		6-Apr	19-Apr	14	-59.02
22		1-Jun	6-Jun	5	-53.28
23		1-Aug	6-Aug	7	-61.36
24		7-Sep	14-Sep	8	-347.20
25		1-Nov	6-Nov	6	-77.07
26	1999	18-Jan	31-Jan	14	-19.21
27		1-Mar	31-Mar	31	-21.244

7. Conclusions

As ultimate goal, this paper aims at the application of a hydrologic model for investigating changes in hydrological drought occurrences in the Chi River basin, Northeastern Thailand. The two mains methods are: 1) assessment of stream flow time series using the SWAT model and 2) the proposal of a proper threshold level to characterize drought conditions.

Overall simulation resultsof the SWAT model illustrated that the model performs sufficiently well to simulate streamflow in the basin, with relatively high values of coefficients of determination and Nash-Sutcliffe coefficient. In this study, a hydrological drought for a particular stream is determined in terms of duration, frequency and severity. The drought trends obtained by a fixed 95 percentile of FDC are broadly consistency with observed data. It can be appropriately defined as a deficit in river discharge coinciding with such a kind of actual drought as El Niño events. These methods are useful and easily applied for monitoring drought for the propose of mitigating the drought effects due to climate change.

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Pu Thala: Beliefs and Social Construction - The Sacred Land of Phuthai People in Renunakorn

Siriyaporn Saleepun

Abstract— *The Pu Thala Shrine is regarded as a sacred space in reverence where ceremonies are organized with regard to sacred beings and the spirits of their ancestors. This study aims to study the Phuthai's beliefs and spiritual ceremonies, the importance of Pu Thala in influencing their thoughts and construction of sacred space reflecting their identities based on related documents and data obtained from fieldtrips using participant observations and surveys, in-depth analysis and group discussions. It was found that their beliefs could be classified into 2 patterns; (1) regarding spiritual worship and ancestor reverence and (2) regarding religious beliefs with regard to Buddhism. Pu Thala is the Phuthai's highly revered spirit. He is believed to have been a late brave fighter in ancient time. Welcoming receptions are held, not exclusively for the spirit but also for other ancestors as Pu Thala's companions. The head of each household are required to prepare liquor as visitors come. However, Pu Thala would be symbolically served before other community seniors. Furthermore, the Phuthai hold an annual festival for the spirit of Pu Thala during the 6th waxing moon during the year's sixth month. At the beginning of the ceremony, a cow would be sacrificed as a source of food supply and as a token for the revered spirits. As what the people had prayed for the spirits yielding fruitful, a number of them could be seen in line to give their tokens to Pu Thala, their high spiritual being. The spirit is locally believed to have a magical power with success being unable to explain using scientific evidence. The reason why Pu Thaila is a famous spirit he was believed to use his supernatural power in granting wishes of the devouts; therefore, he reflects a part of the Phuthai's identity in beliefs in ancestor worship deeply ingrained in their mindset. The Phuthai, therefore, built a sacred space and their high places of worship for organizing spiritual ceremonies and ancestor reverence. These are considered an outstanding identity reflecting their beliefs to be passed on to the next generations as a way of living.*

Keywords— **Pu Thala Shrine/ Phuthai beliefs/ Phuthai ceremonies/ ancestor reverence**

1. INTRODUCTION

As a part of Thailand's ethnicities, the Phuthai have been cherishing their ancient traditions and cultures. Living in scatter in regions, they settle in the country for a long time, especially in the province of Renunakhon of Nakhon Phanom province. In Northeastern Thailand, they live in a large community, passing on their cherished traditions from one generation to another.

In speaking of Renunakhon, what makes it interesting representing the Phuthai is their beliefs in respecting their ancesters deeply ingrained in their minds. One of which is the reverence of the "Pu Thala" believed to be a hero in every occasion as the Puthai were in danger or a dilemma needing assistance (Samlee Raksuthi. 2001: 55-70). However, what the study focuses and presents is that how the Pu Thala had been playing a major role in the lives of the Phuthai, especially in the endless and growing regard of his sacredness.

2. RESEARCH METHODS

The Pu Thala Shrine is regarded as a sacred space in reverence where ceremonies are organized with regard to sacred beings and the spirits of their ancestors. This study aims to study the Phuthai's beliefs and spiritual ceremonies, the importance of Pu Thala in influencing their thoughts and construction of sacred space reflecting their identities based on related documents and data obtained from fieldtrips using participant observations and surveys, in-depth analysis and group discussions.

3. BACKGROUND OF THE PHUTHAI PEOPLE IN RENUNAKORN

Thai Isaan Phuthai Renunakorn is a Thai Isaan Ethnic group in Thailand. The original homeland was located at Baan Na Noi Oi Noo, Dien Bien Phu, in the Sib Song Ju Thai region of Vietnam. Beginning with the Rattanakosin period, the Phuthai at Baan Na Noi Oi Noo encountered starvation from drought. Prayaka, the leader of the Phuthai, led the Phuthai move to Laos in the reign of King Anurutraja of Vientiane city. Prayaka and the Phuthai were allowed to settle in the town of Wang of Vientiane city (Thawin Kesornrat 1969: 101).

Prayatecho, the eldest son of Prayaka, after the death of his father, had become the King. Later, the Phuthai had conflicts and had war with the Yuan. The Yuan developed tricks to get rid of the Phuthai. After the war, The Phuthai, led by Thao Phet, and Thao Sai, migrated to Thailand across the Mekong River by Thao Phet and Thao Sai.

Thao Phet and Thao Sai, the leaders of the Phuthai from Wang, came to Thailand and settled in Baan Pho Saam Ton, Baan Pra Klang Thung, and That Pranom, Nakhonpanom province. Then they migrated to Nong Han, Sakonakhon province. Although it was opulent, the Phuthai were not familiar with the surroundings. Moreover, many people were dying. They decided to return to the town of Wang. Before they left, they went to pay respect to Prathatpanom and the abbot. The abbot suggested a suitable place for them to settle. Later, they settled in Dongwai village, which later became Renunakorn, Nakhonphanom province during the reign of King Rama III. In addition, Thao Sai, or Pra Keaw Komon became the first governor of Renunakorn.

4. WAYS OF LIFE OF THE PHUTHAI RENUNAKORN

The Phuthai Renunakorn lived peacefully and freely. They engaged in agricultural activities and in trade. In the past, some men traveled as far as Bangkok to trade, or went to Malameng city, Burma in the summer and winter. They would return in the rainy season. When they had free time, men would "Fon Kin Law" to court the girls. It is clear that the Phuthai loved aesthetics.

Male members of the community like traditional dancing, a kind of performing art based on their Phuthai community in Renunakhon. Movements of plants and animals are applied in their dance making a joyous environment. They would also invite their female peers to joint as a form of flirting. Later, it was adapted as a male-female dancing as a part of a religious ceremony in paying homage to Prathat Phanom Pagoda, Prathat Renu and the Pu Thala during special occasions. In dancing during the festival in Boon Pawes, Boon Bangfai, Krathin and Phapa, in modern time, it is more open to the traditions of the Phuthai Renunakorn, dancing is perform in different occasions, especially in a welcoming ceremony for foreign guests or travelers after the Baisri Sukwan ceremony.

5. BELIEFS OF THE PHUTHAI RENUNAKORN

5.1 The Phuthai Renunakorn had two ways to believe:

5.1.1 They believed in religion and Buddhism.

Chalermchai Kaewmaneechai (1999: 76) said that the Phuthai believed in Buddhism since the time when King Anurutraja gave Nang Chow Pha or Nang Lao with a monk to Phaya Ka. Nang Lao believed in Buddhism, so she persuaded the Phuthai to follow Buddhist traditions. They built temples, made merit and supported Buddhism. Later, the Phuthai believed in Buddhism and spirits. The Traditions of the Phuthai in relation to Buddhism are usually organized in local temples such as in Wat Burapharam, Wat That Renu, Wat Patchimmawat and Wat Sriwilai, all of which are important. However, the most important one is Wat That Renu or Wat Klang because it is the center of the Phuthai Renunakorn where important Buddhist activities are organized every month as Buddhist peers in other community in Thailand's Northeastern region.

5.1.2 They believed in spirits and ancestors.

The belief in spirits by the Phuthai began in ancient time where their ancestor still lived in Dien Bien Phu. It could be classified into 2 groups.

1. The respect to spirits is believed to pay homage to their late ancestors. Different clans have different offerings such as duck, pig, chicken or liquor or seasonal fruit (Suthep Sunthornpesat. 2005. 12).

2. The respect to the house spirits began with the head of the family inviting the spirit to their house aiming to make it the guardian of the house and of the family members. This belief is also about treatment when there is a patient in the house. Traditional medicine man would be invited and read a sacred text and another man for playing the woodwind, Kan, a kind of Isarn musical instrument in order to invite the house spirit to cure the patient.

Even though the Phuthai had moved to a new place, their belief in spirits still remained. This is the beginning of the ceremony called "Yao" as a means of curing illnesses. To their belief, people got ill because they had been attacked by spirits. The ceremony is essential in helping them understand what made them ill. The head of the ceremony was generally female dancing and playing the musical instrument in the Phuthai style along with chanting sacred texts until the end of the ceremony.

The head of the ceremony is called "Mor Yao" and the process is called "Yao". Mor Yao would begin his prediction by placing grains of rice and an egg in his hand. If it happened that the egg could stand upright, it meant that the sickness would be cured. If it turned out otherwise, it meant it was not easy to go away. He would grasp a saber before plunging it into a cup of milled rice. Likewise, if it happened that the saber could stand upright, it meant that the sickness would be cured. If it turned out otherwise, it meant it was not easy to go away. The head of the ceremony would dance and sing 'till the end of the ceremony. Nowdays, the Yao ceremony is not very popular among the Phuthai. Instead, with advancement in modern medicine, they chose a new kind of remedy in hospital. They found that this kind of treatment did not give them an exact answer of what had affected them. In some cases, the ceremony was still practiced among those believers. However, the belief in the Pu Thala was still popularly practiced.

The Phuthai from Wang city migrated several times. One important aspect of their lives was the building of spirit shrines to be mind-centered by the Phuthai. In addition, the Phuthai Renunakorn believed in the supernatural power of " Pu Thala." Phi Pu Thala at Renunakorn was believed to have been used by a clever warrior called 'Phaya Techow'. Because there were many Phuthai people in the northeastern region, Pu Thala shrines were created in Renunakorn city, Warichpoom city, Komcha-I city, Nong Sung city, Khaw Wang city, and more. Whenever doing anything in daily life, the Phuthai would make a votive prayer. When they met success, they would make a votive offering.

6. THE IMPORTANCE OF PU THALA AT RENUNAKORN

Who is Chao Poothala? He was an ancestor spirit or a sacred spirit of the Phuthai leader in the past. He was a great warrior of the Phuthai.

The figurine of the Phu Thala of Renunakorn (courtesy of the author)

He had a big and strong body. His voice had power. He carried two swords. When going to war, he often dressed in red. He was respected by the Phuthai from the past to the present. Pu Thala governed his city happily until, at the end of his life, he stated that "After his death, if any Phuthai wished for protection from him, they should build a shrine at the end of the city in the west. Additionally, they must engage in a great worship every year." In the first stage, the shrine was a temporary shrine. But in the present, it is a permanent and tremendous one (Suthep Sunthornpesat. 2005: 10).

The Phu Thala Shrine of Renunakorn (courtesy of the author)

The Pu Thala Shrine is a sacred space regarded by the Phuthai Renunakorn located on the west of the village at the road from Renunakorn-Nnnua about 200 meters the west of Patchimmawat Temple. It is a red traditional Thai styled shrine covering more than 2 acres constructed as a 4-squared room with 2 windows. The walls are made using concrete with the Thai-styled roof with patterns and the decorated Naga head close to the running stream.

6.1 The Ritual Tradition and Pu Thala Worship

6.1.1 The Welcoming of Chao Pu Thala

When the Phuthai Renunakorn traveled, they believed that Chao Pu Thala would accompany them. Therefore, any house owner was obliged to welcome Pu Thala by offering him some white whisky.

The house owner would pour some whisky in front of the Phuthai's guests. Then, he would raise the glass of whisky above his head and ask Chao Pu to give a blessing to his family. Later, guests would drink some of the whisky together. The Phuthai believed that if they observed these ceremonies, all would be happy, prosperous, and meet success in every aspect of their lives.

6.1.2 There are three forms of making a votive prayer

1. A big votive prayer should make 'Khan Ha' with a bottle of white whisky and a pack of cigarettes. Furthermore, there is 'Chao Chum' who helps to communicate with Pu Thala's spirit. In this case, the votive prayer should concern big and important issues.

2. A common votive prayer should make 'Khan Ha' and a pair of lit candles with a bottle of white whisky. In this case, one can make a votive prayer by oneself.

3. Lastly, is a votive prayer when one faces tough situations. In this case, one should 'Wai' (Thai respect) above one's head to respect Pu Thala in order to ask for his assistance.

6.2 Kea-Ba Kea-Bon (to make a votive offering)

The medium (or Chao Jump) is regarded by the Phuthai Renunakorn has the duty to communicate with the Pu Thala. It begins with a request for such a ceremony. For those who made their wish but failing to be successful, they did not have to hold the ceremony. Besides the yearly duty, the medium has a daily shore in taking care of the shrine.

The duty of the medium includes (Thawin Thongsawangrat. 1986: 67) ;

1. having a duty to communicate with the spirit when there are those who make a request for praying to the Pu Thala.
2. having the duty to organize the thanking ceremony according to the person's wish.
3. having the duty to be a leader in food-offering ceremony during the 6^{th} waxing moon of the 6^{th} lunar month as generally known as the 6^{th} new day of every year.

After the Phuthai met success, they had to make a votive offering called Kea-Ba Kea Bon. There are three ways to make the offering:

6.2.1) Kea-Ba Kea-Bon Yai (the big votive offering). The Phuthai who were successful would Kea-Ba Kea-Bon by killing a cow and offering its body. Then they would bring its meat to cook and offer it to Pu Thala.

6.2.2) Kea-Ba Kea-Bon Klang (the middle votive offering). The Phuthai bought cow meat to cook to be "Pa Kao Deang Pa Keang Ron", eight trays. Additionally, they would prepare betel and betel nut, a cigarette, a bottle of water, and two candles.

5.2.3) Kea-Ba Kea- Bon Pa Deaw (the common votive offering). The Phuthai offered a plate of Lab Lerd, a bowl of soup, two candles, a cigarette, betel and a betel nut, a bottle of whisky, and a glass of water.

6.3 The annual celebration

In the past, the annual celebration was very sacred. The way to respect Pu Thala like Kea-Ba Kea-Bon Yai, was by offering beef, and cooking it. They made square banana leave vessels decorated with Kao Tok Dok Mai (popped rice and flower) and Kao Dam Kao Deang (black rice and red rice).

Besides, there is a spiritual ceremony called "Nang Thiam" who is going to be possessed by the Pu Thala to give predictions on upcoming future, stating what needs to be done, and giving a warning and finding a solution in cases of flood and drought. Nang Thiam is a representation of the Pu Thala to the village believers. Mostly, "Zune" is a ceremony where spirit possession is allowed exclusively during the annual festival or in cases of disaster. Most of the Nang Thiam consists of female members. However, sometimes, it is a male to take such a job.

After that, they would Fon Ram (Isaan dance) around the Pu Thala shrine in order to be propitious. As the ceremony began, villagers would ask about situations in their community and how to find a solution to bad

situations that would soon come. When the medium, or Nang Thiam, finished eating, the villagers would bring 2 bana tree boats (along with carved oarsmen clad in red cloth and candles used as the oar) to the shrine. After that, traditional music and dancing would begin accompanied by a parade until the stream in front of the shrine. The medium would release the boats by lighting up the candles. If the candles still were attached, it would predicted that the year would be under good rain, full of rice and other food in abundance. The Pu Thai had to be united as a result.

The attendants would return to the shrine. When the female medium reached the site, she would faint knowing nothing of what had happen before. Then the Phuthai would come to respect the shrine offering good luck charm, coins, photos of the Poo Thala and holy thread. Some people grabbed the believed souvenirs in a high volume for their relatives. That is why the fame of the Pu Thala had spread quickly in a larger circle.

6.4 The Faith From the Pu Thala's Supernatural Power

The belief in Pu Thala's sacredness is related to the way of life of the Phuthai people. Whenever they go anywhere or do anything, one question is asked in communication, "Did you tell Pu Thala yet?" If Pu Thala gets it, everything will be successful.

Why are the Phuthai Renunakorn bound, and why do they believe in Pu Thala? In daily life, the Phuthai Renunakorn would hear about the appearance of Pu Thala when he wanted to say something important to the people of a city. Sometimes he lived in Nang Thiem or with his representative to communicate with descendants. When Pu Thala lived in another body, Pu Thala would assume the form of an elderly man and ask for white whisky. Then he would talk about important things and predict the situation in the future. He always helped to protect the Phuthai, and never played the lottery or supported bad people. He always suggested living in morality.

These are examples from Phuthai people who have experience with Pu Thala:

Grandmother Supensri Yingphon told me that she was Chao Chum or the representative of Pu Thala in order to communicate between Pu Thala and the Phuthai. From her experience being Chao Chum, she heard many supernatural stories about Pu Thala's assistance. The Phuthai came to make a votive offering and told her about their experiences.

Situation 1: This story happened recently. The Phuthai were going to go to another province, so they informed Pu Thala and picked him up at his shrine. While they were driving, there was a motorcycle in front of them which stopped abruptly because there was a big snake on the road. The Phuthai then asked for Pu's assistance. Afterward, the car which had picked Pu up in collided with the heavy motorcycle. The man bounced off his motorcycle for 10 meters, and became unconscious. When he regained consciousness, he said that he had seen the big shadow of an old man who carried him. No one thought that he would survive but because of Pu's protection, he survived.

Situation 2: This story happened recently when a couple from Mukdahan took their grandmother to Kea-Ba Kea-Bon to seek help for their son. Two months ago, the couple, who were merchants in Renunakorn market, heard about the supernatural power of Pu Thala. They made a votive prayer for their son because he was an alcoholic. He could not work. One month later, his parents came to visit him. He appeared to be much better. He said that he had stopped drinking entirely because when he became drunk he would vomit. There was always a big elderly man behind him who told him to vomit. The couple knew that the man was Pu Thala. That is why they went to Kea-Ba Kea-Bon.

Situation 3: This story was from Chao Chum's experience. Many years ago, Chao Chum and her family travelled to make merit in Northern Thailand. In the hotel, she took off her golden necklace and put it on the bed. Two hours later, she remembered that she had forgotten her golden necklace in the room. She bought some candles to make a votive prayer to Pu Thala. Then, she called to the hotel and was told that the housekeeper who had cleaned the room had already gone out. The important thing was that there was no golden necklace in the room. When the housekeeper's phone rang, she refused to answer. While she was going home, she could not find her way. Every bus went the same way until evening, and did not go near her home, as they usually did. She could not bear it. She called to the hotel and told them that she had taken the golden necklace. While she was on the road, there was a shadow that blocked the way to her home. She thought that it was because of the supernatural power of something. This is the miracle of Pu Thala.

7. CONCLUSION

With his supernatural power and sacredness bestowed upon the Phuthai Renunakorn, the Pu Thala demanded that his devouts staying in the right path. As danger came, he would use his power to protect the members of the community. This is a small part of presenting his sacredness accoding to some people. There are others who prayed for the Pu Tha for different purposes and becoming successful that ceremonies held to thank the sacred spirit almost everyday. occasionally, there were so many of such cemonies that quiing is needed. It is important to manage that there should never be 3 times as it would be beyond the power of the medium. This is not to count various small ceremonies. Lighting up the candles and praying by pressing the palms serve as a sign of the thanking ceremony elsewhere enabling them not to go to the shrine and not calling for the medim since the settlement of the Phuthai Renunakorn community for almost two centuries after the death of Wanglang Phaya Decho.

The Phuthai Renunakorn settled two hundred years ago, and still believe in the supernatural power of the ancestor spirit today. People have shared stories about Pu Thala's personality from generation to generation, but none has seen the body the body of Pu Thala. Despite this, the Phuthai joined together in building a statue of Pu Thala in a new shrine in order to realize his goodness and his supernatural power. This is the sacred space of Pu Thala from the temporal shrine to be the great one. He is still in the Phuthai Renunakorn's heart today.

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The Model of Spending for Tourists in Nakhon Si Thammarat

Paramet Damchoo

Abstract— *This research aims to study the data of tourism place in Nakhon Si Thammarat and spending Model of tourists to Nakhon Si Thammarat Province, using primary data from interviews with 440 tourists (Thai tourists 400 and 40 foreign tourists) and in-depth interviews Stakeholder in tourism 30 people . The results are summarized as follows: Nakhon Si Thammarat Province is very diverse province with variety resources. According to the Tourism Authority of Thailand, Nakon Si Thammarat, (2012) it can be divided geographically into four tourism categories: 1) Recreational tourism (island/beach), 2) Eco-tourism (forests, lakes, rivers and caves), 3) Cultural tourism (museums, historic monuments and temples)temples and 4. Urban tourism (community cultural centers and housing market). Visitors are men and women aged 20-40, who are students or people employed in the private sector earning between 10,000 and 30,000 baht per month. Most tourists are traveling within the province, mostly by car and bus. Their average expenditure is 8,865 baht with 24.00 percent spent on accommodation, 22.79 percent for tickets and 15.79 percent for fuel. They spend 12.30 percent on gifts and give 2.31 percent to the temples (merit). Only 36.59 percent of the tourists travel overnight. Accommodation types vary and include private homes, hotels of all types and resorts. Most resorts are located on the beach in Khganom and Sichon, but also include some resorts near the forest areas (Phrom Khiri, Amphoe Lan Saka ,Nopphitam). Most tourists travel with spouses accounting for an overall satisfaction level of 41.14 percent. Those who travel with friends account for 16.14 percent level of satisfaction while traveling in the province. Most mentioned aesthetic satisfaction, the variety of attractions available and the convenience of travel. The travel services infrastructure, promotion of attractions to attract tourists were cited as areas that could be improved.*

Keywords— **Spending for Tourists**, **Regression, Nakhon Si Thammarat** , **Cost, Spending Model**

1. INTRODUCTION

Nakhon Si Thammarat province is located in the south of Thailand adjacent to the Upper Gulf of Thailand where mangrove forests and sandy beaches are located. The central coastal region has high mountains and major watersheds with the major attraction the many beautiful waterfalls and fertile forests. The province also has a rich cultural heritage with a long history that includes sculpture, architecture, culture and local wisdom. These traditions unique to the city have long been an attraction for visitors. Tourism has grown steadily every year: in 2005 the number of tourists was 918,263; in 2006 and 2007 the numbers were 1,038,208 and 1,155, 138 respectively. Revenue for the three years increased as well: in 2005, tourism income 504,000 baht, in 2006, 568,000 baht and in 2007 the amount was 620,000 Baht [1]. The study showed that tourism in the province was competitive because of the variety of attractions. The GDP increased every year. However, the relevant authorities should conduct a study of the tourists spending Model in order to develop an overall plan to increase the province's revenue [2]. We studied the distribution of income from tourism in the province as well as the distribution of revenue from business travel to the province as the basis for the preparation of a development plan for investment in the province's sustainable development [3].

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2. The aim of the research:

1. To study general information regarding tourism in the province.

2. To study the Model of spending of tourists in Nakhon Si Thammarat.

3. Research Methodology

This research is integrated (Mixed Methods Research) between qualitative and quantitative methods. The quantitative section included a group of Thai and foreign tourists visiting the province and the qualitative section used structured interviews with people involved in tourism in the province.

3.1 Research populations and samples

The population of the study is a total of 606,140 total tourists in the province during 2009. 592,446 of these tourists were Thai; 13,694 were foreign (Statistics Office, Nakhon Si Thammarat, 2010).

The second groups were those involved in the tourism industry in the province such as entrepreneurs, business owners, owners of accommodations, transport operators, property and accommodation guides and community stakeholders. The sample for the study was 440 tourists (400 Thai and foreign tourists and 40) and 30 people involved in the tourism industry in the province.

3.2 Research tools

Researchers studied the Model of spending for tourists in the province to collect quantitative data using 440 people and collected quantitative data from

interviews structured to query 30 people involved in the tourism industry.

3.3 Data collecting

The data in this study included primary and secondary data as follows: Primary collected by questionnaire interviews with tourists. Purposive sampling and structured interviews with people working in the tourism business. Secondary data included information obtained from other agencies through research and documentation for the purpose of identifying the Model of tourists.

3.4 Data analysis

Researchers analyzed the data using SPSS for Windows and presented it in tabular form with explanations of the data analysis. The statistics used in the analysis are as follows: Statistics were used to describe the personal information of the visitors (age, marital status, religion, occupation, income, educational level and residence), Average (mean) and standard deviation (SD).

4. The results and discussions

Overview of tourism in the province Nakhon Si Thammarat Province, is very diverse province with a variety resources. According to the Tourism Authority of Thailand, Nakon Si Thammarat, (2010) it can be divided geographically into four tourism categories: 1) Recreational tourism (island/bay/beach), 2)Eco-tourism (forests, lakes, rivers and caves), 3) Cultural tourism (museums, historic monuments and temples)temples and 4. Urban tourism (community cultural centers and housing market).Island/bay/beach tourists enjoy sandy beaches in the Khanom area and a rocky beach at Sichon. Attractions include the swimming, pink dolphin watching, boating, fishing and fish spa caves at Khao Wang. Tourists can also help reduce global warming by planting mangroves and sea grass. Moon parties and the beach volleyball event in April are also very popular. Eco-tourism utilizes the forests, lakes, rivers, and caves. In Phrom Khiri Amphoe Lan Saka, Activities include kiking and nature study. Tourists can study reat plants in Khao nan Khao Luang. Krung Ching waterfall is also popular or even watching mist in the morning at Khao Lek and visit Hong Cape, visit swamp forest. Moreover, there are many beautiful waterfalls in Nakhon Si Thammarat such as Krung Ching waterfall, Yong waterfall, Krarom Waterfall and Prom Lok waterfalls, etc. Communnity culture and village life are popular destinations. In Lan Saka, Pak Phanang, tourists cycle, camp and visit organic farms. They look for tie dye fabrics, watch preservation processes of soap, explore beekeeping and participate in agro tourism in the orchards. The most popular locations around Lansaka district because of the fresh country air. Visitors can see the Pak Panang Basin Project by boat cruise; see bird's nests. Historic monuments, Temple and museums such as Phra Mahathat Woramahawihan Temple. In addition, tourists can visit the historic city in which Gore tells the legendary history of the city. There are also other local museums.

Model for the spending of the tourists who visit the province

The Model of visitors in the province are presented by the researcher as follows: 1) General information about visitors, 2) Behavior of holiday visitors, tours of the province and recognition of information and level of satisfaction. General information about the visitors to the province: The results showed that the mean age of tourists was 34.59 years and that the province attracts males and females in similar numbers. These tourists had reasonable spending power. Of the visitors to the province, 16.50 percent were professionals followed by students and the general publics with 15.00 percent and 12.70 percent respectively. With regard to education, 39.70 percent had graduate degrees, 15.90 percent had high school education and 13.00 percent had only an elementary education. These percentages were consistent with the country as a whole. The tourists were mostly middle-income people who earn between 10,000 to 30,000 baht per month. 47.80 percent earned less than 10,000 baht and 35.70 percent of them fall into the lowest income brackets while the high-income in this province is relatively low. Travel Model in the province The majority, 89.00 percent of tourists travel by private car or bus. Only 3.80 percent arrive by plane. Most are under the management of travel agencies in the communities such as clubs and organizations putting on seminars, both public and private. The percent arriving in private car is 74.70 percent with 11.00 percent arrive by bus, minibus, which run within and between provinces.

Most travelers do not stay overnight 36.50 percent and if they do travel overnight, they will most likely stay with relatives or acquaintances 34.30 percent. Most overnight accommodations from no star hotels to resorts are located on the beach in Shanom and Sichon with some in Thasala. Forest resorts are another type of accommodation that has been popular in places such as Lan Saka, Phrom Khiri, Nopphitam. Most travelers travel with family followed by trips with friends. Overall, family visits pay homage to Buddha at a temple. Recreation is an important reason for tourists to visit Nakhon Si Thammarat. The average amount that visitors spend is taken up mostly by travel expenses, followed by accommodation, gift, expenses for entertainment, food, drink and philanthropy (in that order) satisfaction Si Thammarat province in the province Satisfaction with traveling in Nakhon Si Thammarat as a whole remained strong with an average 4.17, which is classified as a review of factors that satisfy the aesthetic satisfaction. The variety of attractions and convenience of traveling are at 4.35 and 4.11 respectively. The excellent level of satisfaction is relatively low. Awareness about the attractions and services of government officials averaged 3.48 and 3.39 respectively. The addition of service providers and signage on location at an average level of satisfaction (3.53 and 3.56 respectively) and were judged as the factors that can be improved along with attraction

infrastructure including adding labels. Services of staff and travel providers can be developed to impress travelers

Spending plan for tourism in the province Spending increases by a simple regression equitation. The income of tourists is the independent variable and cost as dependent variable showed that the cost of travel is related in the same direction with the establishment of a level. Processing was divided into the following income levels.

Y=1 income less than 10,000
Y=2 income from 10,001 to 30,000 baht
Y=3 income of 30,001 to 50,000 baht
Y=4 income of 50,001 to 70,000 baht
Y=5 income from 70,001 to 100,000 baht

Table 1 shows the regression equation to estimate the cost increase

Equation	Coefficient	Sig t
Spending Money	168.186	0.00
Spending on accomodation	176.839	0.00
Spending on food and beverages	128.220	0.00
Spending on gifts/souvinirs	157.163	0.00
Entertainment	118.784	0.00
Entrance fees for attractions	66.263	0.00
Spening for tour guides	20.000	0.00
merit Spending for	79.883	0.00
Total Cost	915.338	0.00

Most accommodation options were based on recommendations from acquaintances 34.00 percent, followed by previous experience of staying in a place 27.00 percent, internet media 68.00 percent, and a tourism event 5.00 percent.

Most tourists choose accommodation facilities in the city 37.00 percent, while 17.20 percent choose sea side accommodation. Money is always a factor and it is noteworthy that tourists often choose from promotions of the big hotels and resorts. Accommodation is quite expensive compared to the same standards in other provinces.

The study found that there are five main tourist routes: 1) Visit Khanom district, pass Hin Ngam beach, Khao Pray Dam, having a meal at Krua Tang Gay restaurant or Ko Ton restaurant, Tasala Seafood restaurant, Kheng Lay, Krua Yada, taking a rest at Khanom and Sichol, buying souvenirs such as seafood products or the symbol of dolphones. The total expence is 2,517 Baht per person. 2) Visit Wat Phra Mahathat Woramahawihan and Tung Talad Park, having a meal at Khanom Jeen Muang Khon restaurant, Pok Ocha restaurant and Ko Pee restaurant, buying souvenirs at the silver shops which behind Na Muang Park. The total expence is 4,033 Baht per person. 3) Visit Wat Phra Mahathat Woramahawihan and Eye Kheaw waterfall, having a meal at waterfall national park, stay overnight at Twin Lotus Hotel, buying seasonal fruits. The total expense is 1,590 Baht per person. 4) Visit Kee Ree Wong Village, having a meal there, buying village souvenirs such as mangosteen's soap. The total expense is 600 Baht per person. 5) Visit Wat Phra Mahathat Woramahawihan, having a meal at Kru Nai Nung restaurant, stay overnight at Hotel in downtown, buying souvenirs such as seafood or bird's nest. The total expence is 2,001 Baht per person.

5. CONCLUSIONS

The results show that tourists in the province of Nakhon Si Thammarat are a diverse group, including students. Tourism in the province is not very high, especially among certain groups of students who travel and stay overnight during the beach season. Marine tourism is their mission and the accommodation rates vary widely. Some rooms are very economical since students want access to the outdoors. Tourists mostly have moderate income (10,000 baht to 30,000 baht monthly), followed by those earning less than 10,000 baht. There are very few high end tourists in the province. This is where researchers need to consider garnering this group. The study showed that most tourists average 8, 865 per trip, which rarely lasts more than 2 days. Travel and accommodation account for most of this since expense of other activities is minimal. Tourism in the province is often related to making merit at the temples and exploring nature. Further evidence exists that confirms that the safety of tourists in the province is optimal. Foreign travelers spend an average of 2.41 days per trip. Night life is something that should be considered when trying to determine why tourists stay a relatively short period. Safety is sufficient, but there seem to be no additional incentives.

6. RECOMMENDATIONS

Some visitors who travel to the province are professionals who are involved with tourism development. The needs of this group needs to be researched and developed as an untapped market for potential income. If the needs of the high-end tourist are in line with what is offered, more of them will travel to Nikhon Si Thammarat. Tourism entrepreneurs can also benefit greatly. Activities should be developed that will attract more tourists. Religion is important to a specific group of tourists and that should be cultivated and their needs met. Tourists appreciate and utilize government services. These government agencies should bring their services up to international standards. Nakhon si Thammarat has a long history of cultural and historical attractions. Tour guides are a source to be developed so that new generations can benefit from the rich history of the province.

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Website Trustworthiness: Medical Tourism in Thailand

Paramet Damchoo and Ann Suwaree Ashton

Abstract— *This research determines to investigate the possibility of designing a user interface for websites that will evoke customer's feelings, particularly in medical tourism. The focus is on the factors that impact on visual design for the feeling of trustworthiness effecting the websites user preferences. Due to high competition among many medical tourism countries they heavily promote their own medical tourism package to attract the target market to travel to their own country. Trustworthy websites are the most important part of user interface design because once the tourists trust the information from the websites the number of tourists will be increased respectively, furthermore, they may be the best marketing tool in advertising, such as word of mouth about hospital services. In this paper the model of trust for e-commerce (MoTEC) proposed by Egger (2000) underpins this study and use as a tool to group factors affecting online user's trust into four main areas. Firstly information reliability, secondly usability, thirdly interface design and lastly information contents. These factors can be pivotal and instrumental in designing future trustworthy websites. The paper concludes by discussing the significant implications of a study from a literature review on the design and implementation of customer interfaces to websites for medical tourism and recommendations for future research.*

***Keywords*— Medical Tourism ,Website Trustworthiness, Medical in Thailand, promote**

1. INTRODUCTION

Medical tourism is one of the fastest rising sectors in the tourism industry throughout the world in that it has the potential to generate tremendous financial benefits for many countries[1]. Countries in Asia that have been popular with medical tourists are such as Singapore, Malaysia, India and Thailand [2]. Thailand was particularly well-suited to become a major destination of medical tourism, especially once the traditional restraints on the commodification of medicine were removed. A highly popular destination, currently attracting around 15 million foreign tourists a year, Thailand enjoys a worldwide reputation for the alleged hospitality[3]. During recent years the ICT (explain what ICT stand for, if you use fort the first time you must write in full and use alphabetical) related tourism innovations have led to dramatic changes in the tourism sector. The tourism supply chain became more complex due to new online intermediaries[4]. With the fast development and increasing use of the World Wide Web as both an information seeking and an electronic commerce tool, web usability studies grow in importance. Consumer behaviour also changed as the internet became one of the most influential information sources for travel. A new type of user is emerging, one who acts as his or her own travel agent and builds a personalized travel package [5]. Trust has received extensive attention in marketing literature as the presence of trust has a notable influence on the cementing of sustainable relationships with customers [6]. While it is observed that trust is a multi-dimensional construct, in research such as this one a single construct has been used. It is the website design that influences consumer trust and consequently impacts online purchase intentions. Research has revealed a great deal of online trust as a precious factor for customer purchase decision online [7].Trust has received substantial attention in website design literature as the presence of trust has a dominant influence on the soldering with consumers[8]. In this paper is aimed at to present a theoretical framework to be used for developing a Website Trustworthiness within medical tourism context by using Thailand as a case study. Hecne, the primary purpose of this study is to investigate the most important factors of user interface for web design.

2. MEDICAL TOURISM IN THAILAND

Recently, in 2012, 2.5 million international patients received medical treatment in Thailand, and the number is increasing annually[9]. Medical facilities in Thailand pride themselves on their high standards, and many have subjected their premises and systems to the most rigorous inspections by applying for accreditation and certification, whereby a qualified standards organization distinct from the healthcare organization under review assesses the hospital or facility to determine if it meets a set of standards and requirements designed to improve the quality of patient care [10]. Thailand has recognition for its high-quality care, excellent medical professionals and highly advanced hospitals. These facilities provide services by internationally trained medical professionals, with the support of exceptional nursing staff and clinical technicians, making Thailand the top destination for

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tourist Medical Tourism; and Thailand is the best destination for medical tourists in terms of quality, service and cost saving procedures.

Although the term is recent, "medical tourism" as a phenomenon is not entirely new.

In the past, wealthy people from countries with underdeveloped medical services would travel to Western countries, renowned for the quality of their medical services. People from oil-rich Middle East countries, for example, received medical treatment in the United States and expatriates living in less developed Southeast Asian countries traveled to Singapore, the regional medical hub at the time. This has since been reversed, nowadays, an increasing number of citizens from wealthy, highly developed nations are traveling to developing countries in search of affordable and readily available medical services, which they typically combine with vacationing or other forms of tourism. give some samples that make people change the destination as such developing countries.

Thailand's reputation for medical treatment has grown; more hospitals are offering services to tourists; new types of specialties have emerged; and governmental promotion of the country as a "health hub" has intensified. Since the expansion of medical tourism in Thailand is a recent phenomenon, it may be too early to gauge its long-term consequences on the Thai medical system. Nevertheless, some tentative conclusions seem warranted. Ironically enough, the growing orientation of private hospitals toward a foreign clientele, and the subsequent upgrading of their facilities and concomitant increase in the price of their services, has been hitting the very social group that constitutes the bulk of their patients: middle class Thais, who do not want to use the 30-Baht scheme, but increasingly find private hospitals unaffordable (Suebsukcharoen, 2006).

Website design trust

The practice of medical tourism depends on successfully informing potential patients about procedure options, treatment facilities, tourism opportunities, travel arrangements, and destination countries. The promotion of medical tourism includes a wide range of marketing materials such as flyers, booklets, and websites[11]. The Website has become the indispenable channel for people seeking to use tourism information [12]. The researcher exposed that the adoption of website has become crucial for the survival of tourism company in the new economy. Applying trustworthiness inducing features to the interface design of websites is the most effective method of enhancing web trust. Also (Who reported? provide some evidence who said that...) reported is that Internet users accepted to make intuitive and rather emotional choices, so their decisions are often based on their trust of a website and design user interface. Trust has received considerable attention in marketing literature as the presence of trust has a notable influence on the cementing of sustainable relationships with customers [13]. (full stop always come after in-text citation) More recently, trust has been examined in the context of the website.[14] Few studies have focused on online trust with reference to tourism. Those that have often have had inconclusive results, such as Company's legal status, Supplies relevant information, Photographs's People .[15].

Trust has received extensive attention in marketing literature as the presence of trust has a notable influence on the cementing of sustainable relationships with customers (Sillence, 2006). While it is observed that trust is a multi-dimensional construct, in research this paper single construct has been used. It is the website's design that influences consumer trust and consequently impacts online purchase intentions. While the specific site design for an online visit is important, it should be realized that it is rare that trust is built during one online session. For obvious reasons, trust has been studied long before the emergence of the website and has been conceptualized within different disciplines.Trust has received substantial attention in website design literature as the presence of trust has a dominant influence on the soldering with consumers (Dianne Cyr, 2008; Morgan & Hunt, 1994).

3. METHOD

This study employed a qualitative approach by using content analysis technique to analyse data. The themes emerged from the data analysis by begin from transcribing, reading through the text and coding the data. Relevant text was then identified and categorised into different themes. Congruence and dissonance in the data and exploration of the relationships between theoretical constructs enabled the development of Website Trustworthiness: Medical Tourism in Thailand Model.

4. Result

As reviewed from the literature, it was found that there are four main categories that are affecting online user's trust, including information reliability; usability; interface design; lastly information contents.

4.1 Information reliability.

It is crucial to understand the link between reliability and a combination of technical aspects, for instance countering spam by bots, issues related to uptime and downtime, the quality (including trustworthiness, credibility and accuracy) of content, and ideas related to end-user behavior (when creating, exchanging or retrieving information). Factors are the necessary link, such as FAQ Reviewer Company's legal as seen in Table1.

Table 1 Factors of Information Reliability

	Factor	References
Information Content	FAQ	(Klindee, 2008; Kim, 2002; Egger, 2001)
	Reviewer	(Siekpe, 2009; Egger, 2001)
	Company's legal status	(Urban, 2009;Siekpe, 2009; Klindee, 2008; Head, 2007; Cao, 2005; Salvendy, 2003)
	Photographs's People	(Siekpe, 2009; Egger, 2001)
	Supplies relevant information	(Siekpe, 2009; Smith, 2004;Egger, 2001)

Usability has been an important theme extensively studied in the website design. Research in this field has emphasized the successful interaction as a key factor in designing and implementing a variety of websites. Using their definition, Usability refers to the

extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in specified context of use. Factor is the necessary link such as Menus are clearly,Load Quckly,Structure the site, External Link as seen in Table2.

Table 2 Factors of Usability

	Factor	References
Information Content	Menus are clearly categorized	(Chen, 2011; Siekpe, 2009; Dianne, 2008; Klindee, 2008; Head, 2007; Zviran 2006; Sillence, 2006; Smith, 2004; Salvendy, 2003; Kim, 2002; Egger, 2001)
	Load Quckly	(Siekpe, 2009; Cao, 2005; Smith, 2004; Egger, 2001)
	Structure the site	(Siekpe, 2009; Dianne, 2008; Klindee, 2008;)
	External Link	(Urban, 2009; Head, 2007; Zviran 2006; Sillence, 2006; Cao, 2005; Smith, 2004; Salvendy, 2003; Egger, 2001; Small, 1999)
	Search function/engine	(Sillence, 2006; Cao, 2005)

4.3 Interface design is the most widespread user front-end for applications today and the dominant user interface for websites on the internet. But graphical elements like windows and buttons are designed for sighted users; blind people can neither perceive nor use them. Factors are the necessary link such as Font Size, Font Color, Background Color as seen in Table3.

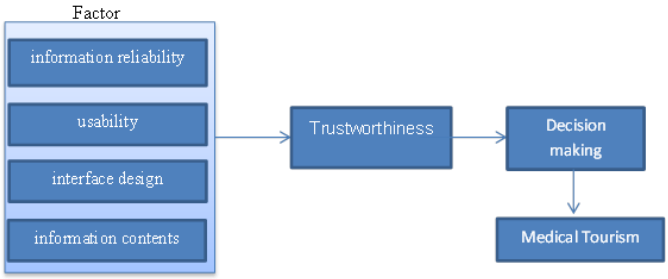
Table 3 Factor of interface Design

	Factor	References
interface design	Font Size	(Chen, 2011; Glen &Urban, 2009; Dianne, 2008; Klindee, 2008; Zviran 2006; Smith, 2004; Salvendy, 2003;Kim, 2002; Small, 1999)
	Layout	(Klindee, 2008; Zviran, 2006; Smith, 2004; Salvendy, 2003)
	Font Color	(Chen, 2011; Urban, 2009; Dianne , 2008; Klindee, 2008; Sillence, 2006; Smith, 2004; Salvendy, 2003; (Small, 1999)
	Background Color	Klindee, 2008; Sillence, 2006; Smith, 2004; Egger, 2001; Small, 1999)
	Navigation	(Chen, 2011; Urban, 2009; Siekpe, 2009; Dianne, 2008; Klindee, 2008; Zviran, 2006; Sillence, 2006; Cao, 2005; Smith, 2004; Salvendy, 2003; Kim, 2002; Small, 1999)
	Brand Position	(Siekpe, 2009; Egger, 2001)

4.4 Information contents refers to information that is of high quality and assessed by the user to be complete, sufficient, and effective. Alternately, Information Design refers to the organization and logical representation of information. component is the necessary link such as Slogan,Display all costs, Reviewer as seen in Table 4.

Table 4 Factors of Information Content

	Factor	References
Information Content	Slogan	(Siekpe, 2009; Klindee, 2008; Sillence, 2006; Smith, 2004; Egger, 2001)
	Display all Costs	(Egger, 2001)
	Reviewere	(Siekpe, 2009; Egger, 2001)
	Physical Address	(Dianne, 2008; Klindee, 2008; Head, 2007; Salvendy, 2003; Egger, 2001)
	Company Backgourd	(Urban, 2009; Siekpe, 2009; Dianne, 2008; Klindee, 2008;Head, 2007; Sillence, 2006; Smith, 2004; Salvendy, 2003)
	Promoting and information	(Siekpe, 2009; Sillence, 2006; Salvendy, 2003;Egger, 2001)



Figurer 1 Model Website Trustworthiness: Medical Tourism in Thailand

Conclusion

In summary, it appears that users have a distinct preference for a local website over a foreign website. At a strategic level, this suggests that the importance of managerial support for website localisation practices. Although there are financial costs associated with website localisation, if online customers are more trusting, satisfied and loyal to an online vendor as a result of country-specific website design, then the benefits can be expected to outweigh costs. Further, as more companies pay attention to website localisation, those companies that fail to adapt in this area are likely to experience a gradual attrition of online customers. This study demonstrates how rules can be effectively generated in the design of e-commerce Websites. These rules provide an opportunity to maximize customer's satisfaction and may increase customer's retention. Thus, they could potentially generate more revenue in the e-commerce industry.

Discussion and Futere Research

The conceptual model proposed in this paper considers that the interface factors influence the trust of using websites especially the medical tourism websites. This model is developed from the existing trust for e-commerce literature applying to the trust for e-commerce (MoTEC) proposed by Egger (2000) which is divided into four components which are information reliability, usability, interface design and information contents, a conceptual model of trust for medical tourism Website is provided. The current literature is related to only the trust

for the general websites while the trust for the medical service websites is still limited. Hence, it is important that future research within the context of the trust for medical Tourism website as a public relations is taken. One approach would be to research the impacts of the number of tourists in making a decision to use the medical tourism.

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Role of Disaster Management Capital in Japan

Saifon Suindramedhi

Abstract— *Disaster management in Japan has been divided into 2 categories which are Human Made Disaster and Natural Disaster. Human Made Disaster is resulting from an atomic bomb in Nagasaki while Natural Disaster is focusing on earthquake, tsunami, Fukushima power plant disaster (3/11 disaster) Kobe earthquake(Hanshin-Awaji earthquake). The objective is to study Capital Role in Japan Disaster Management.*

The research is based on qualitative method and the findings are as followed:

1. *Disaster Management in Japan has been learned by Socialization System.*
   Socialization System has been processed through 6 media: (a) School (b) Museum or Disaster Learning Center (c) Volunteer Groups (d) Local Community (e) Local Government (f) University or Research Institute. Each medium has implemented Socialization systems into their learning process, preparing the community for future risks.
2. *Japan has Preparedness Culture in Disaster Management. Disaster Management Preparedness Culture in Japan incorporates (a) Self Responsibility (b) Social Responsibility (c)Disaster preparedness (d) Self and social trust (e) Warning strategies (f) Dedication*
3. *Disaster Management in Japan, The various dimensions Capital have important role.*
   The capital in this category has been divided into: a) Physical Capital b) Social Capital c) Cultural Capital e) Human Capital f) Financial Capital

In conclusion, the prevention of a natural disaster, the relief of its effect, the preparedness and restoration, as well as development, will result in strengthening experiences and creating learning knowledge for future disaster management. Therefore, a prior education process will also provide a system of Adjustment, Assessment and Development, in order to confront an oncoming disaster. Thus, each catastrophe formulates and develops a Socialization system such as the disaster management dynamic in Japan, which is relevant to Thailand in cultural-based form. In consequence, the system can be simultaneously implemented in order to serve Thailand or in GMS country as well.

Keywords— **Disaster Management, Social Capital.**

1. INTRODUCTION

"Hanshin-Awaji disaster management in Hyogo has taught us that the important of disaster preparedness is not how to prevent a disaster from happening, but preparedness for an emergency situation and rescue town members, plus the rescuers, who are not government officers or police. However, they are the neighbors and people who live next to each other. The reason is, with this type of situation, we can't fully depend on the government. We have to depend on ourselves. Disaster has caused human to form a group and assist group members. A community with high social interaction will reflect in a less number of death tolls as they know the neighbors' house plan such as bedroom location and other living spaces. They spend short time to mark an exact area to search for survivors. On the other hand, a community with low social interaction will result in a high number of death tolls as they have no knowledge regarding the neighbors. As town members are forming groups in Japanese society, they are creating a community with social reciprocity causing a stronger interaction among members. The previous context has been mentioned in "UTOPIA in Disaster" by ……., that a characteristic of collaboration in Japan during the time of disaster is one unique identity of its people."

The above saying is a study conclusion from senior researchers, Kazumori and Nakajima of Hyogo Earthquake Memorial 21st Century Research Institution, and has resulted 2 following aspects:

1. Disaster is unavoidable and meant to happen to mankind. Therefore, we, as every country, should prepare for the emergency once the disaster occurs.
2. Neighbors, those who live together in the community, are in a higher potential than government officers in rescuing town members and victims. Thus, a community with strong positive relationship and generosity is a community with Social Capital and Cultural Capital, the two important capitals to cope with disaster.

The author believes that Japanese communities are in high level of Social Capital and Cultural Capital; the two important factors for Input, Process, and Output in Disaster Management.

2. JAPAN DISASTER MANAGEMENT CAPITALS

Moreover, an increasing knowledge in Japan from experiences of disaster encounter has prepared the country for future risk and outgrown the country in using their capitals for Adjustment, Assessment, and Development. As follows, important capitals in disaster management are commonly developed in order to prepare progressively.

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This article is partially based on a research "Knowledge Synthesis of Socialization in Japan on Crisis Situation". The author has studied 2 categories of disasters which are Human Made and Natural. Samples are commonly known as an atomic bomb in Nagasaki, Hanshin-Awaji Earthquake, tsunami earthquakes, and Fukushima power plant explosive disaster or 3/11. Disaster Management has been defined as the process of prevention, relief, preparation for emergency, recovery, and development of a study based on disaster management knowledge from various correspondents which are private own companies, public benefit organizations, local governments, education institutes, and other related government authorities.

The result of the study shows that important factors in Japanese disaster management are variables. Socialization is a crucial part which has been risen from socialization agents such as school, government authority, community, or individual. The transmission of disaster management knowledge to local practice has built the country to a well-planned society with a culture of disaster confrontation. Meanwhile, social connection in Japan has been strongly constructed in forms of local group, public benefit organization, or volunteering team, in order to react promptly before the arrival of government aids.

The above correspondents act as a community center to relief town members and victims; whereas, local governments and aids funding are aimed for area development and recovery in order to retrieve a pre-disaster living condition.

City planning, correlated with buildings and houses, has been considered as another crucial factor legally required for emergency case such as fire exit, emergency alarm, and vibration control construction.

The above factors are considered to be Japan disaster management capitals, divided into 2 types as followed:

1. Software: cultural capital and mankind capital
2. Hardware: physical capital and social capital

The author has divided 'capital' into 5 categories:

1. Physical Capital
2. Social Capital
3. Cultural Capital
4. Human Capital
5. Financial Capital

2.1 Physical Capital

Physical capital is defined as structures for human basic needs and important factors for human survival. City planning and urban renewal simply reveal city location, residence area, commute safety control, city planning for crisis situation like fire, earthquake and tsunami, building houses according to city planning, piping for gas and water, tidal wave protection wall, tidal wave emergency exit, etc.

We can assume that Japan is a well-planned country with physical capital for crisis and disaster as shown in 1946. After Nankai earthquake, the government has launched Disaster Relief Act. In 1959, the government issued soil protection and water level for flood indicator legislation, followed by coping with disaster legislation in 1961. After Fukai earthquake in 1984, the government has launched Flood Control Act, and Housing Construction and Safety Standard Act. Japan has controlled and developed more efficient basic needs after each disaster such as safer system for housing and commute constructions and a higher tidal wave protection wall.

Otsuchi, a town in Iwate, is an area of the study where a tidal wave protection wall has been built along the coast. However, the wall was constructed to prevent a 10-meter tidal wave, not a 38-meter in March 2011. Death toll rose to 800 and more without an emergency escape plan set by the community. The plan was to gather at community center, located in a higher landscape, once the town was under attack. Nowadays, town members refuse to return to their homes and remain at the temporary shelter provided by the government. They also expect the government to provide an area where they can build a community.

Residents of Kobe prefecture have experienced an earthquake in 1995 and were designated for Disaster Recovery and Rehabilitation and Reconstruction Plans. The objective of the plans is "to build a city with disaster management system where town members undoubtedly resided."

In conclusion of Japan Recovery Plan, some important aspects have been identified as followed:

1. Recovery period and town members capability for disaster preparedness are essential, especially piping system which provides basic needs for survival.
2. Daily accurate information is provided to relief anxiety and to reduce stress.
3. Building demolition fund must be promptly provided in order to deliver an adequate living atmosphere. Opinions and reactions from town members and victims are crucial at this point.
4. Town member and victims must participate in a recovery program concerning city planning and renewal the area from earthquake effects.
5. Recent study has found that the majority of victims are senior citizens and homeless with low-income. Hence, housing construction for these particular citizens must be size-related with communication device installation in order to maintain social interaction and other related activities. Town center or plaza is provided as a meeting point in need of life control and security.

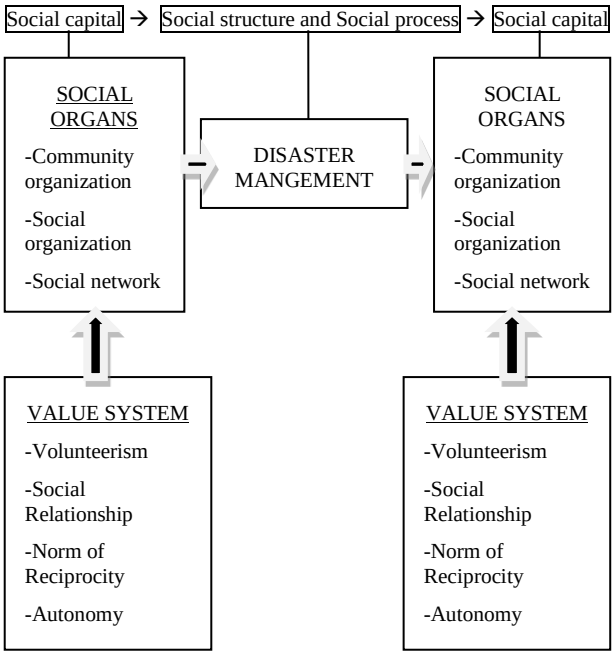
In addition to Japan Recovery Plan conclusion, members of Kobe prefecture also provide the knowledge of building vibration control system to others. Kobe museum has provided learning area for housing and building construction under vibration control with volunteers for demonstration. Besides housing construction, a part of physical capital for human basic needs, the ability to assess updated information is crucial. Once the disaster occurs, Japanese media automatically broadcast news concerning recent situation. The aim is to contribute immediate facts and details in order to provide help and support.

In local area, communities have a shortwave radio set to communicate and exchange updated details regarding their relatives, number of survivors and death toll, etc. As the town members gain concrete development of physical capital, the number of those who suffer is certainly

reduced.

2.2 Social Capital

"Social capital is a result of social structure and social process. In reverse order, social structure and social process are implied to be the results of social capital." Relation diagram is shown below:



In disaster management context, community organization, social organization, social network, volunteerism, social relationship, social reciprocity and self determination or autonomous skill are the outputs of the process. In synchrony, social capital is a community resource in disaster management practice.

(1) Community organization

Community organization occurs in both local and urban. The organization is categorized as a non-profit organization and represents in a form of resident association, local welfare foundation, volunteer group, etc. Organization members are town members and victims only, or town members and victims together with rescue team.

The study of Hyogo Earthquake Memorial 21st Century Research Institution shows that, in Mano district, a community development organization is constructed and called "Community Development Promotion Organization in Mano District". Members of the organization consist of town residents who encountered an earthquake in 1995. They have been maintaining the goal of pollution prevention since 1960.

Community members gathered at the primary school on the first day of the quake. The plan of borrowing heavy tools from manufacturers and companies was introduced and saving 7 lives.

After 3-day, the residents generated the task, helped rescue team providing food, and excavated other town members to safe zone.

Once the temporary shelter was completely closed, Mano Community Center for Development and Recovery was founded. A contribute work of the center was to reconstruct residence area with government support in both permanent and temporary for public. Representatives were required for reconstruction plan and project advisors, coordinated with out-town volunteers and professionals who were in support prior the quake.

Community organization is common in a form of:

- *Resident Association*

Resident Association is partially resulted from an interaction process among town members and victims who adjusted themselves to new rules and regulations at temporary shelter, provided by government in Kobe.

Residents participate in activities and rules concerning child, senior, handicap, and single survivor care programs. The arrangement of living area is focused on building positive responsiveness such as confidence, happiness, and friendliness. Land for agriculture is provided in order to create long term self reliance which are housing relocation, career path set up, government negotiation for basic needs , etc. Group interactions have been developed to a community organization which is called Resident Association. Once the group is stable and concrete with number of members, particular roles are set as followed: (1) to promote temporary shelter services for an individual who requires special care for health and medical treatment, including an efficient local welfare (2) to hold a meeting between local welfare agents and association members (3) to spread an adequate knowledge to survivors, town members and victims (4) to provide center where members can interact (5) to search for more opportunities in funding and development.

- *Local Welfare Foundation*

It was founded after Hanshin-Awaji earthquake with the mission of responding to problems and basic needs. The group was corporate by Resident Association and senior members exchanging opinions, receiving assistance from out-town correspondent, and seeking government social welfare. The request in social welfare concerns housing reconstruction and relocation, career path supply which leads to self reliance. Within 1997 funding, government provided social welfare support in community development and recovery activities which are Disaster Restoration Public Housing Community Plaza, care programs for children welfare, local care and visitor programs. Related projects include welcoming ceremony, tea party, house rules manual, board meeting, eyes-on project, etc. Community hall is a meeting point for miscellaneous task and discussion.

- *Volunteer Group*

Volunteer group is a community organization formed by volunteers in all aspects and run as Volunteer Center. Activities are varied and depended on recovery period. First session implicates medical treatment and nursing, public utilities and supplies, basic tools for survival. Second session focuses on post disaster period of survivors, town members and victims to maintain their daily life. Physical support and housing reconstruction are provided. Volunteer work runs under government authority attentively concerns on the number of the group; therefore, volunteer center has been organized by the government. After Hanshin-Awaji earthquake, local

authorities established Volunteer Information System as a data center to cope with volunteer financial support activities, connecting city council and district council in Hyogo.

Later, volunteer group has been developed to a non-profit organization regarding Non-Profit Organization Law in 1998. Japanese citizens willing to participate have caused conflict among the group and the government. The conflict is obviously shown in the study of disaster management consequences in Otsuchi.

- *Disaster Relief Network or Magokoro Net*

It is considered as a form of Community Organization combining members among town members, victims, and community development and social work scholars in Otsuchi, Iwate. This group of networking has been founded after the tsunami and earthquake and responsible as a center of temporary shelter. Working period relies on post disaster development plan. First session of the plan, the network working area is collecting unidentified bodies for further cremation. Emergency support center, National Defense zone providing, disaster relief and problem hearings are also parts of the network responsibilities and the network members are working both day and night shifts. Their task provides basic needs to relief anxiety and nervousness among members. They also act as a group of representatives requesting government support and welfare negotiation for benefit and encourage long term self reliance in members. Bento shop is one of the examples where women and housewives can earn regular income. Other examples of their contribute work are provided as farming area, senior residents activity, and career path opportunity. The objective of the network is to recover community members focusing on long term self reliance.

- *Nagasaki Peace Promotion Association*

The association is a civil society organization consisting of members with high awareness in wars, nuclear weapon, atomic bomb, and the effects. The majority of the members are senior residents who encountered A-bomb in 1945. The aim is to provide knowledge on nuclear weapon and its effects to children and young generations who sign for anti-nuclear weapon memorandum of understanding, incorporated with local government office in many countries, including Thailand. The organization is funded by Nagazaki municipal.

- *Yamagata Association of Mother Evacuation*

The organization consists of 'mothers' who, after Fukushima nuclear plant radiation leak, recognized disorders and symptoms in their children like facial bleeding. They decided to evacuate to a safe zone with the children and communicate with others by using Facebook. Later, they were set as an 'organization' assisting each other, exchanging children cloths, and sending requests to government.

(2) Social Organization

Social organization is social capital of Japanese people which resulted from international collaboration. A study on the output of disaster management in Kobe has created various Kobe social organizations in order to study, extend, and plan disaster management. These organizations are:

- *Disaster Reduction and Human Renovation Institution: DRI*

DRI is a government social organization, responsible for 6 tasks which are (1) to hold an exhibition regarding disaster and the effects at city museum (2) to conduct an action research for disaster reduction and to increase team profession (3) to provide basic needs for town members and victims by performing as a command center (4) to operate as a center for networking, exchanging information, conducting research and training with ADRC, IRP, UNISDR, OCHA, JICA, etc. (5) to organize a workshop for local government officers and correspondent team members in the country (6) to collect tools and data concerning earthquake in Kobe prefecture.

- *Asian Disaster Reduction Center: ADRC*

The organization is responsible for information exchange and technical collaboration in disaster management among country members, including training courses to increase disaster management team members potential. The 2 courses, which are disaster management and collaboration expansion for recovery and relief, are conducted semiannually.

- *United Nations International Strategy for Disaster Reduction: UNISDR*

It is a United Nation organization for world disaster reduction coordination, one office based in Thailand, and the head office is located in Kobe prefecture. The organization is responsible for corporation among member countries to create disaster reduction and disaster management models.

The objective is to establish a stable development. Kobe based center is aimed to expand Hyogo framework and practice.

DRI, ADRC, and UNISDR are parts of the study in role of disaster management capital. ADRC and UNISDR are funded by international organizations and work relatively.

(3) Social Network

Social network particularly generates vertical and horizontal communication channels which create team work trust and reliance, resulting in a greater approach to other considerable organizations. Post disaster mission is community recovery enforcing private and government sectors to stimulate mutual plan and find a resolution that most benefit the resident. There are 2 categories of social network as followed:

- *Corporation network among civil, community organization, private sectors and government authorities*

An example of the corporation task is public park design combined all related correspondents such as local government, professional landscape designer, town members and victims.

- *Corporation network among local governments*

Disaster management has also created corporation network among local governments in term of assistant perspective. The network is combined 2 local governments in term of towns paring or zone combination once the disaster occurs. This form of network has been founded after Hanshin-Awaji earthquake. Towns pairing sample is among Kobe and Osaka. Once there was an

earthquake in Kobe, Osaka municipal took responsibility in assistance and corporation which included mechanic tools, heavy machines, manpower, and funding. One of the pairing regulations is to avoid towns which are connected. The chosen towns for pairing are distance; therefore, once a town has been stormed, the other is still in high potential to assist. Corporation network among two local governments is under comparable framework, but from a distance.

The following value system is an element of social capital to establish community organization, social organization, and social network in accordance with Robert Putnam's framework; volunteerism, norm of reciprocity, autonomy, and social relationship.

(4) Volunteerism

Volunteerism is human flocking behavior that aims to enter disaster encounter area. Those mentioned among the group are people with their will to help and recover the area and they are considered to be social capital. During post Hanshin-Awaji earthquake, many volunteers gathered to enter the disaster encounter area. Among these, there were people who gained experience in rescue team and 70 percent was without any rescue skill. However, they were in attempt to help town members and recovery plan. Number of volunteers was exceeding and other correspondents were in charge of organizing volunteers' role and task.

Volunteers' role and responsibility are upon post disaster recovery plan. People are motivated to dedicate their power without reward or being paid which is a basic citizen qualification. Moreover, power of the volunteers significantly affects town members and victims as shown in a form of social capital.

A substantial social capital by civil lead develops further solid plan in town policy and civil benefit which have been included in social rules and regulations.

Volunteerism happens in an area of massive disaster, including Thailand. However, volunteerism in Japan is immense and powerful which resulted as a work institution. An act has been launched for volunteers' registration and control, caused a vast establishment of community organizations and social organizations in Japan. The objective in volunteers' registration and control is to clarify precise roles and responsibilities, including limiting of the number of area entries.

(5) Norm of Reciprocity

During post disaster, town members and victims are facing a stage of survival and are forced to help others in recovery program. Reinforce activities are temporary shelter safety and protection, child care, senior and handicap residents care and supportive skill which are collaborative activities among members and families. The result has been focused on a positive relationship among group members and volunteers leading to social capital based on community trust and reliance.

(6) Autonomy

Autonomy or self-determination of town members and victims is social capital. It has been raised from Japan disaster management process. As a country, the government insists in denial of being assisted by other countries with an excuse of language barrier. Community residents and town members repeatedly reject external help and contribution which tends to deconstruction community system and town members' determination process. They generally refuse the distribution of free food as it could affect town shop vendors. Volunteers' entrance is withheld as some are without skills and causing complications. The objective of disaster management is self-determination in all aspects in order to create community or social relationship.

(7) Social Relationship

Social relationship happens between individuals or among group members. They can be implied to volunteer and volunteer, volunteer and temporary shelter member, town member or victim and social work agent, etc. The relationship concentrates on reaction and behavior during meetings, negotiation sessions, including development and recovery activities among volunteers, housewives and senior residents, temporary shelter members, and particularly in child care. The related activities motivate members to express their opinions, to discuss, and to participate in learning center in order to communicate and react to others. For senior residents, a meeting point is where they hold relaxation discussion that reducing the number of *kodokushi*, a Japanese term for dying alone. From social contacts, group members have created social relation that leads to aggregation, norm, rule and regulation. Robert Putnam (1993) describes that human interactions and civil activities have caused moral cycle which is indeed social capital.

2.3 Cultural Capital

Cultural capital means an approach based on culture in disaster management context. It can be identified as planning culture and lesson-experience-set of knowledge.

(1) Planning culture

Planning culture or a culture based on disaster confrontation is obviously shown in a study on organization plan in order to cope with emergency during disaster. At Bunkyo Gakuin University Girls' High School, a concrete sample shows by their preparation of life survival kit as a planning culture. Life survival kit contains canned food with 5 years expiration for 3-day consumption plan. The budget for life survival kit is provided by parents, government, and the school. It has been spent on other school utilities such as sanitary ware, lamps, torch lights, beddings, etc. Students always carry a booklet which provides important details about school, students, and safe route home in case of emergency.

Planning culture on household level has been initiated by the government in providing emergency box that contains life survival kit. Box size is designed differently and it contains food, water, medicine, torch light, hammer, and other life survival tools. Nowadays, housing construction has a special design to resist vibration from earthquake and with other research and development studies on technology and innovation. Throughout failure in strategic management controlled by government authorities and massive attack of particular disasters, new research and innovation might not be able to implement in order to save lives. One of the examples is a tsunami in Otsuchi, 2011. The wall was built for a record of 10-meter tidal wave while at the time; the wave was 38-meter and caused many lives and destructions. Town and

resident areas were demolished. However, town members were agreed to meet at Community Center prior the attack and they were in the safe spot. Some remained home because of the expectation of a small hit and the concern of their properties.

Still, planning culture or a culture based on disaster confrontation runs in support by a set of social norm which are devotion, self-responsibility, social-responsibility, honesty, the important of building learning process and autonomy, etc.

(2) Lesson, experience, and set of disaster management knowledge

After each disaster, Japan generally pays great attention to the establishment of disaster management learning process, experience record for next generations, study and collecting data. These are organized by related sectors and correspondents such as local government, research institution, government authorities, etc. Moreover, a set of knowledge will be transferred and broadcasted to public, young generations, and world population. The evidences are presented as Atomic Bomb Museum, Nagasaki City Nagai Takashi memorial, and Disaster Reduction Museum by Disaster Reduction and Human Renovation institution.

From knowledge and experiences, various aspects have been focused and expanded. Knowledge and experience are the content held in exhibitions for disaster opening area, ceremonies of Memorial Day, learning channel through experience and discussion by volunteers who are town members and victims, town libraries with data and related objects concerning the strikes, conclusions from researchers and Kobe, Hyogo, in disaster management process towards Hanshin-Awaji earthquake. Further aspects of the study include researcher conclusion from Hyogo Earthquake Memorial 21st Century Research Institution engaging 108 researchers, both full time and by project. The conclusion is summed in 3 aspects:

(1) Immediate actions in response to disaster are put rescue team on task, apologize to public, and adjust government authority work plan.
(2) Problem in disaster management process is Japanese law that particular materials are not allowed to operate as they are again town regulation of the autonomous town and the administrative receives orders from line of command only.
(3) Lesson from Hanshin-Awaji is disaster awareness and preparedness is that the first area rescuer is the neighbor, not government officers or police. Therefore, norm of reciprocity must be promoted to create a sustainable community. The research also found that trees have a potential in saving life while flowers have the power of pain and sorrow relief. As suggested, trees and flowers are benefit to town members and victims in their new zone. The important lesson is not disaster protection, but the relief program.

After 15-year experience of disaster, Kobe prefecture in Hyogo has a summary of their knowledge in various aspects such as lesson from reconstruction and recovery, summary of work procedure in lesson communication and earthquake experience. There are some important lessons which are immediate responses to earthquake such as saving lives, locating temporary shelter, recovering environment and surroundings, and acquiring daily routine. Temporary shelter is basic government funded; however, to be constructed in short term, it requires collaboration from local administration, private and government authorities. Recovery period of town members and victims depends on temporary shelter establishment.

Industrial plant relocation, tax modulation, investment campaign, policy and regulation cancellation are required for industrial recovery in order to propose the area for tourists and traveling site.

Regarding senior residents, it is essential that the living zone must be surrounded by mobilization facilities for daily routine activity. The most valuable lesson form Kobe earthquake is knowledge transfer in order to reinvent practical program and to develop human potential for an upcoming disaster. Knowledge transfer channels include a training session for city governors, mayors, government officers, researchers, volunteers, members, and students in all levels.

2.4 Human Capital

Human capital is a qualification of community members considered by education system, level of self-determination, and morals. Human capital plays an important role in Japan disaster management. A community with an adequate level of social morality in each member is able to handle disaster with self-conscious.

(1) Education System

Education has been applied to all Japanese people; however, the government also provides a study curriculum for disaster management. New set of knowledge in disaster management is the consequence from repeated experiences in disaster management. It is crucial for the country to set an education system for disaster management to its population. For example, all high school students must attend Nagazaki Atomic Bomb Museum or Hiroshima before graduation. In case of long distance, a volunteer is provided to school and conduct a relevant training or seminar. Likewise, students in Kobe must visit Disaster Reduction Museum where they can practice earthquake preparedness which everyone has experienced. Therefore, Japan population is deliberately trained for disaster preparedness and has combined the knowledge to their daily routine. This education system has been generated in all units such as school, education institution, related government sectors and organizations which are museums and research institutes, not only by the government.

(2) Autonomy

An important characteristic of Japanese people in disaster preparedness is self-determination which reflects in various stages as followed:

Individual stage:Japanese children are taught to look after themselves during disaster because an ability of self-rescue leads to the next step of survival.

Community stage : Community members refuse to constantly accept food from volunteers as they believe that external assistance tends to deconstruct community autonomous system and overturn community shop

vendors. In case of acceptance, donated items are beneficially considered only as new devices for survival and in a proper amount.

Government stage:The government has limited international contribution and considered one carefully. Only certain number of volunteers can enter disaster area.

(3) Morality

Even though morality is an abstract element and difficult to clearly identify, we can recommend individuals who have been devoting in regards of post disaster recovery. The examples are Dr. Nakai from Nagazaki University who generously treats radioactive patients, a group of senior residents volunteering in raising disaster effects awareness by repeating their stories at Atomic Bomb museum and Disaster Reduction museum, and Uzasawa who decided to encourage community members in maintaining lives after lost. The 3 cases clearly reflect morals in community members in terms of social responsibility, ethics, and social reciprocity. Morals awareness is revealed once the population is obligated in disaster.

Citizens of Japan have been abided with morals and ethics from a family unit through the spirit and teaching of Confucius which are loyalty, honesty, disciplinary and social responsibility. Until present, Feudalism has been crucial for social system, interaction in social stratification, and education structural plan for each hierarchy. Hence, socialization for Japanese family members has been influenced from social foundation in the past, adjusted and transferred to next generations in terms of loyalty, honesty, collaboration, proper manners and rules, frugality, patients, and self-discipline. Communities in Japan are adjusted to various influences, including political system; however, family culture remains. Family has become the first unit in providing a potential human resource through socialization. Moreover, education system, autonomous skill, and morals are essential in acquiring high potential and building pride in disaster preparedness for its population.

2.5 Financial Capital

Financial capital is a resource spending while funding need is highly demanded by town members during post disaster. It can be analyzed by capital resources, opportunities, and approaches.

(1) Financial capital resources

Financial capital is divided into 2 categories: a) Available Stock which are savings in cash, deposit, jewels, including financial institutions, and b) Regular Inflows of Money which are earning income, pension, payment and others from government or funding.

The government allocates high amount of funds to rescue town members and victims in case of disaster in various forms. Hyogo Phoenix Plan is a 10-year recovery plan and is allocated as followed:

- 17 thousand million yen for emergency during the first session
- 57 thousand million US dollar for primary facilities recovery projects
- 9 thousand million US dollar for loan in recovery plans in housing reconstruction, daily life expenses, habitat compensation, industrial units, education and other extra expenses in restoration of old buildings

Funding allocation policy as supportive budget by the government is from central government and local government in order to increase autonomous skill in locals.

(2) Opportunity for financial capital

Besides cash, financial capital also includes creating an opportunity to make an income or to obtain a job. In Otsuchi, housewives have formed a bento shop. The shop owners are still capable in continuing their business at the provided shelter. After Kobe earthquake, a community plaza was reconstructed and turned to a commercial area.

(3) Financial capital approach

The government provides financial capital approach in many channels which are a community-run social welfare foundation for financial capital management and a recovery and registration work office for town members and victims. It also performs as a data center among local offices.

Financial capital is highly important for post disaster and unexpected situations. It forces projects to be accomplished before schedule.

In conclusion, disaster management relies on 5 capitals which are physical, social, cultural, human, and financial which provide a secure and strong community in disaster management.

Disaster management systems are different in order to manage emergency preparedness, recovery program, and solving problem skills in each community. The potential is partly depended on the acquired capitals. Community based on full capitals will be able to proceed well in disaster preparedness and management.

The 5 capitals are substantial community program inputs for disaster preparedness to save lives, recover, and encourage town members and victims to live their ordinary life. In sequence, output of the 5 capitals will be diverted to an input as a set of developed skills for next disaster management. The question is how locals and communities manage their capitals and the diversion process of output to input for next disaster preparedness.

3.DISCUSSION

First, the research result has revealed Japanese disaster management community existence. However, a community alone is insufficient to manage throughout the time of disaster. Preparedness is required in degrees of physical capital, social capital, cultural capital, and funding capital. In case of strong society and weak state, a community is forced to play an important role in preparedness at emergency stage such as saving lives, neighbors rescue, public sector organization establishment, social responsibility mind set, including town members and victims recovery program. Recovery activities which are the evacuation to temporary shelter, shelter construction, basic needs recovery, are partially responsible by the community. Some activities are responsible by government and international authorities such as area recovery, funding support foundation, nuclear power plant explosive maintenance, and laws legislation.

Therefore, disaster intensity can be minimized by strong state and strong society with tasks divided into community base, city or local government base, and nation base.

Second, a community combined with degrees of physical, financial, and cultural capitals has performed a strong disaster management in local government that is known for high potential in management. In fact, there are particular tasks which cannot be processed by local government, but by the community or others related organizations. Mafia gangsters, Yakuza, are allowed to help town members and victims during the first period while Kobe prefecture responds in coordination and collaboration.

The other aspect causing a perspective towards strong local governments is the belief in social structures and titles of bureaucracy which is greater than in any particular leader or staff. Hence, a task accomplished by local government has frequently been spread as an important issue.

Last, disaster management relies on degrees of physical capital, social capital, cultural capital, financial capital, and human capital. A community usually proceeds fluently with all 5 capitals. Without one, work flow is interrupted. Otsuchin is in difficulty to rebuild a community because cultural and physical capitals have been disqualified. Residents are panic to return to town area and reconstruct. Moreover, the death of all local government officers has caused a negative perspective towards the situation.

In this study of disaster management, catastrophe in Japan and Thailand are incomparable in various angles such as town area, disaster intensity, and local government authority. However, result of the study has shown social process in disaster management focusing on input, process, and output. During time lapse of the 2 disasters, we can monitor on how experience and knowledge have been transferred. Moreover, we can investigate disaster management workflow and process of socialization. Knowledge of the study can be applied to Thai society, especially in socialization process for disaster preparedness, the creation and utilization of capitals.

One of the main findings is that development process and connection have been revealed between Nagazaki disaster management and Hanshin-Awaji earthquake preparedness, including knowledge development based on Hansin-Awaji earthquake towards Tohoku disaster management. Another finding is a development procedure of social process in Japan in order to transfer disaster preparedness to next generations, particularly in knowledge management and socialization through community agency, school and other sectors as shown below:

Social process in disaster management is an important process in knowledge transfer from one disaster management to the next. The study has identified steps of passed-on knowledge from nuclear power plant explosive in Nagazaki to Hanshin-Awaji earthquake disaster management, and to tsunami and nuclear power plant explosive in Tohoki. The crucial factors are disaster management procedure, recovery plan, transferred knowledge and experience. The factors are applied and utilized by local governments, related organizations, schools, and community members to prepare for an upcoming disaster. Medium of the transfer is socialization which can be delivered in term of cross-culture. Japanese experiences towards disasters can be channeled to Thai culture in the same context without an expectation of disaster in the future. Socialization process with disaster demonstrations of fire and collapsing cinema can be flown in school, local government, family, press, religious office, and other related organizations.

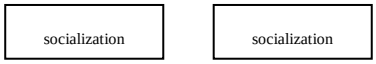
4. SUGGESTION

- ***Suggestion in Cross Cultural Disaster Management Knowledge***

Even though there are differences between Thai and Japanese societies, disaster management throughout socialization can be implemented in term of cross cultural in Asian country. The study suggests an application of Japanese best practices which are:

(1) Lesson summary

The important aspect in disaster management from disaster experiences in Japan is lesson summary or knowledge management which is a strong point. Thai society can learn the lesson and apply the knowledge from disaster



management in Andaman tsunami and central flood experiences accordingly.

(2) Socialization agents

Thailand has socialization agents which are school, government sector, local government, etc. The agents are responsible to transfer crucial factors of disaster management which are acknowledging, training, practicing, planning, and expanding the knowledge to next generations. The knowledge can also be specified in school curriculum variedly regarding each geographic area of disaster prediction. A curriculum of school located in the north combines knowledge on land slide and earthquake while school in the south contains tsunami and storm knowledge. School in the central considers water and flood. Besides, National Disaster Prevention and Mitigation Plan 2010-2014 should be fully activated.

(3) Making good value

Good value in Thai society is necessary as it is considered to be Japanese strong point in disaster management. It has been shown in cultural perspectives of substantial autonomy, disaster preparedness, Western influences of disciplinary, honesty, responsibility in society and other people. Another remarkable Japanese social value is an experiment for standard measurement before the knowledge is transferred and utilized. To conduct a training course and demonstrate best practices in order to create basic qualifications among young generations in Thailand is required.

From the interviews and perspectives of Japanese representatives in the field of disaster management, they have denied the success of disaster management in Japan. However, the researcher believes that experience and knowledge of Japan disaster management can be customized in cross cultural practice in all Asian country.

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The Investment Plan to Develop the Tourism Sector in Nakhonsrithammarat Thailand

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Abstract— *This research aims to construct a plan to develop investment of tourism industry in Nakorn Si Thammarat province. The study reveals that there are five issues which should be promptly taken action from related organizations. Tourism information as well as publicity every tourism activity should be concerned. In addition, the skills of human resource in tourism sector should be strengthened. Furthermore, the government should grant entrepreneurs or help them to easily access financial sources. Other to consider is that developing destination management systems to sustain tourism destinations. Finally, it is important to note that the strategic plans should be continuously developed including initiating new tourism routes.*

Keywords— **Investment developing plan, Tourism business.**

1. INTRODUCTION

Nakorn Si Thamarat is a province locating in the south of Thailand nearing the gulf of Thailand .In 2005, the number of arrival tourists was 918,263 increasing to 1,1013,208 and 1,155,138 in 2006 and 2007, respectively. Tourism industry can generate income to the province 540 million bath growing to 568 and 620 million bath in 2006 and 2007 , respectively (National statistic organization, 2010). The province has high potential to be a famous tourism destination due to the abundant resources in the province having both cultural and natural destinations which can induce both Thai and foreigner visitors. The increasing of arrival visitors the province leads the growth of GDP of the province as well as increasing the income of proprietors relating tourism. Therefore, related organization should pay more attention studying expense patterns of the visitors for making a plan to develop tourism destinations and also tourism businesses to meet the needs/wants of tourists resulting in the increasing of income in every organization. The aim of this paper to study the needs and wants of arrival tourists in Nakorn Si Thammarat for developing tourism industry, study the opinions in tourism development of entrepreneurs and other stakeholders in tourism sectors and construct an investment developing plan for tourism in Nakorn Si Thamamarat. The article is composed of four parts, section 2 presents the methodology, while Section 3 presents the results. Section 4 concludes

2. METHODOLOGY

The study is mixed method research by combining both quantitative and qualitative research. In the case of quantitative research, questionnaires are conducted to investigate both Thai and foreigner tourists visiting Nakorn Si Thammarat. While, structure interviews are applied to study tourism entrepreneurs in addition group discussions are also held to brainstorm various opinions from tourism related stakeholders. Furthermore, the study focuses on tourism stakeholders such entrepreneurs, souvenir shops, restaurants, accommodation businesses such as hotels, resorts, etc., transportation organizations, guides, communities and other tourism stakeholders. The samples are investigated in this study composing of 400 Thai visitors, 30 foreigner visitors and 30 tourism stakeholders .The researchers take a random of the arrival tourists to study the consume patterns by applying purposive sampling and snowball sampling being non probability method.

3. THE RESULTS

This section discuss in 3 parts first discuss the general requirement of tourists in Nakorn Si Thammarat in terms of tourism places , tourism information, service, transportation, Public organization, Entrepreneurs and The satisfaction of tourists toward tourism in Nakorn Si Thammarat. Section 2 discuss for suggestions of the entrepreneurs toward developing tourism in case of tourism places, tourism information, service, transportation, Public organization, Entrepreneurs and requirement of tourism entrepreneurs from the public organizations .Section 3 analyze SWOT of tourism and investment plan to development tourism in Nakorn Si Thammarat

3.1 The general requirement of tourists in Nakorn Si Thammarat

The requirement of tourists with Tourism places found that tourism destinations should be neatly managed. The landscape should be clean. The local public organizations should well organize stalls. In addition, the public facilitate should be well organized such as a public service, beautiful and clean bathrooms, pavilions and trashes. New tourism routes and new destinations should be explored and set up to attract more tourists. Tourism activities and more scenic routes should be added to concern reducing tired from the trips in a remote locations. Meanwhile tourism information should be updated and added more new information. In addition, new routes, related tourism destinations and activities should be published. Various media should be chosen to advertise the tourism information to cover the tourist

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targets and to access to the information easily. The finding revealed that service providers in tourism sector in Nakorn Si Thammarat should be friendly. Moreover, tourism destination signs should be clear and enough to lead tourists to the right destinations. In addition, the service and price standard of public transportations should be improved. Furthermore, the number of public transportation should be increased to cover every tourism destinations. Finally, the related organization should clearly publish the all public transportations to tourists. For souvenir, it is also true that Nakorn Si Thammarat has unique souvenirs and various souvenir types and prices therefore the related organization should arrange database of the various souvenirs to build awareness of tourists leading to increase sales and profits to the community as well. The research disclosed that the tourists suggested that the government should improve every service to tourists including fundamental facilities such as roads, electricity and water supply being ready to serve the tourism expanding in the future. In case of entrepreneurs, some entrepreneurs exploit tourists and lack of service and products quality concerns. Therefore, the tourism businesses should enhance the service standard level by training their employees. On the other hand, the satisfaction of tourists toward tourism in Nakorn Si Thammarat shows that the overall satisfaction is high in which the mean is 4.17. Transportation is the highest satisfaction being 4.04 while the satisfaction level of the samples toward tourism issue is 3.86. While, entrepreneur issue, public organization and tourism information has the less satisfaction than other issues. (Table 1)

Table 1 : The satisfaction level of the respondents toward tourism service in Nakorn Si Thammarat

Items	Very high satisfied	High satisfied	moderate	Unsatisfied	Very unsatisfied	Mean	Standard Deviation (S.D.)	Satisfaction level
1. The overall of tourism in Nakorn Si Thammarat	126 (28.60)	267)60.70(	45)10.10(	2)0.60(	0 (0.00)	4.17	0.61	High
2. Tourism issue	94 (21.40)	214 (48.60)	109 (24.90)	23 (5.20)	0 (0.00)	3.86	0.80	High
3. Tourism information issue	64 (14.50)	169 (38.40)	148 (33.50)	57 (13.00)	3 (0.60)	3.53	0.91	High
4. Service issue	88 (20.10)	220 (50.00)	109 (24.70)	22 (4.90)	1 (0.30)	3.85	0.80	High
5. Transportation issue	113 (25.70)	243 (55.20)	75 (17.10)	8 (1.70)	1 (0.30)	4.04	0.72	High
4 Souvenir issue	93 (21.20)	215 (48.80)	118 (26.70)	12 (2.60)	3 (0.60)	3.88	0.79	High
5 The public organizations	56 (12.70)	130 (29.50)	191 (43.40)	56 (12.70)	8 (1.70)	3.39	0.92	Moderate
6 Entrepreneurs	67 (15.30)	137 (31.20)	181 (41.00)	47 (10.70)	8 (1.70)	3.48	0.93	Moderate

Table 2 : The satisfaction level of the respondents toward tourism government service

Items	Very High	High	Moderate	Low	Very Low	Not Specified	Mean	Standard Deviations	The requirement Level
Business Knowledge	81 (20.20)	163 (40.80)	91 (22.70)	17 (4.20)	45 (11.30)	3 (0.80)	4.35	0.813	Very High
Financial Assistance	159 (34.90)	94 (23.50)	79 (19.70)	30 (7.60)	54 (13.40)	3 (0.80)	4.39	0.836	Very High
Foreign language training for human resources	106 (26.50)	129 (32.40)	74 (18.50)	40 (10.10)	47 (11.80)	3 (0.80)	4.32	0.830	Very High
Good service providers training	58 (20.60)	110 (38.70)	62 (21.80)	110 (38.70)	58 (20.60)	2 (0.80)	4.33	0.814	Very High
Developing fundamental facilities such as roads, signs, water supply and electricity	156 (39.10)	139 (34.90)	55 (13.90)	27 (6.70)	20 (5.00)	7 (0.40)	4.37	0.261	Very High
Tourism information Publicity	220 (55.00)	123 (30.70)	39 (9.70)	12 (2.90)	5 (1.90)	2 (0.40)	4.76	0.196	Very High

Source:Author

Table 3 : TOWS Matrix

TOWS Matrix	**Strengths** 1. The province is the center of Buddhism town of Srivichi Kingdom 2. There are elegant tourism destinations 3. Being well know and popular destinations 4. There are still traditional life, folkways, markets, villages and cultural center 5. There are the varieties of tourism destinations 6. Having adequate fundamental facilities 7. Having convenient transportations	**Weaknesses** 1. Lacking of tourism strategic plan 2. Lacking of linking each tourism activities inner the province 3. There is unobvious the plan for develop and maintain antiques and ancient places 4. Less publicity 5. There is inadequate tourism information 6. There is less concern to train human resources 7. Souvenirs are not unique
Opportunities 1. The province is the center of cultural tourism 2. Increasing the number of foreigners 3. Free Trade Area and the government's policies stimulating investment. 4. Receiving the assistance from the tourism and sport ministry	**SO Strategy** 1. The government should enhance tourism activities having high potential to international brand) S1,O2(2. The government should campaign entrepreneurs to apply international standard to build a selling point and to enhance confidence of service users in the global market) S3,O2(3. Emphasizing MICE such as Meeting, Exhibitions, Seminar, etc. to attract more visitors both in aboard and domestic market)S1,S2,S3,O2,O3(	**WO Strategy** 1. Setting a tourism strategic plan)W1,O1(2. Creating publishing and releasing tourism information) W5,W6,O2(3. Strengthening human resources to serve the growth of tourism industry in the future) W6,O2(4. Developing the uniqueness of souvenirs) W7,O3(
Threats 1. Tourists do not stay overnight 2. Economic problems 3. High rivals from other provinces nearby 4. There is less accommodation investment having international standard 5. Natural disaster 6. Energy crisis	**ST Strategy** 1. The government should promote entrepreneurs accessing easily to financial organizations to gain enough budgets for developing production and marketing in their business)S5,T4(	**WT Strategy** 1.Initiating new tourism routes which link to events or activities) W2,T1(2. Exploring the real situation of the destinations leading to setting solutions or improvement)W3,O3(

Source:Author

Table 4 : The relations between strategic issues and tourism strategies

Strategies goal	Strategies
Developing the sufficient methods to advertise tourism information	1.Creating the activities to publish and advertise tourism 2.Supporting tourism statistic and information for making a decision of entrepreneurs and others
Strengthening tourism human resources to serve the expanding of the industry	Strengthening tourism 1. human resources to serve the expanding of the industry
Promoting and/or supporting grants to tourism businesses	2. Permitting tourism business access to financial institutions
Developing destination management systematically to sustain tourism destinations	1.Exploring the current situations of destination before setting solutions or improving plans 2. Developing the uniqueness of souvenirs
Improving strategic plans focusing on tourism destination and activities	1. Constructing tourism strategic plans 2. Initiating tourism routes linking activities occurring 3. Enhancing potential tourism activities to international brand 4. Focusing on Exhibitions,Meeting and Seminar) MICE)

Sources : Author

3.2 The suggestions of the entrepreneurs toward developing tourism in Nakorn Si Thamarat Tourism issue

The suggestions of the entrepreneurs illustrated that, tourism networking between private and public organizations should be set to strengthen competencies of tourism in the province to show other counties that the destinations of Nakorn Si Thammarat are very attractive for visiting. In addition, the conservative natural tourism destination activities should be addressed to sustain these destinations to the next generation. Exploring and

initiating new routes, new destinations, amazing destinations or activities should be created more to remain tourists stay longer or overnight in Nakorn Si Thammarat which can generate more income to local people. Moreover, the related organizations should advertise tourism information in various channels of media to both domestic and foreigner tourists to give them know more about the tourism places and highlight destinations in the province. The tourism information in each district should be separately informed in a tourist centre such as the tourism center of Nakorn Si Thammarat or branches in each district. The publication and tourism events should be emphasized on oversea to attract more foreign visitors. Tourism events or activities should be set and made up maps illustrating the detail of routes both in billboards or brochures while in local destinations should manage setting sings to destinations clearly. The documents, brochures or leaflets should be laid down in crowded target tourist places such as train stations, bus terminals, airports, piers, restaurants, etc. including the tourism service centre. Furthermore, local tourism service centers should be set up to serve and release depth information or informs one or two day or attractive trips in the communities to visitors. In the brochures, history, important places, tourism destinations, maps, accommodations, restaurants, transportations and also telephone number of important places in the case of emergency should be specified in media. These information should also be developed to multi-media, web sites or other social web sites. In the points of entrepreneur's view, the weaknesses of tourism in the province are still providing service. Due to personalities of people living in the south of Thailand normally are outspokenly, loudly and serious looking leading visitors misunderstanding and dissatisfaction which can cause the decrease of tourist number further. The public organizations should cooperate with private business to train and improve service quality both service skills and also communication in foreign languages to service providers such as taxi drivers, guides, conductors, waiters/waitresses, etc. In the term of foreign languages should emphasize in languages in ASEAN region such as Chinese, Malay, etc. and also the outside such as English, Russian, German, etc. It is certainly important that local communities should have local guides who know exactly local information and can explain tourists correctly. Other issue to concern is that training marketing and sales to businesses to reach a new market or make a sufficient strategic plan for their businesses. According to the vast area of Nakorn Si Thammarat, each tourism destination is very far away, hence, fundamental facilities such as roads or public transports should be constructed to access each destination easily. The planners of public transports should set reasonable prices or single price concurrently the drivers should pay more attention in safety and service quality. The transport services should be announced to cover the targets. In Nakorn Si Thammarat, there are several types of souvenirs which are very unique and different products and prices. However, the gift shops should focus on local or traditional souvenirs rather than outside products which can erode uniqueness of the province. Developing uniqueness and new products should be focused on traditional or local materials and international standard to add more value to the products leading to increasing sales and profits. In addition, the area of shops should be neatly decorated and systematically managed. Furthermore, the public organizations should have high involvement in promoting, new product developing including packaging of businesses to meet the needs/wants of markets. The entrepreneurs have requested that the government should improve their working to be approach strategies rather than reactive strategies. They should pay more attention and have high commitments to support doing business to local entrepreneurs. They should hasten publicity and inform depth information to reach and cover target tourists, promoting tourism investment, developing tourism destinations, doing research to develop products and reducing production costs, making a strategic plan to promote tourism consecutively, training tourism officers providing good service to tourists and others, training communication in tourism focusing participations of communities and creating a project to conserve and rehabilitate tourism destinations. Finally, walking streets should be set to induce more visitors and remain them stay longer in Nakorn Si Thammarat. Some entrepreneurs opined that some tourism businesses are dishonest to their customers which can cause the damage of image as a whole. They don't concern the quality of products and service. Some do something being impolite to customers. As a result, the tourism players should concern more their products and service quality furthermore they should develop their products and service continuously or train their employees to enhance their competitive advantages and tourism image of the province as well. The overall assistances needed level of tourism businesses from the public organization is in the highest level. In the case of publication, the tourism information is the highest level, while financial assistance, developing base facilities such as roads, water supply, signs, electricity and training doing businesses being 4.76, 4.39, 4.37, respectively. (Table 2)

According to the demand and supply side, tourists, entrepreneurs and stakeholders of tourism in Nakorn Si Thammart. We found the SWOT and developing tourism plan in Nakorn Si Thammart can be concluded in table 3 . From the focus group of stakeholder of tourism in Nakorn Si Thammart found that investment plan should have 5 Strategies goal and 10 strategic in table 4. The definition of Nakorn Si Thammarat is a dignified city of righteous kings. Currently, the province is a great well know and famous province. The province is an ancient town having propensity from the part being more than 180 years. There are unique culture and important traditions which are inherited from previous generation to current generation. Furthermore, there is important and well know culture which is held every year in September being called as Han Daen Sib- Tenth month festival; Buddhism ceremony to make merit to their ancestors or deceased. The province still has Buddha's relics being called Wat Pra Tad where is very famous and well known. The vision is the province will become a famous culture town in both domestic and aboard market in 2014

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Strategies to Support in Term of Learning for Voluntary Tourism in Thailand

Kamolvun Laoyoung, Anuman Chanthawong, and Mongun Somkua

Abstract*— *The objective of this research were to analyze the government policies and conditions that promote the process voluntary tourism in Thailand. The result shows that the government policies and conditions that promote the process voluntary tourism in Thailand should be developed in 4 issues. The first issue about all sectors are participate on the strongly about voluntary tourism. The second issue about make ensure the safety of voluntary tourism about the rules and system to ensure in safety standards for foreign tourists, preparing the guide for safety such as safe travel on the road and cooperation of the relevant agencies with the Tourism Authority of Thailand. The third issue involved thedevelop on information and publicity activities to promote the voluntary tourism and the last issue to create and communication on brand volunteer products.

***Keywords*— Policy, voluntary tourism.**

1. INTRODUCTION

The voluntary tourism in Thailand have beginning from the NGOs receiving foreign visitors participate activities beneficial in the local, in January 2005. After the tsunami has been established The Tsunami Volunteer Center in Khao Lak, Phang Nga province, where international volunteers from 51 countries around the world had 3,500 people by having age amount 19-67 years old. Almost volunteers to help build new homes to replace homes damaged from the tsunami, english teaching and shipbuilding. While the Koh Phi Phi in Krabi province has set up The Phi Phi Dive were found international volunteers has 4,000 people to the garbage and ruins off the island is 290 tons. When tsunami happens will encourage people to turn to the more interesting by subscribing to Thailand to work as volunteers to help the victim. When on the trend of voluntary tourism has increased, the Tourism Authority of Thailand (TAT) and university cooperate the project with learning community tourism project is offering a voluntary tourism for the 4 regions across the country. The value derived from the practice of voluntary tourism is an opportunity for students to travel to various tourist location about to learning something such as, way of life, arts and culture. The important cultural differences in lifestyle that is to broaden the students from tourism and those students to share their knowledge, ability, the thinking, the energy for creating benefit for the community and include that to enhance the potential market of community lead to real perfect of voluntary tourism. This paper aim to analyze the government policies and conditions that promote the process voluntary tourism in Thailand. The article is composed of three parts, section 2 presents the methodology, while Section 3 presents the results and concludes.

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2. METHODOLOGY

The research used mixed methods research between the quantitative and qualitative research. The quantitative research using questionnaires and qualitative research using structured interviews by collection sample from stakeholders of voluntary tourism in Thailand. The sample used in this research is the official Tourism Authority of Thailand, Ministry of Tourism and Sports, Nonprofit organization, Provincial Administrative Organization, Municipality, entrepreneurs, and foreign tourists about 400 samples from 10 provinces (Chiang Mai, Chiang Rai, Ubon Ratchathani,Udon Thani, Kanchanaburi, Bangkok, Ayutthaya, Loei, Phang Nga and Phuket). Research sampling using purposive sampling that is selected randomly from stakeholders of voluntary tourism in 10 provinces consider from the most number of voluntary tourists in Thailand that is sampling using Snowball. This research collection of quantitative data by using questionnaire and collected qualitative data using structure interview.

3. RESULTS

This section starts with an analysis of government policies and conditions that promote the process voluntary tourism present the results in the study to obtain: 1) study of government policies and conditions that promote the process voluntary tourism.2) The process of learning management for tourism at present day in Thailand and 3) study of approach to the preparation of the policy and conditions that promote the process voluntary tourism

3.1 Government policies and conditions that promote the process voluntary tourism

The results from stakeholder interview with government policies and conditions that promote the process voluntary tourism to explore in-depth interviews about government policies and conditions that promote the process voluntary tourism of the 10 provinces are Chiang Mai, Chiang Rai, Ubon Ratchathani,Udon Thani, Kanchanaburi, Bangkok, Ayutthaya, Loei, Phang Nga and Phuket provinces.

Focus group for representatives to brainstorm ideas related to voluntary tourism from the official Tourism Authority of Thailand, Ministry of Tourism and Sports, Nonprofit organization, Provincial Administrative Organization, Municipality, entrepreneurs, and voluntary tourists. All provinces making follow the tourism strategy for the tourism marketing plan of The Tourism Authority of Thailand (TAT) in year 2010 and 2011 as a framework for the tourism policy of the province. The tourism strategy to promote the tourism sustainable in issue valuing and worth for balance social and economic growth coupled with the promotion of market orientation to enhance a clear image to recognize and remember and linking to region under the strong brand and unique. The plan to solve the situation of crisis according in current situation and the change in the behavior of tourists combined with effort to maintain market share from the traditional market, expanding tourist market to high-income markets and special market to increasing the cost per trip of tourists. To promote on special international groups such as tourism of health and beauty products and other products. Increase of efficiency by using online media to promote the market. The opportunity of information technology growth is developing continuously. To reach customers around the world as well as broad and as specific for example handbooks for planning a trip (Thailand Travel Planner) Information service 1672 Tourist Hotline Video Call Center, developing products and services online (e-Marketing Online) through website www.tourismthailand.org, Publicity through blogs. (Blog.tourismthailand.org / eugenetang). The tourism marketing plan for 2011 focuses on advertising and public relations strategy of TAT under provided by Key Message in communication to accelerate the reliability of tourists again in the year 2011 will continue to campaign "Amazing Thailand: Always Amazes You " to reinforce confidence in the tourists constantly and go together with the maintain image of Thailand through the tag line "Always Amazes You" by the directly media to tourists for confirmation to be given the impression to visitors. Part of international market will be operation to reinforce the recognition of "Amazing Thailand: Always Amazes You" to create various media around the world by using modern media such as digital media as a marketing tool into the consumer, Event Marketing and Celebrity Marketing have invite media team, the beauty pageant team and filming team joint activity in Thailand. The Tourism Authority of Thailand have operates a customer relationship management through build on the member network of Thailand Fan Club with the database in European market contains more than 50,000 people to build loyalty including expand sales through partners both in and out industry for increase target. In the current, the change of marketing are developed follow by the attention. The Tourism Authority of Thailand has a operated to expand to the market by forward market in special groups consist of golf groups, weddings and honeymoon groups, driving groups, health and beauty groups and a group of Green Tourism. For the domestic market will be present value "Discovery Thailand Travel" through a new perspective to all sectors. It helps to create value and sustainability of Thailand. However, considering the travel policy of The Tourism Authority of Thailand that there is no policy with the voluntary tourism and the other agencies in tourism there was no policy on tourism.

3.2 The process of learning management for tourism at present day in Thailand

A study on the process of learning management of Voluntary Tourism in Thailand, researcher has collected all the essential data by creating the questionnaires for foreign tourists, who were working as Volunteer in Thailand. And also in-depth interview was part of the questionnaires. We also had group meeting in order to brainstorm the ideas from participants involved with the process of Voluntary Tourism at all 9 provinces include: Chaing Mai, Chiang Rai, Ubon Ratchathani, Nong Khai, Phuket, Phang Nga, Bangkok, Karnchanaburi and Phra Nakhorn Si Ayutthaya with the final results from study as follows:

The process of learning management for tourism at present in Thailand can be concluded as the chart in Figure 1.

Foreign tourists who traveled to Thailand and became volunteers came from 3 different locations: (1) European Union countries such as England, France, Germany and etc. (2) Scandinavian countries such as Iceland, Sweden and etc. (3) Asia-Pacific countries such as Korea, Japan, China, Myanmar, Laos, Australia, New Zealand and etc. Moreover, there were 3 main channels that foreign tourists used to help them arrive Thailand include: through organizations, through travel agencies and by him/herself. The number of foreign tourists, who traveled to Thailand for volunteer purposes each time can be separated into 3 groups: (1) Travelling alone – this kind of foreign tourist preferred to be a volunteer by his/her own interest, for example willing to look after elephants or dogs. And these volunteers applied through the websites. (2) Travelling in group – foreign tourist gathered from 2 persons or more, the most common type of Volunteer Tourist found in Thailand. (3) Travelling with family – similar to a family vacation, preferred comfortable activities, focused on recreation along with volunteer works. In addition, the average number of days during their stay in Thailand can be divided into 3 periods as follows: (1) Short period – approximately 1 – 2 weeks. (2) Medium period – takes about 1 – 3 months and. (3) Long period – starts from 6 months and up to 1 year. The following volunteer's activities found in Thailand were: (1) Teaching/knowledge sharing aspect – foreign volunteer tourists will teach English, souvenir making, book making at school including missionary school. (2) Patients care aspect - foreign volunteer tourists will look after expatriate patients. (3) Child care aspect - foreign volunteer tourists normally look after children. (4) Animal care aspect – such as elephants, tigers and dogs. (5) Infrastructure development aspect – such as building roads, constructing water reservoirs for the villages, building public toilets. (6) Community learning participation aspect – for example building earth houses, agriculture and handicrafts (7) Environmental aspect – such as mangroves growing, garbage cleaning.

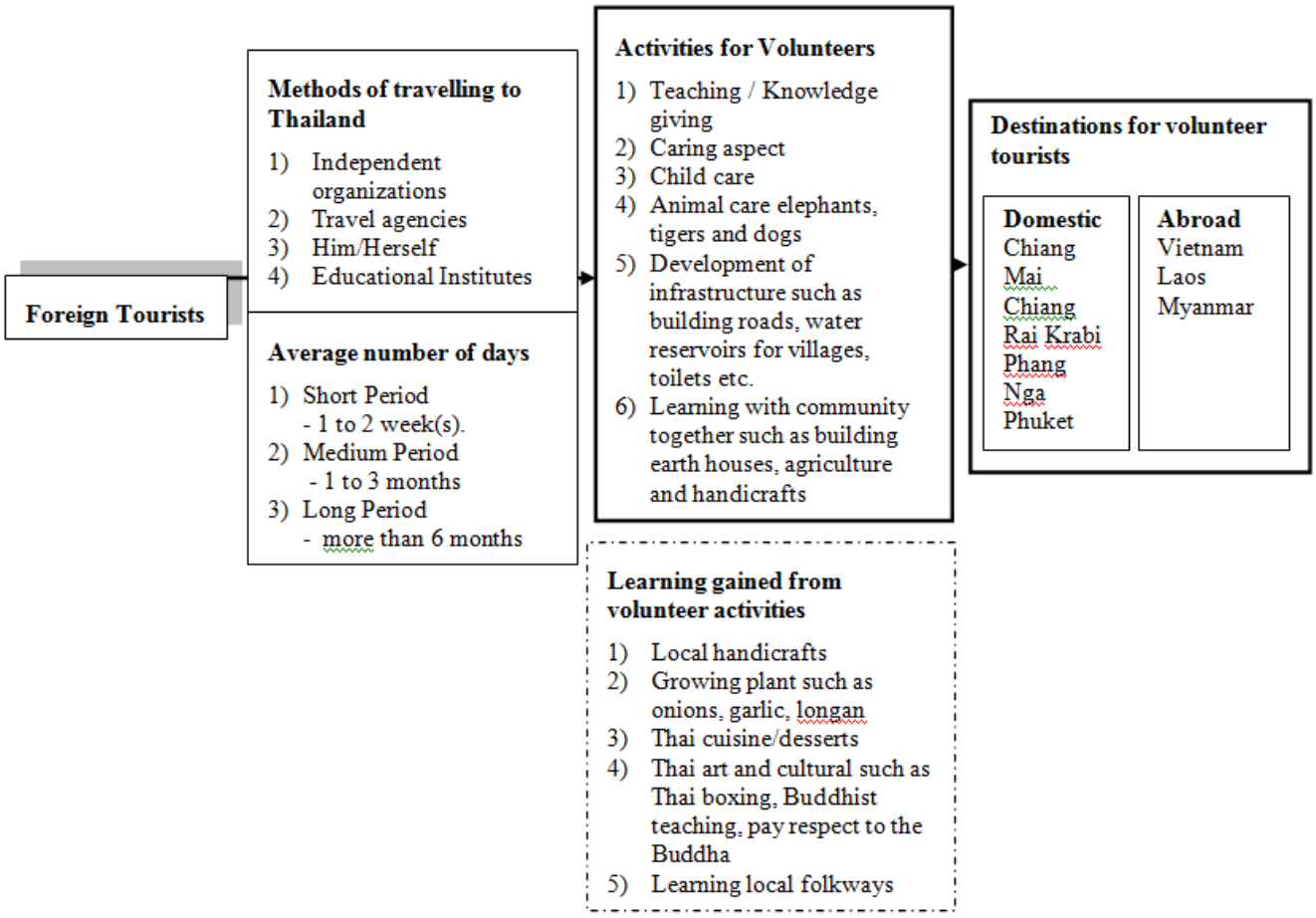

Figure 1 Pattern of Voluntary Tourism in Thailand

Source : from the study

3.3 Approach to the preparation of the policy and conditions that promote the process voluntary tourism

The results from pattern of voluntary tourism in every province in Thailand which is importance in determining of voluntary tourism strategy to analyzed using qualitative data analysis (SWOT Analysis) , brainstorm ideas and in-depth interviews with stakeholders of voluntary tourism to suggestion for develop policies and condition government that promote the voluntary tourism in Thailand the following;

- All sectors are participate on the strongly about voluntary tourism by consider of participation of communities and local people are share in thinking, planning implementation, monitoring, maintenance in tourism resources and welcome tourists with companionship. English training on how to communicate with tourists for direct and indirect benefit in community participation-based tourism
- Make ensure the safety of voluntary tourism about the rules and system to ensure in safety standards for foreign tourists, preparing the guide for safety such as safe travel on the road and cooperation of the relevant agencies with the Tourism Authority of Thailand. The main agency is police agency may be combined with other relevant agencies and including the metropolitan police and the immigration police. Ministry of Tourism and Sport and other agencies raise the capacity to solve crimes and to encourage the potential of security managing of foreign tourists.
- The develop on information and publicity activities to promote the voluntary tourism were found the most tourists lack of information about volunteers from the travel agencies but be aware of word of mouth or find information by yourself on the internet. Therefore, the main issue is that tourists want to get public relations and information through the media for volunteers into the distant area when the complete the mission will be no information to the decision to next travel. Accordingly, Increase the public relations by establish a center for volunteer activities in the province to study the requirement of volunteer tourism, tourist information, appropriate route for travel, basic information on weather, temperature, and time on travel for an alternative of tourists.
- Create and communication on brand volunteer products by design and branding voluntary tourism and advertising voluntary tourism brand for stakeholders of tourism both government, private and local people to acknowledge and understand about the same information of voluntary tourism.

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Promising integration: letting the weak join the game

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Integration of any kind is not any easy task, even when the parties involved share similar levels of development and the projected distribution of benefits seems to be equal. In the case of the Greater Mekong Sub-region (GMS), where all of its member countries are at very different stages on the road to development, this not only is a never-ending work in progress, but risks to become an endeavour that could easily degenerate into further unsettling discontent.

Particular attention has recently been given to the transition from sub-regional infrastructure development to a more holistic approach towards sustainable inter-sectoral cooperation. Overall achievements in this regard have been remarkable, with high levels of economic growth, significant socio-economic development, slow but steady poverty reduction, and significant but uneven progress in state institution-building and reforms.

Notwithstanding such improvements, the pace of development and its gains vary consistently from country to country, with some of them clearly losing the race.

This paper is divided into three sections. The first introduces the decades-long development efforts in the GMS, by particularly analysing implementation priorities that have been considered by member states and the international community. The second section looks at the two countries that currently face the most serious challenges in catching up with the pace of development in the sub-region, namely Cambodia and Laos. The third section analyses the implications that some of the recent global crises and natural disasters have had on the sub-region, explaining how external factors can reverse the gains of years of cooperation efforts. The concluding part will therefore provide and support some recommendations to minimise an adverse distribution of benefits between GMS countries and to pre-emptively mitigate the negative impacts of unforeseeable events.

The core of this paper is about the participation of the bloc's weakest countries to development projects that are more and more global in scope.

In international development literature, Cambodia is often defined as a post-conflict, aid-dependent, least-developed country, all terms with potentially negative implications. This paper will present a more balanced overview of Cambodia's recent development in its historical, geopolitical, and economic contexts, highlighting its achievements while carefully weighing its constraints. It will also present a positive future scenario for Cambodia and the strengths and weaknesses that will determine whether and how this scenario can be achieved. A major factor will be the country's further and more active integration into sub-regional and regional economies, institutions, and strategic relationships. Cambodia's development paradigm will be then explained through an analysis of benefits and liabilities brought about by the current model. Particularly, the "short-termism" of commitments in general and the focus on supply-driven assistance will be put under the spotlight, while arguing that those are the causes of a still very uneven progress in development harmonisation and coordination, and the elimination of counter-productive competition, duplication and waste. Nevertheless, the country's strengths far outweigh its vulnerabilities, and the potential for a full integration lies in the country's abundant resources and young population. A balanced comparison between pros and cons of Cambodia's integration in the GMS framework will be provided and supported with tangible arguments. In particular, the utilisation of its land and water resources will be taken into consideration for being both an important asset and a problematic caveat for the country's bargaining power in the sub-region.

Similarly, Laos will be taken into consideration because of its peculiar stance within the GMS integration discourse. Its land-locked geographical position puts it in a very delicate and indeed exploitable situation, and its currently weak bargaining power does not help. In particular, Laos runs the risk of becoming the sub-region gold mine, given its abundant mineral resources, and its huge potential in hydropower energy generation. Nevertheless, alike its southern neighbour, it counts on the powerful hope of a young population, which is already starting to develop innovative ways to maximise the country's potential, such as the establishment of locally-driven agri-business and modern smart agriculture projects. For the sake of comparison, a balanced analysis of the pros and cons of Laos' integration in the GMS framework will be provided and supported with tangible arguments. In particular, the utilisation of its land and water resources will be taken into consideration for being both an important asset and a problematic caveat for the country's bargaining power in the sub-region.

The paper's third and last section will argue about the very essence of integration in the region, projecting it against a more global internationalisation of all spheres of human life, while cautiously considering the both unifying and destabilising effects of interdependency in a still very diverse sub-region. Implications on health, food, water, and energy that global crises and natural disasters have on the single countries are indeed to be considered the most unforeseeable, yet powerful variables that might

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overturn the fate of even the most commendable efforts. Surprisingly enough, some of the countermeasures adopted by Cambodia and Laos turned out to be the most successful in minimising the negative impacts of such adverse events. Hence, this paper analyses the behaviours of both the local population and the governments that avoided the weakest members of the GMS to topple in such unfavourable circumstances.

The underlying argument of this paper is therefore the degree of interdependence that all of the countries in the sub-region are experiencing. Sustainable integration can only be achieved if the weak and more vulnerable parties can keep up with the pace of development set by the leading members, and this paper gives an insight about how that can be made possible.

***Keywords*—Cambodia, Sub-regional integration, Laos.**

Public Spending, Aid Effectiveness and Poverty Reduction in Lao PDR

Keoviengxay SOURYA, Saykhong SAINASINH, and Phanhpakit ONPHANHDALA

Abstract:- *The allocation of the budget (both domestic resource and foreign aid) is a key instrument for governments to promote economic development and reduce absolute poverty. In the case of Lao PDR, the government and donors have increased their spending significantly over the past decades. The critical challenge is how to strike the right balance between the spending by domestic/foreign fund and by sector that focuses primarily on reducing poverty.Existing studies face a debate on the methodology intensively used time-series, cross-countries and CGE analysis. The paper attempts to revisit this issue by provincial panel data analysis using public spending and aid over 1995/96 to 2011/12. This study finds that both domestic budget and foreign aid contribute to the poverty reduction, though statistically insignificant. The major determinants are initial poverty level and the scale effect of each province's population. This means the current success in poverty reduction is more pronounced relatively to less poor and large provinces. Moreover, expenditure on education is significantly helpful compared other sectors. Therefore, both the Lao government and donors should strengthen the cooperation to tailor the budget allocation in further fighting against the poverty in Lao PDR.*

Keywords: Panel Analysis, Disaggregated Data, Provinces, Laos

1. INTRODUCTION

Back in 1940, the political scientist Valdimer O. Key presented the basic budgeting problem: 'On what basis shall it be decided to allocate x dollars to activity A instead of activity B' [1]. In the context of the modern challenge of promoting pro-poor growth, this problem is as real and contemporary as ever. What can be said about the growth and poverty reduction effects of a dollar spent in one sector compared with another?The allocation of the budget (both domestic resource and foreign aid) is a key instrument for governments to promote economic development and reduce absolute poverty. Its role has become even more prominent in recent years as donors concerned the implementation of national poverty reduction strategyis a conditional on the increase of spending labeled as "pro-poor".

Public spending has the potential to affect growth and poverty reduction in two ways: it can raise the overall growth performance of the economy, and it can increase the chance of the poor to contribute to the growth process (mainly by strengthening human capabilities and reducing transaction costs). The critical challenge is how to strike the right balance between spending that focuses primarily on growth and spending that aims at reducing poverty. But it is difficult to quantify the impact of public spending as its effects are complex and may vary depending on the composition of growth, policies and country conditions. Moreover, the landscape of aid policy has changed in the last decade. The basic objective of development (usually interpreted as GDP growth) in the recipient country has been replaced by the objective of poverty reduction [2], so that for most donors growth in the developing world is only valuable if it can be construed as pro-poor.

This paper explores how the composition of public spending and aid, and the manner in which the resources are spent may have affected the poverty reduction through the case study of Laos over 1995/96 to 2011/12. Following a review of the principles guiding public spending and foreign aid determining the impact on the poor in Section 2, weoverview the changes in fiscal management, and then formalizes the structures of public spending and foreign aid by center-province relations and by sectors in Section 3. A brief description of conceptual model and data is presented in Section 4. Moreover, weexamine the evolution of the composition of expenditures, the extent to which resource or sector expenditurewas benefitedto poverty reductionoutcomes in Section 5. Section 6 ends with some concluding remarks.

2. LITERATURE REVIEW

Public spending and aid effectiveness studies reveal a micro-macro paradox. Consideration of specific projects or operations financed by public spending and aid most often leads to a positive appreciation of their results, whereas the macroeconomic studies of government expenditure and aid effects seem to lead to more nuanced results. The paradox may result from the methodological pitfalls of the macroeconomic studies, or of, less frequently stressed, microeconomic ones. For instance, it could result from negative externalities generated by public spending and aid specific projects, not captured by microeconomic studies. But, as we shall see, government expenditure and aid projects are also likely to generate positive externalities, not easily captured at the micro level. Here we focus on a review of macroeconomic and cross-sectional studies of the contribution of public spending and aid to poverty reduction.

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Public Spending and Poverty Reduction

Public spending can affect growth and poverty reduction in two ways: it can raise the overall growth performance of the economy, and it can increase the chance of the poor to contribute to the growth process (mainly by strengthening human capabilities and reducing transaction costs). Both types of expenditures may reduce poverty, but in the case of more growth-oriented expenditures, the poverty impact is usually more indirect. For both types of expenditures, the impact on poverty levels is likely to be experienced with a time lag.

The 1990s brought a new paradigm for fighting poverty by the World Bank with emphasis on strengthening capabilities of the poor and an increased focus on the non-income dimensions of poverty. Public intervention was supposed to follow a twofold strategy, promoting labor-intensive growth and investment in human capital via primary health care, primary education and targeted social spending to reduce poverty, thus, avoiding a trade off between growth and poverty reduction. The experience of the East Asian Miracle economies with their high investment in human capital (first, universal primary education, followed by the increasing availability of secondary education and skill building) resonated well with this view [3]. Later in the decade, public investment in infrastructure was emphasized as a means for poverty reduction by facilitating access to markets and reducing the high transactions costs of poor households [4].

The Millennium Development Goals adopted in 2000 also encouraged social sector spending by broadening poverty objectives to include non-income dimensions. In their aspirations to meet MDG related goals, countries may focus too much on achieving individual targets rather than pursuing integrated cross-sectoral policies - taking into account the impact of interventions on other targets. This calls for a better understanding of the multi-sectoral nature of interventions and development goals [5]; and more evidenced based analysis on what steps need to be taken to achieve these goals.

Concerns are also being raised that the observed shift to social sector expenditures was implemented in an ad hoc manner without a better understanding of how different expenditure options help to address country specific bottlenecks to growth; and without a rigorous economic analysis of their projected impact on poverty and growth. There are also concerns that necessary public investment in infrastructure has been constrained by fiscal stabilization programs to the detriment of economic growth. Finally, there is a growing recognition in many countries that the effectiveness of public expenditures directed to the poor was undermined by weak targeting, elite capture, and an overall poor quality of the public service delivery mechanisms [6].

The Allocation of Public Spending and Aid, and its Impact

The broad principles for guiding public expenditure allocations are based on the need to address market failure (public goods, externalities) to promote growth, and improve distribution and reduce poverty through public interventions. However, the notion of what constitutes a public good may change over time, and what is considered a market failure may vary with country conditions.

Many studies have attempted to analyze the impact of government spending (education, health, infrastructure, agriculture, or a combination thereof) on economic growth and poverty reduction. Their results vary significantly in terms of the detected effect and efficiency of different expenditure categories in various countries, as the impact of public spending is limited by various factors and constraints. However, a clear understanding of these factors is needed to determine if, and how to intervene.

Expenditure policy interventions can be complementary in two ways as they can either enhance or diminish the desired outcome. First, the benefits of higher expenditure on a particular sector may not be fully realized unless expenditure on other sectors is increased. For example, a better access to basic infrastructure services (water and sanitation) has an important role in improving infant mortality and child health outcomes. Similarly, the construction of rural roads is critical for access to education and education investment may enhance the marginal return of irrigation projects. Better targeting of services is essential for reaching the poor. Specific country conditions, such as urbanization, demographics, and regional poverty patterns can also play an important role in the efficiency of public expenditures. Moreover, countries with better governance tend to have faster growth in the poorest quintile than poorly governed countries [6].

Finally, the impact of public expenditures on income growth is subject to lags as outcomes may be achieved in a direct or indirect way. While well-targeted transfer schemes usually have a direct and immediate impact on the poor by raising their incomes, targeted investment in education has a lagged effect via improved educational attainment, thus increasing the chances of the poor to participate in the growth process in the future. Targeted infrastructure investments can have both, a direct and immediate effect on income as well as an indirect lagged effect via human capital formation (i.e. clean water effect on health outcomes). Investments in agricultural research can lead to increased productivity which directly affects the income of poor farmers, or can have an indirect effect on the poor through cheaper food or higher wages as a result of increased demand for farm and non-farm employment in rural areas [7].

Aid Effectiveness and Poverty Reduction

Following the adoption of the MDGs, particularly the first one that is to reduce poverty by half between 1995 and 2015, numerous studies have examined how external aid can contribute to their achievement. The formula "doubling aid to reduce the poverty by half" relied on the implicit assumption that aid was an effective instrument for poverty reduction. The formula and corresponding assumption have of course been debated. Two opposite views have clearly appeared, one, well represented by Jeffrey Sachs in his *End of Poverty*, underlining the need for a big push to get low income countries out of poverty traps, the other one, exemplified by the attacks of

William Easterly against aid, a big push and the idea itself of a poverty trap, but also including arguments about a limited absorptive capacity. The absorptive capacity of aid depends on aid modalities and can be enhanced by a reform of aid.

As summarized by Guillaumont, there are mainly three macroeconomic channels of aid effectiveness for poverty reduction as of: 1) the growth-poverty channel; 2) the public expenditure channel; and 3) the stabilization channel [8].

The first, traditional channel is from aid to growth and from growth to poverty reduction. In the late 1990s was a watershed in the literature of aid effectiveness, from the circulation and publication of the paper by Burnside and Dollar (1997, 2000), and the debate which followed. The most innovative aspect of the Burnside-Dollar paper was to assess aid effectiveness by a way where it depends on specific features of the recipient countries (macroeconomic policy, an average of indicators of openness of fiscal balance and of monetary stability). Its most debatable aspect was to consider the country policy as the only such feature.The next step, Collier and Dollar, aimed at designing an optimal aid allocation among countries in order to minimize the number of the poor in the world [9-10]. These two papers used another concept and measurement of policy, the "Country Policy and Institutional Assessment" (CPIA) index, reflecting the World Bank staff opinions on the recipient countries used for the allocation of IDA funds. This "ABCD paradigm" (for Assessing, Burnside, Collier, Dollar), has been very influential in donors, bilateral as well as multilateral aid policies. However, the aid-growth relationship has been extensively debated. Several kinds of criticism of the ABCD paradigm have been pointed such as the measurement, the specification of the model and the robustness of the econometric, and other conditioning factors [8].

The second channel involves the impact of aid on the volume and composition of mainly social public expenditures, particularly on education and health, and the impact of these expenditures on corresponding poverty indicators. The impact of aid may involve its total amount or its social expenditures allocation, which raises a problem of fungibility. The various kinds of public expenditures likely to be influenced by aid have different effects on poverty reduction. Thus, we have to disentangle lessons from the literature on how aid can influence the structure of public spending in favor of the poor. Special attention will be paid to the kinds of conditionality attached to aid given in the form of budget support.

Numerous works have examined to what extent aid increases total public revenue, considering possible crowding-out of domestic sources of revenue. A positive impact of aid on public revenue is found in most of the panel works recently done, as well as in several country studies using time series analyses.This result is explained by the fact that aid can improve the effectiveness of public administrations in order to compensate for the negative effect due to additional funding [11].

The third channel, to some extent neglected in the literature, has been linked to the macroeconomic stabilizing effect of aid, as suggested in several previous works. The effect of aid on economic growth, and the contribution of growth to poverty reduction are linked to their stabilizing impacts. By making growth less volatile, aid both accelerates growth and makes it more pro-poor. With more equivocal findings, this double stabilizing effect on poverty may be supplemented by a third one, as public expenditures are influenced by macro economic instability. Paying a special attention to macro-vulnerability issues is needed for an analysis of aid effectiveness focused on poverty, particularly in the present world economic context[12].

Above existing studies have their advantages and limitations. An appropriate specification of the models used, including conditional and non-linear effects, may address this issue to some extent. However, the quality of statistics, as well as the relevance of the aid concept, is often criticized.Country regressions used to test the effect of aid on any variable have been highly criticized for their inability to take the heterogeneity of the country situations into account. For an improvement against the issue, this study applies the unified aid concept and statistics by provincial level of one country.

Background of the Study in the Lao Context

Fiscal Management and the Decentralization

Raising the revenue effort and improving the efficiency in public spending have been longstanding objectives in LaoPDR. At around 13 percent of GDP, Lao PDR had a low revenue effort in 2003/04, severely constraining the government's ability to meet the country's pressing development needs. The sharp decline in revenues in early 2000s partly reflected lower resource revenues (timber royalties), following the government's decision to impose a ban on the export of unprocessed logs in 2002. A rationalization of the finances of the state-owned commercial banks and state-owned enterprises had also reduced income taxes and dividends from the state sector. Weak technical capacity had also played a role. However, a decentralized revenue administration, in which provinces have responsibility for collecting major taxes, was widely seen as the most important contributory factor[13].Currently, the bulk of revenues are collected at the provincial level. All import duties, naturalresource taxes, timber royalties and more than half of profit and income taxes, turnover and excises are collected by the provinces. Apart from SOE dividends and hydro-royalties, the only revenues collected by the center are from few hundreds largest taxpayers administered by the central large taxpayer's unit (LTU).

Reforming the current fiscal system is difficult because provinces have historically been very powerful in Lao PDR(see Box 1). Provincial governors have strong support from regional factions within the party hierarchy and are also individually powerful, often outranking cabinet ministers. Central control over fiscal affairs in the provinces has therefore tended to be weak. The power of the provinces also explains why efforts to centralize fiscal management may not succeed in the absence of broader reforms to center-province relations.

Box 1: A chronology of decentralization in Lao PDR

	Historically, local governments have enjoyed considerable autonomy in Lao PDR.
1975	Since the formation of Lao People's Democratic Republic in 1975, all political power has been vested in the Lao People's Revolutionary Party.
1986	A "New Economic Mechanism" was introduced, which reflected an overt policy of decentralization and led to substantial devolution of power to the provinces.
1991	To address these problems, a new Constitution was introduced in 1991, which sought to reassert central control over fiscal management.
1992	- First National Budget is approved since 1975, which includes both central and local government expenditures.
1994	- New budget law is approved, which establishes the principles of State Budget formulation.
2000	Towards the turn of the century, there was a new move towards decentralization with the adoption of the Prime Ministerial Decree 01 on March 11, 2000. - Decree 192/PM on the Implementation of the Budget Law - Instruction 475, defining revenue sources by levels of government. - Instruction 128, detailing planning responsibilities at each level of government.
2007	- New Budget Law. Orders the centralization of Treasury, Customs and Tax Administration functions.
2008	- National Budget Law Implementation Decree
2011	Ninth Party Congress Resolution on decentralization by reinforcing the PM Decree 01/2000, known as "the Three Builds" - which aims to transform the province into strategic units, the district as comprehensive units, and villages as development units.

Source: IMF (2006), Gomez et al. (2008) and LPRP (2011)

In sum, the lack of central control over revenue and treasury operations in the provinces has long been seen as a key impediment to raising national revenues and improving fiscal management in Lao PDR. However, there has been greater recognition in recent years that reform of center-province fiscal relations is central to making progress in these areas. This reflects the fact that powerful provinces are unlikely to cede control over revenue and treasury functions until a credible revenue-sharing mechanism is in place. Moving towards a centralized or deconcentrated fiscal system will be difficult. The focus, therefore, needs to be on establishing a robust decentralized fiscal system.

Aid Profile

During 1975 and 1985, Laos received foreign aid (both grant and loan) in total amount of 2.5 billion USD. In this period, the regimereceived aid dominantly from the socialist countries, which accounted 77.9% of the total. The remainders were from multilateral and international organizations 16.6%. Only 5.6% of aid was from western countries. Between 1986 and 1990, Laos had gradually opened the country to the world. Of 1.4 billion USD, the proportion of aid from the socialist countries dramatically declined to 44.5%, and the shares of aid from western countries, and multilateral and international organization increased significantlyup to 32.5% and 22.9%, respectively[14].

Over 1991-1995, after the collapse of former Soviet Unions, Laos was forced to reform the aid policy. It showed that the share of aid from western countries account for 67.4% and the rest was from multilateral and international organizations. Since 1996, the aid profile has no distinction in wording of neither socialist nor western countries. The government has categorized aid received by type of bilateral, multilateral, NGO and institutions. As shown in Table 1, over 1996-2010, Laos has increasingly absorbed foreign aid from various sources. Roughly one-half of the total aids are from bilateral cooperation. The second largest assistance is from international financial institutions such as ADB and IDA. As to be noted, though still a small share, the role of NGOs is increasing significantly [14-15].

Table 1: Aid Statistics 1996-2010 by type

	1996-2000	2001-2005	2006-2010
Bilateral Cooperation	47.3	50.8	52.8
Multilateral Cooperation	9.5	8.4	8.4
Cooperation with EU	2.3	2.3	2.7
International Financial Institutions	38.6	33.6	28.9
Mekong River Commission	0.7	0.8	2.3
NGOs	1.7	4.2	4.8
	100%	100%	100%

Source: MoFA (2006) and MPI (2012) (Unit: Million USD)

In November 2006, the government of Lao PDR and 25 partners (countries and international agencies) had signed the "Vientiane Declaration", which is the Lao version for the Paris declaration on aid effectiveness. The action plan formed the aid coordination scheme under the initiative of the Lao government and UNDP in May 2007, which each sector-working group would target the priority sectors under the National Socio-Economic Development Plan. Since then, the government is monitoring the progress of aid management platform with the assistance of UNDP.

Table 2: Top Bilateral Aid Profile to Laos

Year	1st Rank	2nd Rank	3rd Rank	Total
2006	Japan	Sweden	France	201.2
2007	Japan	France	Germany	239.6
2008	Japan	Germany	Australia	225.2
2009	Japan	Australia	Germany	260.0
2010	Japan	Australia	S. Korea	285.9
2011[a]	S. Korea	Japan	Thailand	375.5

Source: OECD/DAC and [a] MPI (2012)(Unit: Million USD)

Table 3: Top Multilateral and International Organization Aid Profile to Laos

Year	1st Rank	2nd Rank	3rd Rank	Total
2006	ADB	IDA	EU	123.7
2007	ADB	IDA	GFATM	132.2
2008	IDA	ADB	IFAD	147.6
2009	ADB	IDA	EU	136.9
2010	IDA	ADB	EU	105.5
2011[a]	ADB	IDA	NGOs	329.3

Source: OECD/DACand [a] MPI (2012)(Unit: Million USD)

Table2 shows the top bilateral aid profile to Laos over 2006-2011. Japan, South Korea, Australia and European nations are major donors. Despite the global financial crisis, most donors continue to support Laos at about the same level. In recent years, the neighboring countries such as Thailand, Vietnam and China has increased the amount of aid to Laos year by year. In

terms of multilateral and international organizations, ADB and IDA are top two major donorslargely providing aid to Laos as shown in Table 3.

Progress in Poverty Reduction

The poverty in Laos has been steadily reduced over the past decades. As shown in Table 5, the average poverty level has declined from 46% of total population in 1992/93 to 13% of total households in 2012. However, there exists a large different among provinces. Generally, provinces in the northern areas e.g. Phongsaly, Oudomxay and Huaphanh tend to have a higher poverty level than provinces in the central and southern areas. At the present, Vientiane capital succeeded in poverty eradication. Major cities such as Luang Prabang, Savannakhet and Champasack also achieved a significant progress in poverty reduction, whereas some provinces are still facing a big challenge in fighting against poor.

Table 4: Progress in Poverty Reduction in Laos

	Province	Code	1992/93	2012[a]	1997-2012
1	Phongsaly	PSL	72	40.4	-17.6
2	Luang Namtha	LNT	41	25.2	-25.8
3	Oudomxay	ODX	46	44.2	-21.8
4	Bokeo	BK	42	19.2	-19.8
5	Luang Prabang	LPB	59	12.8	-28.2
6	Xayabury	XYB	22	3.6	-14.4
7	Huaphanh	HP	71	44.8	-26.2
8	Xiengkhuang	XK	63	8.8	-34.2
9	Vientiane C.	VTC	34	0.1	-13.9
10	Vientiane P.	VTP	31	5.2	-22.8
11	Borikhamxay	BRK	17	15.1	-12.9
12	Khammouane	KM	47	4.8	-40.2
13	Savannakhet	SVN	53	10.8	-31.2
14	Champasack	CPS	41	2.8	-34.3
15	Salavan	SRV	44	15.5	-23.5
16	Sekong	SK	67	29.8	-20.2
17	Attapeu	ATP	61	29.4	-18.6
	Lao PDR		46	13.0	-26.0

Source: Results from LECS 1992/93 and [a] MPI (2013)

3. CONCEPTUAL MODEL AND DATA SOURCE

Most studies have examined the impact of aid on poverty measured by the growth channel (e.g. rate of economic growth and per capita income). Some studies have considered the effect of aid on the change in the level of another indicators of development or of welfare, such as the Human Development Index, infant mortality, and school enrolment ratio [8].

Nevertheless, some studies have applied the traditional indices of monetary income poverty such as the headcount index or the poverty gap been directly examined. This paper utilizes their attempt [16-17].

Moreover, some researchers have emphasized the need of disaggregating aid flows and considering their impact on various time horizons, since the concept of net ODA flows, set by OECD and used in most of the papers, obscures its heterogeneous composition [18-19].One can also wonder which type of expenditure benefit the most the poor? For instance, expenditures dedicated to agriculture are generally pro-poor [17]. However, public education expenditures are not necessarily pro-poor as they are mainly for secondary and tertiary education and are biased against primary education in most African economies, leading to an unequal distribution of human capital [20]. Similar findings for health expenditures are also evidenced [21].In this paper, we test expenditures (both sourcing by domestic and foreign fund) by four sectors including agriculture, infrastructure, education and health.

While most studies utilize time-series or cross-countries data in their analysis of the effect of public spending on poverty reduction,in this study, we attempt to apply panel data analysis method using provincial (disaggregated) data collected from unpublished official statistics from Ministry of Finance and Ministry of Planning and Investment over fiscal year 1995/95 to 2011/12. The econometric regression models are described as below:

$$y_{ij} = \alpha_i p0_{ij} + \beta_i pop_{ij} + \gamma_i pub_{ij} + \delta_i aid_{ij} + \mu_{ij} \quad (1)$$

$$y_{ij} = \alpha_i p0_{ij} + \beta_i pop_{ij} + \gamma_{i1} dagri_{ij} + \gamma_{i2} dinf_{ij} + \gamma_{i3} dedu_{ij} + \gamma_{i4} dhl_{ij} + \delta_{i1} fagri_{ij} + \delta_{i2} finf_{ij} + \delta_{i3} fedu_{ij} + \delta_{i4} fhl_{ij} + \mu_{ij} \quad (2)$$

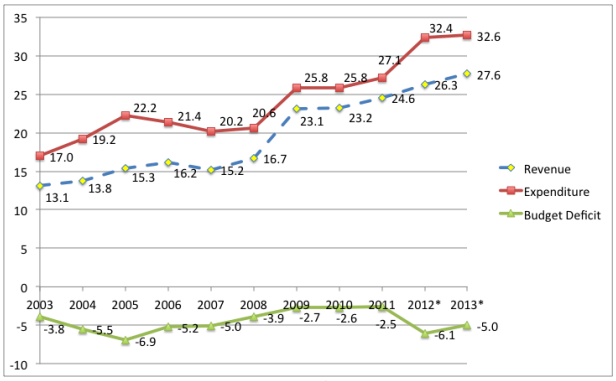
Variable	Definition/Description	Unit
y	Poverty incidence measured by headcount	Percent
p0	Initial poverty level in 1992/93	Percent
pop	Population size for control the scale effect in 2005	Persons
pub	Public spending sourcing by domestic fund	Million kips
aid	Aid sourcing by foreign fund	Million kips
d-agri	Expenditure on agriculture by domestic fund	Million kips
d-inf	Expenditure on infrastructure by domestic fund	Million kips
d-edu	Expenditure on education by domestic fund	Million kips
d-hl	Expenditure on health by domestic fund	Million kips
f-agri	Expenditure on agriculture by foreign fund	Million kips
f-inf	Expenditure on infrastructure by foreign fund	Million kips
f-edu	Expenditure on education by foreign fund	Million kips
f-hl	Expenditure on health by foreign fund	Million kips
i	Each province (all 17 provinces)	-
j	Each panel year [1997/98 (1995/96-1997/98); 2002/03 (1998/99-2002/03); 2007/08 (2003/04-2007/08); and 2012 (2007/08-2011/12)]	-
μ	Residuals	-

4. FINDINGS AND DISCUSSION

Public Spending by Source, Region and Sector

As shown in Figure 1, we find that the total expenditure is rising steadily from 17.0% of GDP in 2003/04 to 27.1% of GDP in 2011/12. Gauging from its share to GDP, the government has been increasing the role on economic growth and poverty reduction. Using the unpublished official data from Ministry of Finance

and Ministry of Planning and Investment, however, we find that the Lao government has a limited ability to mobilize the domestic fund and heavily rely on foreign fund (see Table 6a and Table 6b). Although expenditures by source, region and sector are largely fluctuated from time to time, we observe that most of the budget has been spent in central level rather than in provincial level. Within domestic fund, the majority of budget is allocated to provinces. In other word, since most foreign fund is concentrated on central level, the government shall allocate the domestic fund back to provinces.



Source: MoF (2013). (Unit: Percent of GDP, *estimate)

Figure 1: the Lao Government Revenue and Expenditure, 2003/04 to 2013/14

With respect to expenditures by sector, similar trend can be observed (see Table 6a and Table 6b). Both domestic and foreign funds have allocated budget primarily to infrastructure sector especially for road construction. Education sector has also received a substantial budget in particular to primary education. Agriculture and health sectors have received relatively less budget allocation.

Table 5a:Expenditures by Source, Region and Sector in 2001/02 and 2005/06

	2007/08			2011/12		
	Domestic	Foreign	Total	Domestic	Foreign	Total
by Adm.(%)	18.5	81.5	100	25.8	74.2	100
Central	46.4	73.9	68.8	67.6	92.5	86.1
Provinces	53.6	26.1	31.2	32.4	7.5	13.9
by Sector(%)						
Agriculture	9.8	9.3	9.4	7.5	10.8	9.9
Infrastructure	27.8	36.7	35.0	34.0	47.5	44.0
Education	9.0	18.9	17.0	8.9	33.7	27.3
Health	3.6	4.1	4.0	2.9	2.6	2.7

Source: Authors' calculation (Unpublished official statistics).

Table 5b: Expenditures by Source, Region and Sector in 2007/08 and 2011/12

	2001/02			2005/06		
	Domestic	Foreign	Total	Domestic	Foreign	Total
by admin.(%)	43.5	56.5	100	10.5	89.5	100
Central	26.4	59.3	45.0	44.1	63.6	61.5
Provinces	73.6	40.7	55.0	55.9	34.4	38.5
by Sector(%)						
Agriculture	28.2	9.6	17.7	9.1	13.7	13.2
Infrastructure	25.3	34.6	30.5	39.2	47.9	47.0
Education	8.0	14.1	11.4	10.2	22.2	21.0
Health	3.7	12.5	8.7	4.0	6.3	6.0

Source: Authors' calculation (Unpublished official statistics).

Agriculture remains the most important sector in Lao PDR, accounting for one-third of GDP and providing employment for some 70 percent of the workforce. Because of its strong growth over the last decade, agriculture has been the most important driver in reducing rural poverty, but agriculture's share of total public expenditure decreased slightly in recent years.Moreover, centrally approved budgets often do not materialize at the provincial level. Capital expenditures account for substantial percentage of total sector expenditure and remain biased toward physical investments, without appropriate consideration for recurrent spending requirements. Furthermore, the government should achieve a better redistribution of public funds between richer and poorer provinces. Equally important is to promote agricultural research and provide more effective extension services and rural credit to strengthen farmers' capacity and competitiveness. Redressing geographical inequalities is important as well. Helping subsistence-based communities become more productive and market-oriented is also a key task in the medium term.

Road travel is the dominant mode of transportation in Lao PDR. Nevertheless, it is vulnerable during the rainy season. The spending on road construction improved the network and connected an increasing number of rural inhabitants to both markets and social services, resulting in significant socioeconomic benefits. Looking forward, the government will face competing demands for road maintenance, providing all-weather road access to district centers and villages, and upgrading primary roads to handle growing traffic. However, the available financial and human resources will be far from adequate to meet all of these needs. The government should make more effort to increase the efficiency and cost-effectiveness of road spending. This can be achieved by strengthening local institutional capacity and by promoting market competition and private sector participation in delivering road works.

Education developmentin 2000s has recovered strongly after the collapse in public expenditure in the late 1990s. A high proportion of education spending consisted of capital spending, mainly externally financed. Salary increases for teachers were a high priority, under teachers' conditions in the past, many graduates did continue to take jobs outside teaching and caused a continuing shortage of teachers, especially in poor and remote districts. In recent years, the Lao government has increased the proportion of national resources allocated to education. A sharp salary increases for teachers is achieved in 2012/13, but this put a significant challenge to tackle jointly the problem of recurrent and capital budgeting.

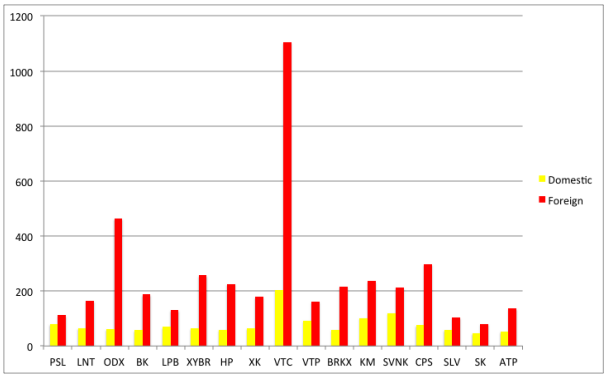
Health outcome indicators in Lao PDR have improved over the past decades, from its significantly low level. The government is facing challenges in delivering adequate public health services to the population. The coverage of key maternal and child health programs is low. Capital expenditures account for a substantial share of government health expenditures, reflecting significant donor support. However, there is a shortage of recurrent funds for the operation of health

services. Domestically financed government health expenditure is declining slightly and is biased toward the central level. The government should strengthen the targeting of the poor to ensure that they have access to essential health services and are protected from catastrophic health expenditures. Low execution rates reflect a need for strengthening financial management systems to ensure transparent execution and effective monitoring of public spending. It also is important for the GOL to harmonize and align its own and donor programs with its health sector priorities.

Difference between Domestic and Foreign Funding by Province

Figure 2a and Figure 2b show the difference between domestic and foreign funding by province.Most of the expenditures at provincial level are funded by foreign aid, except for some provinces. Overall, the accumulated budget allocation to provincehas declined during 2008/09-2011/12 compared to 2003/04-2007/08, despite the increase in the total expenditure over that period.

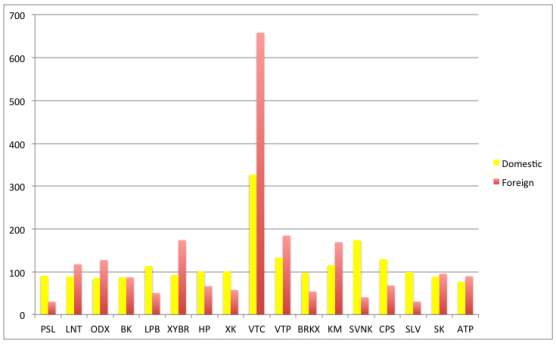
During 2003/04 to 2007/8, in all provinces, the accumulated foreign funding arrangement was dominated domestic source. In opposite, fewer foreign funding arrangements are allocated to provinces, even smaller than domestic funding in some provinces. This is due to the national calendar that Lao PDR has hosted many international conferences and events such as the 25th SEA Games in 2009 and the 9th ASEM Summit in 2012.Thus, the budget allocation is concentrated on central government in line ministries. Consequently, there is a growing concern the decline in public spending and aid at provincial level will affect on the progress of poverty reduction in the nationwide.



Source: Author's compiled (Unpublished official statistics).
(Unit: Billion Kips)

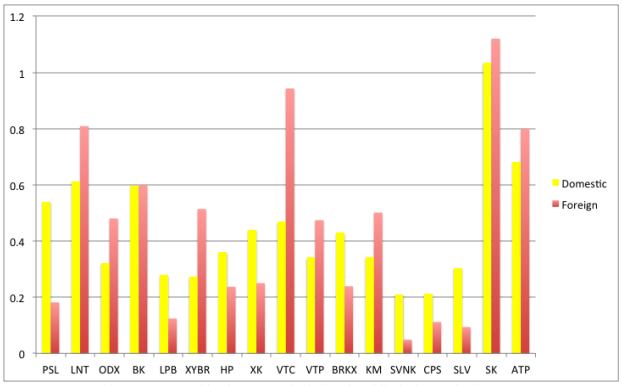
Figure 2a: Structure of Domestic and Foreign Funding Arrangements by Province, 2003/04-2007/08

Figure 3 shows a different view on per capita accumulated public spending and aid by province over 2008/09-2011/12. We find that there exists a significant gap in the distribution of budget among provinces. As presented in Table 5 above, per capita public spending and aid does not fit with the poverty level of each province. For instance, Sekong, Attapeu, Luang Namtha, Vientiane capital and Bekeo provinces in orderly have received a very high per capita public spending and aid, whereas the ranking of poverty incidences are Sekong, Huaphanh, Phongsaly, Xiengkhuang and Salavan in 2007/08. As a result, the progress in poverty reduction in Huaphanh and Phongsaly is lagged behind other provinces.



Source: Author's compiled (Unpublished official statistics).
(Unit: Billion Kips)

Figure 2b: Structure of Domestic and Foreign Funding Arrangements by Province, 2008/09-2011/12



Source: Author's compiled (Unpublished official statistics).
(Unit: Million Kips)

Figure 3: Per Capita Public Spending and Aid by Province, 2008/09-2011/12

Panel Data Analysis on Poverty Reduction

In this session, econometric models are tested using panel data techniques in order to find the determinants of poverty reduction in Lao PDR over 1995/96 to 2011/12.The estimated coefficients could be interpreted directly since we have unbalanced panel, namely first period has 3 years data, second and third periods have 5 years data each, and fourth period has 4 years data. Nevertheless, three methods of OLS, fixed effect and random effect are applied to both basic and extended models.

The result of the regression of basic model is presented in Table 7 using fixed effect model. This study finds that both domestic budget and foreign aid contribute to the poverty reduction as both coefficients show a negative sign, though they are statistically insignificant. The major determinants are initial poverty level and the scale effect of each province's population. The estimated initial poverty level is positive with statistically significant at 99%. This means the current success in poverty reduction is more pronounced

relatively to less poor provinces, not to those having a high poverty incidence.The result is consistent with observed statistics shown in Table 5 that provinces having a relatively low poverty incidence tend to succeed in accelerating poverty reduction. Furthermore, provinces having a larger population are likely to achieve a faster poverty reduction. Therefore, the result shows that current status of poverty reduction in Lao PDR is pro-rich rather than pro-poor. This shows the implication for both Lao government and donors to improve and/or reform the policy that better targeting to the poor provinces.

Table 7: Estimation Result of Basic Model

	Coefficient	Std. Err.	t-statistics	P-value
Initial Poverty (p0)	0.481491	0.077293	6.23	0.000
Population (pop)	-0.000017	7.51e-06	-2.31	0.025
Domesticfund (pub)	-5.66e-06	0.000032	-0.18	0.860
Foreignfund (aid)	-3.74e-06	0.000010	-0.37	0.715
Constant	15.8621	4.8522	3.27	0.002

Number of Observations = 68 (4×17)
R-squared: 0.373
Huasman Test: chi2 = 0.02 [Prob>chi2 = 0.9999], use Fixed Effect Model

Table 8: Estimation Result of Extended Model

	Coefficient	Std. Err.	t-statistics	P-value
Initial Poverty (p0)	0.446603	0.106224	4.20	0.000
Population (pop)	-0.000019	8.94e-06	-2.15	0.031
d-agri	0.000092	0.000067	1.38	0.167
d-infra	-0.000136	0.000136	-1.00	0.316
d-edu	-0.001030	0.000503	-2.05	0.040
d-hl	0.001885	0.000921	2.05	0.041
f-agri	-0.000026	0.000054	-0.48	0.628
f-infra	0.000014	0.000018	0.78	0.435
f-edu	0.000083	0.000149	0.56	0.578
f-hl	-1.85e-06	0.000067	-0.03	0.978
Constant	20.3147	6.6286	3.06	0.002

Number of Observations = 68 (4×17)
R-squared: 0.457
Huasman Test: chi2 = 19.03 [Prob>chi2 = 0.0147], use Random Effect Model

The result of the regression of extended model is presented in Table 8 using random effect model. The estimation shows that initial poverty level and population size remain the significant determinants. Regarding to domestic spending and foreign aid allocation by sector, only domestic spending on education and health sectors are statistically significant. Of which, expenditure on education sector shows a negative sign, meaning that domestic spending on this sector is contributing to poverty reduction over the period of study. In opposite, expenditure on health sector shows a positive sign, meaning that domestic spending on health does not contribute to poverty reduction. This is perhaps expenditure on health sector has indirect effect on poverty reduction and it is more pronounced for mid- and long-term rather than short-term. Moreover, the estimated coefficients of domestic expenditure to infrastructure, foreign spending to agriculture and foreign aid on health show negative sign, meaning that they are on direction of reducing poverty though statistically insignificant, while other expenditures have no significant impact on reducing poverty.

This result raises a question to both Lao government and donors to reconsider their priorities in allocating budget to each sector. It is particularly true for foreign aid that needs further improvement for restructuring the allocation. All together, the finding shows that both Lao government and donors should further allocate the budget to education sector in order to enhancing capability of human resources that needed for all activities of development agenda.

5. CONCLUDING REMARKS

The allocation of the budget is a key instrument for governments to promote economic development and reduce absolute poverty. The critical challenge is how to strike the right balance between the expenditure by domestic/foreign fund and by sector that contributes to pro-poor.

In the case of Lao PDR, the government and donors have increased their spending significantly over the past decades. Although overall poverty incidence has declined significantly from 46% in 1992/93 to only 13% in 2012, this study finds that the total budget allocation remains concentrated on central government rather than provincial level. Most foreign aid focuses on the central, though domestic fund pay more attention on provinces but it constraints with limited budget. Moreover, there are also imbalanced in budgeting between rich and poor provinces. By usingpublic spending and aid by provincial panel data over 1995/96 to 2011/12, this study finds that both domestic budget and foreign aid weakly contribute to the poverty reduction with statistically insignificant. The major determinants are initial poverty level and the scale effect of each province's population. This means the current achievement in poverty reduction is more pronounced to less poor and large provinces, or so-called pro-rich. Moreover, among sectors, we find that expenditure on education is significantly contributing to the poverty reduction in Laos. Thus, both the Lao government and donors should strengthen the cooperation to improve the efficiency in each spending and to tailor the budget allocation right to appropriate region and sector.

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Simulation Modeling for Urban Freight Transportation in Vientaine City, Lao PDR

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Abstract— This paper purposes a simulation model for urban freight transportation in which the behaviour of freight agent and their relationship, the purpose of model is developing a simulation model the urban freight traffic flow, the result from model will be truck OD matrices is estimate on the basis of the collected real data, theses paper will discuss the issues on the model framework, model formulation and results of model applying to analyze the urban freight transportation in Vientiane City.

***Keywords*— Urban Freight Transportation, Traffic Survey, and Origin-Destination (OD)**

1. INTRODUCTION

A number of attempts have been made to describe freight transportation systems for decades. The earliest models estimated freight transportation as the percentage of passenger trips from the traditional four-step approach. The current freight demand modeling tends to model truck flows explicitly. This type of models can be categorized into two groups: trip-based and commodity-based approaches (*1*). Trip-based approach mostly deals with truck trips at the aggregate level. The truck trips are generated directly from the factors such as number of employees, floor area, and any other related factors without concerning the amount of commodity production and consumption. The example of this approach is the work of Park and Smith (*2*), which developed the model for truck estimation at statewide level. The model applied the traditional four-step approach including trip generation, trip distribution, and traffic assignment. Trip rate technique was used in the trip generation model together with truck traffic volumes for adjustment of trip production and attraction to be matched to the actual volumes. List and Turnquist (*3*) estimated the truck trips matrices by different truck classes with multi-time period in urban area from the counted truck volume on the network. The model attempts to deal with various kinds of input data, including link volumes, partial OD estimates for various zones, and originating and terminating data, in order to improve the accuracy of estimates. Eriksson (*4*) discussed the empirical approach to freight transport forecasting in urban area. The model generated OD matrices from the traffic flow by considering the changes of demographic variables and time variation of traffic over day and year. In addition, the model included the effects of economic control (such as road pricing, and change of fuel price). Matt and Visser (*5*) utilized a geographic information system (GIS) for simulation model of urban freight transportation. The simulation was able to incorporate trip chain of freight transport using GIS. The GIS was used as a tool for route simulation which resulted in the sequence of visits for picking up or delivery at the optimum distance, time, or cost. However, the limitation of trip-based approaches is that it is difficult to evaluate logistic policies because the trips are derived directly from the empirical data. In addition, it should be noted that the freight transportation is originated from the movement of commodities.

To overcome the drawback of trip-based approach, commodity-based approach focuses on the movement of commodities. At the stage of trip generation, instead, the approach generates the level of commodity production and consumption. Consequently, they require the additional stage for the conversion of the commodity flows to vehicle tours. Applied examples of the approach are shown as follows. Sivakumar and Bhat (*6*) applied the fractional split distribution model at the statewide level. The model focused on only the stages of trip generation and distribution. They determined the consumption level at the trip generation stage and used the fractional split distribution model which is similar to a multinomial logit model. They stated that the consumption demand at the

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Paper titles should be written in the title case letters. Avoid writing long formulas with subscript in the title; short formulas that identify the elements are fine (e.g. RE). Full names of authors are preferred in the author field, but are not required. Put a space between authors' initials.

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destination was the key factor to generate the freight movement. In addition, the model could include the impact of spatial patterns at the commodity production. Boerkamps et al. (*7*) proposed an urban freight movement model, which integrated the behavior of the freight decision makers in the supply chain including shipper, carrier, receiver, and politics. The model predicted the commodity flow based on the consumption demand of end users. The demand was linked to the supply according to the spatial distribution and market share resulting in commodity flow. Once the commodity flow was estimated, the commodities were allocated to vehicle tours and modes. Then, tours were assigned to the infrastructure network. His remarkable is that the logistic concepts are incorporated within the model and better reflect the actual behavior of freight movement. Garrido and Mahmassani (*8*) developed the distribution of a freight transportation demand model over space and time. They modeled the distribution of the choices of shipments (defined as commodity type, origin, destination, mode, and time) taken place using multinomial probit model. The model was able to define the origin-destination by commodity type, mode, and time simultaneously. It was validated to the actual shipment in Texas at the variation of seasons. The recent development on microscopic freight models can also be seen in the works of Liedtke (*9*) and Wisetjindawat (*10*).

Vientiane, which is located in the capital of Lao PDR, is the first most populated city in Lao PDR. It is facing a rapid increase in the volume of traffic and is suffering from serious limitations in its transportation infrastructure due to rapid population increase and economic growth, as observed in other provinces. Although urban transportation master plans were formulated for the Vientiane city, the social, economic, and political situations in Vientiane City has changed considerably in the 2005s. However, recently, the transportation policy has never been studied or discussed in depth in Vientiane City. This study aims to report an analysis of the local freight transportation in Vientiane by using the real data collection.

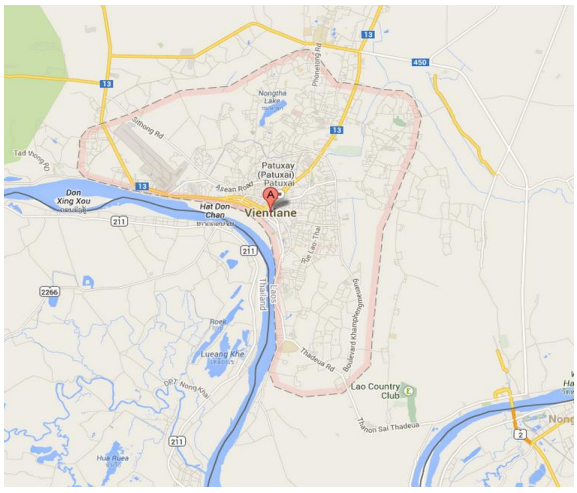


Fig.1. Road network of Vientiane City

2. Survey on transportation in Vientiane capital

2.1 Outline of the survey

We have conducted a survey on freight transportation in Vientiane in order to collect data on basic transportation. The survey consists of two parts: (1) a preliminary survey that includes a rough observation of the urban structures and the infrastructure by visiting various sites in the city, (2) and a field survey that includes a survey on the volume of traffic on major roads in Vientiane and a survey on goods transportation by various locations. First, we visited Vientiane in June, 2012, in order to collect general information related to the local freight transportation. We observed the transportation facilities in the city, including the (1) Lao-Thai border, (2) 13 South road, (3) the Asean road (T4), (4) the KaysonePhomvihane road, (5) the Dongdok road, the national university of Laos (NUOL) area, (6) 13 north road.

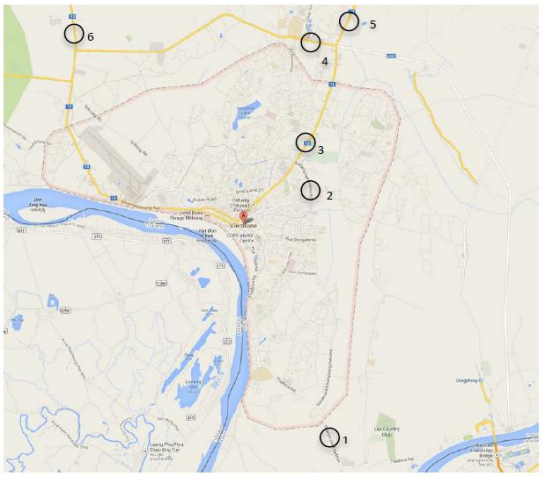


Fig.2. Observation point of the survey on traffic volume

2.2 Survey on the traffic volume

We conducted a survey on the traffic volume along the main roads in the city based on vehicle type. The surveyors standing beside the roads observed the change in traffic volume. The observation locations were divided into two groups. One group including 3 observation points was selected for a 16-h survey, where the major roads across the border connecting the regions outside and inside Vientiane were observed. The other group including 3 observation points on the major road approaching the central areas of Vientiane City from 06:00-22:00. The 3 points on the major road approaching the central areas was selected for a 16-h survey. We began the 16-h survey after the completing the 16-h survey; one of the reasons for conducting the 16-h survey was that it was necessary to observe the general characteristics of the traffic patterns, including the dynamic change in the traffic volume in 16-h; the other of the reasons was that it was necessary to observe the vehicles as efficiently as possible in the following 16-h survey. We decided the number of observers for each observation point and the number of observation points in the 16-h survey on the basis of the information obtained from the 16-h survey.

2.3 sixteen-hours traffic volume survey

We selected three major points in Vientiane City, as shown in Figure.2. During the traffic observation, we classified the vehicles into the following seven types: motorcycles, cars, pickup trucks, vans, buses two-axle medium-size trucks, and three-axle large-size trucks. The surveyors determined the traffic volume based on the vehicle type, time of the day, and direction. The results of the 16-h survey at Point 1, 5, and 6 are shown in table.1. Table.1 shows the 3 points in the observed traffic volume for 16h for all types of vehicles in the observed traffic volume approaching from suburban areas into the city center and from the city to suburban. The motocycles is the highest with 64%, 70%, 59%, and the second, there are 2 axle with 10%, 11%, and 16% of the total traffic volume at the point, 1, 5, and 6 respectively. Table.2 shows that for freight vehicles from inside to outside, out side to inside at the point of 1, 5, and 6 respectively. First, the modal share of medium truct is the highest with 42, 50%,and 56% of the total freght traffic volume. Second, there are small trucks with 31%, 29% and 32% at the point 1, 5, and 6 respectively.

Table.1. All types of vehicles results of 16-h

Direction 1: inbound

	All types of vehicle							
Point No.	2 axle	3 axle	Motorcycle	Car/Taxi/TT	Pickup	Van	Bus	Sum
Point: 1								
16-hr Traffic	538	340	3,287	354	402	211	8	5,140
(%)	10	7	64	7	8	4	0	100
Point: 5								
16-hr Traffic	160	82	1,011	40	95	45	7	1,440
(%)	11	6	70	3	7	3	0	100
Point: 6								
16-hr Traffic	640	138	2,321	199	364	219	44	3,925
(%)	16	4	59	5	9	6	1	100

Direction 2: Outbound

	All types of vehicle							
Point No.	2 axle	3 axle	Motorcycle	Car/Taxi/TT	Pickup	Van	Bus	Sum
Point: 1								
16-hr Traffic	616	316	3,454	296	417	215	5	5,319
(%)	12	6	65	6	8	4	0	100
Point: 5								
16-hr Traffic	1310	283	4285	409	1027	430	92	7836
(%)	17	4	55	5	13	5	1	100
Point: 1								
16-hr Traffic	391	325	2,721	174	304	201	49	4,165
(%)	9	8	65	4	7	5	1	100

1: inbound (direction TO the center of Vientiane Capital)

2: Outbound (direction FROM the center of Vientiane Capital)

Table.2. All freight of vehicles results of 16-h

Direction 1: Inbound

	Freight vehicle				
Point No.	ST	MT	LT	DT	Sum
Point: 1					
16-hr Traffic	402	538	11	329	1,280
(%)	31	42	1	26	100
Point: 5					
16-hr Traffic	88	151	11	51	301
(%)	29	50	4	17	100
Point: 6					
16-hr Traffic	364	640	11	127	1,142
(%)	32	56	1	11	100

Direction 1: Outbound

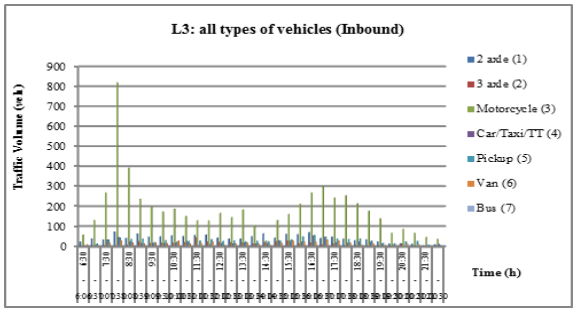
	Freight vehicles				
Point No.	ST	MT	LT	DT	Sum
Point: 1					
16-hr Traffic	417	616	12	304	1,349
(%)	31	46	1	23	100
Point: 5					
16-hr Traffic	108	191	11	93	403
(%)	27	47	3	23	100
Point: 6					
16-hr Traffic	304	391	11	4	710
(%)	43	55	2	1	100

1: inbound (direction TO the center of Vientiane Capital)

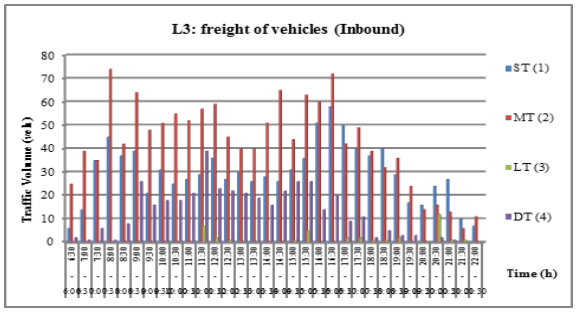
2: Outbound (direction FROM the center of Vientane Capital)

2.4 sixteen-hours traffic volume survey

We observed the traffic volume at 3 points on the major road approaching the central areas of Vientiane, from 06:00 to 22:00. The 3 observation points are showed in the Figure 2 at the point 2, 3, and 4. Results of 16-h survey of Point 3 in Figure 3a are showed the all traffic volume running from suburban to central areas or called Avenue Kaysone Phomvihane. First, the motocycles travel mainly and modal share is 60% of total traffic volume. Second, there are two axle and pickup are 14% and 10% respectively. Third, threre are two peaks for all types of traffic volume: one between 07:30-08:30 and the other 16:00-17:00. Forth, the meduim trucks (MT) of freight is the highest with 49% of total freight traffic volume, 35% for the small trucks (ST) as showed in the Figure 3b.



(a)



(b)

Fig.3. Results of 16-hours survey at point 3

3. Freight traffic flow model

3.1 Outline of the freight traffic flow model

The process of developing the freight traffic flow model is shown in Figure 4. First, an origin-destination freight traffic demand matrix is estimated on the basis of the collected real data from the results of our survey mentioned in Section 2. Then, a route choice model is

calibrated by minimizing the differences between the frieght simulated and total vehicle silulated.

3.2 Unit freight traffic generated by a firm

We estimate the unit freight traffic volume based on the vehicle type and the size and type. The unit is estimated from the average frequency of freight vehicle dispatch on the basis of real traffic volume. The estimated unit traffic volume is shown in Table 3.

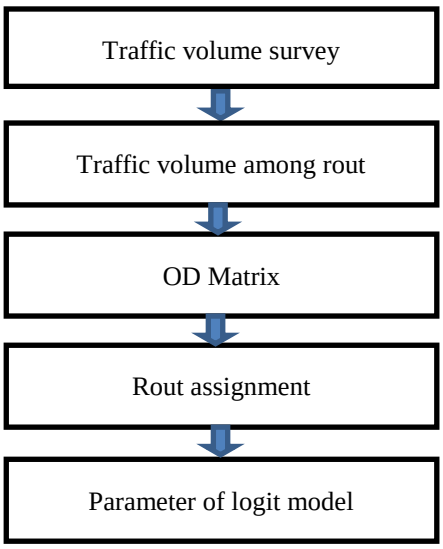


Fig.4. process of developing a freight traffic flow model

3.3 Traffic volume from the route

We estimate the number of vehicles in each route according to the size and type of the vehicle; this is based on the results of the survey on the distribution of the sizes of vehicles in Vientiane. Then, we calculate the freight traffic volume from each direction route based on the vehicle type by real data collection in the field. The traffic volumes observed at the point 1, 5,6 are used for the outside areas and the poin 2,3,4 used for the central areas.

Table.3. Freight traffic vs total traffic volume

Direction 1:Inbound

Point No.	Freight vehicles vs total traffic volume			
	ST	MT	LT	DT
Point: 1	0.04	0.02	0.02	0.02
Point: 2	0.02	0.10	0.00	0.00
Point: 3	0.03	0.11	0.00	0.01
Point: 4	0.05	0.02	0.00	0.01
Point: 5	0.00	0.10	0.00	0.00
Point: 6	0.05	0.23	0.00	0.07

3.4 Estimation of origin-destination matrix

We estimate a route-based origin-destination traffic flow matrix by using the distribution of the destinations of freight vehicles travel. The distribution data is estimated from real data collection in each route. In this estimation, the Flator method is applied under the condition that the traffic volume generated from a zone is equal to that traveling toward it.

3.5 Route choice model

First, the two routes are selected as alternate routes for all pairs of an origin and a destination route on the basis of the real data collection. Next, an aggregate logit model is applied to the route choice behavior of the freight truck drivers. The logit model can be expressed as:

$$P_{k,i}^{od} = \frac{\exp(-\theta V_{k,i}^{od})}{\exp(-\theta V_{k,j}^{od})} \qquad (1)$$

Where $P_{k,i}^{od}$ means the probability of a freight truck driver selecting route i while traveling from zone o to zone d with vehicle K (K = {ST, MT, LT, and DT}; $V_{k,i}^{od}$, the utility of the route; and θ , an unknown parameter of the error variance.

The utility of route is defined as a linear function of the travel time and travel cost of the OD pair shown as follows:

$$V_{k,i}^{od} = \omega_k . T_{k,i}^{od} + C_{k,i}^{od} \qquad (2)$$

Where $T_{k,i}^{od}$ means the travel time; $C_{k,i}^{od}$, the travel cost; and ω_k, the value of time of vehicle k. In addition, $C_{k,i}^{od}$ include the fuel cost, which is proportional to the distance.It is assumed that $T_{k,i}^{od}$ depends on the traffic congestion on the routes.

3.6 Estimation of unknown parameters

The unknown parameters of the route choice model shown in equation (1) are represented as θ and ω_k . In addition to these parameters, we add two other parameters to the utility function of a route shown in equation (2). The first parameter is set for a dummy variable for large size trucks using the Dongdok (DD) road (Point 5, from Lao-Thai friendship bridge to 13N road); it is equal to one if a large-size truck uses the Dongdok raod and zero otherwise. The second parameter is set for a dummy variable for large-size trucks entering the central area (CA) or (Avenue Kaysone Phomvihan); it is equal to one if a large-size truck enters the CA zones and zero otherwise.

We calibrate the unknown parameters by minimizing the differences in the observed and estimate link traffic volumes. For this calibration, vehicles other than freight vehicles are assumed to have a fixed value of the traffic volume. .It is observed that small- and middle size trucks tend to use the all route more frequency tahn large-size

trucks. However, the large-size trucks tend not to pass the city center. The ω_k value of large-size trucks is larger than that of small and middle-size trucks. The comparison between the truck flows is shown in Figure 5.

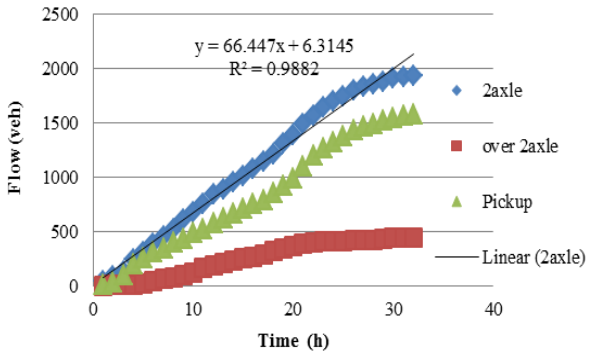


Fig.5. process of developing a freight traffic flow model

4. Conclusions

We surveyed the freight transportation system in Vientiane, which is one of the medium-size developing cities in Lao PDR, and developed a freight traffic flow model with the data collected from the survey. By applying this model, although this research successfully analyzes the transportation policy even in the city such as Vientiane, where basic local statistics are not available, further research is still required. First, we discovered some limitations of the methods we used in the survey. Next, the accuracy of the model developed in the study may not be sufficient to analyze detailed countermeasures against specific transportation problems. This is simply because the model is estimated with substantially limited data. However, it is still useful for a preliminary discussion on the future direction of transportation policies and the model may be valuable for local people to understand the mechanism of the impact of a specific transportation policy. Consequently, this type of analytical model could also be beneficial from the educational viewpoint.

ACKNOWLEDGMENT

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ECONOMIC RENT FROM HYDROPOWER DEVELOPMENT IN THE CASE OF LAO PDR.

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Abstract: Hydro Power is the backbone of the Lao economy. The rugged terrain, compounded by the fact that the Country is land locked does not provide much economic advantage to Lao PDR. Transportation costs are high and unless Lao PDR can think of certain niche products, its exports are not going to be competitive. The decision by the Lao Government to exploit its water resources for production of electricity has changed the economic scenario for Lao PDR. The mountainous and rapid rivers have made Lao PDR a natural haven for hydro power production. The neighboring countries have provided the necessary political will and the market for Lao's power, as Thailand and Vietnam has a huge power deficit.

While electricity has provided the much needed revenue, the Lao Government has also prioritized network expansion in the Country. It is expected that by 2020, the entire Country will have access to electricity about 90%. Industrial activities are expected to increase with the commissioning of Hydroelectric Projects. There is however, a need to ensure that internal electricity tariff is kept affordable so that it becomes the main source of energy in the Country and also to stimulate industrial activities.

This paper highlights the role and importance of hydropower for social and economic development of Lao PDR and covers aspects related to planning and policy initiatives being pursued by the Hydropower sector to fulfill the national objectives. The introductory sections provide the baseline information on hydropower resources of Lao PDR, development potential and existing situation in the supply and demand of hydroelectricity. Subsequent sections cover the planning and policy interventions that the Lao Government is undertaking in order to maximize on the benefits from hydropower development..

Keywords - **Hydropower, public private partnership investment, concession fee, generation expansion plans, least cost**

1. INTRODUCTION

Approximately three quarters of the Laotian population has access to an electricity supply; this level is relatively low compared with China, Thailand and Vietnam, but considerably higher than the rates in Myanmar and Cambodia. Laos has a low population density and an overall small population which makes it challenging to expand electrification to the entire population.

Electricity demand in Laos has grown very significantly and steadily in the period since the year 2000. The growth is mainly due to growth of the countrys mining sector. More specifically, in the period between 2000 and 2011, total electricity consumption (in GWh) increased by 15% annually [4]. The trends of consumption in different sectors of Laos are shown in Fig. 1.

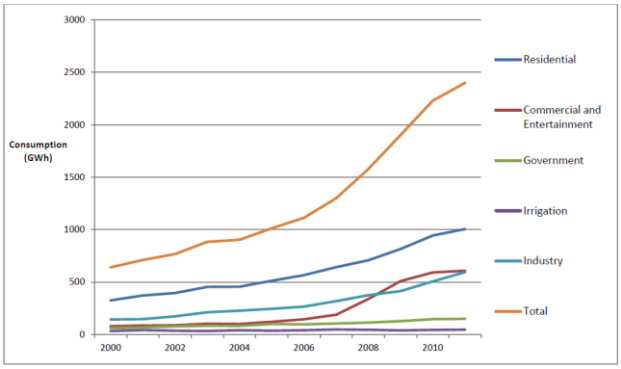

Fig 1: Electricity consumption in Laos (2000 - 2012)

The considerable increase in electricity demand has not generally led to further problems in meeting electricity demand. Throughout the period of sustained electricity demand growth the country has enjoyed a relatively stable power supply due to power trading with neighbouring countries. Fig. 2 shows the development of annual levels of electricity generation, imports, exports and total sales, from 2000 to 2012.

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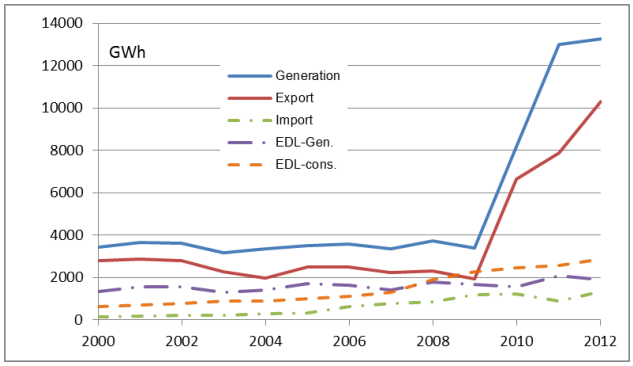


Fig. 2: Electricity generation, imports, exports and domestic consumtion

Without power trades with neighbouring countries, domestic system would have suffered considerable electricity supply problems because of the current limits of its power system. As a general trend, between 2000 and 2012 the volumes (in GWh) of power imported by domestic system from its neighbours has increased annually; this can be seen in contrast with the volumes of power exported by domestic system, which has generally decreased but with more year-on-year variation. One last important point to note from the data shown in Fig. 2 is that total export volumes show strong coupling with generation volumes.

2. HYDRO POWER POTENTIAL IN LAO PDR

Hydropower is the cornerstone for power development in Lao PDR. Currently, more than 99% of the power generated in the country corresponds to hydropower stations. The total installed hydro power generation capacity in Laos is 3,213.25 MW, of which 990 MW are for domestic electricity supply and 2,210 MW is for export purposes. The development of installed hydro power capacity in Laos is shown in Fig.3. Details of hydropower installed (and operating) generation plant are provided in Annex-1.

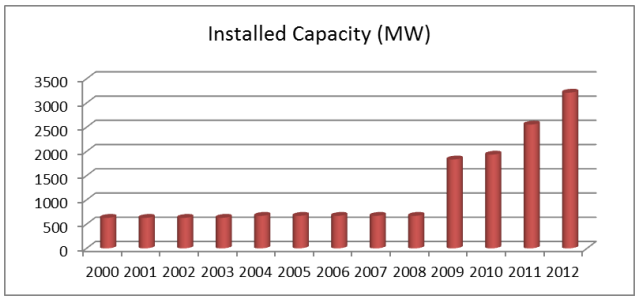


Fig. 3: Existing power generation (Source: Own elaboration of EdL data 2011)

According to the World Energy Council, there is still potential to develop 18 GW of hydropower

capacity in Laos, which is equivalent to around 63 TWh per year assuming a 40% capacity factor.

The absolute hydro power potential of Laos is lower than the levels in neighbouring China,

Myanmar and Vietnam; however, the per capita generation potential is very significant in that it is

around 30 times the size of the country current per capita consumption. This per capita potential (9,844 kWh per year) offers Laos (which has a small population) the opportunity to close its electrification rate gap and substantially increase its levels of electricity exports.

It is currently planned that between 2013 and 2020, 55 new power generation projects will be developed, adding an approximate additional total generation capacity of 5,718 MW to existing Laos power generation capacity. The planned addition of generation plants is shown in Fig. 4: generation capacity additions are shown in terms of annual capacity added (MW/year) and in terms of cumulative total additional capacity in the period 2013 – 2020 are shown in the Annex-2.

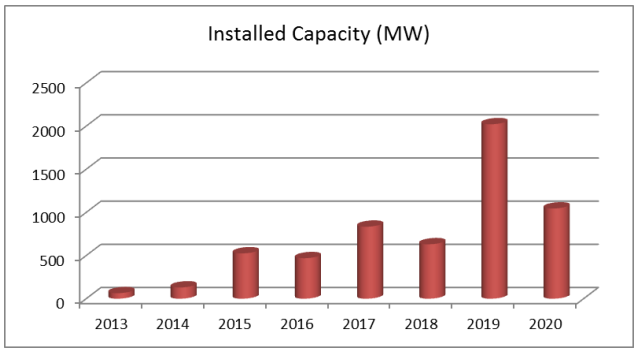


Fig. 4: additional capacity in the period 2013 – 2020 (Source: Own elaboration of data published by EdL, 2013

The detailed plan of project developments, scheduled for the period 2020 to 2030 (as published in the Power Development Plan 2010, formulated in August 2011) is detailed in annex 3.

Regarding the investment process for hydro power plants, developers follow a staged process which involves the agreement and signing of three key pieces of documentation, namely: the MoU, the Project Development Agreement (PDA), and the Concession Agreement (CA). The entire process, including negotiations, is due to take between 6 months and 24 months to complete.

The main fiscal arrangements for hydro power IPP projects are set out within three key pieces of legislation: the Tax Law 2011; the Investment Promotion Law; and the Enterprise Law.

In summary, IPP hydro projects are required to pay the following main taxes:

- Profit tax;
- Salary tax;
- Royalty payments;
- Dividend payments; and
- Customs payments.

General tax exemptions are set out in the Investment Promotion Law, based on the zone in which a project is located and taking into account the socio-economic infrastructure and geographical conditions of the country.

Projects are typically exempt from having to pay import customs for the construction of hydro plant. Royalties are always negotiated on a project by project basis, while profit tax and other taxes in some cases are subject to negotiation, further to what provided in the investment law, and the agreed arrangements are included in the project CA as agreed with the investment committee.

3. METHODOLOGY

One of the main objectives of the relation with hydro development is “Maximizing revenue inflows over time from export projects while still attracting high quality

developers".

This conceptual contradiction (or trade-off) in any case requires some numerical information in order to assess the impact that different kind of royalty policies will have on GoL revenues and investments. In order to get an initial quantitative indication of the trade-off we developed a simple model of the hydro power development aimed at estimating the impact on return on investments (specifically return on equity - ROE) of different royalty's policies.

3.1 QUANTITATIVE ANALYSIS

Base on basic information on 141 hydro sites. This information and some assumptions on financial parameters, we estimated the ROE of each project as a function of the royalty. Assuming that investors will require a minimum ROE to develop a project, the model allowed us to know the total investments and the linked GoL revenue as a function of the percentage of royalty.

We used the following assumptions

- Energy selling price: 65 USD/MWh, flat
- Equity debt relationship: 30/70
- Loan interest rate: 8%
- Load amortization period: 12 years
- Operation and maintenance costs: 20 USD/kW/year
- Concession period: 25 years
- Incomes tax: 24%
- Minimum ROE: 13% (real)
- Calculation in real terms

The quantitative analysis on potential outcomes of taxation arrangements shows how GoL revenues and the amount of investments start to decrease when the royalty percentage overtakes certain levels, on the one side, and they emphasize the risks of reaching a non-optimal royalty level due to changing investment conditions and imperfect information on projects and investors, on the other.

3.2 APPROACH TO FISCAL OPTIONS

The analysis can be divided into three main steps:

1. Mapping the Institutional background

Map the institutional background detailing all the instances in which a hydropower project must interface with government entities, in order to determine the procedure that is used in the determination of taxes and revenues sharing.

2. Link Institutions to Legal framework & enforcement

Once the institutional background has been mapped, the following activity is to assess the link between each one of the mapped instances to the corresponding Laws, decrees or regulations that enable each specific office to determine the tax or revenue implications in the project. Under this procedure, the Consultant will be able to clearly identify the specific, corresponding binding regulation, if any.

3. Determine risks, needs and priorities

After this process, it will have a clear perspective of the relationship between institutions and regulations that is being properly determine the risks, needs and priorities from different GoL institutions

The specific project information is: installed capacity, average yearly energy production and overnight costs. Based on this information and assumptions, we made the calculations necessary to create the Fig. 5 This figure shows clearly that as long as the royalty increases, the number of profitable projects go down. In order to quantify the impact on GoL revenues and total investments, collection in concept of royalties and income tax (IT), as a function of the percentage of royalty. For preparing this figure we assumed that investors require a minimum ROE of 13%.

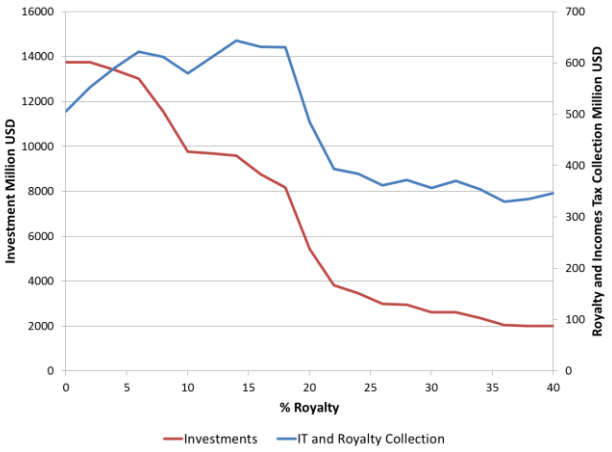


Fig 5 - Investments and GoL Revenues as a function of %Royalty - Minimum ROE=13%

We repeated the analysis for a minimum ROE of 10%, which is presented in Fig 6.

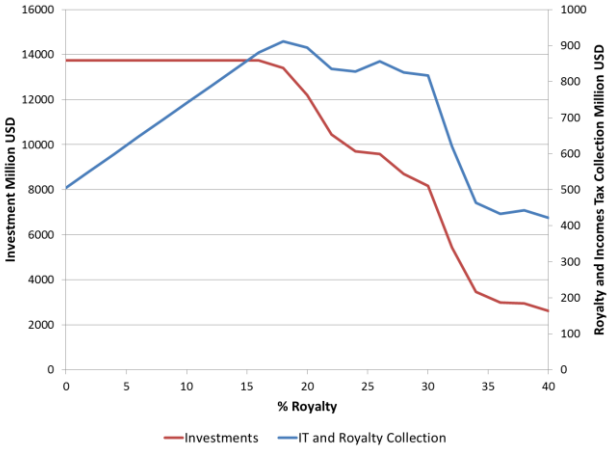


Fig 6 - Investments and GoL Revenues as a function of %Royalty - Minimum ROE=10%

This figure confirms the trend that both GoL revenues through royalties and IT and investments have a decreasing trend when the royalty percentage increases. However a more clever strategy could increase collection and investments (that as shown in these figures are closely interrelated) simultaneously. The most convenient strategy from a purely economic point of view is to assign to each investor a royalty percentage that allows achieving exactly the minimum acceptable ROE

If it were possible to use this strategy, the GoL, under the assumptions of this analysis, could collect 600 million USD annually, against 550 million in case the fixed royalty were 5%, that which maximize revenues in Fig 5.

The present strategy, based on a project by project negotiation aims to achieve this objective. However this

approach has some weak points:

- Lack of transparency,
- Need to agree previously on several assumptions, some of them managed by the developer or the developer financial institution, like financial conditions, indirect costs, etc.
- Impossibility to know the minimum ROE that the developer is willing to accept.

These drawbacks may be eliminated with a tender process awarded to the bidder that offers the highest royalty (or combination of royalty + IT). Tenders properly designed are by nature transparent, and encourage bidders to internalize in the economical offer their expected ROE. However in the Lao PDR's context tenders faces some difficulties:

- a tender awarded based on the royalty + IT requires to know in advance the electricity price, which in the case of exports would require a previous negotiation;
- it is also necessary to have a feasibility study with a tight estimation of costs and a geological survey;
- there is no experience in the use of tenders for this type of projects yet.

Nevertheless it would be possible to identify solutions to the above problems, so tenders are an alternative that deserves to be taken into consideration.

Based on this previous and preliminarily diagnosis, we will pose a set of alternatives that will be assessed in detail. The set of alternatives to be analysed may include, but not limited to [3]:

- fixed royalties and IT;
- fixed royalties and IT, with some flexibility to consider low ROE projects;
- project by project negotiation, with a more transparent procedure;
- tenders were the concession is awarded to the bidder that offers the greater royalty;
- combinations of the above.

Others form of benefits for the GoL will be analysed, as participation in the equity, obtaining of part of the energy for internal consumption, etc. However the methodology of analysis would be the same, as in all the cases the GoL participation leads to a reduction in the project ROE.

The combination of different components and the relative information needs, coordination issues, financing conditions, risks and opportunities will be analysed and clearly presented in the options paper (Fig 8.)

3.3 OPTIMAL OF PUBLIC EXPENDITURES

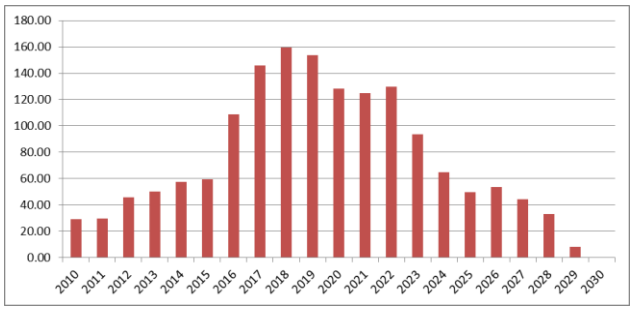
How much to consume, save or invest abroad, or invest domestically? The answer to this question depends on the relative rates of return to investments, as well as on the discount rate for the future consumption (the so-called social discount rate) [1]. If the social discount rate is higher than the domestic and international rate of return to investment, then all resource revenues should be consumed today. Otherwise, they should be invested into those activities with the highest returns

The rate of return to investment abroad depends on a country's debt levels and its intention to borrow or pay back external debt from the resource revenues. For Laos, it is probably quite high. The rate of return on domestic investment for a developing economy with high growth rates and scarce investment may be higher than the world interest rate (indeed, Lao interest rates are higher than abroad), but it also depends on a country's risk and its ability to implement projects and thus may be not as high in Laos as it is in an average middle-income developing country.

Assuming a 20 percent equity for projects in the pipeline, the financing needs for taking equity stakes could go up to almost $160 million a year by 2018 (Figure 7). Given the constraints in borrowing that Lao PDR is facing, a financing strategy or a change in approach would need to be taken regarding the equity stakes. There has not yet been any clear indication of the government's IPP investment policy.

Taking equity is risky. Getting a high percentage of revenues from equity stakes rather than taxes and royalties increases the risk taken by the government in each project and could lead to losses in the future. Currently, for Laos it is projected that around half of all government revenues will come from dividends. However, equity stakes, especially if they are taken up-front when the risks of the project have not yet materialized, are the riskiest source available. Instead, shareholding based on a small free carried interest (i.e. 5 percent) could be considered to reduce risk. Moreover, it could consider requiring developers to give it the option of acquiring additional shares when a project is confirmed to be commercially attractive, instead of taking large stakes up-front in projects with potentially high risk. To ensure appropriate participation in export-oriented hydropower projects, the LHSE should be designated as the government's shareholder in these projects (see MacGeorge et al., 2009)

Fig 7: Projected Equity Investments by theGovernment of Lao PDR in Hydropower Projects (million US$)



4. RESULT AND DISCUSSION

To evaluate the fiscal options available for Laos, we propose to adopt the classification of the existing taxation system for hydropower projects that was proposed in the "Lao PDR Development Report 2010" [2] by the World Bank, in which a distinction was made between Primary and Secondary taxation levels.

Primary taxation level corresponds to those taxes that affect all businesses in Laos, irrespective of their nature; they include: Corporate profit tax, Business turnover tax,

Excise tax and Import-Export Duties.

Secondary taxation level corresponds to those alternatives that the Government of Laos can use to extract the economic rents from a specific project. They include: Royalties, Equity participation and/or discount electricity sales.

Within the primary taxation lever, we classify those taxes included in the Lao Tax Law. This law provides clear instructions on the application of the four types of taxes that relate to hydro power projects:

- The business turnover tax on the production of electricity turnover is 5% on domestic production.
- Excise tax applies to some 15 categories of goods and services.
- Profits from the electricity exports are subject to the profit tax. A flat rate of 24 percent

  applies to total annual net profit.
- Dividend tax is fixed at 10 percent

Further to the Tax Law, the key for understanding the fiscal options is in the Law on the Investment Promotion which grants project developers attractive benefits, including tax holidays on: Profit tax, import and export duties.

Taking into account that most hydropower projects in Laos are aimed to export electricity to neighboring countries, the target of the options to be analyzed below will focus on evaluating alternatives for transferring economic rents from the developer to the Government. On the contrary, when projects are aimed to supply electricity to Laos, the rent extraction process will be mainly made in the PPA tariffs to be signed between the developer and the government, apart from possible revenue sharing requirements. The projected revenue of Lao PDR in Hydropower projects are shown below

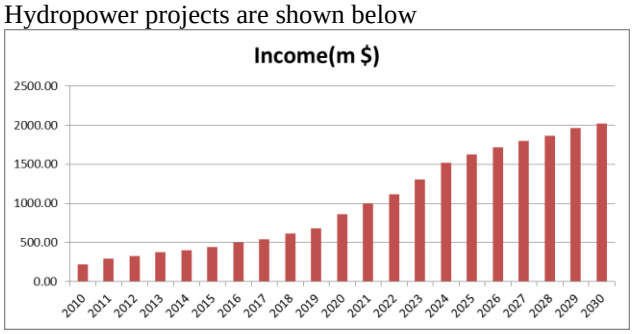


Fig 8: Projected Fiscal Revenue of Lao PDR in Hydropower Projects (million US$)

It is important to mention here that in the case of domestic projects, as the rent extraction process is based on the PPA tariffs, the introduction of primary and / or secondary taxation levels will trigger an increase in the PPA tariff, which in practical terms mean that the electricity consumers will finance the revenue sharing requirements (introduced by primary or secondary taxation tools).

This is the reason why, in the case of domestic projects, it is necessary to distinguish between rent extraction tools and revenue sharing tools. Unlike what happens in the case of projects dedicated to export, the pure rent extraction target should not be part of the taxation framework, but on the contrary, should be delivered by the PPA price level.

5. CONCLUSIONS

Further to the rent extraction process, equity participation in the project presents some advantages that may be interesting for the Government of Laos. A significant advantage is that the government backs the development of a strategic sector which is key for Laos, both in terms of exports and social improvement.

Also, becoming a shareholder gives the government access to voting rights and detailed cost information which can be used to benchmark the performances of their generation portfolio. Moreover BOT/BOOT projects will be transferred to the GOL after the concession period.

One additional advantage is represented by the revenue stream coming from the dividends; most probably, this flow of revenues will not directly enter into the national budget but would remain in LHSE and EdL. Under this assumption, the revenue flows could be used either to reduce electricity costs in Laos or to promote development in Laos, for instance, through the electrification of the country and further investments in the sector

Based on the Lao PDR's fiscal profile and projections until 2030, an "optimal" fiscal strategy would allow for higher investment than the pure "permanent income strategy" but would also allow for a buildup of modest savings. Specifically, if primary expenditure was around 17 percent of GDP after the spike in 2010 and gradually was increased to 20 percent of GDP, then 1 percent of GDP could potentially be saved each year, as well as will help reduce foreign debt below the LIC threshold by 2020. Such a strategy takes into account the country's development needs as well as the macroeconomic challenges related to managing large resource revenues.

Most importantly, the revenues need to be used effectively for poverty reduction and in public investment programs as part of the implementation of the government's development program under the NSEDP. For example, rural infrastructure has been shown to be the single most important driver of growth in Lao PDR. Other investment options that increase growth in the long run, such as human capital (including education and health as well as professional training) also should be considered.

6. REFERENCES

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Abbreviations:

Abbreviation	Words
Lao PDR	Lao People's Democratic Republic
GOL	Government of Lao
IPP	Independence Power Producer
BOT	Build Operate Transfer
BOOT	Build Own Operate Transfer
GDP	Gross Domestic Product
EDL	Electricity du Laos
IT	Income Tax
ROE	Return on Equity
USD	United State Dollar
MWh	Mega Watt hour
KW	Kilo Watt

Annex-1

No.	Project	Location (Province)	Installed capacity (MW)			Energy	Commercial Operation date	Ownership	Planned market
			Total	Domestic	Export	GWh			
1	Nam Dong	Luangprabang	1	1		5	1970	EdL	Laos
2	Selabam	Champasak	5	5		21	1970	EdL	Laos
3	Nam Ngum 1	Vientiane	155	155		1002	1971	EdL	Laos / Thailand
4	Xeset 1	Saravane	45	45		134	1990	EdL	Laos / Thailand
5	Nam Ko	Oudomxay	1.5	1.5		8	1996	EdL	Laos
6	Theun Hinboun	Bolikhamxay	210	210		1620	1998	IPP	Laos / Thailand
7	Houay Ho	Champasak/Attapeu	152.1	2.1	150	617	1999	IPP	Laos / Thailand
8	Nam Leuk	Vientiane	60	60		218	2000	EdL	Laos / Thailand
9	Nam Ngay	Phongsaly	1.2	1.2		5.2	2003	EdL	Laos
10	Nam Mang 3	Vientiane	40	40		150	2004	EdL	Laos / Thailand
11	Xeset 2	Saravane	76	76		300	2009	EdL	Laos / Thailand
12	Nam Theun 2	Khammouane	1,088	75	1,000	6,000	2009	IPP	Laos / Thailand
13	Nam Lik 1-2	Vientiane	100	100		435	2010	IPP	Laos
14	Nam Ngum 2	Vientiane	615		615	2218	2011	IPP	Thailand
16	Nam Tha 3	Luangnamtha	1.25	1.25		5	2011	IPP	Laos
17	Nam Nhone	Bokeo	3	3		12	2011	IPP	Laos / Thailand
18	Nam Song	Vientiane	6	6		25	2012	EdL	Laos
19	Nam Ngum 5	Xiengkhuang	120	120		507	2012	IPP	Laos
20	Theun Hinboun Exp.	Bolikhamxay	220		220	1440	2012	IPP	Thailand
21	Tad Salen	Savannakhet	3.2	3.2		17	2012	IPP	Laos
22	Nam Gnuang	Bolikhamxay	60	60		316	2012	IPP	Laos
23	Xe Kaman 3	Xekong	250	25	225	982	2012	IPP	Laos/Vietnam

Annex-2

No.	Project	Location	Installed capacity (MW)			Energy	Commercial
		(Province)	Total	Domestic	Export	GWh	Operation date
1	Nam Long	Louanamtha	5	5		30	2013
2	Nam Ngiep 3A	Xiengkuang	44	44		145	2013
3	Xe Nam Noy 1	Attapeu	15	15		110	2013
4	Nam Kong 2	Attapeu	66	66		263	2014
5	Nam kong 3	Attapeu	45	45		170	2014
6	Xe Nam Noy 6	Champasack	5	5		40	2014
7	Nam Sana	Vientiane	14	14		49.6	2014
8	Nam Phanai	Vientiane	15	15		126	2015
9	Nam Sim	Huaphan	8	8		29.4	2015
10	Nam Hao	Huaphan	15	15		110	2015
11	Nam Peun 1	Huaphan	27	27		127	2015
12	Nam Peun 2	Huaphan	12	12		56	2015
13	Nam Samouay	Vientiane	5	5		28	2015
14	Nam Khan 2	Louangprabang	130	130		558	2015
16	Houylamphan	Xekong	85	85		452	2015
17	Nam Chiane	Xiengkuang	104	104		448	2015
18	Nam Mang 1	Vientiane	64	64		224	2015
19	Nam Lik 1	Vientiane	60	60		249	2015
20	Xe Kaman 1	Attapeu	290	32	258	1096	2016
21	Xe Kaman Xanxay	Attapeu	32	32		121	2016
22	Nam Beng	Oudomxay	34	34		137	2016
23	Xe Set 3	Saravan	23	23		86	2016
24	Nam Khan 3	Louangprabang	60	60		240	2016
25	Nam Hinboun	Khammouan	30	30		197	2016
26	Nam Ou 2	Louangprabang	120	120		546	2017
27	Nam Ou 5	Phongsaly	240	240		1049	2017
28	Nam Ou 6	Phongsaly	180	180		739	2017
29	Nam Ngiep 2	Xiengkuang	180	180		723	2017
30	Nam San 3A	Xiengkuang	69	69		277	2017
31	Nam San 3B	Xiengkuang	45	45		168	2017
32	Xepian-Xenamnoy	Attapeu	410	40	370	1788	2018
33	Nam Nga 2	Oudomxay	14.5	14.5		62.5	2018
34	Nam Mo 2	Xiengkuang	120	20	100	503	2018
35	Nam Phay	Vientiane	86	86		420	2018
36	Xayaburi	Xayabury	1285	60	1225	7370	2019
37	Houykapeu	Saravan	5	5		38	2019
38	Houaypo	Saravan	9.5	9.5		60	2019
39	Xelabam Exp.	Saravan	7.7	7.7		37	2019
40	Nam Tha 1	Bokeo	168	168		756	2019
41	Nam Ngiep 1	Bolikhamxay	272		272	1515	2019
42	Nam Ngiep reg.	Bolikhamxay	18	18		105	2019
43	Donsahong	Champasack	256	56	200	2000	2019
44	Nam Ngum 1 Exp.	Vientiane	40	40		56	2020
45	Xe Set 4	Saravan	10	10		110	2020
46	Nam Ou 1	Louangprabang	160	160		800	2020
47	Nam Ou 3	Louangprabang	150	150		710	2020
48	Nam Ou 4	Phongsaly	116	116		570	2020
49	Nam Ou 7	Phongsaly	190	190		915	2020
50	Houaykapeu 2	Saravan	5	5		22	2020
51	Nam Pha	Bokeo	195	195		735	2020
52	Nam Phoun	Xayabury	60	60		280	2020
53	Nam Pot	Xiengkuang	14.5	14.5		70	2020
54	Nam Phouan	Vientiane	52.5	52.5		205	2020
55	Xe Katam	Champasack	62	62		380	2020

Annex-3

No.	Project	Location	Installed capacity (MW)			Energy	Commercial
		(Province)	Total	Domestic	Export	GWh	Operation date
1	Nam Ken	Vientiane	5	5		19.7	2021
2	Nam Sum1	Huaphan	94	94		323	2021
3	Nam Sum3	Huaphan	197	196		635.8	2021
4	Xanakham	Vientiane	660	60	600	3696	2021
5	Pakbeng	Oudomxay	921	121	800	4775	2021
6	Phou Ngoy	Champasack	651	151	500	3278	2021
7	Nam Suang1	Louangprabang	90	90		167	2022
8	Xe Kaman-4A	Attapeu	80	80		315.8	2022
9	Nam Phak	Champasack	150	150		511	2022
10	Xe Kong 3A	Attapeu	105	105		419.8	2022
11	Xe Kong 3B	Attapeu	100	100		393.6	2022
12	Xepian-Houaysoy	Attapeu	115	115		283	2022
13	Nam Bak1	Vientiane	160	116		744.2	2023
14	Paklay	Xayabury	800	100		4476	2023
16	Louangprabang	Louangprabang	1200	200		6500	2023
17	Nam Ngiep-Mouangmai	Bolikhamxay	25	25		160	2023
18	Nam Mouan	Bolikhamxay	124	124		524	2023
19	Xekong Downstream	Attapeu	76	76		387	2023
20	Xelanong 1	Savannakhet	60	60		300	2023
21	Nam Et1	Huaphan	93	3	90	333.9	2023
22	Nam Et2	Huaphan	160		160	641	2024
23	Nam Et3	Huaphan	107		107	447	2024
24	Nam Sum4	Huaphan	40	40		170	2024
25	Xe Xou	Attapeu	60	60		280	2024
26	Nam Leng	Phongsaly	50	50		240	2024
27	Nam Theun1	Bolikhamxay	600	100	500	2370	2024
28	Nam Nga1	Louangprabang	100	100		420	2025
29	Xe Banghieng 2	Savannakhet	12.5	12.5		68	2025
30	Xelanong 2	Saravan	45	45		170	2025
31	Nam The	Xiengkouang	12	12		50	2025
32	Nam Ngiep 2A	Xiengkouang	12.55	12.55		60	2025
33	Nam Ngiep 2B	Xiengkouang	8.94	8.94		31.7	2025
34	Nam Ngiep 2C	Xiengkouang	14.5	14.5		44.7	2026
35	Nam Ham	Xayabury	5	5		16	2026
36	Xedon	Saravan	20	20		80	2026
37	Nam Boun2	Phongsaly	15	15		60	2026
38	Xepon3	Saravan	54	54		222	2026
39	Nam Ang-Tabeng	Attapeu	25	25		176	2026
40	Nam Ngum 3	Vientiane	460		460	2047	2026
41	Nam Suang2	Louangprabang	96	96		442	2026
42	Nam Pui	Xayabury	60	60		294	2026
43	Houay Champi	Champasack	5	5		27	2026
44	Nam Ngao	Bokeo	20	20		85	2026
45	Ban Khoum	Champasack	1872	272	1600	8430	2026
46	Nam Ngum4	Xiengkouang	220	220		822	2026
47	Nam Mo1	Xiengkouang	55		55	222	2026
48	Xebanghieng2	Savannakhet	52	52		180	2026
49	Xetanouan	Savannakhet	30	30		118	2026
50	Xekong Downstream-B	Attapeu	80	80		315	2027

51	Nam Emuen	Xekong	70	70		276	2027
52	Nam Theun4	Bolikhamxay	54	54		200	2027
53	Xenea	Khammouan	53	53		209	2027
54	Nam Bak2	Vientiane	40	40		205	2027
55	Xekong5	Xekong	330		330	1613	2027
56	Nam Kong1	Attapeu	75	75		469	2027
57	Xe Kong4A	Xekong	153	153		670	2028
58	Xe Kong4B	Xekong	258	258		1130	2028
59	Nam Neun1	Huaphan	80	80		318	2028
60	Nam Neun2	Huaphan	50	50		250	2028
61	Nam Neun3	Huaphan	20	20		78	2028
62	Nam Feuang	Vientiane	28	28		113	2028
63	Nam Ma1	Huaphan	44	44		180	2029
64	Nam Ma1A	Huaphan	39	39		156	2029
65	Nam Ma2	Huaphan	30	30		117	2029
66	Nam Ma2A	Huaphan	18	18		74	2029
67	Nam Ma3	Huaphan	18	18		76	2029

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