Helsinki University of Technology Construction Economics and Management
A Research reports 3
Doctoral dissertation
Espoo 2005 TKK-RTA-A3

MEASURING PERFORMANCE AND DETERMINING SUCCESS FACTORS OF CONSTRUCTION SITES

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Juha Salminen

Dissertation for the degree of Doctor of Science in Technology (Doctor of Philosophy) to be presented with due permission of the Department of Civil and Environmental Engineering for public examination and debate in Auditorium R1 at Helsinki University of Technology (Espoo, Finland) on the 4th of February, 2005, at 12 noon.

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Editor:
Dr. Arto Saari
Helsinki University of Technology
Construction Economics and Management
P.O.Box 2100
FIN-02015 HUT
FINLAND
E-mail: arto.saari@hut.fi

Distribution:
Helsinki University of Technology
Construction Economics and Management
P.O.Box 2100
FIN-02015 HUT
URL: http://www.rta.tkk.fi
Tel. +358 (9) 451 3743
Fax +358 (9) 451 3758
E-mail: leena.honkavaara@hut.fi

ISBN 951-22-7493-0
ISBN 951-22-7494-9 (pdf)
ISSN 1795-2700

Picaset Oy
Espoo 2005
1. edition

HELSINKI UNIVERSITY OF TECHNOLOGY
P.O. BOX 1000, FIN-02015 HUT
http://www.hut.fi

ABSTRACT OF DOCTORAL DISSERTATION

Author Juha Salminen

Name of the dissertation

Measuring performance and determining success factors of construction sites

Date of manuscript March 8, 2004

Date of the dissertation February 4, 2005

☑ Monograph

☐ Article dissertation (summary + original articles)

Department	Civil and Environmental Engineering
Laboratory	Construction Economics and Management
Field of research	Business Management, Construction
Opponent	Prof. Harri Haapasalo (University of Oulu)
Supervisor	Prof. Jouko Kankainen (Helsinki University of Technology)
Pre-examiners	Prof. Eila Järvenpää (Helsinki University of Technology), Prof. Russell Kenley (Unitec New Zealand)

Abstract

Construction site performance has been measured using various key figures and monitored with the aid of checklists, but no systematic, comprehensive performance measurement systems exist for comparison and development purposes. The aim of the study was to develop a system for measuring and developing construction site performance, and to determine the central success factors for a construction site by analyzing the measurement results.

The performance measurement system developed was based on a system model of the operation and results of a construction site. The main parts of the system model were 1) preconditions, 2) the operation process, and 3) results. The operation process elements were management systems, leadership, and work behavior. The results of a construction project were measured from the standpoints of cost, schedule, quality, and safety. Specific measurement methods were developed for each elements. The measurement process included a procedure for feedback to sites and company units, and the performance measurement system was therefore also a development tool for companies.

The research material came from a total of 47 construction sites of four construction companies. A discriminant analysis revealed that the data didn't fall into clear groups that would demand dividing the body of material into several parts. The measurement system contained over 300 variables. The number of these was reduced by combining dimensions of different meters into sum variables. Work behavior and leadership were measured by means of a questionnaire, and reduction of the number of variables was performed via a factor analysis, which yielded six dimensions of organizational behavior on a construction site.

Relationships between result and explanatory variables were studied through regression and correlation analysis. It was concluded that cost, deviation to schedule, quality, and safety form a coherent unit representing project success, although it can be the case that sites fail in some respects and succeed in others. Success of a construction project is highly dependent on the management skills of site managers and in the examination of management style, focus on production was found to be most important. However, an advanced management system does not guarantee that a site is managed efficiently, but the implementation and practical use of the planning and production control methods are most important. The preconditions created by the client/consultant, designers, and corporate headquarters for the site are related to construction site success, but the operation of the site itself has much more influence. However, there are other factors in the environment of a construction site that are not covered by the measurement system but that may affect project success.

Keywords construction site, performance measurement, system model, success factors, work behavior and leadership

UDC		Number of pages	175
ISBN (printed)	951-22-7493-0	ISBN (pdf)	951-22-7494-9
ISBN (others)		ISSN	1795-2700

Publisher Laboratory of Construction Economics and Management

Print distribution Laboratory of Construction Economics and Management

☑ The dissertation can be read at http://lib.hut.fi/Diss/

TEKNILLINEN KORKEAKOULU PL 1000, 02015 TKK http://www.hut.fi	VÄITÖSKIRJAN TIIVISTELMÄ

Tekijä Juha Salminen

Väitöskirjan nimi

Rakennustyömaan suorituskyvyn mittaaminen ja menestystekijöiden määrittäminen

Käsikirjoituksen jättämispäivämäärä 8.3.2004	Väitöstilaisuuden ajankohta 4.2.2005
☑ Monografia	☐ Yhdistelmäväitöskirja (yhteenveto + erillisartikkelit)

Osasto	Rakennus- ja ympäristötekniikan osasto
Laboratorio	Rakentamistalous
Tutkimusala	Liiketaloustiede, rakentamistalous
Vastaväittäjä	Prof. Harri Haapasalo (Oulun yliopisto)
Työn valvoja	Prof. Jouko Kankainen (Teknillinen korkeakoulu)
Esitarkastajat	Prof. Eila Järvenpää (Teknillinen korkeakoulu), Prof. Russell Kenley (Unitec New Zealand)

Tiivistelmä

Rakennustyömaan suorituskykyä on mitattu erilaisilla tunnusluvuilla ja arvioitu tarkastuslistoilla, mutta systemaattista ja konaisvaltaista menetelmää suorituskyvyn mittaamiseen, toiminnan vertailemiseen ja kehittämiseen ei ole ollut käytössä. Tutkimuksen tavoitteena oli kehittää järjestelmä työmaan suorituskyvyn mittaamiseen ja kehittämiseen sekä määrittää mittaustulosten perusteella työmaan onnistumiseen vaikuttavat keskeiset tekijät.

Kehitetty suorituskykymittari perustui systeemimalliin työmaan toiminnasta ja tuloksista. Systeemimallin pääosat olivat 1) toimintaedellytykset, 2) toimintaprosessi ja 3) tulokset. Toimintaprosessin osia olivat ohjausjärjestelmä, johtaminen ja työkäyttäytyminen. Työmaan tuloksia mitattiin talouden, aikataulun, laadun ja turvallisuuden näkökulmista. Jokaiselle mittariston osalle kehitettiin oma mittausmenetelmä. Suorituskyvyn mittaukseen kuului myös menettely tulosten raportoimiselle ja palautteen annolle niin työmaa- kuin yksikkötasolla, minkä vuoksi kehitetty järjestelmä oli myös työkalu rakennusyritysten toiminnan kehittämiseen.

Tutkimusaineisto saatiin neljän rakennusyrityksen 47 työmaan suorituskykymittauksista. Mittaustulosten erotteluanalyysin perusteella aineisto ei jakautunut selviin erilaisiin ryhmiin, minkä takia aineisto olisi täytynyt analysoida useissa osissa. Mittaristo sisälsi kaikkiaan yli 300 muuttujaa. Muuttujien määrää vähennettiin yhdistämällä eri mittarien alakohtia korkeamman tason summamuuttujiksi. Työkäyttäytymistä ja johtamista mitattiin kyselyllä, ja muuttujien yhdistäminen toteutettiin faktorianalyysilla, joka antoi kuusi ulottuvuutta rakennustyömaan organisaatiokäyttäytymiselle.

Tulosten ja selittävien muuttujien yhteyksiä tutkittiin regressio- ja korrelaatioanalyyseilla. Havaittiin, että työmaan onnistumista kuvaavat elementit; kustannukset, aikataulunpito, laatu ja turvallisuus, muodoivat yhden toisiansa tukevan kokonaisuuden, joskin työmaa voi myös onnistua joillain alueilla ja epäonnistua toisilla. Työmaan onnistuminen on voimakkaasti riippuvainen työmaan johdon taidoista, ja johtamistyylien analyyseissa tuotannon asiakysymyksiin painottuva tyyli osoittautui tehokkaimmaksi. Kuitenkaan korkeatasoinen ohjausjärjestelmä ei taannut tehokasta johtamista, vaan suunnittelun ja ohjaamisen käytännön toimeenpano osoittautui ratkaisevaksi. Rakennuttajan, suunnittelijoiden ja oman yrityksen taustaorganisaation luomat toimintaedellytykset edesauttavat työmaan onnistumista, mutta työmaan omalla toiminnalla on suurempi merkitys. On myös ulkopuolisia, mittariin kuulumattomia tekijöitä, joilla voi olla huomattava vaikutus työmaan toimintaan.

Asiasanat rakennustyömaa, suorituskyvyn mittaus, systeemimalli, menestystekijät, työkäyttäytyminen ja johtaminen

UDK	Sivumäärä 175
ISBN (painettu) 951-22-7493-0	ISBN (pdf) 951-22-7494-9
ISBN (muut)	ISSN 1795-2700

Julkaisija TKK Rakentamistalouden laboratorio

Painetun väitöskirjan jakelu TKK Rakentamistalouden laboratorio

☑ Luettavissa verkossa osoitteessa http://lib.hut.fi/Diss/

FOREWORD

The writing of this thesis is actually the third phase in a series of research projects concerning the performance measurement of construction sites. This thesis sums up the earlier results, expands the theoretical background and deepens the statistical analysis of the research data. Therefore, the three research phases must be treated as one totality, where the later phases are built up on the earlier ones.

This is why the foremost acknowledgements go to those persons that made possible for me to "dedicate" for almost ten years in the wondrous world of performance measurement. The "godfather" of these studies has been prof. Jouko Kankainen, who from the first believed in my ideas and has supported implementing them to the end. Also the whole research community of HUT CEM has given an inspiring background for carrying out the studies, especially Juha-Matti Junnonen who has helped both scientifically and practically in many of my attempts.

Prof. Eila Järvenpää has also, besides being a pre-examiner of the thesis, supported and advised me from the beginning. Without her, the scientific profoundness and contribution would have probably suffered considerably, as would my understanding of the human aspects of organizations. From this perspective, the help from my one-time employer PSYCON and especially collegues Erkki Lehti, Kari Komonen and Kari Lahti, was also indispensable. I wish also thank the second pre-examiner Russell Kenley for his wise comments and encouragement in the last phase of the venture.

The contribution of the companies that become stimulated by my ideas and offered their sites for me to study I owe a commendation. The persons that gave their experience and insight in my use are too numerous to mention here, but I especially remember the input of Jalo Takala, Leo Jokisalo, Ano Korhonen, Jussi Kivistö and Petri Wegelius. A special thank belongs to Kauko Wasenius, with whom the co-operation started in connection with the performance measurement, but continues in our common place of employment every day.

The major financial contributor to the studies has been TEKES, where Jukka Pekkanen had an essential role and participated also in steering the studies. Työsuojelurahasto, Rakennusteollisuuden keskusliitto, Tekniikan edistämissäätiö, RIL-säätiö and Rakennustietosäätiö have financed the series of studies as well.

Of the three phases of the studies, the last one has perhaps been the most exhausting, because it has almost completely been accomplished in side of the daily work. The time for writing the thesis has been mostly stolen from my family, to which I address my warmest thanks for constant support and tolerance for the "absent" father during the evenings of working. I hope that the sacrifice turns out to be worthwhile and that the love that has carried us through these long years will endure also in the years to come.

Espoo, January 2005

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1 INTRODUCTION

1.1 BACKROUND OF THE STUDY

The construction industry in Finland is responsible for about 10 % of the gross national product. In 2003, construction investments made up 56 % of all investments in Finland (Confederation of Finnish Construction Industries, Web page). Therefore, improvements in construction industry performance have a major economic impact. Systematic performance improvement demands also systematic means to measure performance and its development.

Companies in the Finnish construction business have used some key indicators and checklist-type “meters” as part of their project follow-up and quality control. However, no systematic and comprehensive way to measure the performance of a construction site as a whole has been in use. As a consequence, companies don’t actually know what the most important construction site success factors are, or know their relative influence on a construction site’s results.

At the same time, more attention has been paid to measuring company operations and managing company strategy through systematic measurement systems, because of the popularity of Kaplan and Norton’s (1996) Balanced Scorecard system and other management approaches involving measurement (see Section 2.6). Also, several research projects and doctoral dissertations have been completed that consider project performance and its measurement alone in Finland in recent years (Poskela 2001, Hirvensalo 2003, Saravirta 2001, Nikander 2002). The idea of this study is, however, rooted in the ’90s, when the expansion of the use of the TR (*Talonrakennus*, house-building) meter for measuring construction site safety (Laitinen et al. 1994) proved to have a strong effect on occupational safety. This awaked interest among construction companies in developing a measurement system with a similar effect on the overall performance of a site.

These discussions initiated a series of research projects (Salminen 1998a, Salminen 1998b, Salminen 2000a), which constitute the basis of this study. The studies were undertaken in collaboration with three construction companies, and the research plan was based on their needs. They wanted a practical tool for measuring and developing construction site performance. The intended use of the tool was assessment of the performance of individual sites, comparison of the results with those of other sites and business units, and use of the feedback in improving their operation.

The first research project, implemented in 1997-1998, was called “The Effective Production Culture of a Construction Site” (Salminen 1998a, Salminen 1998b). It concentrated on developing a model to describe construction site “production culture.” A preliminary measurement system was developed and then used at seven sites of one company. The measurement system enabled dividing the sites into successful and less successful ones and seeking features common within the two groups. A key result of the study was that the "human" aspect of operations was found to have a remarkable effect on project success. In the study, a preliminary model of the dimensions of construction site culture was also presented.

The next project was "Using Performance Measurement in Developing the Management System of a Construction Site" in 1999-2000 (Salminen 2000a, Salminen 2000b), where the focus was on further developing the measurement system and making it a tool for performance development. A system model of construction site performance was presented, new meters were added, and some meters were renewed. Although in the study construction site success factors were analyzed also, the main focus was on practical implementation of measurements and on comparison of the operation of the three participating companies. After the research, additional measurements were made in one of the participating companies as well as at a fourth company as a consultancy task, with 47 sites covered by measurements made with the same meter. This material forms the body of research data for this study.

Although in the second study (Salminen 2000a) the measurement system was "finished" and the results were analyzed in some depth, the research was still unfinished, because a proper analysis and conclusions about construction site success factors were not prepared. This was the starting point for the present study, which summarizes the development and use of the construction site performance measurement system in the earlier research projects and analyzes the research material for purposes of determining success factors for construction sites.

1.2 RESEARCH QUESTIONS AND AIM OF THE STUDY

The measurement method developed for construction site performance, as used in this study, is based on a few basic assumptions. The first is the demand for *comprehensiveness*, which means that the entire measurement method must form one totality and not be just a group of separate meters. Therefore, if a given "meter" is not a part of the same totality, it is not part of the measurement system either. This leads to the second basic assumption, that a construction site is a system and *systems thinking* is used in developing the construction site performance model. The third assumption originates from the practical need of the companies, which initiated the whole research project, that the measurement system be a *practical tool* for developing construction company operations.

The aims of the study are to develop a system for measuring construction site performance and to use it in analyzing the success factors of a construction site. The scientific contribution of the study is, thus, a new understanding of factors that should be taken into consideration in trying to improve the performance of a construction site.

The **research questions** are:

1. What are the elements of construction site performance?
2. How can the performance elements be measured?
3. How are the performance elements related, and how can they be integrated in a measurement system model?
4. What are the most important success factors in construction site operation?

This study focuses on studying the performance of a *construction site*. This means that performance is studied with relation to the construction phase of a construction project. The performance measurement system measures the operation and results of a construction site, and thus it focuses on activities taking place during the construction phase.

The research material for this study consists of performance measurements for 47 cases, or construction sites. Out of these, 25 were studied in the earlier study (Salminen 2000a) and 22 cases were measured afterwards using the same measurement method. The results of the study consist of the conclusions on the relative importance of different elements of construction site performance. Another purpose of the analysis is to assess whether the performance measurement system developed is a functional tool for measuring and developing construction site performance. The research hypotheses and the manner in which the study was carried out are based on the aim and research questions stated here.

1.3 RESEARCH HYPOTHESES

The study can be divided into a methodological phase, where the method for measuring construction site performance is developed, and an analytical phase, where the new performance measurement system is used as a research instrument in exploring the relationships among elements of construction project performance.

The research hypotheses are derived from research question 4, and they clarify the problem's setting in terms of the relationships between performance elements, as well as describing the research data analysis process. Six hypotheses are used, and they are presented in three pairs, where each pair concerns different aspects of the problems related to answering research question 4.

The first hypotheses (H1 and H2) concern construction site success, and the answers are a prerequisite for studying the success factors. In the performance system model, the elements of construction site success are presented, based on a literature review. If success consists of several elements, the success elements can be dependent on each other, and thus describe different aspects of the same thing. However, if the success elements are independent of each other, this would indicate that they don't belong to the same entity. It is necessary to know the relationship between success elements before analyzing the success factors. The first pair of hypotheses can be derived from this dilemma.

Construction site success

H1: If a construction site is successful in one respect, this doesn't mean that it is successful in every respect.

H2: If a construction site is successful in one respect, it is probably successful in others as well.

Construction sites are different, and a number of factors influence construction site implementation and results. Many of the factors are outside the sphere of influence of the site personnel, like situational factors and the predetermined project characteristics. The success factors that are common to all construction sites and that the site can influence may be difficult to isolate among the other, potentially confounding factors. However, in order to improve the performance of a construction site, one has to assume that some common factors that the site can influence can be identified as general success factors applicable to practically every construction site.

Construction site success factors

H3: Many factors influence construction site success, and factors the site can influence and that are common to all construction sites cannot be identified.

H4: A group of common success factors that the site can influence exists and can be identified from other, confounding factors.

One starting point in this study is that the organizational behavior of site personnel is one angle from which construction site performance is explored. But what exactly are the dimensions of organizational behavior that promote successful site operation? The organizational behavior of project performance needs more subcategorization so that the different dimensions of organizational behavior can be studied. If a functional categorization system is found, it should prove interesting to analyze whether a common, recommended relative level of strength for the dimensions associated with successful construction sites can be determined.

Organizational behavior at a construction site

H5: No optimal relative strength of the dimensions of organizational behavior on construction sites exists; successful behavior depends on situational factors.

H6: A generally recommended relative strength of the dimensions of organizational behavior at construction sites can be determined.

The hypotheses above demonstrate the structure of the analysis for answering research question 4. First, the concept of project success must be clarified by analyzing how the success elements are related (H1 and H2). Then the relative importance of success factors can be explored (H3 and H4). This makes possible also study of how the dimensions of organizational behavior relate to project success, which proves or disproves the last hypotheses (H5 and H6) as well.

1.4 THE CONCEPTS OF PERFORMANCE AND PERFORMANCE MEASUREMENT

A central objective in management sciences is to improve the competitive ability of a company. **Performance** is a concept that is very closely connected to a company's competitiveness. However, it is a broad and flexible concept that is used in a wide range of contexts in the literature.

Early definitions of performance have been based on motivation and behavioral theories. Vroom (1964) suggested that performance is a function of "ability and motivation." Porter and Lawler (1968) presented a model where performance consists of "effort, ability and role perception." Effort is the result of expectation of a reward and the probability of earning it, ability comprises individual characteristics, and role perception is what the individual wants to do or thinks one is required to do.

Kast and Rosenzweig (1985) define the basic concept of performance as a function of ability, effort, and opportunity. The performance of an organization is a result of the performance of individuals and groups. However, in addition to doing things right, which is *effectiveness*, performance includes also the idea of doing the right things, which is *efficiency*. Moreover, these authors expand the concept of performance to cover *participant satisfaction*, because no operation is successful in the long run if it doesn't give satisfaction to those involved.

According to Williams (1998), performance is not the same thing to all organizations, and it even means different things to different stakeholders of the same organization. **Performance measurement** includes "hard" financial and non-financial metrics as well as "soft" metrics like employee attitudes. Performance measurement covers both *processes and results*.

Hannula and Lönnqvist (2002) support this conception in their handbook on "concepts of performance measurement," where performance is defined as a phenomenon that consists of several different factors. In a broad sense, it is the company's ability to maximize profit for all concerned. It can also be examined from different angles, such as financial, customer, or process perspectives. It is the ability to perform and also the achievement based on this ability; in addition to actual achievements, it is the factors affecting the ability to perform.

This reveals that performance includes practically everything that describes, or is behind, the success of an organization. On the other hand, performance must not be confused with business strategies and decisions, which are major factors in business success in their own right. Performance is the ability of an organization to implement a chosen strategy (Hannus et al. 1999). If strategy is faulty, the business may very well be unsuccessful regardless of its high level of performance. However, within the framework of business strategy, performance comprises many innovative, process-level decisions and choices and is a much more extensive concept than plain effectiveness is.

As the concept of performance has been concluded to be an essential part of the competitive ability of an organization, interest in measuring performance has increased accordingly. In the context of organizations, **measurement** is a method for knowing where an organization is now, to help it plan where it wants to go and to tell when it has arrived there (Chang & Young 1997).

In this study, where the organization under consideration is a **construction site, performance** is understood as the quality of the operation of a construction site, and also how successful the site's operation is. A performance measurement must thus include methods for evaluating the operation of a site and also the results of the operation.

It is a well-known fact that attention is focused on operations that are measured. The famous business management adages "what you measure you get" and "you can't manage anything you can't measure" describe the connection between managing and measuring. Therefore, measuring performance is also a way to control and improve it, and performance measurement is a way to evaluate and develop a company's competitiveness. Consequently, **construction site performance measurement system**, as used in this study, is a method for evaluating and developing construction project operation and results.

1.5 RESEARCH FRAMEWORK

The subject of the study belongs to the research tradition of **management science**. Management science is influenced by many other disciplines, such as economics, technical sciences, social sciences, and human sciences (Kaikkonen 1996). Management science is further divided into the sciences of **business economics** and **business management**. In the former, the purpose is to acquire theoretical knowledge about business operations. The latter aims to provide practical knowledge and recommendations to aid in company decision-making (Kaikkonen 1996).

This study stems from the practical needs of the construction industry. Therefore, the study can be situated roughly in the body of business management research. Business management research is, according to Sekaran (2003), an organized, systematic, data-based, critical, objective, scientific inquiry or investigation into a specific problem, undertaken with the purpose of finding answers or solutions to it. The purpose is generally to guide managers to make informed decisions to deal with problems successfully. In this study, the final purpose is to help managers to solve their problems in developing the performance of construction sites, using basic knowledge of economics, psychology, etc., and thus it can be further classified as applied research (Sekaran 2003).

In the technical sciences, the closest discipline to management sciences is **industrial economics**, where business operations are studied from a technology standpoint. One area of industrial economics is **project management**, which concentrates on tools and techniques for implementing a project successfully. The science paying particular attention to the management sciences point of view on the construction process is **construction economics and management**, which is also the official domain of this study, although it has influences from other scientific disciplines as well.

Human actions are an important aspect of business economics and management, and they are studied also in the field of **work psychology**. Work psychology research is often explanatory, where the aim is to find patterns in organizational behavior, by studying and analyzing organizations. Another important element considered in work psychology is the actions of managers, which is covered in **leadership** studies (Järvenpää & Kosonen 1996).

Studying the influence of managers or other elements on project implementation leads to **success factor** studies. Finding the success factors of a particular operation is a common research problem and can itself be considered a research approach. It bears a resemblance to the **contingency studies** research tradition, where the compatibility of an organization with the demands of its environment is studied (Kast & Rosenzweig 1985).

Performance management has become such a popular subject in the management literature that it can also be considered a sub-discipline of its own, one that also has strong connections to general **measurement and organization analysis** studies. One central approach in both performance management and work psychology is **systems thinking**, where organizations or business units are studied from a system theory perspective.

The scientific framework of this study can be illustrated with a mind map outlining the main approaches (Fig. 1), but this cannot explain all the linkages comprehensively.

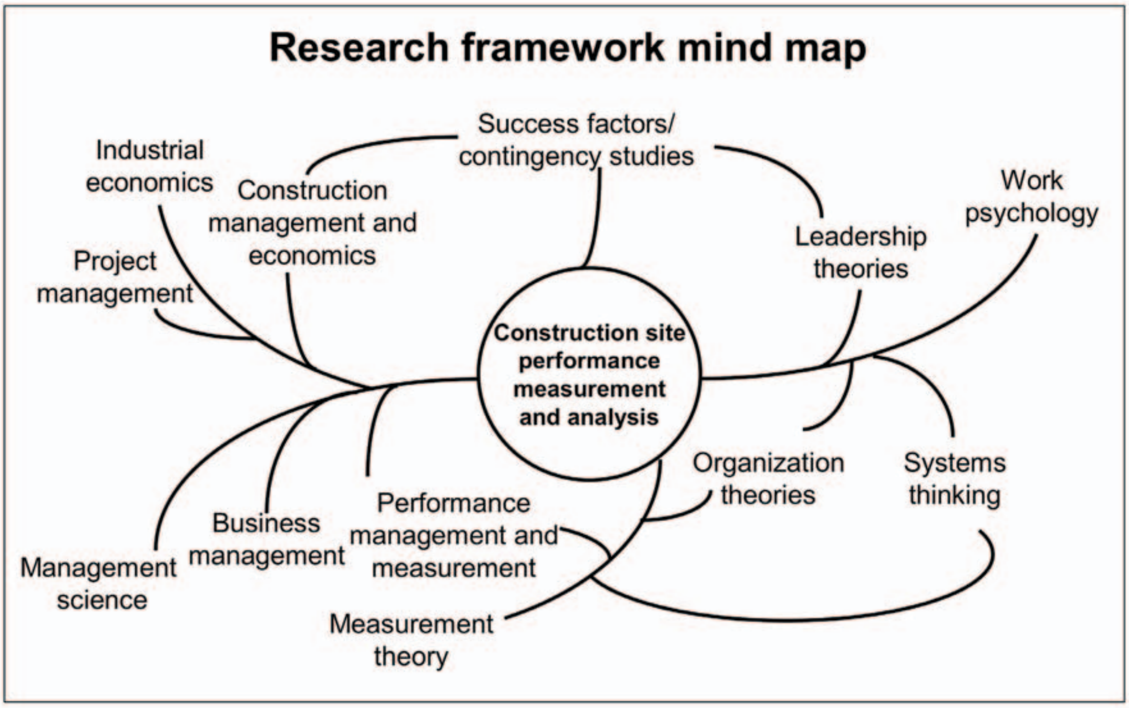


Figure 1. The research framework of this study.

1.6 RESEARCH APPROACH AND METHODOLOGY

The research approach determines which established convention is chosen for conducting a piece of scientific research. The choice of research approach is based on the research problems and questions of a study.

The approach chosen is based on the epistemological nature of the study. Epistemology is the study of knowledge, where questions such as “What is knowledge?” and “What can be known?” are asked. Two basic approaches in trying to answer these questions are **rationalism** and **empiricism**. In rationalistic studies, rational or intuitive thinking creates the conception or model of the research subject and speculative tests are then conducted in order to verify or disprove that conception. In empirical studies, observations of the research subject are made and the conception or model is compiled afterwards based on those observations (Kaikkonen 1996, Kenley 2003).

In the case of this study, the research advances in two phases: developing the measurement instrument and using it to explore and determine causal relationships between elements of construction site operation. The measurement system is based on existing knowledge, previous studies, and rational thinking. The rational model that is developed and the research hypotheses specifying the essential assumptions about its function are tested by analyzing the measurement results. Therefore, the approach is to employ rationalism sooner than empiricism, although empiricism is also used in a limited way in testing and further developing some characteristics of the performance system model and individual meters.

The creation of the theoretical model of construction site performance was mostly based on a **literature review**. However, to ensure that this model corresponded with the views of the future users of the system, the development process demanded plenty of **fieldwork** in the form of discussions and group work in the companies. Thus, the theoretical model and measurement system were completed in parallel with the field research. The theoretical model concerning the performance of a construction site was then transformed into a measurement system by developing the corresponding meters.

Methods for analyzing and measuring organizations were explored during this phase to find the appropriate metrics for each component, as well as general performance measurement principles to ensure that the reliability and validity requirements for the meters were reached. The two basic approaches for analyzing organizations are quantitative and qualitative methods.

In **quantitative analysis**, the research focuses on finding statistical relationships within numerical data. The research data obtained from structured interviews, questionnaires, tests, structured observations, key indicators, etc. are transformed into dependent variables, which are influenced by independent variables. Also, additional test variables can be used to ensure that the causal relationships indicated are real (Bryman & Cramer 1995, Alasuutari 1994).

While in quantitative methods a large amount of information is gathered over a wide area, in a qualitative study a small sample is studied in depth. The research material is considered holistically, not just as relationships between variables. The purpose of qualitative research may be finding an explanatory model for a phenomenon, or sometimes describing the phenomenon (Silverman 1995). Quantitative and qualitative methods can be used in parallel to shed light on the same problem from different angles (Brannen 1995).

In this study, quantitative research is applied for the most part. This is a direct consequence of the demand for practical applicability of the measurement system. Construction site performance measurement must produce plenty of information in a small amount of time and in such a format that it can be quickly analyzed. However, in drawing conclusions on the measurement results for an individual site, qualitative information was received from project personnel and used in preparing the site reports, although qualitative data were not systematically collected and analyzed in this study.

The making of performance measurements for the 47 construction sites included many features of the **case study** method, although the number of cases was high for typical case study research. Yin (1989) defines a case study as an approach in which "how" and "why" questions are asked about a contemporary set of events over which the investigator has little or no control. When the measurements were made, individual reports were produced for the companies for each site. In these, results, other observations, and the best explanations for the results were presented. These were also given as feedback to the sites. However, the use of the data in this study

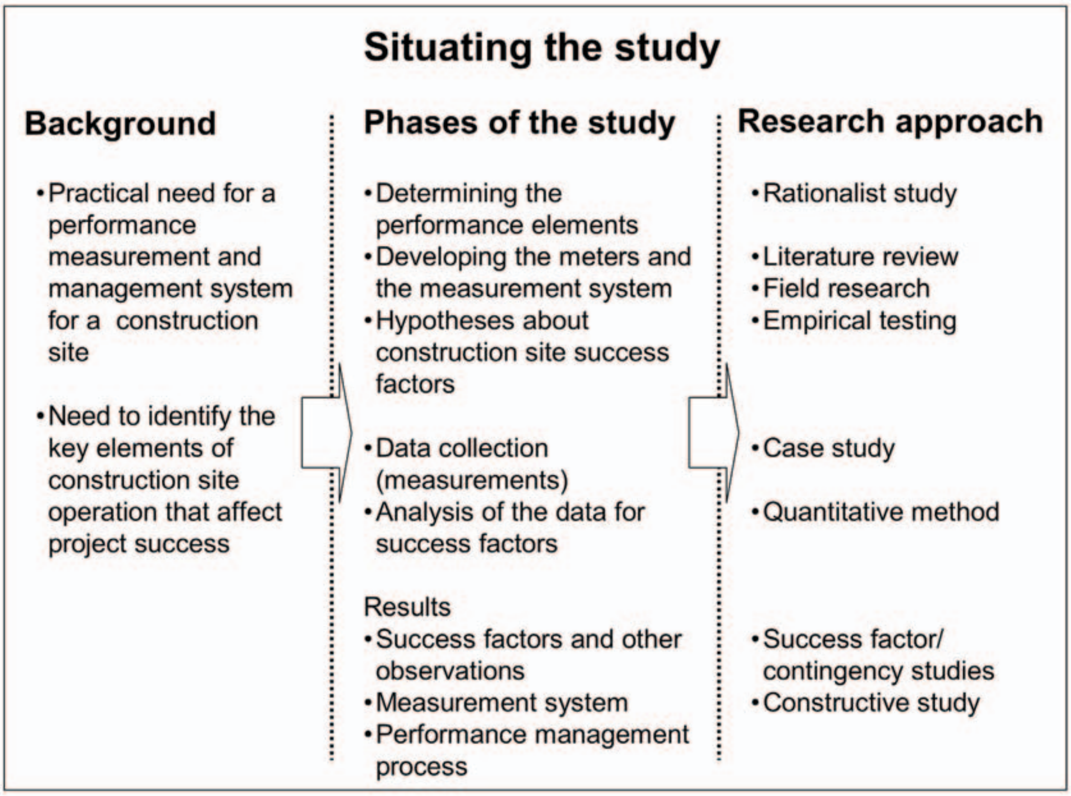


Figure 2. Research approach and methodology in relation to phases of the study.

follows the tradition of **success factor** or **contingency studies**, where the focus is on identifying the factors influencing organization's success.

Although the overall approach of the study is a rationalist one, the developing of the measurement system and the method for using it in performance development can be considered also to be a **constructivist study**. Constructivist research is used when an organization detects a problem that is also of scientific interest. The research project tries then to develop a solution construct, which is based in part on existing business management knowledge and partly on the research process. During the research process, the functionality of the solution is tested in practice, and finally its general applicability is discussed (Kasanen et al. 1991, Lukka & Tuomela 1998). In this case, the problem is developing a method for measuring and improving construction site performance.

When a solution is sought through constructivist research, the phases of the research are the following (Lukka & Tuomela 1998):

1. Developing the solution model
2. Testing the usability and functionality of the solution
3. Studying the general applicability of the solution, and connecting it to existing theoretical knowledge

In this study, the performance measurement system is developed, tested, and applied to several companies. The success of the study can be evaluated against the success criteria of a constructivist study, from the standpoint of practical applicability of the solution developed. However, developing and using the measurement system is only one part of this study, and the new knowledge produced, through analysis of the data collected with the measurement system, is the main scientific contribution of the study.

1.7 EXECUTION OF THE STUDY

The practical execution of the study included the following phases:

1. **Theory and earlier studies of performance measurement** (sections 2-3)
   Approaches to performance measurement in the management literature and previous studies concerning the construction industry are presented.

2. **Developing a system model of construction site performance** (Section 4)
   The use of systems thinking in organization studies is presented, and a suitable performance measurement system for construction sites is concretized and determined.

3. **Developing the meters in the performance measurement system** (Section 5)

The theory and methodology of performance measurement are presented, and the meters for each performance element in the system model are developed.

4. **Data collection and preparation** (Section 6)
   The data are collected via the measurements for the construction sites. The raw data are described and prepared for analysis.

5. **Data analysis and results** (sections 7-8)
   Statistical analysis of the data is implemented according to the analysis plan, and the results are presented.

6. **Discussion of the results** (sections 9-10)
   The research questions and hypotheses are discussed in relation to the results. The contribution of the study is summarized.

2 APPROACHES TO PERFORMANCE MEASUREMENT IN ORGANIZATIONS

2.1 PERFORMANCE MEASUREMENT AND FINANCIAL ACCOUNTING

Monitoring company performance has traditionally been associated with accounting, and the purpose has been to determine a company's financial success. Success has been judged via comparison to previous years' results and various key indicators, such as return on investment, turnover, gross margin, and net profit. The nature of the financial monitoring and control has had a strong influence on the structure of organizations, and ever since the 1920s operations split into divisions and among profit centers have predominated (Merchant 1998).

However, a control system concentrating only on financial key indicators has shortcomings. Short-term goals lead to short-term actions, and a consequence of striving for short-term profits is cutbacks on activities leading to long-term profitability, such as education, research and development, and marketing (Laitinen 1998, Olve et al. 1998).

As a result of criticism, companies began to rethink and develop their monitoring and measurement systems at the end of the 1980s. Johnson and Kaplan's (1987) **Activity Based Costing** (ABC) was a remarkable reform. In ABC, the indirect costs were tracked not in terms of cost pools but by activity, where the real costs of operations and products are examined with the aid of so-called cost drivers. The ABC system solves some problems of traditional cost accounting. **Activity Based Management** (ABM) is a management approach based on Activity Based Costing. In ABM, the business areas that are strategically most important as determined through ABC are promoted (Johnson & Kaplan 1987, Salminen & Uitti 1996).

Since then, there has been a tendency to make the financial control system of a company more like a strategic tool for management, which has led to the emergence of the concept of **strategic accounting**. Management approaches connected to strategic accounting are **Strategic Cost Management** (SCM) and **Strategic Management Accounting** (SMA). In the former, the attention is focused on those factors that are strategically essential according to financial reports and that produce the greatest added value for the customer over the whole value chain, beginning with suppliers and ending with the customer. In the SMA approach, financial accounting is closely connected with the strategic management of the company and the strategic management system consists of a business idea, aim, goals, operative strategies, and performance measurement (Laitinen 1998).

Extensive control systems integrate strategic management, human actions, and operations over the whole value chain, including suppliers and customers. The literature terms such approaches, for example, **Total Management Accounting** (TMA) (Laitinen 1998) or **wide-ranging performance monitoring** (Liukkonen 1997), which comes close to the principles of general performance measurement. One component tightly coupled with TMA is **human resources accounting**, which has been put into practice in many companies. However, it has often meant just presenting employee-related key indicators (training costs, recruiting costs, social costs, absence costs, etc.) in the context of financial statements (Liukkonen 1997).

In considering construction site performance measurement, it is necessary to acknowledge the close linkage between performance measurement and strategic accounting. Originally the role of accounting was only to provide financial facts to managers, but nowadays its role is systematically expanding to cover all kinds of measurements that yield strategically valuable information. One qualification for a performance measurement system should therefore be to complement the financial accounting system of a company and produce strategic information for company management. This is accomplished if, for instance, performance meters yield numerical information that can be used in preparing summaries and comparing the information with results from other business units and earlier measurement periods.

2.2 USE OF PERFORMANCE MEASUREMENT IN GENERAL MANAGEMENT PRINCIPLES

Performance measurement has an important role in many popular management approaches. A management approach originating from as early as the 1970's but still actively in use is **management by objectives** (MBO). The objectives are based on the critical success factors of a company. These are broken down into lower-level goals for organizational units and individuals, which form a goal hierarchy. Goals can be divided into business-, operational-, and supportive-level goals. Determining the goals is followed by measurement. Each goal area has three to eight important key goals and key indicators. The prerequisites for understanding and committing to goals are committed planning, supervising, and feedback conversations (Santalainen et al. 1987).

Process management is an attempt to avoid partial optimization and inflexibility in interactions between profit centers, which was the basic criticism of MBO. The attention is focused on core processes instead of organizational units. Core processes are operational chains cross-cutting the company and its interest groups; they begin with customer needs and end with their fulfillment. Process management is about recognizing these core processes and eliminating functions that don't add value for customers or produce innovations. Managerial approaches used in these contexts include teamwork, performance measurement, and business process re-engineering. Moreover, a range of different development tools can be utilized (Hannus 1994, Salminen & Uitti 1996).

In process management, management systems intended for horizontal control are used, in which performance metrics are determined for each core process. Setting goals and measuring performance has an important role also in process management. Measurements are focused on general and situational critical success factors – for example, profitability, growth, customer service, delivery reliability, competence, and motivation (Hannus 1994). Thus, the measurement system in process management has similar elements to other holistic key indicator systems. However, the key indicator systems employed in this approach are built on a model of core processes and their connections to other operations.

The management approach that combines most of the other management approaches falling under quality development has been given the name **total quality management** (TQM). It is a comprehensive and systematic approach to management. Originally developed in Japanese industry, it was spread worldwide by quality gurus Juran, Feigenbaum, and Deming, after it was adopted in the USA in order to respond to the Japanese competition. It consists of a collection of tools that are all supposed to improve quality, which in its broadest sense covers nearly all aspects of a company's actions (Hardjono et al. 1996).

Quality-related technology is based on Deming's PDCA ("Plan, Do, Check, Act") circle principle. Quality management, on the other hand, is the means to implement quality technologies and to get them accepted and used in an organization. A combination of quality technologies and management skills, TQM is a way to make the organization produce quality. Values and actions common to employees in an organization are expressed in choices related to quality, and these can be called quality culture (Lillrank 1998). While TQM does not offer any clear systematic approach to performance measurement, it emphasizes the use of many different quality tools, such as measurements, statistical methods, quality systems, and quality circles (Lillrank 1998, Salminen & Uitti 1996).

An approach called **benchmarking** is mentioned as being part of many management principles, including process management and total quality management, and the term is used in a general sense to refer to comparisons between companies or operations. In a wider sense, it is a systematic way to improve a company's competitiveness (Hardjono et al. 1996, Salminen & Uitti 1996, Czarnecki 1999).

Benchmarking can be applied in comparing company divisions, units, or processes, or between separate companies with enough equality to enable meaningful benchmarking. Although meters and key indicators are an essential part of the comparisons, benchmarking consists of many elements: products, processes, methods, cultures, and so on. The measurement system or key indicators are compiled according to the scope and purpose of the benchmarking. Thus benchmarking is not a measurement system in itself, but it can utilize many measurement systems. However, the basic idea of benchmarking is very close to that of performance measurement, the key element of both being comparison of performance to that of other business units or to historical data.

Emhjellen (1997) analyzed 13 different benchmarking models found in the literature. Those models could easily be applied as performance measurement systems as well. He ended up proposing a seven-step process for benchmarking and developing company operations. The steps were Organise, Plan (including metrics development), Find (companies for benchmarking comparison), Collect, Analyse, Adapt, and Improve.

Although some attempts have been made, benchmarking is not a very common approach in the construction business. Garnett and Pickrell (2000) identify several obstacles to effective benchmarking that are related to the characteristics of the construction industry. The project-based nature and fragmentation of the industry hinder team building, learning from experience, and feedback. Best practice cannot be identified, and measurement processes are hard to implement. Bad experiences of benchmarking lead to unwillingness to apply it again.

Measurement of company operations has been a central part of many business management models. In developing a performance measurement system, it is important to recognize the management principles used in a company and, if possible, integrate the performance measurement system into it, utilizing key indicators and methods that have been used before. In this way, the performance measurement system and performance management procedure becomes a part of company operations and not a separate effort that is likely to see only short-term use.

2.3 KEY INDICATOR SYSTEMS

Performance measurement produces numerical values describing certain aspects of the performance of a system, organization, or other relevant entity. Performance measurement systems are often, in practice, groups of key indicators that are used to monitor different areas of operations in an organization. At best, key indicators include essential and compact information from inside and outside the company, in an understandable format (Tuottavuuden kehittäminen 1982, Chang & Young 1995).

In the 1980s, the focus of key indicator systems was on financial and productivity measurements, but also quality and human resources were evaluated through quickly calculated numerical key indicators (Uusi-Rauva 1987, Rahiala 1985, Tuotannon tunnusluvut 1987). For example, quality was evaluated with fault costs, and human resources with absenteeism and administration costs.

In the ’90s, more attention was paid to “consequential” factors, which do not shed light on attainment of the intended achievement directly but instead provide information on factors that help in achieving the result. Examples of these key indicators are work climate, work conditions, and other functions supporting the process that are not a direct consequence of the process. They can seldom be calculated from process output, necessitating separate data collection methods or meters, like systematic observation or questionnaires (Uusi-Rauva 1996).

In the early 1990s, MET (the Federation of Finnish Metal, Engineering, and Electro-technical Industries) conducted a study on the usage of measurement systems in industrial companies (Andersin et al. 1994). The most common meters focused on efficiency of the production process and financial results. Areas considered to be in need of measurement were customers, suppliers, and quality. One observation in the research was that measurement had a strong effect on the behavior of the employees. The conclusion was that companies should use not only the "official" key indicators indicating financial success but also meters that reveal causal factors behind the results, such as quality, delivery reliability, flexibility, customer satisfaction, and motivation.

Key indicators may have many functions, such as control, alarm, diagnosis, learning, and motivation. Key indicators can be categorized also by their scope, from the level of the national economy to those of business area, company, and division, and all the way down to the individual level. The wider the scope of the key indicator is, the more standardization is needed to ensure the comparability of key indicators over the longer term. Lower-lever key indicators can be tailored to certain situations, admitting only comparisons to earlier development of the same unit (Uusi-Rauva 1987).

Key indicators must be connected with central objectives, and they should indicate whether the targeted results are achieved. The objective can be based on, for example, the best result in company history, the employee producing his or her best results, competitors' results, or the best possible result in theoretical terms. Objectives can usually be expressed in terms of measurements of the following types, or by a combination of them (Uusi-Rauva 1987):

- amount (count, unit),
- time (hour, week), and
- index number.

Common problems connected with the use of key indicators relate to validity, reliability, and relevance. Also, addressing the key indicators to the right time period is often problematic (Tuottavuuden kehittäminen 1982). However, the main problem is usually not the correct calculation of the key indicators but, rather, the use and interpretation of the results. Understanding and interpreting key indicator information demands close cooperation with the personnel groups that are included in the focus of measurements (Tuottavuuden seuranta 1988).

Key indicators can be just a list of figures (or graphs and other graphical materials for added clarity). Sometimes they are combined into key indicator systems that give a better general view of the situation. A simple system may include just the indicators, their critical or reference levels, and enough history to illustrate changes. Key indicators can also be combined, perhaps through the use of some formula, and prioritized using weight coefficients (Rehnström 1996).

One example of combining different key indicators in the same system is a goal matrix. A goal matrix is a table where key indicators describing different aspects of the operation are covered in a single presentation where selected values can be weighed. These values can be translated into an appropriate format for comparison between business units or time periods. The choice of what to emphasize in the matrix depends on the purpose of the matrix; is it a productivity, marketing, quality, or some other type of matrix (Rehnström 1996)?

One aspect of using meters is the technology by which they are implemented: are they integrated into a company financial control system, or are separate manually or spreadsheet-generated reports used? The risk is that the technology used in processing the data might be insufficiently powerful, too heavyweight, or in some other way inappropriate for the task (Andersin et al. 1994).

2.4 INDEX METERS

In quantitative research, measurements provide data about the variables measured. In performance measurement, the values associated with variables are a result of meters or key indicators. Sometimes the key indicators are easily calculated from available information. But in many cases, what is measured is not in numerical format. Site safety is such an issue; it refers to the extent of safety precautions on the site, not the consequences of those precautions, which can be expressed directly in terms of accident rates. For quantitative analysis, information that is not numerical in the first place needs to be transformed into numerical form.

For this purpose, the concept of index meters can be applied. An index meter is a sort of checklist where each measurement item is a written criterion. Each item is given a numerical value, such as 1 or 0, according to whether the criterion is met or not. All items together form the complete index meter, where the results for all measurement items are added up and an index number, usually a percentage value, calculated. This index, or percentage, expresses the state of the measured variable in comparison to the reference level, which might be, for example, the mean of all measurements or of all measurements from the previous time period (Salminen et al. 1998).

An index-type key indicator, with its many sub-items, makes it possible to compile a meter in such a way that it is independent of different practices in separate business units and its applicability is not limited to making numerical data available. However, individual items of the index meter must be clearly focused and unambiguous in the criteria for their acceptance. The number of measurement items the meter uses must be sufficient for the effect of interpretation problems involving single borderline cases not to affect the result significantly.

A typical scope for an index meter is quality, safety, and housekeeping. Index meters have been systematically used in the Finnish development tool called TUTTAVA (*Turvallisesti Tuottavat Työtavat*, Methods for Safe, Productive Work), which was developed by the Finnish Institute of Occupational Health. In a TUTTAVA project, a customized index meter measures the safety and housekeeping level and feedback about the measurement results is given to the employees via a poster campaign. The index values were improved during the gathering of measurements, and the effects on working conditions have been significant (Saarela 1992, Saarela et al. 1989, Saarela 1989, Saarela 1990).

The same method has also been used to improve order and efficiency at construction sites (Salminen 1991) and in mobile assembly jobs (Salminen et al. 1995).

In addition to company-specific safety index meters, general index meters for specific production environments have been developed, namely ELMERI for industrial plants, the TR meter for house construction sites (*TR-mittari* 1994, Laitinen & Ruohomäki 1994, Laitinen & Ruohomäki 1996), and the MVR meter (MVR= *maa- ja vesirakentaminen*, civil engineering) (Laitinen et al. 1998) for civil engineering sites. Index meters had a central role also in the previous studies (Salminen 1998b, Salminen 2000a), and they continue to do so in this one. Index meters provide a tool applicable for measuring functions where the source data are not originally in numerical format.

2.5 FRAMEWORKS FOR MEASURING PERFORMANCE

In practice, performance represents a variety of items that describe a company's competitiveness. But for an advantageous performance measurement system it is not enough just to compile a group of meters or key indicators, combining them and building some kind of system to operate them, then call it a performance measurement system. Laitinen (1998) emphasizes that the use of strategic meters has to have a theoretical grounding, a model of ideal operation of the company. The model is often a system or framework illustrating the aspects of the operations of an organization that are important for its success.

Brown (1995) ties performance measurement strongly to the organization process, which consists of inputs, process, and outputs and also the long-term results and final goals of the company. Financial results and process efficiency still play a central role, but factors related to business environment and employees are equally important. The six elements of performance, according to Brown, are:

- financial performance,
- product/service quality,
- supplier performance,
- customer satisfaction,
- process and operational performance, and
- employee satisfaction.

Hodgetts (1998) leaves the traditional financial and production meters aside altogether and elevates the meters related to business environment and employee development as the most important indicators of a company's future success. According to him, a company must monitor and evaluate, above all, customer and employee needs. He thinks also that there cannot be enough meters and necessary data, whereas Brown (1995) recommended that a company limit the number of meters used on one organizational level to 20.

Lynch and Cross (1995) have described the performance measurement system as a **performance pyramid** (Fig. 3). The system covers all company operations top-down and forms a hierarchy where key indicators connected to management and strategy are on the top and departmental-level operative meters are on lower levels.

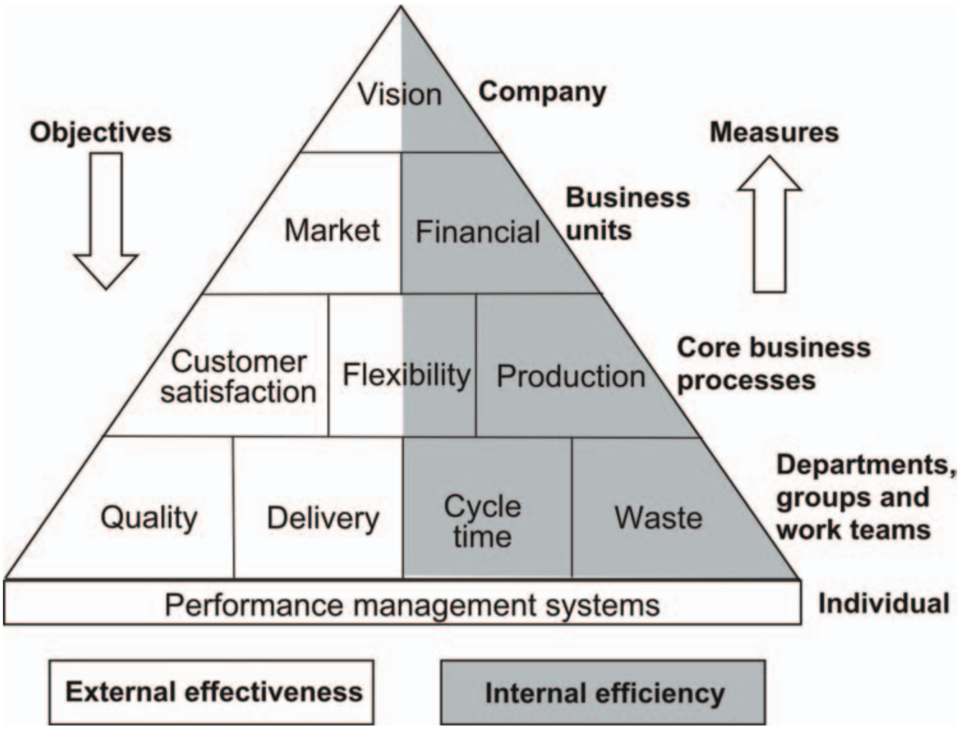


Figure 3. The performance pyramid of a company. The actual metrics differ in every organization (Lynch & Cross 1995).

The purpose of the measurement system is to give the management information about company performance, and to transmit company goals to the organization.

The **quality award** principle offers one approach for performance measurement. The quality award is a tool for managing quality and developing quality culture. It gives general criteria against which company management and operations are evaluated. Quality award criteria concentrate on company management, strategic planning, customer-orientation, competitiveness, and competence (Fig. 4). The quality award represents a company management approach to quality, and it is not meant to include criteria for operational-level quality (Laamanen 1997).

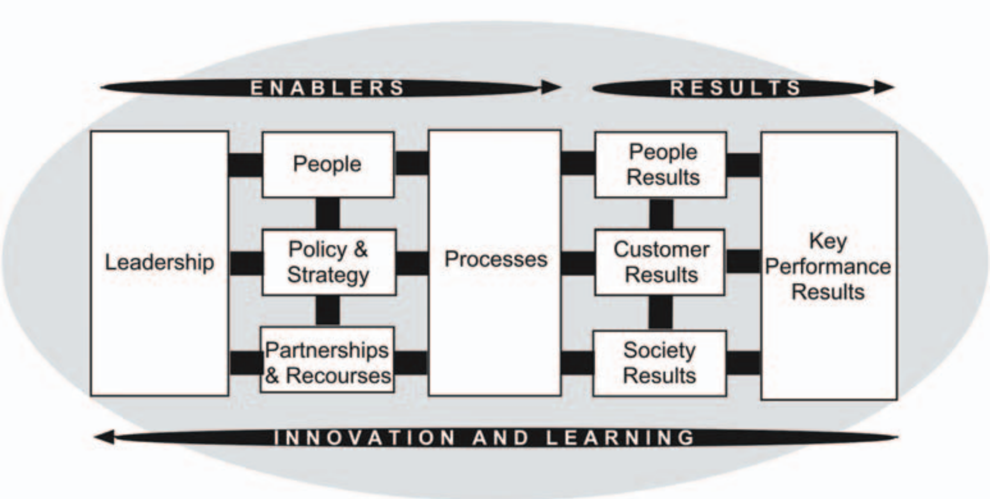


Figure 4. The EFQM Excellence Model, by the European Foundation for Quality Management, on whose European Quality Award the Finnish Quality Award is

Another strategy and performance development framework that was very influential in the 1990s is the **Balanced Scorecard** (BSC), introduced by Kaplan and Norton (1996, 1998). It is a concept in which company strategy is implemented using a customized measurement system and an accompanying development process.

The basic principle of the Balanced Scorecard approach is to provide a snapshot of the state of a company such that both the results of the operations and the causes behind them are presented. This requires "balancing" of the measurement system so that all essential perspectives affecting company success are brought into focus. In a Balanced Scorecard, a company is looked at from four points of view (Kaplan & Norton 1996) (Fig. 5):

- financial,
- customer,
- internal processes, and
- innovation and learning.

A Balanced Scorecard does not consist only of a group of meters that give information on the operations from four viewpoints; the meters must form an integrated, connected structure throughout the company. Company vision and strategy is the foundation of the whole system, forming a cause-and-effect chain reaching all parts of the organization. The hierarchy of the measurement system is such that the high-

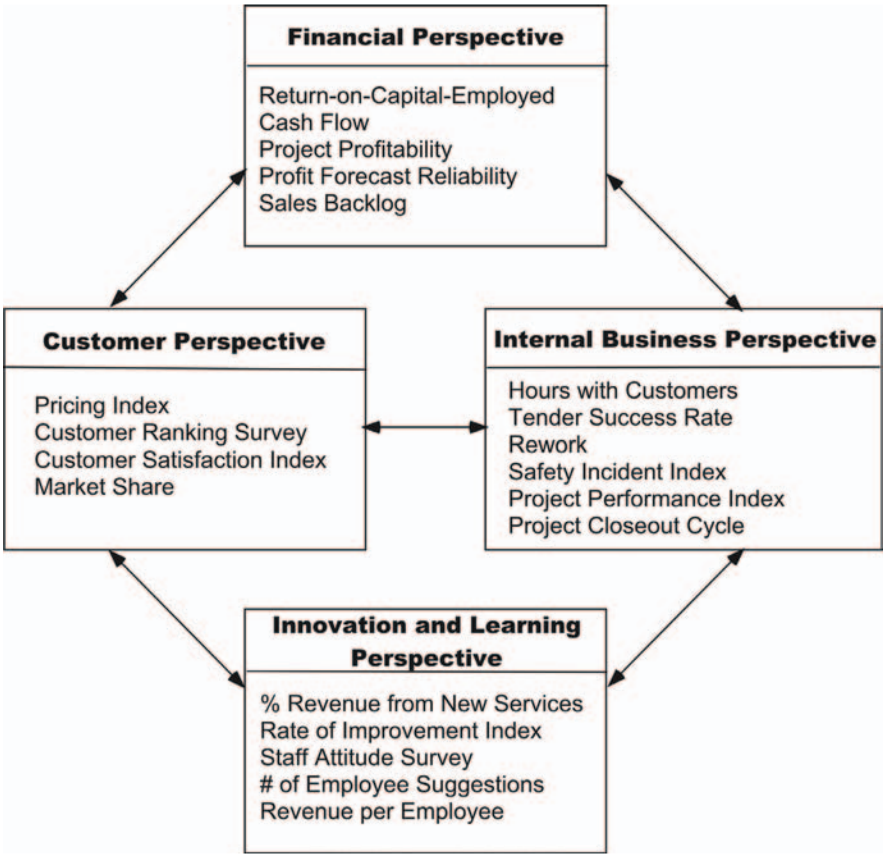


Figure 5. Balanced Scorecard for Rockwater, an American company involved in underwater engineering and construction (Kaplan & Norton 1998).

est goal of the company is its financial success. Behind it is customer satisfaction, which is expressed by customer fidelity and company trustworthiness. The preconditions for this are efficient internal business processes. They are again predicated on employee skills that are maintained by learning and growth. Each unit has its own meters that are connected to the upper-level meters. There can also be overlapping meters in line with the logic of business processes (Kaplan & Norton 1998).

The Balanced Scorecard approach has combined the management approach with a measurement framework. While BSC does not tell what the strategy should be, or what exactly should be measured, it gives a general framework for measurements and for the process of implementing a strategy in practice. It suggests, however, that the four perspectives should be considered as cornerstones of the measurement system. It is aimed at not only the company level but also reaching through every business unit.

The risks connected with performance measurement systems lie in both developing the system and using the meters. The wrong meters can be chosen, consequently leading operations in the wrong directions – for example, reinforcing divisional barriers instead of promoting processes, or focusing attention on unimportant matters instead of matters of great strategic importance. Meters can also be misunderstood in an organization as instruments of control rather than, as initially intended, supports for self-steering. Finally, it is not obvious that the interconnection between strategy and meters is successful, and the traditional key indicators can be used in reality instead of new, more innovative meters (Kaydos 1998).

Performance measurement systems in the general business management literature do not come with a ready-made list of meters that should be applied in certain types of organizations. Although actual lists of recommended meters are found in the literature, the general idea of performance management systems is that the content has to be tailored to each organization. Frameworks of measurement systems are ways to describe which items are important for an organization. Choice of the actual meters is left to the organizations themselves, and actually many writers put more weight on the process of developing the meters than on the substance of the meters themselves. In fact, many “performance management systems” are more like descriptions of the process of developing the measurement system than description of the structure of the system.

2.6 PERFORMANCE MEASUREMENT AS A MANAGEMENT SYSTEM

The purpose of performance measurement lies not only in acquiring information on the state of operations but also in influencing and managing them. The whole process of developing a measurement system, measuring performance with it, using the measurement results in the formation of strategy, and giving feedback is called performance management (Williams 1998).

Williams (1998) acknowledges that definition of performance management proves just as difficult as many other management concepts do. He nonetheless does describe three major aspects of a performance management system.

1. Performance management is a system for managing organizational performance.
2. Performance management is a system for managing employee performance.
3. Performance management is a system for integrating the management of organizational and employee performance.

In the business management literature, many models for performance management are presented. Hronec (1993) presents his "Quantum Performance," the strategic development model of that was used by Andersen Consulting. A variation of a similar process has been presented by Chang and Young (1995), using the terms **key result areas** (KRA) for success factors and **key indicators** (KI) for their meters. Schiemann & Lingle (1999) talk about measurement-managed culture as a key to company success, and they divide the measurement process into four phases: define, design, cascade, and embed.

The use of a performance measurement system is central also to one of the management approaches of the late '90s, **Six Sigma**. In Six Sigma, data gathering and statistical analysis are used to find sources of errors and ways to eliminate them (Harry & Schroeder 2000). The four main phases of the Six Sigma approach are Measure, Analyze, Improve, and Control. A key indicator system is used to collect data on company operations, which are then analyzed using statistical methods and tools. Improvements are made, and as the procedure is repeated the Sigma level is raised (Harry & Schroeder 2000).

The general idea of performance management is illustrated in Figure 6. Corporate strategy is in the background of the performance cycle, which starts with determining departmental purposes and individual goals, continuing with evaluating performance and utilizing the results in feedback and development. The cycle occurs, e.g., once a year, and both operations and measurement system are further developed in each cycle (Storey & Sisson 1993).

The performance cycle as shown in Figure 6 might as well describe a general strategy process, but when the issue is performance management, the weight is on developing and using the performance measurement system in implementing the strategy. The central principle in measuring performance is to use the right kind of meters in each business unit or process. Meters have to constitute a logical system covering the whole company from top to bottom. The use of performance measurement in strategic management can lead to good results if goals are set at the right levels; if there is a clear causal relationship between the measured fact and the intended result; if the results can actually be affected; and if the meters are accurate, objective, and understandable (Merchant 1998).

By contrast to performance measurement, performance management emphasizes the connection to business strategy or department objectives and, on the other hand, also the commitment of the personnel involved in the operation. This brings

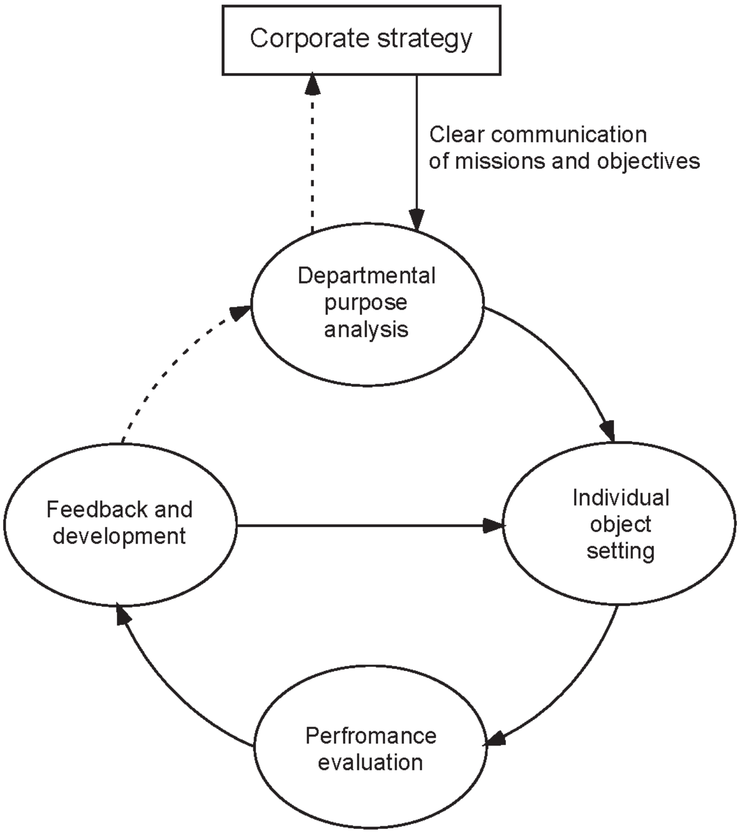


Figure 6. Performance management cycle (Storey & Sisson 1993).

to attention not only the substance of the meters as important but also the process of developing and using the measurement system. The measurement system is an entity consisting of the meters themselves, a database or spreadsheet that produces the necessary calculations and reports, and also the system of continuously developing meters and giving feedback to those whom the measurements concern.

2.7 THE HUMAN ASPECT OF PERFORMANCE

The human aspect of performance was emphasized in many of the performance models covered in Section 2.5. As business management and especially the technical sciences concentrate on the mechanical side of organizations, other theories apply to organizational behavior and human actions in working life. In these, organizational behavior is studied at the level of the whole organization, groups, and the individual (Juuti 1992). It is common to speak of the “hard” structural/mechanical side and “soft” human side of organizations (Burns & Stalker 1961).

This study concentrates on the performance of a certain type of organization, namely that of a construction project. The behavior of individuals and groups is not in the central focus; rather, the organization is considered as one entity, although it consists of groups and individuals having different cultures and attitudes. Therefore, the study focuses on aspects of general organizational behavior and also the actions of managers.

Early organizational theories concentrated on mechanical or human elements. In the **mechanical approach**, the means to improve performance were structuring, organizing, and creating detailed rules for the operation (Fayol 1916, Taylor 1916, Weber 1946). With the **human approach**, the discussion focused on human issues like work satisfaction and motivation (Mayo 1946, Maslow 1943, McGregor 1957) – making the work more suitable for people and not vice versa.

In the ’50s and ’60s, the major trend in organizational research was the use of **system thinking** (von Bertalanffy 1968, Trist & Murray 1990, Katz & Kahn 1966, Kast & Rosenzweig 1985). Systems thinking is about describing an entity as a group of elements and the interaction between them. Especially in the 1960s, system theorists tried to combine organizational and behavioral theories (Lindström 1994, Vartiainen 1994). An organization was seen as a socio-technical system consisting of two autonomous but interdependent part-systems: technical (production process, tools, materials) and social (relationships between humans). More recently, the operation of an organization has been studied as an open, socio-technical system in interaction with its environment (Scott 1992, Rollenhagen 1997).

Contingency theories are based on the idea that there is no single most efficient organization model; rather, an efficient model is dependent on many variables connected to the situation and environment where the organization functions. Contingency theories have similarities with systems theories, but the focus is on the implications that environment has for the operational conditions of the organization (Kast & Rosenzweig 1985, Steers & Black 1994, Lawrence & Lorsch 1967, Mintzberg 1983). Contingency theories claim that an organization is a product of its origin and environment, with its success determined by finding the best possible inner and outer compatibility (Mullins 1996, Adler 1997).

Organizational culture research can be seen as a “counterstrike” of the human relations school wherein the views of psychology and sociology have been reawakened by terming the mental programming of people working in organizations “organizational culture” (Schein 1991, Hofstede 1993). Culture is a learned attribute, which is separate from basic characteristics and the personality of the individual. Another concept connected to culture is the organizational climate, which can be seen as part of culture or a separate variable in an organization (Juuti 1994).

One aspect of organizational culture is its relative strength: strong culture is more easily characterized, and it affects performance more than weak culture does. It has been argued that a company should have strong culture to be efficient (Hampden-Turner 1991), but a counter-argument is that strong culture is a trap, making adaptation to market changes difficult (Mullins 1996). Collins and Porras (1994) are among those who have claimed that a strong culture is typical of successful organizations. Yet, when Kotter and Heskett (1992) studied the relationship between culture and performance, using material covering over 200 companies, their observation was that culture strength may be important but that the most important success factor was cultural fit with the environment. Rollins and Roberts (1998) too have found that characteristics of culture are related to the performance of an organization. They presumed, however, that the causal relationship applies in both directions: also, high performance reinforces the culture.

Different cultures have been classified according to several principles – in other words, classified according to typologies. Many models of culture are illustrated as fourfold fields that describe cultural dimensions along the axes of a two-dimensional graph. One representative of fourfold models is the *competing values framework* (Quinn 1988, Cameron & Quinn 1999), which is used in this study as a framework for measuring dimensions of work behavior on a construction site and therefore presented in detail here.

The competing values framework is based on the observation that different organizations function effectively in different situations. The aim of the developers was to find out what kind of organizational culture is appropriate in particular situations and whether the existing organization was a match. The competing values approach is based on the principle that different value orientations compete within the organization, with some stronger than others. Determining the dominant values and comparing them to the requirements of the environment can serve to evaluate the organization's performance.

The competing values framework introduces four types of organizational culture: Team, Adhocracy, Hierarchy, and Firm (Fig. 7). The Team is a family-type participatory culture, where management is caring and supportive, and where employees and teams have a shared goal and are committed to the organization. In an

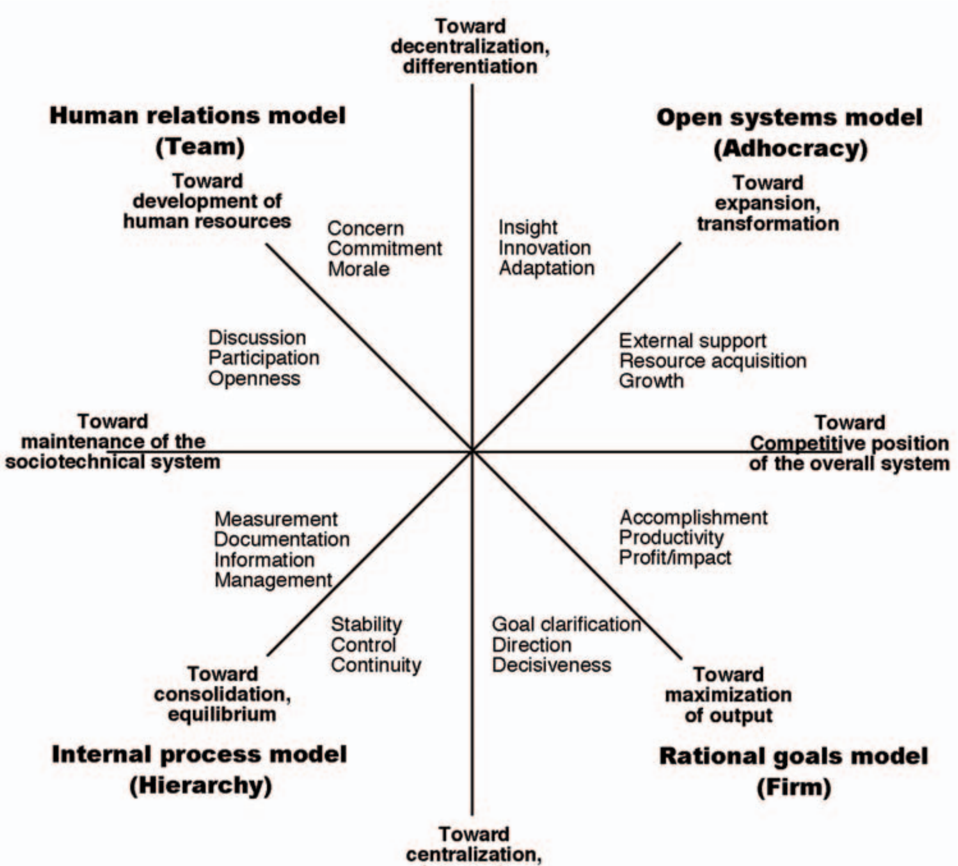


Figure 7. Competing values framework for organizational culture (Quinn 1988).

Adhocracy too, there is a common vision, but otherwise an individual and creative way of working is encouraged. A Hierarchy is a bureaucratic organization that is based on rules and control. The Firm is aimed at competitiveness, placing a focus on efficiency, goal setting, and strict-result-oriented management.

Quinn (1998) stresses that although the characteristics of different types of culture seem to be “opposite,” they don’t in practice exclude each other. Rather, there appear characteristics of each culture in every organization. The objective is to find the ideal balance between the different culture characteristics.

When the existence of different competing values characteristics in managers was studied (Quinn 1988), it was observed that the most successful leaders were not only exceptionally capable in one area but better than average in other areas as well. It was concluded that weak areas could not be compensated by one strong area – even one especially weak area was enough to bring down the others. Thus, it was concluded also that, although it is important to promote above all those culture characteristics that are most important, the other areas must not be completely neglected either.

Mintzberg (1979) distinguishes seven types of organizations and claims that organizations are “pulled” towards one of them depending on their business area, size, location, and so on. The seven types of organizations are the following:

1. Entrepreneurial (little technostructure and hierarchy)
2. Machine (strong technostructure, control, and rules)
3. Professional (autonomous specialists)
4. Diversified (different business units without much in common)
5. Innovative (research-based, informal)
6. Missionary (ideology as the control system)
7. Political (no overall control, based on conflicts)

Hofstede (1993) has presented in his study different cultures in business units of international companies by describing six dimensions of organizational culture. The continua were 1) process-/result-orientation, 2) people-/work-orientation, 3) company/work task identifying, 4) open/closed system, 5) loose/tight control, and 6) normative/practical orientation.

Another central approach to organizational behavior is the **leadership** aspect. Leadership theories focus on the actions of managers, while organizational theories consider an organization as the sum of actions of individuals. Leadership theories’ approach is more psychological, while organization theories look at workplaces more in terms of sociological elements.

The first actual leadership theories, formulated in the ’40s and ’50s, focused mainly on the **attributes and qualities of a manager**. Leadership skills were considered a quality that a manager is born with, and the purpose was to find someone with the right managerial properties for the job. Later, the capacity to learn was considered by this approach, and the question of what to learn remained central, as the main purpose was to determine the characteristics of a good manager (Mullins 1996).

In the late ’50s and in the decades that followed, interest was focused on **behavioral research**, where the actions, roles, values, and communication of leaders were studied. A basic approach was McGregor’s (1960) XY theory, which described continua for how managers relate to their employees and thus their own role in the organization. The behavioral approach to management led to discussion about leadership styles. The main styles of leadership were considered to be authoritarian, democratic, and laissez-faire leadership. The authoritarian style, based on a negative conception of humans, was defined as manager-centered, dictatorial leadership. The democratic manager was described as more a member of a group than the leader, with everybody able to participate in decision-making. Laissez-faire leadership was defined as not leadership at all, with things allowed to take their own course.

One widely known categorization system dealing with dimensions of leadership was *Blake and Mouton’s managerial grid*, first published in 1964 (Blake & Mouton 1994). It includes the two main dimensions of leadership: concern for production and concern for people, which are set in a two-dimensional grid, with each given values from 1 to 9 (Fig. 8). Managers are given ratings that describe their orientation towards production or people. For instance, a leadership style of 9.1 indicates that the manager is of the authority-compliance type. The model makes the 9.9 style accessible and shows that the choice is not between production- or people-

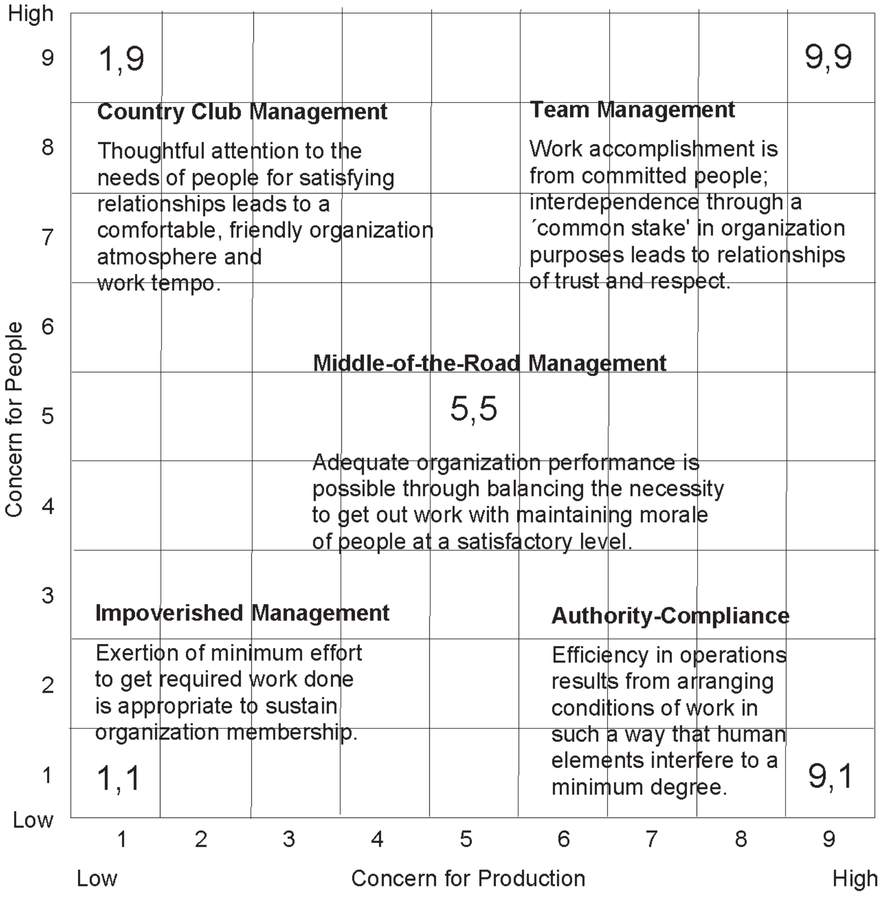


Figure 8. The principle of Blake and Mouton’s (1994) management grid, as adapted from Mullins (1996).

orientation; rather, the ideal is to integrate the two. The Grid theory approach is also relevant to this study and therefore presented in greater depth.

The characteristics and leadership styles of managers still were not able to explain the success of a manager conclusively. In the ’70s, contingency theory was transformed into leadership theory and called the **situational approach** (Fiedler 1967, Hersey & Blanchard 1982, Mullins 1996). The focus was on how the actions of managers relate to the environment in which they operate.

Organizational and leadership theories form the framework for measuring performance from the human perspective: which are the components of human actions, and how should they be included in the measurement system? As well as the overall operation of a construction site, the organizational behavior must also be outlined and modeled so that it can be measured.

2.8 MEASURING HUMAN ELEMENTS IN AN ORGANIZATION

In this study, the purpose is to gather the data in numerical form in order to make comparisons and perform statistical tests, and thus answer the research questions in a manner accounting for interdependencies between variables in the construction project system. On the other hand, the aim is also to develop a measurement system applicable in practice for benchmarking and developing construction projects. The demand for analyzable data and a rapid measurement process calls for rigorous, systematic data gathering methods.

The most common method for analyzing human aspects of organizations in a quantitative manner is the use of surveys or questionnaires. Ease of use, rapid availability of results, and wide comparability are the advantages of this method. On the other hand, more in-depth information can be obtained through interviews, observations, analyses of organizations’ materials (documents, records, raw data, speeches…), and workshops or group discussions (Harrison 1994, Rollins & Roberts 1998). The more structured and predetermined the method of analysis is, the easier it is to use statistical analysis methods, but sometimes the more informal qualitative methods aid in understanding different aspects of the situation better.

The design of a questionnaire begins with questionnaire specification. This involves determining the variables to be measured, and the result is a list of variables. The choice of variables is based on the framework and design of the study. The process used in responding to the questionnaire should be attractive and made clear/simple by means of the layout, grouping of questions, wording, and directions for answering used on the form. An essential phase in developing the method is piloting. Proper testing of the questionnaire indicates whether the respondents understand the questions in the intended way and how well the questions and the variables actually fit within the framework of the research. Another essential element is to decide on the sample to use, if it is not possible to use the whole population as a sample (Oppenheim 1996).

In this study, a questionnaire-based survey with a written list of questions is the most practical method for measuring the characteristics of organizational behavior in construction sites. However, an appropriate framework for measuring the relevant dimensions of organizational behavior must be determined.

2.9 SUMMARY AND APPLICATION TO THIS STUDY

Performance measurement is a common concept in general business management. Traditional financial accounting has been expanding into strategic accounting, which concerns all measurement systems that touch on the state of a company or organization. On the other hand, measuring performance has been widely done as part of many management approaches of the past and present.

The simplest models are key indicator systems, where a group of meters or key indicators has been combined in a systematic way. More advanced measurement systems are based on a model of company success factors or strategic goals, and form a hierarchy of metrics for each level of the organization. A complete performance management system includes also a schema of continuous action addressing how to implement strategy or company goals and at the same time develop the system of operation and measurement itself.

The general performance measurement models are intended for company level and can therefore be applied for almost any company, including construction companies. However, the aim of this study is to develop a measurement system for a construction site. For that purpose, a directly applicable model cannot be found in the general performance measurement literature, because a construction site is basically a production unit and doesn't have the same functions as an entire company does. However, certain elements of general performance measurements systems can be applied also to construction projects, and the general idea of performance management is necessary to acknowledge in management of performance at the company level.

Many models have been put forth concerning what the success factors or performance elements of an organization might be. The main principle is that every important element of both results and factors affecting the results should be measured, including "hard" factors like structure and technology and "soft" issues having to do with the human element.

Once the performance elements that should be measured are determined, development of the meters themselves can begin. The meters can be key indicators, index meters, or some other kind of numerical indicators. For measuring the organizational aspects of performance, a survey employing a questionnaire can be used.

The general performance management process can be applied in developing a construction site performance measurement system. However, in seeking the model on which a construction site performance measurement system and associated meters can best be based, more knowledge is needed from previous studies directly connected to construction projects.

3 APPROACHES TO CONSTRUCTION PROJECT PERFORMANCE

3.1 CONSTRUCTION PROJECT SUCCESS

The studies about determining project success consider what it means when a project is successful, and to whom. This is a question that should be answered first, before trying to solve the puzzle of the factors that influence success. Project success is studied both in general project research and also that concerning construction projects. Many studies concentrate on determining the characteristics of successful project managers.

Distinguishing project success and the success of a project manager's efforts, de Wit (1988) states that a project can be successful despite poor project management performance, and vice versa. This all depends on what the expectations of different parties involved in a project are. Project success can be evaluated against project objectives and specific success criteria, which are different with every stakeholder. He presents a project success framework including different expectations of the contractor, the client, and external stakeholders such as government entities and the community.

Munns and Bjeirmi (1996) state that evaluation of project management success is a complicated matter. Project success is usually evaluated only at the end of the project, which yields only a partial picture of the project manager's success in the long term. Often the objectives of project management and other stakeholders conflict. In addition, as measurement of cost and time is so easy, involving comparison of results to the budget and schedule, success elements that are qualitative or not easily measured are neglected. The authors also argue that a distinction should be drawn between the success or failure of the project and that of project management.

Baccarini (1999) too divides project success into two components, product success and project management success. Project management success consists of 1) meeting time, cost, and quality objectives; 2) the quality of the project management process; and 3) satisfying project stakeholders' needs related to the project management process. Product success means 1) meeting the project owner's strategic organizational objectives, 2) satisfaction of users' needs, and 3) satisfaction of stakeholders' needs when related to the product.

Kerzner (1998) argues that the traditional determinants of project success – cost, time, and performance/technology – are too narrow for today's circumstances and lists a more comprehensive set of criteria for determination of project success, according to which the project must be completed:

- within the time allocated,
- within budget,
- at the proper performance or specification level,
- with acceptance by the user/customer,
- when the customer's name may be used as a reference,
- with minimum or mutually agreed upon changes in scope,
- without disturbing the main work flow of the organization, and
- without changing the corporate culture.

Few recent studies have concentrated on the success of construction projects in particular. Liu and Walker (1998) approached construction project outcomes from the organizational behavior perspective. They argued that the theoretical basis for defining general, non-project-specific criteria for evaluation of project success lies in the field of industrial and organizational psychology. Project success is determined by individuals' perceptions of project outcomes, and factors influencing these perceptions included efficiency, project complexity, commitment, expectations, rewards, goals, and environmental variables.

The main stakeholders in a construction project are contractors, project managers, clients, consultants, subcontractors, suppliers, and manufacturers (Chua et al. 1997). Each project participant has a different view of success, which may have technical, financial, educational, social, and professional aspects. Sanvido et al. (1992) found additionally, however, that few objectives are common to all participants. Everyone expects financial profit and wants projects to be completed on schedule. The absence of any legal claims or proceedings is an outcome desired by all.

Although many success criteria from general projects apply to construction projects, the latter also have characteristics that differ from those of, for example, development, software, or marketing projects. Construction projects are primarily production-oriented activities that exist for predetermined, short-term purposes, although on the business unit or company level they fall under continuous project business.

Even if the evaluation of project success depends on different viewpoints and expectations, many authors propose one or more general criteria for construction project success. If suggestions related to construction project success elements are collected from several sources (Ashley et al. 1987, de Wit 1998, Hatush & Skitmore 1997, Liu & Walker 1998, McKim et al. 2000, Chua et al. 1997, Winch et al. 1998, Kagioglou et al. 2001, Russell et al. 1997), the following list can be compiled:

- keeping to budget, profitability;
- schedule adherence;
- quality / technical specifications / low number of defects;
- product functionality;
- client satisfaction with the product and service;

- cost and time predictability / minimization of client surprise;
- contractor satisfaction;
- project manager/team satisfaction;
- environmental sustainability; and
- safe performance / low accident rates.

The basic assumption seems to be that project success is determined by cost, time, and quality, and then by a set of issues describing more the way the project is delivered than the results themselves. When the list of success elements is considered from this study's perspective, it is important to separate those elements that determine the final success from those that are part of the project process, because the project process elements are the success factors that are separated from success elements in the performance system model.

The scope of this study covers construction site operation, an area somewhat more limited than the whole project. However, the success of a construction site should correlate with the whole project's success, and thus the success elements of the whole project are relevant for the construction site also.

3.2 MEASURING CONSTRUCTION PROJECT PERFORMANCE

3.2.1 Components of performance in construction projects

Construction projects, as are projects in general, are always measured at least by comparing achievements to project objectives, determined by budget and schedule. Certain key indicators such as cubic meters of concrete poured or quantity of installed elements have been used to indicate the state of the project. These meters are related to project goals, and they tell as much about the standard of goal setting as they do about the standard of performance in comparison to that for other projects. The problem is that conditions on each site differ and therefore comparable results from measurements are hard to come by. If performance of different construction sites is to be measured and compared, objective and comparable meters are needed.

A typical problem in studies concerning the objective measurement of construction project performance is what the performance components are and how to measure them. Most of these studies don't try to cover performance as a totality but concentrate on a certain limited perspective. In trying to determine what the performance components for a construction site are, and how they can be measured, it is necessary to review what performance areas have typically been studied for construction projects, and what means have been used to measure them.

In this section, four major classes of construction project performance measurement approaches are recognized. They are:

- productivity,

- quality,
- safety, and
- key indicator systems, which integrate many aspects of performance in the same system.

3.2.2 Measuring productivity

Performance is a relatively new concept in the construction project context. Previous attention was focused on productivity (Kiiras 1977, Immonen & Rejström 1987, Kiviniemi & Alanen 1996). Productivity means in principle the efficiency of the use of production inputs (Peltonen 1991). In construction, it usually means the productivity of work, and often attention is focused on selected phases of work (Kiviniemi & Alanen 1996). A typical way to measure productivity is in man-hours per unit of work. The measurement demands constant follow-up and consideration of other associated variables, like crew size, absenteeism, construct design, and weather. One result of these studies has been the Finnish productivity database, which has been published by Rakennustieto as part of the RATU series (RATU= *Rakennustuotanto*, construction production).

Winch and Carr (2001) studied the productivity of structural concrete operations in order to draw a comparison between the UK and France. The method used in data collection was "activity sampling," meaning constant on-site observation of work input. Four sites were involved in the study, two from each country. The pattern of daily work routines was documented in detail, and output was measured in cubic meters of concrete. It was concluded that a more elaborate division of labor and the use of more sophisticated technology made French sites more productive.

In a study by Herbsman and Ellis (1990), daily data collection from work sites was used to verify a theoretical factor model of construction site performance. The model consisted of a series of key indicators found specifically for each work phase that were supposed to have an effect on productivity. In the study, large fluctuations in productivity rates were found and it was stated that many variables have an effect on productivity, and that the dominant factors should be identified.

In an earlier study (Salminen 1998a), measurement of the productivity of certain phases of work was applied, but achieving comparable results was difficult because, first, phases were often subcontracted and the work consumption was not available and, second, many factors affect the productivity of a single phase and the attempts to separate these factors led to a web of speculations. Therefore, reliable productivity measurement that could have been used to indicate the productivity of the whole site would have demanded more data and constant follow-up over a longer period of time.

Some attempts to measure the productivity of a whole construction site have been made. At the Helsinki University of Technology (HUT) Construction Economics and Management unit, the concept and measurement of productivity were already being studied in the '70s (Kiiras 1977). The conclusion was that, as a concept, the term “productivity” is clear and there are several methods to measure it. The problem is that applying productivity measurements and interpreting the results is difficult in the construction industry because the source information is often incomparable. For example, design solutions, input structure, and level of prefabrication influence the overall productivity of a construction site, and the influence of the site’s own actions is difficult to isolate.

Jonsson (1996) studied in Sweden a way to measure construction site productivity using the data envelope analysis (DEA) method. In the DEA method, the relative productivity of a production unit is estimated, or units with a similar type of operation are compared to the best-performing unit, which determines the upper bound for the efficiency scale. The comparison was made in terms of input and output quantities. In the study, many key indicators were tested in evaluating the operation of a construction site. According to this research, it is possible to measure construction site operation by using different key indicators. However, acquiring the source information for some of the key indicators required specific follow-up on a daily basis.

The key indicators used in Jonsson’s study were the following:

- actual time taken compared to that scheduled,
- actual costs divided by budgeted amounts,
- consumption of materials divided by the ideal quantities,
- hours used divided by expected hours according to the reference material,
- hours used divided by hours budgeted,
- hours worked divided by total hours it was possible to work,
- physical units produced divided by hours used,
- physical units produced divided by machine rental costs,
- quality costs divided by total costs,
- capital cost for materials in stock,
- rental cost for unused machines divided by total machine rental cost, and
- value added divided by hours used.

After performance of DEA analysis for 104 projects (Jonsson 1996), the key indicators suggested for evaluating construction site productivity were labor productivity, machine productivity, machine utilization, material stock, material consumption, quality, actual hours versus hours budgeted, actual time compared to that scheduled, and attendance. The study concentrated more on the measurement system than on analyzing the variables affecting productivity, and it concluded that the measurements were considered to serve two purposes: that of a strategic tool for finding development needs and that of a continuous improvement tool for construction sites.

In a study about the relationship between formal quality assurance and productivity, the productivity of a whole site was measured (Langford et al. 2000). The method was to express inputs including labor, materials, and plant and outputs in monetary terms. It was considered a problem that also different technologies, specifications, ground conditions, etc. influence productivity. In the study, this effect was eliminated by selecting 24 sites that were as uniform as possible for the sample, with company type, location, and building type taken into consideration. Therefore, this approach is limited to application for similar cases.

Productivity of a construction site can be measured both as the combined productivity of single phases of work and as that of an entire site using different key indicators. Productivity measurement for a phase of work demands continuous follow-up, and for comparable results to be generated, the effect of many conditional variables has to be considered. The key indicators used to measure the productivity of a whole site don't necessarily measure productivity directly, because the total inputs and outputs of the site are very difficult to measure, which raises the question of what they actually measure. It seems that no generally accepted or commonly used method for measuring the productivity of a whole construction site exists.

3.2.3 Measuring quality

Quality is another often-used performance component. In this study, the relevant categorization of aspects of quality is based on product and process quality. The product quality, which has the most to do with the customer's financial input or designers' choices, is beyond the scope of this study, and therefore the more exact term for quality would here be faultlessness. In the construction business, the traditional meter for product faultlessness is the length of the defects list. However, this is by no means a valid meter. In the theory and in practice, the main focus is on measuring and analyzing process quality, because it eventually affects the faultlessness as well, and product quality is taken care of with the usual quality control procedure (with hand-over procedures and so on).

One basic approach in quality measurement is the attempt to determine quality costs. Quality cost consists of the cost of quality management activities (prevention and appraisal) and the cost associated with deviations in quality (Ledbetter 1994). Ledbetter used the QPMS tool (quality performance management system), which is a self-assessment system for construction sites that is based on project personnel keeping track of the time spent on quality work. He established that measuring quality costs is one way to focus management on where quality improvements could be made and thus reduce quality costs, and that when used in combination with other measurement tools the measurement makes it possible to improve overall project performance.

At the construction site level, quality "measurements" have mostly been conducted with quality audits. Quality audits involve, however, merely checklists or a series of questions to be processed in a qualitative way, as opposed to actual meters. With quality criteria, the actual operation is compared to the requirements of the quality system. Although in some cases it is possible to calculate indexes from these checklists, the purpose of these lists is to find deviations in the operation, not to produce a comparable index. Quality audits concentrate on planning and documentation and therefore are mostly to do with process quality. Quality audit systems have strong connections with measurement-like methods such as key indicator systems, quality costs, and performance measurement systems (Laamanen et al. 1997).

One approach to on-site quality measurement has been developed in HUT's Construction Economics and Management unit (Wegelius 1998, Salminen et al. 1998, Salonvaara 1998). A quality scorecard is a series of index meters applied for each phase of work. It contains specified checklists for the chosen, typical work phases. These are completed after observation or questioning by the quality measurer. The checklist has a binary scale for each criterion, which is the most simple.

The quality criteria were separated into five categories (Salonvaara 1998):

- planning of quality control measures;
- the familiarity of the quality criteria within the work group;
- implementation of quality control measures;
- conformance with quality requirements for the work phase; and
- reaction to deviations, and implementation of corrective measures.

Methods for measuring quality costs or quality indicators on the company level have been developed. At site level, process quality can be measured in connection with quality audits via checklists or questionnaires. However, those checklists are seldom used for measurements but more as means to assist in the auditing procedure and highlight deviations from the quality system. No uniform or generally applied method for construction site quality process measurement exists. Product quality is controlled by the normal supervision and hand-over procedures, where checklists are sometimes used. These checklists can be transformed into a form involving numerical measurements, as was done in the Finnish study (Salonvaara 1998), but these methods have not entered general use and systematic quality measurements have not been made so far.

3.2.4 Measuring safety

Safety is perhaps not as highly valued a key performance element as productivity and quality for an individual construction site, because with good luck, the safety risks aren't actualized. However, at the company, industry, and societal level, safety has a great impact in economic and human terms, especially in the construction industry, where accident rates are almost twice as high as those in other industries, according to the Finnish Centre for Occupational Safety (*Työturvallisuuskeskus*, Web page). That is why safety research has been financed and conducted quite extensively, and why it is considered separately in this study also.

The usual way to measure safety is by accident frequency (accidents per 1,000,000 work hours) or accident incidence rates (accidents per 1000 workers). Absenteeism due to accidents and accident costs in relation to operation turnover are also used. However, the focus should be on preventive measurement, which means that those factors influencing accident rates should be measured as well.

Laufer and Ledbetter (1986) studied the effectiveness with which, and the extent to which, the various safety measurement methods utilized at construction sites were used. They conducted a survey using a questionnaire in the USA, to which 67 companies responded. The commonly accepted ways to measure accident rates were widely in use, but safety process meters were not frequently used or they functioned badly as meters from a reliability and validity standpoint.

The basis for safety measurement lies in the regulations and control systems of public authorities. Authorities have for some time conducted safety inspections with forms or checklists, where deviations in safety precautions have been recorded. These checklists can also be transformed into safety measurement systems.

Duff et al. (1994) developed a safety audit checklist of 24 items, which functions as a safety performance meter. Safety measures were divided into four categories: scaffolding, access to heights, housekeeping, and personal protective equipment. The meter employed an 11-point rating scale, and the measurement procedure incorporated goal setting and feedback to site personnel in order to affect safety-related behavior. The campaign proved to be successful, and the measuring improved the safety level remarkably at the six sites where observations were made.

As a united effort of Finnish safety authorities, researchers, and the construction industry, a reliable way of measuring safety performance was developed (Laitinen & Ruohomäki 1994, Laitinen et al. 1994, Laitinen & Ruohomäki 1996). The TR meter gives a safety index as a percentage. The measurement takes place during observation rounds on site, where observations of “right” and “wrong” elements are noted. The meter is accepted by safety authorities as an official safety inspection tool and is widely used in the Finnish construction industry. An analogous meter has been developed for civil engineering works (Laitinen et al. 1998).

Valid methods for measuring construction site safety exist, for measuring both the results of safety procedures and practical safety measures on site. Making safety measurements comparable is possible because safety regulations are the same for all construction sites and all sites are quite similar where safety precautions are concerned. The safety meter developed in Finland is widely used in the construction industry and has become a national “standard.” Therefore, a valid method for safety measurement exists.

3.2.5 Measuring construction project performance with key indicators

The operation and results of construction sites are measured from various other angles as well, usually with different key indicators. A key indicator describes an aspect of company operation with one figure. When these are bundled together, they may form a kind of measurement system. Key indicators may concentrate on certain elements of performance, but in practice the same indicators can be used to measure “productivity,” “quality,” and just general performance. As the terminology may be confusing, the different approaches using a set of key indicators for measuring some aspects of construction site performance are presented as a single entity.

Several studies have been made in Finland compiling key indicators clustered around certain subjects related to construction. Jokiniemi (1993) collected numerous key indicators that have to do with construction site productivity. Vuolio and Wegelius-Lehtonen (1996) have done the same with construction site logistics. Lakka and Sjøholt (1994) have gathered together many ways to measure quality performance via key indicators. In these studies, various key indicators describing some viewpoint on a construction project have been gathered together, but they do not constitute any model illustrating the relative importance or interrelationships of the key indicators. Moreover, the studies were theoretical and the key indicators not tested in practice.

At HUT's Construction Economics and Management unit, a study on the use of key indicators in measuring the success of a construction site was conducted in 1998 (Salminen et al. 1998). Key indicators describing the success of the site were split into four categories: cost, time, productivity, and faultlessness. Moreover, several key indicators were used to describe the characteristics of the site in order to aid in interpretation of the results. The 25 key indicators were selected based on their ability to describe the intended item and the ease of data collection, which meant that they could work in practice also (Fig. 9).

Yasamis et al. (2002) developed a theoretical framework for measuring contractor quality. It contained both corporate and project elements, where corporate-level quality was expressed by quality culture. Project-level quality was divided into product and service quality. A contractor quality performance (CQP) tool was represented containing a list of "quality indicators" that were weighed and given points to. Thus, CQP was a system for measuring both corporate and project quality performance through a key indicator system.

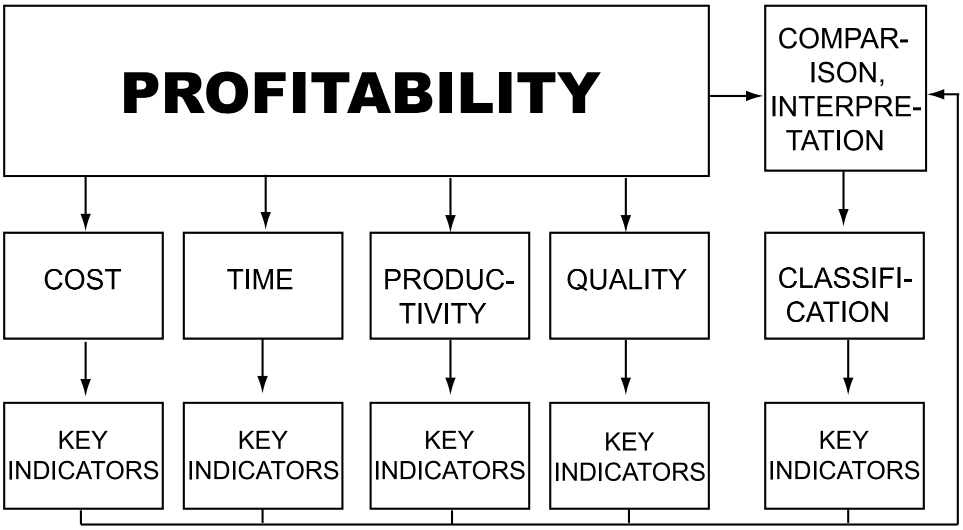


Figure 9. Key indicator system for evaluating construction site results (Salminen et al. 1998).

Kagioglou et al. (2001) suggested a conceptual framework for a construction company's performance measurement system based on a Balanced Scorecard (Kaplan & Norton 1996) performance management process framework (PMPF). In addition to the four Balanced Scorecard perspectives, the framework presented additional "project" and "supplier" perspectives for a construction company.

Russell et al. (1997) developed a Continuous Assessment of Project Performance (CAPP) intended primarily for use by owner, engineer, and contractor to assess construction project performance and predict project outcome with a model based on continuous variables, meaning time-dependent variables that change during the project. As many as 76 variables were tested in 54 completed projects, and the change in variables was expressed as S-curves. Posing a problem was that for most of the variables, only limited information was available, and that determination of project success was made on the basis of only cost and schedule and not, for example, quality and safety as well. It was nonetheless concluded that continuous variables can predict project success but that predictive ability changes depending on the type and phase of the project.

Frameworks for measuring construction project performance, at least from some perspectives, have been developed. The usual method is to use many key indicators and some framework to loosely connect them together. However, the key indicators are often theoretical and the implementation of data collection has not even been considered at this point yet, let alone processing of the data. Moreover, the effect of project or building type and so forth on the comparability of measurement results should be known in order for reliable conclusions to be made. The questions of practical applicability and comparability of results may limit the use of otherwise interesting key indicators.

3.2.6 Summary of construction project performance measurements

Specific measurement techniques have been developed to measure construction site productivity, quality, and safety. In addition, key indicator systems have been used to measure either performance in general or a certain aspect of performance. The scope of key indicator systems overlaps, and sometimes it is a matter of opinion whether the key indicators actually measure productivity, quality, or just general performance. In addition, many other key indicators are suggested in the literature. The studies and the approaches encountered are presented in Table 1.

No widely used or accepted method for measuring an entire site's productivity has been developed, though some aspects of productivity can be measured with key indicators. The same applies to quality. Safety, by contrast, is controlled by government-based authorities, with numerical data therefore easily found, and functional ways to measure site-level safety in particular have been developed.

It appears that many approaches to measuring performance exist, but the field of construction site performance measurement is disorganized. Some of the existing metrics are certainly usable, but choosing the metrics that are important and valid

Table 1. Approaches to construction site performance measurement.

Performance Component	**Measurement**	**Studies**
Work productivity on site	Man-hours per unit of work	Kiviniemi & Alanen 1996, Winch & Carr 2001, Harbsman & Ellis 1990, Salminen 1998a
Total productivity (at site level)	DEA analysis Inputs and outputs as money	Jonsson 1996 Langford et al. 2000
Quality	Quality costs Key indicators Index meter for on-site quality	Ledbetter 1994 Yasamis et al. 2002 Wegelius 1998, Salminen et al. 1998, Salonvaara 1998
Safety	Accident frequency and incidence rates (widely in use) Index meters for safety processes on site	Laufer & Ledbetter 1996 Duff et al. 1994, Laitinen & Ruohomäki 1994
Key indicator systems focusing on:	Productivity Quality Logistics Construction project success General performance	Jokiniemi 1993 Lakka & Sjøholt 1994, Yasamis et al. 2002 Vuolio & Wegelius-Lehtonen 1996 Salminen et al. 1998 Kagioglou et al. 2001, Russell et al. 1997

demands prioritization and discarding unimportant or non-useful areas of measurement. This leads to the research approach of success factor studies, where the most important aspects of construction project performance for achieving the desired project outcome are sought.

3.3 STUDIES ON CONSTRUCTION PROJECT SUCCESS FACTORS

3.3.1 General project success factors

The common method for determining project success factors has been to conduct a survey and ask project stakeholders' opinions. Such studies are valuable for this project in providing ideas as to factors that could be included in the system model for construction site performance. However, the survey approach doesn't necessarily reveal the actual success factors, only people's opinions about them.

Belassi and Tukel (1996) studied success factors in different business areas and found that the same factors were not considered important in different businesses. For example, "top management support" was considered important in many business areas, but in construction projects factors related to project teams and environmental issues like technology and clients were considered more important. Thus, the success factors need to be specified for construction site operation in particular as well.

The success factors may also be different in different phases of the project. Sidwell (1990) concluded in a case study of three projects in Australia that one factor influencing a construction project's success is "the project organization's ability to metamorphose along with the progression of the project." Also, Pinto and Slevin (1988) studied critical success factors for projects over their whole life cycle and found that different factors were considered critical in different phases of the project.

Important factors leading to project success can be viewed the other way around as well: what are the major problems in projects? Nikander (2002) studied project operation from the early warnings theory approach in four power plant delivery and renovation projects. He identified the most typical problems, their causes, and early warnings in projects. The most common causes of problems had to do with:

- poor professional skills,
- organization type,
- management and leadership style,
- differences in project culture,
- lack of resources,
- attitudes, lack of motivation and
- a person as the cause of the problem.

Saravirta (2001) divides project success "enablers" into two categories: resource factors and process factors that precede the result factors determining project success. In the case study, he didn't explore the actual relationship between enablers and project results but stated that project goal setting, evaluation of success, and decision-making constitute an integrated process resulting in project success. He also detected that the substance of goals, measurements, target values, etc. must be specific to a program or project, although common criteria should also be applied in order to enable comparisons.

Poskela (2001), Hirvensalo (2003), and A. Salminen (2000) are others who touch on the subject of project success factors, but as their focus is on development projects, it becomes obvious that the approaches and possible factors in general project performance are numerous and studies connected to the construction industry should give a better picture of which are the relevant ones for this study.

3.3.2 Studies aiming to determine construction project success factors

The studies on success factors in the construction industry either cover the whole area of performance and compile a wide rangeof dimensions to be studied statistically or focus on certain relationships between dimensions. The most usual data collection method is a questionnaire, although it is sometimes supplemented by some key indicators or other meters providing a picture of project success.

Sanvido et al. (1992) studied the critical success factors of 16 construction projects. They arranged the projects in eight pairs, where each set of projects was similar in scope but contained one project considered successful and one viewed as less successful. The questionnaire included 35 variables in seven categories, which were: facility team, contracts, experience, resources, optimization information, product, and external elements. Those were assessed via a pairwise analysis against success variables in each project phase: managing, planning, designing, constructing, and operating. The analysis verified that facility team, contracts, experience, and optimization information were the critical success factors and that the other three were less influential.

In the study by Russell et al. (1997), continuous variables were used to develop a model in predicting project outcome. Continuous variables are such that they change constantly during the project. The result was that different continuous variables predicted project results in different kinds of projects. Also, the phase of the project had an influence on which variables indicated the outcome best. For the group of construction projects, the four best indicator variables for project success, which was measured in terms of cost and schedule, were: 1) total commitments of material and equipment, 2) cost of owner commitments, 3) cost of contractor project commitments, and 4) invoices for material and equipment.

Chua et al. (1999) studied the effect of 67 success factors on the cost, time, and quality performance of a construction project. Variables were divided into four groups: project characteristics, contractual arrangements, project participants, and interactive process. The data collection method was a questionnaire, and the sample size was 20 respondents. The result was that there were different sets of success factors for different project objectives. Project success was not determined exclusively by the project managers; project characteristics and contractual arrangements too influenced project success.

McKim et al. (2000) performed a survey of 25 reconstruction and 15 new construction projects, followed by structured interviews with project participants. A performance comparison was conducted between new and reconstruction projects, and factors contributing to schedule and cost overruns were analyzed. New construction projects proved to perform better in relation to schedule and cost overruns. The factors influencing these overruns most in reconstruction projects were unforeseen site conditions and changes in the scope of work.

Chan et al. (2001) studied success factors in design-and-build projects. A survey using a questionnaire was completed for a sample of 53 respondents from 19 projects. Factor analysis of 31 variables revealed six project success factors. Those were project team commitment, the client's competencies, the contractor's competencies, risk and liability assessment, end users' needs, and constraints imposed by end users. The first three mentioned were found to be the most significant.

Factors affecting productivity were sought in a couple of studies. Thomas and Yiakoumis (1987) measured productivity in several work phases over 78 project workdays. The changes in productivity were studied in relation to other variables, such as weather and temperature, and learning models for the work phases were presented. In another study, by Thomas and Zavrski (1999), the focus was on work productivity for masonry construction, concrete formwork, and structural steel in 42 projects. In the study, the influence of project management and design was examined. It was determined that the more complex the structure, the less productive the work.

The studies presented various approaches to determining construction project success factors, but they all aimed at determining the most significant factors among a group of dimensions. Other studies focus on certain performance elements and look at the influence of only the chosen elements on project success.

3.3.3 Communication and integration as success factors

The efficiency of communication is one item that has been the subject of several success factor studies. Thomas et al. (1998) conducted a study of construction project communications' effectiveness. Using a survey, they measured six communications variables: accuracy, procedures, barriers, understanding, timeliness, and completeness. A positive correlation was found between effective communication and project success.

A concept related to communication is project integration, which refers to a construction project being organized and implemented in such a way that it increases the participants' interaction, such as in partnering and design-and-build work. In those contract types, the contractor is responsible not only for the construction phase but for the design phase as well, and as the project managers are involved in the project earlier and know the plans well, planning and communication are supposedly improved. The interesting question is whether greater integration, and thus better communication, also improves performance.

The degree of interaction (DOI) system has been developed to measure the amount of communication and to study its effect on performance (Pocock et al. 1996, Pocock et al. 1997). This involves using a questionnaire and a numerical formula to calculate an index called the DOI score. The DOI index was used in two studies: 25 projects were analyzed in the first study and 38 in the second. Project performance was evaluated by cost growth, schedule deviation, number of contract modifications, and modifications due to design deficiencies. It was observed that the degree of interaction indeed had an impact on project performance. In special projects having more variability, both performance and DOI were better than in more standard ones (e.g., housing projects).

Faniran et al. (1998) studied project interaction from the planning process point of view. In the study, a questionnaire survey was conducted for a sample of 52 companies, and factors with critical influence on construction planning were identified. It was determined that substantial time should be invested for construction planning prior to the commencement of work on the site. Instead of developing schedules for monitoring and controlling project progress, one should increase the emphasis on developing operational plans for project implementation.

Moshini and Davidson (1992) studied the performance of “traditional projects.” Traditional projects are typical contracting projects involving the sequential design, tendering, and construction phases. The study focused on organizational conflict variables. Six variables were included in a regression model attempting to explain cost, time, and quality performance. The material was acquired from four projects via a questionnaire. The result was that two variables – the sufficiency of the initial information and the extent of tasks’ interdependence – affected all three result components and other variables affected only one or two components.

Konchar and Sanvido (1998) studied the effect of contract type on project performance. The contract types covered were cost and fee, design-and-build, and traditional design/bid/build contracting. Data were collected from 12 cooperating parties in the USA, including classification information on the projects and the necessary performance data. Cost and schedule performance were measured through comparison to the objectives, and quality was defined by the degree to which the facility met the requirements set. Projects carried out using design-and-build delivery were found to achieve significantly greater cost and schedule advantages and were equal, or in some cases better, in quality performance.

In all the studies mentioned, an added input on communication and planning improved project performance. The conclusion that projects with contract types in which the contractor was responsible for more than just the construction work performed better supports this supposition also. Therefore, communication and planning are probably important elements for construction projects also.

3.3.4 Time performance as a success factor

Another element of performance that is of constant interest in construction projects is time. Time performance is a concept describing the amount of time needed to produce specified output. The aim in these studies is to find factors that influence time performance in construction projects.

Nkado (1995) conducted a survey of factors affecting construction project time performance in South Africa. The 33 factors proposed were listed under six categories: client, design consultants, contract, project, site management, and external influences. According to the answers of 29 respondents representing senior planners in construction firms, the three factors affecting the most were the client’s specified sequence of task completion, contractor’s programming of the work, and form of construction (steel, concrete, etc.). The factors with the least effect were contract type, the work of stationary undertakers, and prior working relationship.

Walker (1995) studied factors affecting construction site time performance in a sample of 235 projects in Australia. Time performance was determined using theoretical, predicted construction time, which was calculated with an equation including several variables describing site characteristics. A survey was made to determine the causal model of time performance. The main sum variables were:

- challenges outside the construction management team's control (project complexity etc.),
- effectiveness of the client representative team,
- the effectiveness of the design team's communication, and
- the construction management team's effectiveness.

Effectiveness of a construction management team was the most significant factor, and the client representative teams' operation was also worthy of note. Project characteristics and the design team had less influence on the effectiveness of the construction site. Although there is great variance in the variables that project management could not influence, these personnel were capable of reducing the potential problems through risk management, planning, manner of reaction, and so on.

Walker and Shen (2002) later studied time performance with two case studies. Their interest centered on how effective planning and control contribute to time performance. They developed a model describing the flexibility in overcoming unexpected problems on site and concluded that the ability to understand the project's complexity and to prepare flexible plans for solving unforeseen problems are essential to good time performance.

Chan and Kumaraswamy (1995) studied significant factors affecting construction duration in Hong Kong. They explored relationships between construction duration and project characteristics such as construction cost, gross floor area, number of storeys, and also productivity in some case studies. Project characteristics influenced construction duration, and government, private-sector, and civil engineering projects behaved differently. It was revealed that there existed "micro" factors not included in the study, embodying site organization actions that affect duration.

3.3.5 Summary of construction project success factors

Projects in different business areas differ in their success factors. Although certain factors probably are common to all project types, the factors specific to construction projects are, by nature, not the same as those applying especially to, for example, IT development or marketing projects. Success factors can be different also in different phases of projects. If a construction project is considered as a totality with a group of desired results, the question is which success factors are most important from the standpoint of the whole project.

Table 2 presents the factors with the most influence on a construction project's success as indicated by some previous studies. The studies don't have a common framework of possible success factors; some of them concentrate on certain issues in construction project operation, while others have a larger scope in terms of factors under investigation. This makes it difficult to get a comprehensive picture of the potential factors with the greatest influence on a construction project's success. Moreover, most of the studies were based on survey questionnaires, and thus they

Table 2. Summary of the construction site success factors mentioned in the literature.

Success factor source	Success factors	Studies
Project characteristics	Structure/project complexity	Thomas & Yiakoumis 1987, Chan & Kumaraswamy 1995
	Type of structural frame	Nkado 1995
Contracts	Contractor having design responsibility	Pocock et al. 1997, Fanifran et al. 1998, Konchar & Sanvido 1998
	Specified sequence of completion	Nkado 1995
Project members	Experience, competence	Sanvido et al. 1992, Chan et al. 2001, Walker 1995,
	Project team commitment	Sanvido et al. 1992
	Communication	Thomas et al. 1998, Pocock et al. 1997
	Planning/programming the tasks	Nkado 1995, Fanifran et al. 1998, Walker & Shen 2002
Environment	Site conditions	McKim et al. 1997
	Materials and equipment	Russell et al. 1997
	Initial information (from client and end user)	Russell et al. 1997, Sanvido et al. 1992, Moshini & Davidson 1992, Chan et al. 2001
	Client's competence	Chan et al. 2001, Walker 1995
	Changes in scope	McKim et al. 1997

shed more light on what project participants *think* the success factors are than on the actual situation that the measurements were intended to reveal.

The classification of factors is similar to the main classes of factors cited by Chua et al. (1999), who had three classes: "project managers, project characteristics, and contractual arrangements." Additionally, the class of "environment" has been included, which consists of different potential success factors cited that do not fall into the previous classes. These fall under environment because they are typically outside the sphere of influence of the project members. In presenting the success factors, compromises had to be made in the accuracy of the variable names used, for simplicity. The terms used in Table 2 have been chosen to best describe the findings of the studies.

Understandably, the complexity and degree of technical difficulty affect productivity and time performance. Contractual issues may exert an influence in many ways, but one factor seems to be that the performance is better when the contractor has greater responsibility in the project. The competence of the project team, and thus the standard of planning and management of the project, is one important group of factors. In the environment, one factor appearing in many studies is the amount of initial information from the client and end users, which seems to affect performance.

In this study, the focus is on those success factors that the site personnel can influence. Other success factors are part of the environment from the site perspective and can be analyzed as background variables but not as parts of the system model. The list of potential success factors provided in the literature gives some idea as to the elements that could be included in the performance model.

3.4 ORGANIZATIONAL BEHAVIOR IN CONSTRUCTION PROJECTS

3.4.1 The role of organizational behavior in construction site performance

The majority of the project management literature, especially where it deals with the construction industry, approaches project performance from the management systems point of view and concentrates on planning, controlling, and other management functions. However, the idea of emphasizing the effects of human actions in project operation has been discussed in some studies concerning the construction industry.

Rwelamila and Hall (1995) used a system theory approach by combining the ideas of total quality management and traditional project management, focusing on cost and schedule. They argued that quality should be an equal goal in a project, and the means to reach this would be that the organization be considered as a sociocultural system, where the "human" aspect of culture is included within the management scenario. This would lead to a "paradigm shift" from project planning, management, and problem solving to leadership and organizational behavior issues.

Also, some of the studies concerning success factors that are covered in Section 3.3 emphasize the role and actions of the project managers and teams in project success (Sanvido et al. 1992, Chan et al. 2001, Walker 1995, Sanvido et al. 1992, Thomas et al. 1998, Pocock et al. 1997, Nkado 1995, Fanifran et al. 1998, Walker & Shen 2002). Thus, construction site performance cannot be measured comprehensively without considering the human-related issues of project operation.

Human issues in projects are approached in studies typically from three perspectives.

1. The characteristics of a successful project manager.
2. The effectiveness of construction project culture.
3. Preconditions for the efficient work of the employees, focusing on issues like work conditions and stress.

3.4.2 Effective project management

Briner et al. (1995) found in their study that, even in projects that demand technical abilities, technical competence is not the factor that makes the difference between good and bad project managers. It is more important that a project manager be able to interact and communicate while managing the project's tasks. The authors list five key characteristics of successful project managers in general projects.

1. They can explain complicated things simply.
2. They don't panic in difficult situations but stay calm and find a step-by-step way forward with the team in the project.
3. They face up the problems, find out the causes, and make proposals to remove them.
4. They let people know what's happening all the time.
5. They keep in mind the big picture of the project environment while performing project tasks.

Abdel-Razek (1997) studied, in the Middle East, how project managers themselves would like their performance to be evaluated. With a structured group technique, he identified 52 ideas from the 110 participants. These were combined into 12 attributes. They were then voted upon and scored, and the relative importance of each was determined. The 12 measures were divided into five areas.

Efficiency
1. Efficient resource utilization (14,1 %)
2. Administrative and managerial efficiency (13,9 %)
3. Technical efficiency (5,5 %)
4. Record-keeping and documentation of experience (2,2 %)

Personal traits
5. Ability to innovate and develop (11,6 %)
6. Personal integrity (6,8 %)
7. Ability to communicate and establish contacts (5,3 %)
8. Discipline and adherence to company regulations and procedures (4,3 %)
9. Honesty (0,3 %)

Effectiveness
10. Achievement of planned, agreed objectives (14,6 %)

Quality
11. Adherence to requirements and achievement of quality (12,6 %)

Profitability
12. Profitability after analysis (8,5 %)

The criteria for a project manager's success involved factors having to do with both a manager's personal characteristics and project results, but the criteria focusing on the manager were clearly split between the traditional two aspects of management: production- and people-orientation.

Maloney (1990) developed a model for a construction manager's performance. According to him, the four key factors influencing a construction manager's performance are:
- effort,
- knowledge and skills,
- ability, and
- organizational constraints.

According to Maloney, although some of a project manager's capabilities are innate, it is nonetheless necessary to determine whether he or she has the skills needed for fulfilling his or her responsibilities, in order to improve the selection, assignment, and training of project managers. A performance appraisal system providing performance measurements with regular feedback should be used to eliminate organizational constraints.

Rowlinson et al. (1993) studied the leadership style of construction project managers of different cultural backgrounds in Hong Kong. They used Fiedler's (1967) Least Preferred Co-worker (LPC) scale and another questionnaire based on a four-dimensional model of leadership style to explore the influences of the situation on the preferred leadership style. The four leadership styles were: directive, supportive, participatory, and achievement-oriented. On the basis of two questionnaires with a sample of 28 projects and 29 site staff respondents, they determined that local Hong Kong project managers were more supportive and relationship-oriented than those of Western companies operating in Hong Kong. The directive and participatory styles of project management were those most appreciated by construction project staff.

Dulaimi and Langford (1999) explored how the behavior of project managers in the UK was connected to their effectiveness. First, a set of dimensions describing managers' behavior was determined with a group of 57 project managers, and then a questionnaire was applied to find out how they contribute to effectiveness. The authors found five dimensions.

1. Managing the project's environment and resources.
2. Organizing and coordinating.
3. Handling information.
4. Providing for growth and development.
5. Motivating and handling conflict.

The result of the second part of the study was, however, that project performance, measured by cost and time, and project managers' behavior varied independently of each other. Some aspects of behavior correlated with project performance, but individual and situational variables were also present and rendered the latter relationships insignificant in comparison. This illustrates again the complicated interaction of factors affecting construction project operation.

Egbu (1999) derived 75 management skills and competencies necessary for refurbishment project managers from previous research. Using semi-structured interviews of 32 training officers in 32 organizations in England, he determined that the most important skills / areas of knowledge were leadership, communication (oral/written), motivation of others, health and safety, decision-making, forecasting, and planning. The relative importance of forecasting and planning, managing conflict and crises, tenant welfare, team-building, and decision-making was higher in refurbishment projects than in other construction areas.

Fraser (1999) developed an effectiveness index for construction site managers that included 52 competence elements. It was used to measure the efficiency of 61

Australian site managers via an evaluation of 329 peers, superiors, and subordinates. Three groups of managers were tested: an elite group; adequate performers; and a group of poor performers, who were chosen as a control group from among those who had been recently dismissed or voluntarily left site management work due to inefficiency. The competencies of well-performing managers were not prioritized in the study, but it showed that similarities in character exist between managers of the same effectiveness level.

The study continued (Fraser 2000) by bringing in a set of 26 personal characteristics influencing the effectiveness of construction site managers, determined by a panel of 16 experts. These characteristics were tested using the effectiveness index, among 61 site managers. Only half of the factors that were supposed to indicate effectiveness showed a correlation. The factors correlating significantly with effectiveness were involvement in continuing professional development, number of firms worked for, use of addictive substances, education level, membership of professional bodies, job satisfaction, motivation, career aspirations, stress level, leadership style, and need to work.

Sotiriou and Wittmer (2001) studied in four sequential studies the methods of influence exerted by project managers. With questionnaires given to a large sample of project managers, they developed a model of how project managers can influence their team members. The means of influence were: creation of challenging projects, proper exercise of authority, competence, rewards and incentives, professional integrity, negotiation, personality, and persuasion. These means of influence form one framework for project managers' leadership dimensions, although limited only to interaction with team members.

Arditi and Gunaydin (1998) studied the factors affecting project process quality with a questionnaire administered to persons responsible for companies' quality operations. There were 137 respondents in the sample. Generally, the means to improve process quality were, according to them, management commitment and leadership, training, teamwork, use of statistical methods, supplier involvement, and customer service. It was found that project managers indeed have a strong impact on process quality and especially on the scale of the whole company's training, teamwork, and cooperation networks. However, statistical methods were applied less successfully at the construction project level, because of the differences between projects. Industry-specific quality factors were clarity of specifications; efficient supervision; and a detailed maintenance manual, which improv the building maintenance in the future.

Graham (1996) studied how a "Machiavellian" leadership style functioned in project organizations. This refers to the capability of engaging in "politics" in organizations, meaning the skill to maneuver in the fight for power and authority. Based on a survey, he found that the cynical and manipulative Machiavellian leadership style does not suit projects well, and that a more straightforward, result-focused style is more advantageous.

Managers of construction projects have been the subject of a couple studies in Finland. The approach of construction site managers was studied in the early '90s in the Tampere region (Hyttinen 1994). The behavior of 31 foremen and general foremen was studied at 16 construction sites, in a study conducted using a systematic observation method called OSTI (Operant Supervisory Taxonomy and Index), with which behavior of foremen was monitored by outside observers. The management style of successful foremen was compared to that of less successful ones. Success was measured via a questionnaire administered to workers; workplace housekeeping measurement; and "productivity," which meant in practice the cost predicted for the site in comparison to the target budget.

Hyttinen (1994) found that the best management style was interactive, cooperative, and democratic. Workers liked foremen whose presence was felt but who were not too strict in their goal setting and control. However, workers were specifically asked in the questionnaire how they evaluated foremen as leaders of people and "servers" of workers, and the basic assumption of the study was thus that a participatory leadership style was the most effective. The results as regards the actual foremen were thus not tested by reliable means.

Management style and performance of site managers has been studied also by a Finnish management consultancy company PSYCON, where a leadership questionnaire was used and the research included 78 project managers at 30 construction companies (Lahti 1992). The management style of general foremen was compared to that of foremen in other industries, and a questionnaire-based study was performed also for subordinates in order to find out the orientation of foremen's leadership style.

According to their subordinates, foremen achieved the best results when they were determined and goal-oriented but also listened to workers and gave them responsibility. In this management style, foremen concentrate on creating the preconditions for production and let workers do their jobs in an atmosphere of trust. The problem in the study was that, again, the result is based on the opinions of subordinates and not on objective measurements.

Many studies have been conducted to find out the characteristics of effective project managers. The typical method is the survey, and the result is usually a list of important characteristics of project managers. The characteristics are divided roughly along the lines of those relating to a manager's personal characteristics and leadership skills and, on the other hand, technical and control system management competencies. The weakness in these studies often is that the data on effectiveness of managers come from opinions of subordinates or managers themselves and objective and comparable measurements of effectiveness are not used.

3.4.3 Successful construction project culture

One aim of organizational culture studies is to find the most beneficial set of culture dimensions in the relevant environment. Different typologies of culture dimensions are presented in many studies, as presented in Section 2.7. Lansley (1994) analyzed organizational theories from the construction business standpoint and found that many typologies can be presented at a simple level using four common categories. The names of the cultural dimensions of some models are banded together accordingly as follows.

1. Bureaucracy – task culture – hierarchy
2. Organic – clan – family
3. Mechanistic – role culture – market
4. Adhocracy – person culture – village market

Wang (2001) identified the key dimensions of the project culture with a questionnaire administered to a sample of 323 Australian project managers. He found through factor analysis that four dimensions existed: professional commitment, project team integration, work flexibility, and work performance.

Hughes (1989) used system theory to analyze construction project organizations. The system included the perspectives of objectives, control system, operations, hierarchies of decisions, and roles and responsibilities. Certain criteria for ideal operation were determined, and a case study was conducted to find out whether these characteristics existed. The study focused on the structural aspects of organizations, but the importance of organizational behavior was acknowledged. The most important success factor was **integration**, which means in this context that the organization must ensure that people with different capacities and skills complement each other in a cooperative way. Integration is a concept connected also to the amount of communication in a project, as used in several of the studies presented in Section 3.3.3. In addition, Jennings and Kenley (1996) argued that integration is the key factor for a successful construction project. Completion of a construction project requires a number of special competencies, and additionally the integration of the different specialist tasks is a specialty in its own right.

Handa and Adas (1996) conducted a study on organizational effectiveness from the perspective of a whole construction company, applying a competing values framework. In the study, 14 variables connected to the fourfold model of competing values were determined and a questionnaire was composed to determine their strength in 76 companies. Efficiency was measured with three variables: percent of projects completed on schedule, percent of projects completed within budget, and percent of projects completed without claims and with an acceptable level of compliance with client specifications. Through correlation analysis, five out of 14 variables were found to be related to efficiency. These were organizational attitude towards change, ability to handle multiple projects, level of planning by management, strength of organizational culture, and level of worker participation in decision-making.

A framework approaching most closely that of the competing values approach was used in the HUT Laboratory of Work Psychology and Leadership as well, as part of an international study where organizational cultures in companies in different countries were compared. The study measured organizational culture using the Focus method (Järvenpää & Eloranta 1997, Järvenpää & Martinsuo 1997).

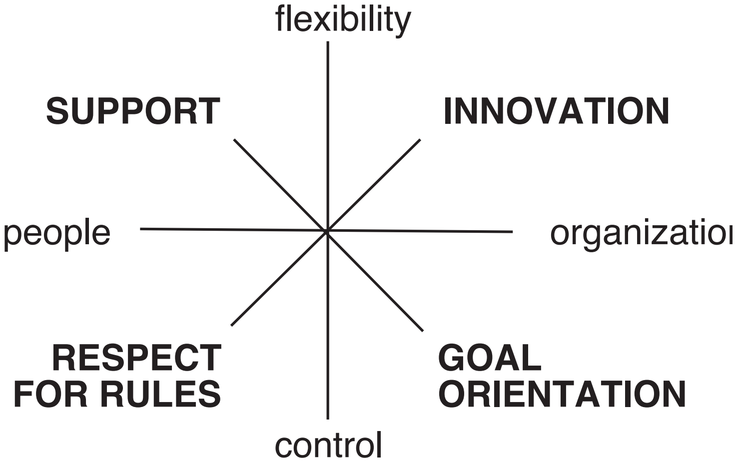


Figure 10. The organizational culture model associated with the Focus questionnaire (De Witte & van Muijen 1994).

In the Focus model, the Team culture was called “Support,” Hierarchy “Rules,” Adhocracy “Innovativeness”, and Firm “Goal orientation” (De Witte & van Muijen 1994). The concepts described culture types in more practical terms, but the content of the model was essentially the same (Fig. 10).

The Focus questionnaire was used in a slightly modified form to analyze the organizational culture of seven construction sites (Salminen 1997). Although the number of sites analyzed did not make a proper statistical analysis possible, it was concluded that the dimensions of Support (clan) and Goal orientation (market) seemed to be the most important in a construction site context. The other two dimensions didn’t seem to describe the culture of a construction site very well, because they varied independently of the other meters and key figures describing the characteristics of the sites.

At the construction site level, interest has primarily been shown in the characteristics of project managers, and few studies have been done on the organizational culture. This is unfortunate because construction projects offer a fruitful ground for analyzing the common features of an efficient culture. According to Wang (2001), every professional environment creates its own culture tying members of a profession to the professional community that ensures the continuation of a profession and guides its members to think and behave as the profession requires. Because a profession is not limited to the confines of a particular organization, industry, or nation, the professional culture stretches across their boundaries. Therefore, construction projects should also have their common preferred cultural characteristics, and knowledge of these would guide companies to emphasize the right things in their operation.

3.4.4 Work conditions

Efficiency on a construction site can also be studied on the individual level from the workers' perspective. Although in this study the scope covers the construction site as a whole, work conditions and related issues concern not only single workers but also the operation of the whole site. In this study, the interesting question is how important the work conditions and motivation of individual workers are to the performance of the whole site.

The concept of work conditions includes both the concrete environment and the workers' psychological environment. Smithers and Walker (2000) studied the effect of work environment on worker motivation in Australia. The survey asked respondents to rate motivating and demotivating variables in terms of their importance and degree of presence. In the study, it was found that workplace environment indeed affected motivation level. The main demotivating influences among environmental factors were long work hours, chaos, non-recognition for work, and aggressive management style.

In Finland, the connection between work environment and performance has been the subject of a couple of studies carried out in the construction industry. One applied an action study approach on two construction sites in the Tampere region. On the sites, special attention was paid to safety and housekeeping by setting goals and measuring the level of housekeeping with a checklist (Hyödynmaa et al. 1986, Ariluoto 1986). The effects were examined through accident follow-up and a questionnaire. In a new study by Kemppilä et al. (2002), the safety meter results for 142 construction sites were analyzed and the connection to productivity was inspected. The problem with both of the studies was the failure in finding proper metrics for productivity; thus, the relationship between safety and productivity was not established.

Stress and conflict are often present in a construction project. In the study of Sommerville and Langford (1994), 54 UK project managers responded to a questionnaire asking them to rank causes of conflict and stress. The most important stress and conflict sources as indicated by the study were union issues (breaks etc.), role of the individual, personnel matters, contractual matters, and roles of others. This suggests that the issues causing the most trouble have less to do with technical or design matters than they do with relationships between people. Special stress management programs in companies were suggested as the solution to stressful situations.

Junnonen (1992) studied what causes stress to construction site foremen with a questionnaire measuring both the stress experienced and what the respondents thought caused most of the stress. The material consisted of 99 responses from major Finnish construction companies' foremen. A tight schedule was found to be the major cause of stress and rushing. Bad work climate and responsibility for costs and quality were the other most common stress factors. It was concluded that when the construction process is better planned and controlled, there was less stress.

Thus, the result was contradictory to those of Somerville and Langford (1994), who found the most critical stress factors to be people-related issues.

Using a multiple-case study, Laurikainen (1999) studied construction site work groups and the relationships among cooperation, "work joy," and quality. By work joy he meant whether the workers liked their work, which was a slightly more superficial attitude, varying on a daily basis, than job satisfaction. Process and product quality was measured with a quality meter, and questionnaires were used to measure cooperation and work joy at ten construction sites. The conclusion was that genuine cooperation in work teams improved quality but work joy did not necessarily promote high quality.

The results are slightly contradictory, and it seems that the connection between work conditions and performance is ambiguous. The same applies to general work condition studies, with Mullins (1996) stating that no clear connection between work conditions and efficiency has been established despite the many studies addressing the issue. In addition, what causes stress and what are the most important elements of "work conditions" are not clearly defined for the construction project environment. It may be that in the construction business, the term "work conditions" means something else than it does in other, more stabile workplaces.

3.4.5 Summary of organizational behavior in construction projects

The crucial influence of project managers and the project team on construction project performance is widely acknowledged in the research. The most common area of research is the qualities and competencies of project managers. The studies produce long lists of widely ranging competencies, but a comprehensive and generally accepted list is not easy to present, because the approaches and frameworks of the studies are seldom comparable. If the results of the studies presented in this thesis are summarized, the important areas of project manager performance can be said to be related to:

- personal character: self-assurance, capability to tolerate stress,
- experience and education,
- communication and negotiation skills,
- competence in planning and control,
- problem solving and decision-making capacity; and
- leadership and teamwork skills.

Which areas are most important cannot be determined from the literature and perhaps depends a great deal on project characteristics and environment. However, the background and characteristics of project managers are issues that are not appropriate for the approach used here. This study is behavioral and thus concentrates on the actions of managers and their consequences, not on the managers as persons. Therefore, the elements that describe the observable actions of managers are those that should be included in the meter. It should somehow measure, for example, whether project management is oriented more to planning and controlling or to motivation and team-building.

As for general project culture and the preconditions for work activities, a comprehensive picture is even harder to draw, because of the many different approaches to these subjects. Every project has certain cultural dimensions, which are of course closely related to the managerial issues. If a framework or model for these relevant dimensions is found, then the ideal balance among them could be identified.

3.5 SUMMARY AND APPLICATION TO THIS STUDY

The concept of project performance concerns both the results and the operation of a project. Prior studies relevant to this piece of research can be roughly categorized as those examining:

- the components of “project success,”
- the measurement of components of performance,
- the interrelationship between the results and operation – or “success factors” – of a project, and
- organizational behavior in projects.

The definition of project success is a precondition for studying the success factors. Another precondition for studying them is that ways to measure the elements of performance have been developed. Previous studies are a source of ideas and methods that could be used in this study in choosing the relevant means of measurement for the research framework. Naturally, this study cannot include all possible elements suggested in other studies but only those that have a high probability of being the most important ones.

The important question at this stage is the elements of the construction site performance measurement system and the research framework the measurement system is based on. The system has to include the components of expected project results and the important elements of project operation, including the organizational behavior and leadership perspectives, and it should present how the various elements relate to each other. It must determine also which elements belong to the system and which are considered as part of the environment. This leads to consideration of the problem of developing the theoretical performance system model of how a construction site operates as a system.

4 DEVELOPING THE CONSTRUCTION SITE PERFORMANCE SYSTEM MODEL

4.1 APPLYING SYSTEM THEORY TO ORGANIZATIONS

In his general system theory, Ludvig von Bertalanffy (1951) explains the principles of how the originally mathematical system models can be applied to biological and social systems. In the ’60s, system theory become a major trend in organizational research (Scott 1961, Katz & Kahn 1966, Kast & Rosenzweig 1985, Trist & Murray 1990). In system theory, an entity is described as a group of elements and the interaction between them. One concept related to systems is the boundaries separating a system from its environment. If a system interacts with its environment, it is an open system, and otherwise it is closed. The parts of a system, its components, can be systems of their own subsystems. Quantitative tools and techniques are used to understand the cause-and-effect relationships, information flows, and feedback loops between system elements (Katz & Kahn 1966).

According to Scott (1961), the central goals in applying systems thinking to organizations are to determine:

- the strategic parts of the system,
- their mutual interaction,
- the main processes linking the parts together, and
- the goals sought by the system.

To understand what is the essence of systems thinking in the context of business management, Ackoff (1999a) compares systems with machines. Machines can be taken apart, and each of their parts can be studied separately. A system is more than the sum of its parts. It operates as a unit, and the emphasis is on the interaction and control of its elements. A system ought to be analyzed as a totality because the performance of a system depends more on how its parts interact than on how they act independently of each other.

Ackoff (1994, 1999a, 1999b) identifies three kinds of systems: deterministic, animated, and social. Deterministic systems don’t have a purpose of their own, and neither do their parts. Animated systems are organic creatures, or animals. They have a purpose as a totality, but each individual part functions only as a part of the whole. Social systems have multiple purposes: an organization has its own purpose, and so does every member of it.

Churchman (1968) outlines five basic considerations that should be kept in mind in studying systems:

1. the total system objectives and the performance metricst related to them;

2. the system's environment and fixed constraints;
3. the resources of the system;
4. the components of the system and their activities, goals, and performance metrics;
5. the management of the system.

Gharajedaghi (1999) presents five principles that are an attempt to define essential characteristics and assumptions about the behavior of a social system. *Openness* means that the behavior of open systems can be understood only in the context of their environment. *Purposefulness* is about understanding the rationale of different actors in systems. *Multidimensionality* means that instead of acting counter to each other, opposing tendencies in systems can coexist and interact, also forming complementary relationships. Having an *emergent property* means that in addition to the properties of parts of a system, the system has properties as a whole. *Counter-intuitiveness* means that actions intended to produce a desired outcome may in fact generate the opposite results.

Recent organization research applying system theory has focused especially on the interaction between the organization and its environment (Katz & Khan 1966). An organization is seen as an open system that is affected by pressures coming from its environment. Outer pressures are even more important than internal components in modifying the operations and functions of an organization. For efficient operation, it is essential to find harmony between internal components and external environment (Scott 1992). This approach brings us closer to the approach of contingency theory (Kast & Rosenzweig 1985, Steers & Black 1994, Lawrence & Lorsch 1967, Mintzberg 1983).

Senge (1994) looks at systems from an organizational behavior and learning perspective. He calls systems thinking the "fifth principle" tying together the other four principles, these being personal mastery, mental models, shared vision, and team learning. This proves that systems thinking can be applied for many purposes and is not as mechanical an approach as it is sometimes accused of being.

However, system theory has been criticized as unable to provide comprehensive description of the full complexity of an organization with all its elements, interactions, and feedback loops. From this criticism emerged a concept called Soft Systems Methodology (SSM). It is a technique of illustrating and developing systems consisting of both mechanical and human elements (Checkland 1999).

In SSM, the models are "human activity systems" describing situations where people attempt to take purposeful actions that are meaningful to them. The purpose of SSM models is to solve problems. Because the world is full of systems linked to each other, one has to make a choice as to which ones are most relevant in exploring a problem. This means that the perspective and viewpoint of the system must be decided upon to ensure that relevant activities are covered in the model. These models are used not as accurate descriptions of reality but as conceptual models for understanding and learning about factors and factors' relationships connected to the problem. Soft systems methodology models are often presented as a "rich picture" containing drawings to indicate elements of human actions (Checkland 1999).

According to system theory, in an organization, doing the obvious thing does not necessarily produce the obvious, desired outcome (Scott 1961). According to Gharajedaghi (1999), forecasting and business analysis often fail, as do strategic plans, because they concentrate on handling the complexity of details, trying to determine all the numerous elements and causalities in a system. Instead, one should strive to understand dynamic complexity in the short run and the long run, and the different consequences of changes in different parts of the system. A way of coping with dynamic complexity is to learn to use feedback showing how actions can reinforce and counteract each other. Thus, one doesn't have to know every detail of the system; with learning from feedback, even a general knowledge of central elements and characteristics of the system can aid in understanding how and why different inputs influence the system.

The system dynamics approach to organizations means assuming a holistic view and using system models and feedback to understand an organization's operation. Rodrigues and Bowers (1996a, 1996b) suggest it as an alternative to traditional project management techniques concentrating on detailed planning. Instead of having this focus, the system dynamics approach emphasizes the behavioral aspects and feedback function of projects and their relation to managerial strategies. They end up recommending as an ideal situation the combination of the traditional and system dynamics models in a single practical methodology.

In this study, systems thinking is applied as the general framework for developing the measurement system and also analyzing the measurement results. More important than the creation of a detailed model is applying the general principles of systems thinking in determining the site operation characteristics leading to a successful implementation, when the environment is the Finnish construction industry.

4.2 SYSTEM MODELS OF ORGANIZATIONS

System models typically describe organizations in terms of input, transformation, and output. Organizations are the transformation systems that turn resources into products; services; and other, perhaps non-measurable results (Fig. 11). According to Handa and Adas 1996, four general approaches to system models of organizations can be distinguished. These are system models that view the performance of a system as the ability to exploit its environment (resource models), ones where performance is judged by the efficiency of the internal process (internal process models), those judging performance by the degree of adaptability to external forces (strategic adaptation models), and ones that view organizations as open systems (open system models).

The interesting question is what the specific elements of the organization's operation are. Kast and Rosenzweig (1985) determined the components of an organiza-

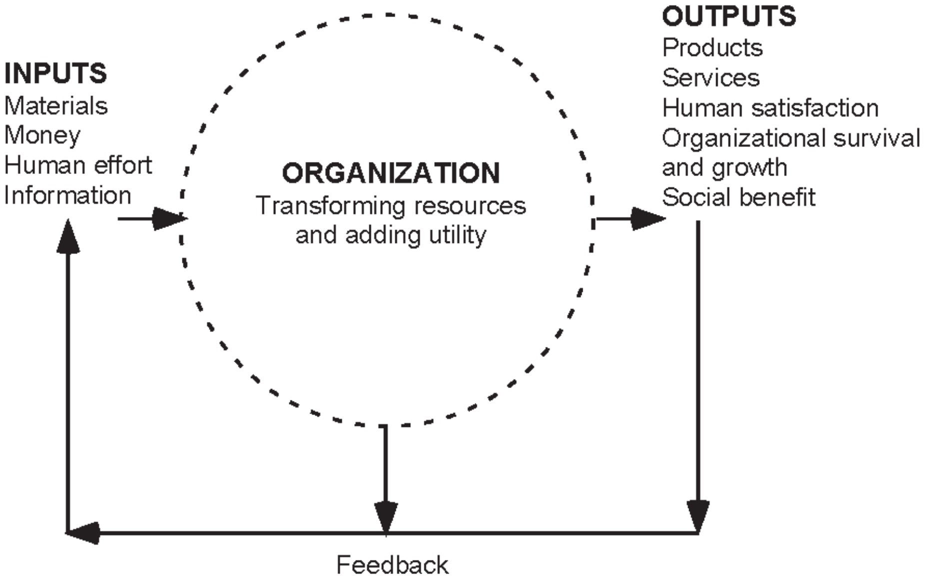


Figure 11. The organization as a transformation system (Kast & Rosenzweig 1985).

tion to be goals and values, technology, the psychosocial system, and the structure of the organization, with all of these controlled by a management system (Fig. 12). The authors emphasize that an organization is not simply a technical or social system but, rather, the structuring and integrating of human activities around various technologies. The technologies affect the types of inputs into the organization, the nature of the transformation processes, and the outputs of the system. However,

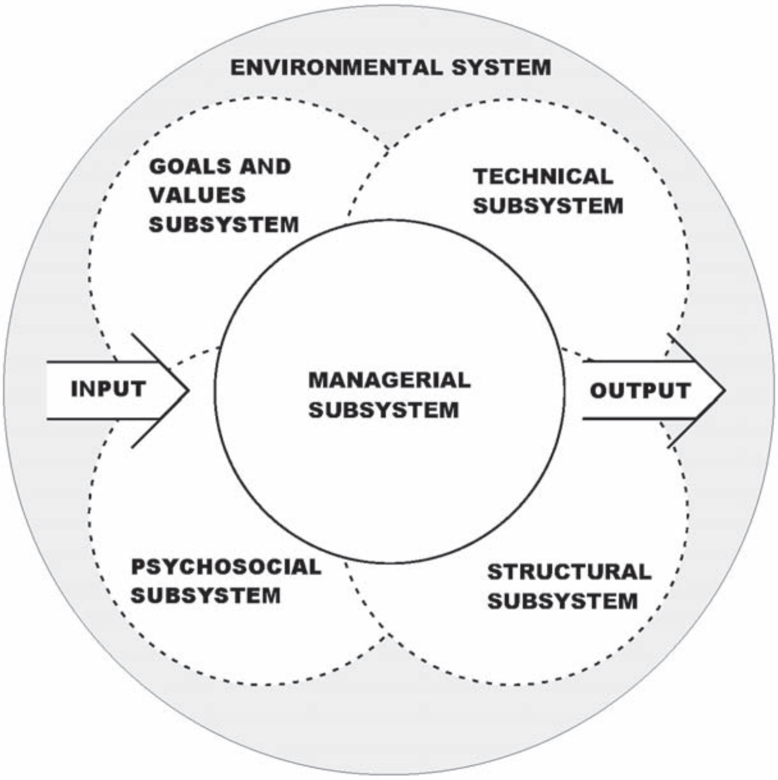


Figure 12. Kast and Rosenzweig's (1985) organization model.

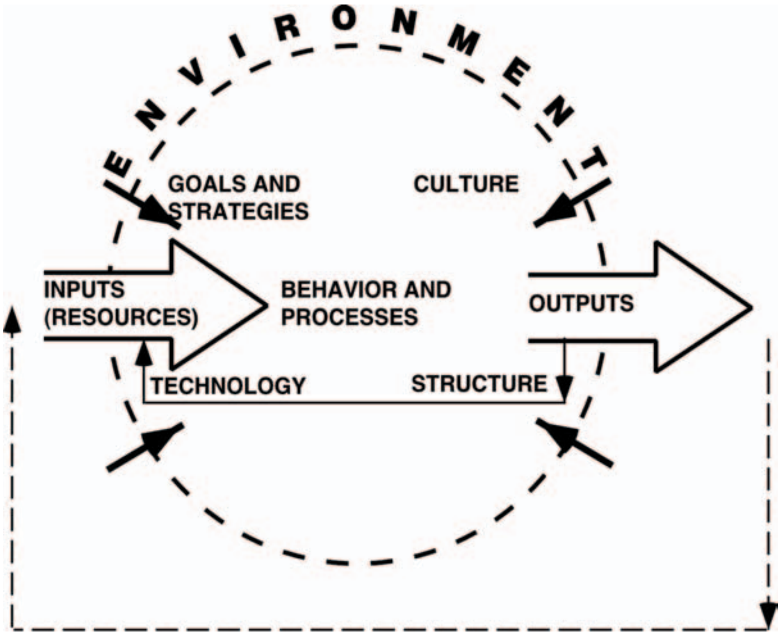


Figure 13. Organization system model of Harrison (1994).

the social system determines the effectiveness and efficiency of utilization of the technology.

The interesting question is what the specific elements of the organization's operation are. Kast and Rosenzweig (1985) determined the components of an organization to be goals and values, technology, the psychosocial system, and the structure of the organization, with all of these controlled by a management system (Fig. 12). The authors emphasize that an organization is not simply a technical or social system but, rather, the structuring and integrating of human activities around various technologies. The technologies affect the types of inputs into the organization, the nature of the transformation processes, and the outputs of the system. However, the social system determines the effectiveness and efficiency of utilization of the technology.

The model of Kast and Rosenzweig carries similarity with a system model presented by Harrison (1994). This too is an input/output system with environmental influence, but the process parts are goals and strategies, culture, technology, structure, and behavior and processes (Fig. 13).

Mullins (1996) describes the operation of an organization as a series of activities and the related subsystems. Subsystems include an organization's tasks or objectives, technology, structure, people, and management. Management is the integrating element that coordinates subsystems and directs activities. Mullins emphasizes that in order to improve organizational effectiveness, attention should be focused on the total work organization and the relationships between the variables affecting organizational performance.

Gharajedaghi (1999) calls an organization's operations "throughput processes" containing all the activities necessary to obtain the required inputs, convert inputs into outputs, and bring the final products to market. Marketing, sales, order pro-

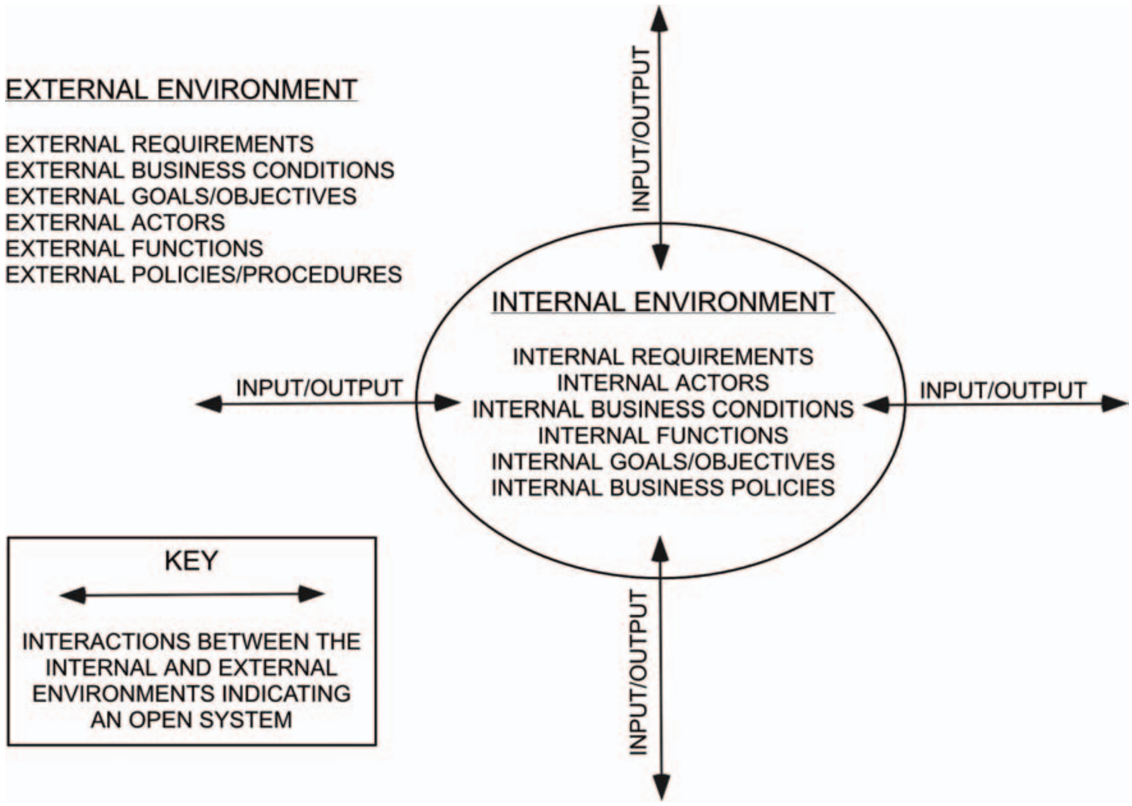


Figure 14. A project as a system containing both the external and internal environment (Kliem & Ludin 1995).

cessing, purchasing, producing, shipping, billing, and accounting – including all management systems to control quality, time, and cost – are parts of the throughput chain. In addition to these technologically driven processes, an organization as a social system needs four other basic organizational systems: membership, a decision system, conflict management and learning, and control.

Kliem and Ludin (1995) describe project components with a system model. It features both external and internal environments, and their components interact with each other. A component can be an actor, function, policy, procedure, goal, or requirement that performs a significant function. Actors or key players in a project are the client, senior management, project manager, and team. Each contributes to the successful execution of a project (Fig. 14).

The examples in this section illustrate organizations or projects at a general, conceptual level, pointing out the different perspectives that are part of an organizational system. It is possible to separate different components as subsystems, continue the distinguishing and characterization of different elements, and try to determine causalities accurately. However, an attempt to accurately describe every element and causal relationship in a system does not necessarily produce any useful information, because such a model may be impossible to create or verify as accurate. The model must be appropriate for the purpose at hand, and it has to include the essential elements of the operation of a construction project.

4.3 CONSTRUCTION PROJECT SYSTEM MODELS

Completing or choosing the construction project system model is the first step in developing the performance measurement system. According to Liu and Walker (1998), the problems in performance evaluation arise expressly from the difficulty of modeling performance. The difficulties they identified are the complexity of performance variables and the focus of the model (performance outcome or performance process). Thus, what to include in the model has to be decided upon, and, consequently, the indicators have to be determined.

Often, the choice of model elements is made through the use of interviews or questionnaires administered to project managers, and via correlation or factor analyses. According to Ashley et al. (1987), the analysis procedure can be biased by the manager's or researcher's beliefs or by the available data. The model may be simple but not representative of the actual environment. Also, because humans often have difficulties in dealing with causality, it might be hard to see whether the association between performance elements and project success is a true causal relationship.

Hughes (1989) analyzed construction projects from a system theory perspective. In the study, a system theoretical model of construction site operation was developed and the ideal organization structure was sought. Components of the model included goals, control, operations, tasks, decision hierarchy, and responsibilities. The central issue in the analysis was the operational environment of the site, which was the basis for comparisons between site organizations. The study concluded that a flexible, dynamic, and adaptive operative model was recommendable over the existing static structure. The study focused on structure, and a psychological viewpoint was not included, which the author himself acknowledged as a deficiency in the study.

Jennings and Kenley (1996) argued that the dynamic approach of systems thinking is more appropriate in understanding and developing construction project operation than the traditional structural and hierarchical approach is. In addition to the numerous specialties demanded in a construction project, an integration function is needed for "relationship management of the system contemporary." According to them, it is necessary to identify the significant elements of the construction project system model, and to incorporate the human and cultural issues into the model as well. With the system approach, it would be possible to determine the role the external and internal elements play in characterizing a construction project's performance, which is exactly the approach taken in this study.

Fryer (1990) compiled a "system model" describing construction sites' process from the management point of view (Fig. 15). The system includes a strong emphasis on the manager's duty to deal with designers, the client, and unforeseen events, which is similar to the organizational behavior function in many system models. Fryer sees the outer environment of a construction process as pressures from designers, consultants, the company head office, and suppliers. It is remarkable that

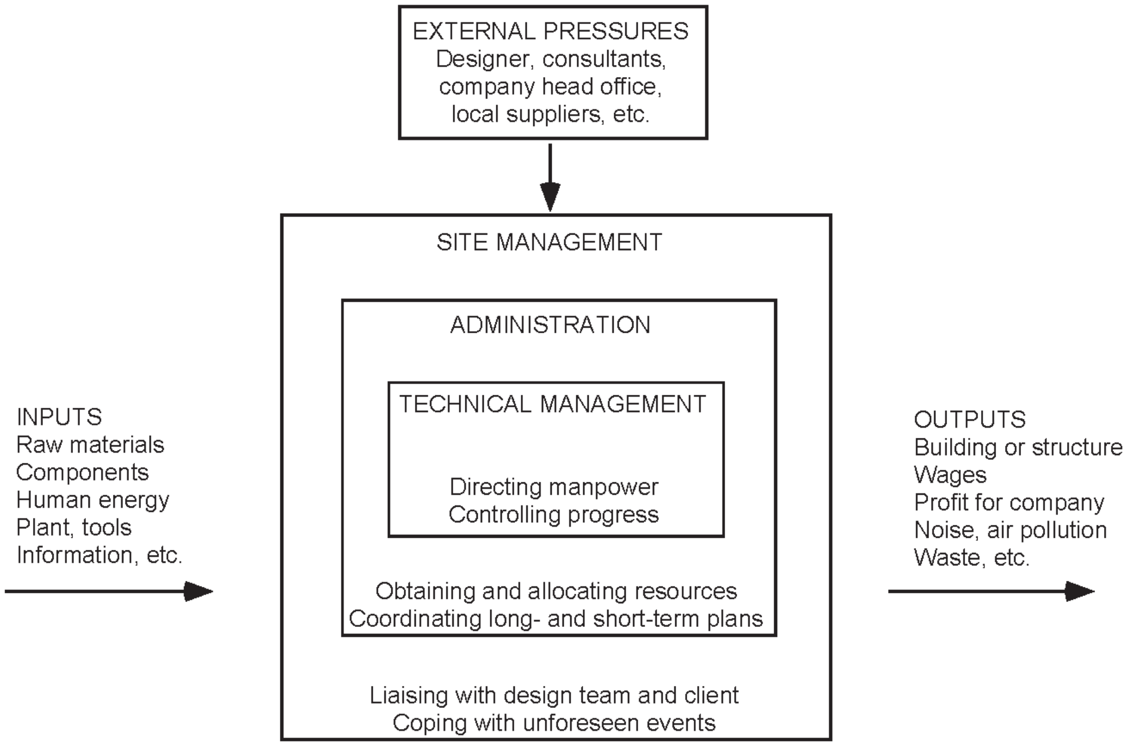


Figure 15. System view of management of a construction site (Fryer 1990).

although a site is, in a sense, a company of its own in many respects, the concept of environment is more limited than it is for the whole company. After the project has been initiated, the existence of, for example, competitors is irrelevant and the focus is on carrying out the project tasks according to plan.

Liu and Walker (1998) used in their study a system model to describe construction project operation (Fig. 16). They used it to analyze the behavioral aspect of project management. Their argument was that behavior is purposeful and actions are triggered by project goals whenever the feedback link is operative. Goals are likely to be organized into a system with no structure, which is capable of change according to context.

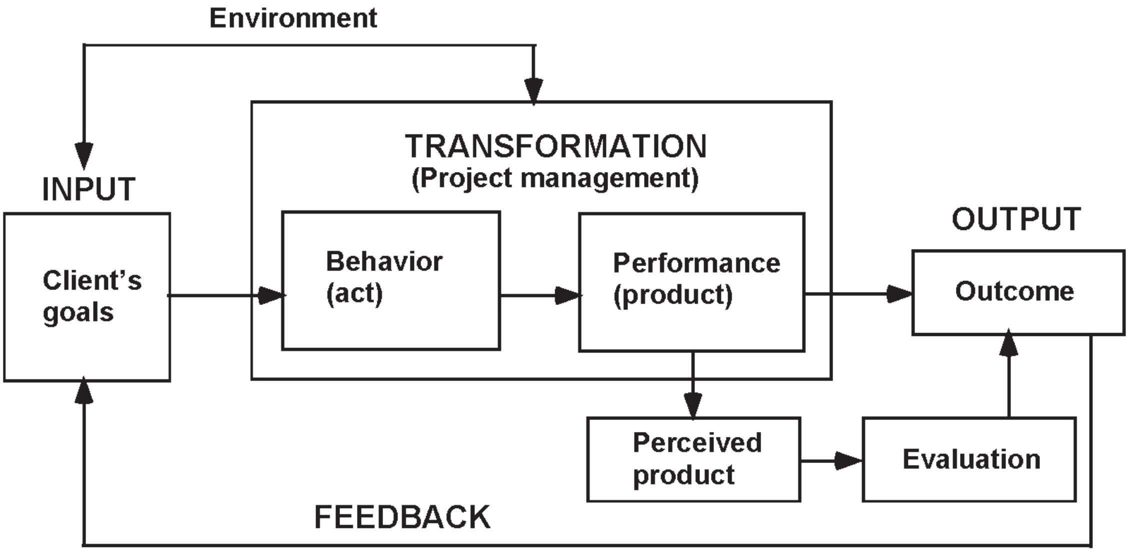


Figure 16. Project operation process (Liu & Walker 1998).

Stewart and Fortune (1995) use systems thinking in identification and prevention of construction project risks. They use the soft system analysis approach in combining the softer "human" elements and hard, tangible factors, such as structure and processes. The tools and techniques used were rich pictures illustrating a holistic view of the situation, systems maps offering a snapshot of the structure of the area examined, and influence diagrams exploring the important relationships between components. The ideal situation is presented as a formal system model with the capability of purposeful activity without failure. The formal system comprises subsystems for decision-making, performance monitoring, and all the elements that carry out the tasks involved in the system transforming its inputs into outputs.

Although construction projects are full-blooded projects with their own unique characteristics, all construction projects have much in common, as contrasted against the variety of projects implemented in organizations. Since their characteristics in fact include some traits of serial production, from a construction company's perspective they should be considered as such. That construction projects have repetitive tasks and phases allows for the possibility of developing general models and processes for project implementation. This justifies assigning importance to developing a construction-project-specific system model with the appropriate performance meters.

4.4 THE CONSTRUCTION SITE SYSTEM MODEL

In systems thinking, organizations are considered as series of actions, where the starting point is that of input and the results of the actions are the output. In the middle is the organization's transformation process with its various components. Moreover, the system includes interaction between the organization and its environment, and the items belonging to the system must be separated from those that are part of the environment, through definition of the system's boundaries.

In the system models presented in Section 4.3, the typical elements of a system model of an organization or project are:

- input,
- process,
- technology,
- organization structure,
- management/control system,
- organizational behavior,
- contract (especially in construction projects), and
- output.

A construction project has several phases, starting with the awareness of the need for a new building or renovation (Fig. 17). In principle, the project's phases can be also viewed individually so that the phases constitute separate processes following one another in successive order, although in reality the roles may vary and

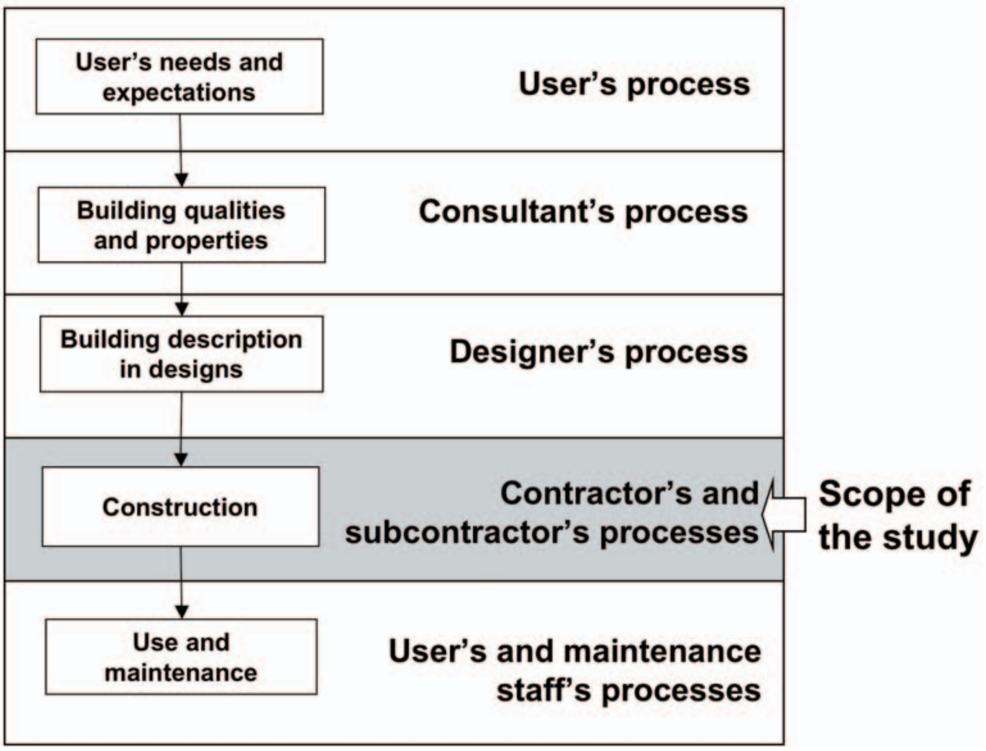


Figure 17. The scope of this study in relation to a construction project phases.

the phases overlap. The chosen scope of this study is that of the contractor, the actions taking place in the physical environment of the project, and the functions immediately supporting them. The construction phase begins upon commencement of preparation and initiation of the actual construction work In this phase, the means to influence the preconditions of the project are limited and what is imperative is to implement the construction process as cost-effectively as possible, fulfilling the other specifications set for the product. Thus, the items included in the performance system model should be those that potentially influence project success in the construction phase.

First, the elements of **input** are to be determined. Fryer (1990) determined inputs to consist of raw materials, components, tools, etc. (Fig. 15). In a concrete sense, they undoubtedly are, but in this study, the aim is to find those elements that cause a project to succeed or fail. It is characteristic of materials and suppliers in the construction industry that they are equally available to everyone. If the availability of resources doesn't vary from site to site, they consequently can't be the critical success factors, which separate successful projects from less successful ones. Moreover, many decisions and contracts related to major resources have already been made when the project commences from the project manager's perspective – for example, the annual supplier contracts. A method for including the vast array of variables covering the variety of materials and suppliers would be a research subject of its own, and resources and suppliers were therefore considered to be beyond the scope of this study.

Fryer has placed the influence of designers, company headquarters, etc. in a box labeled "external pressures." Earlier studies (e.g., Russell et al. 1997, Sanvido et al. 1992, Moshini & Davidson 1992, Chan et al. 2001, Walker 1995) indicate that initial information and client competence have an influence on a project's success. Initial information and other preconditions for projects are expressed in documents compiled by consultants, designers, and the construction company's own office where the line manager and other staff have prepared the project. Project management has some potential to influence these items, such as by actively demanding the information that is needed. Also, the model of Liu and Walker (Fig. 16) has the client's goals as input, which is similar to the concept of initial information. Therefore, the actions of consultants, designers, and company office staff establish the critical preconditions for the project, which can be considered as the input in the system model of this study.

As for the elements of **process** – technology, organization structure, the management/control system, the decision-making/management process, organizational behavior/culture, and the contract – all seem applicable to a construction project as well. However, some of them don't fulfil the requirement of being potential success factors, of separating more and less successful projects.

Although **technological** complexity certainly affects productivity, it isn't a success factor in the sense used in this study. Technical difficulty is a project-specific characteristic, which should be taken into consideration when estimating and planning the project goals. Therefore, success does not depend as much on the technology as on the skills and competencies of the project personnel to use it. If by technology is meant the technical advancement of methods, machines, tools, and such, it must be acknowledged again that in the construction business it seldom is a competitive factor. New methods and technologies are usually available to all from suppliers and subcontractors, and the competitiveness gained is short-term in nature. Although technological improvement is of great benefit to the construction industry as a whole, it isn't normally the issue on which competitive advantage depends. In any case, a method for measuring "technology" in a construction project in some rational way is yet to be invented. However, the central technical solutions may be considered as parts of the environment of the construction site system and treated as external variables.

The project organization is established according to the needs and demands of the project type, and the decisions are made before the actual operation commences. The management team consists of the project manager or responsible supervisor and other foremen plus, according to the size and degree of difficulty, possibly engineers and procurement personnel. The company's own workers, subcontractors, or subsidiary contractors perform the actual work, although the amount of subcontracting varies. Although the number of project personnel varies according to project size, the **organization structure** is essentially the same at the project level, at least in Finland. Structure was thus considered as not a potential success factor in the project process but, rather, a consequence of project or contract type.

A potential component in project operation is the contract. It means in practice the commercial framework of the project – whether it is a lump sum, unit price, cost and fee, or some other type of contract – and what is included in the contract

– just building, design-and-build operations, or some other responsibility. But like technology and organization elements, the decisions on contract type have been made before the construction phase, and the consequences of the contract are external factors that may influence the project but cannot be changed by the project personnel. Therefore, as are technology and organization, contract type is considered in this study as part of the construction project system's environment and included to the appropriate extent in the background variables describing project characteristics, but not in the system model itself.

Planning and programming is suggested as a success factor by Nkado (1995), Fanifran et al. (1998), and Walker and Shen (2002). Efficient planning and programming presumes that the project has a functional **management/control system** that is used properly in implementing the project. The management system certainly is in the sphere of influence of the project team and also a potential success factor that should be included in the model.

The important role of **organizational behavior** is one basic assumption in many classic organizational theories (Mayo 1946, Maslow 1943, McGregor 1957). Therefore, the organizational behavior in construction site operation is one potential success factor. The classic theories concerned with organizational behavior, or the "human aspect of performance," were presented in Section 2.7. Organizational behavior was approached from two main perspectives: those of organization theories and leadership theories. Organization theories explain the roles and actions of all people in organizations, and leadership theories concentrate on the actions and attitudes of the managers.

Project team experience and competence is cited as a success factor by Sanvido et al. (1992), Chan et al. (2001), and Walker (1995). Sanvido et al. (1992) suggest project team commitment, and Thomas et al. (1998) and Pocock et al. (1997) emphasize the role of communication. As both the importance of the leadership function and the performance of all people on a construction site have been acknowledged in the research, it is appropriate to divide the organizational behavior aspect into two sub-elements: **leadership** and **work behavior**. Leadership covers the actions of the project management team, and work behavior refers to the actions of all people on the site, such as workers. Work behavior is roughly analogous to the concepts of work climate and culture, but the word "behavior" is chosen because the intention is to focus on concrete and observable actions before the deeper structure of culture.

In Section 3.3.1, the indicators of project success provided by various studies were listed. The general project **results** – cost, time, and quality – are applicable also here. Other central indicators were customer satisfaction, safety, and environmental issues. In this study, the final outcomes of project results were expressed as time, cost, quality, and safety. Certainly, customer satisfaction would have been an important addition, but the companies already had their own methods for measuring this after a project's conclusion, and using a comparable meter would have necessitated measuring customer satisfaction twice. Also, the focus of this study was on items measurable in the middle of the project. Environmental impacts were

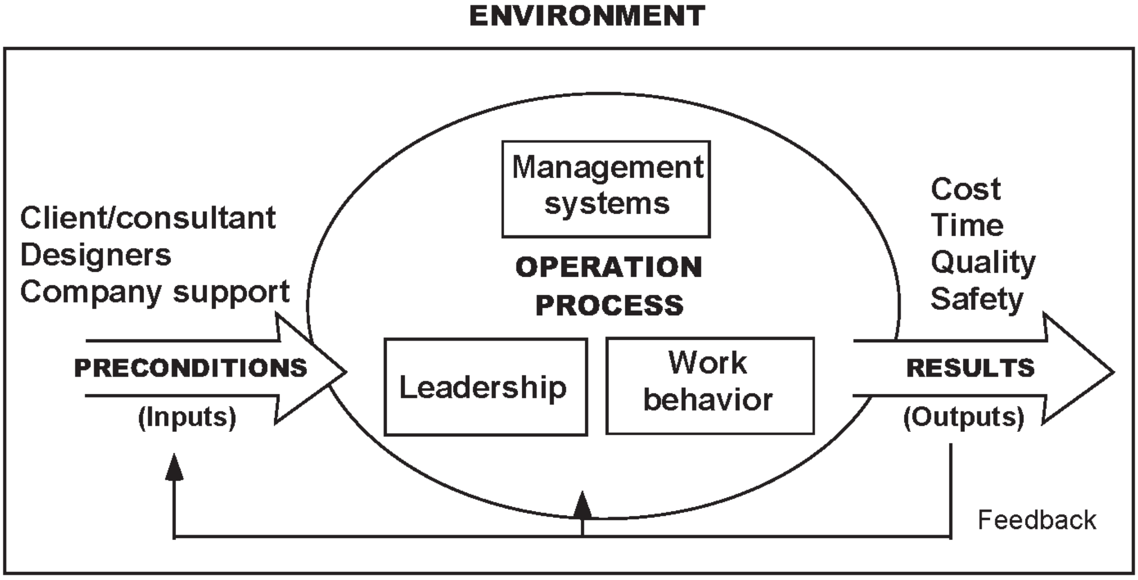


Figure 18. The construction site performance system model used in the study.

also left outside the scope of the measurement system, because adding them was not considered important enough (for the time being) in companies in relation to the resources demanded for developing a valid meter.

The construction site performance system model is compiled for the input/output process, where the process itself includes three elements: **management systems**, **work behavior**, and **leadership** (Fig. 18). Inputs are the combination of information and support from the client/consultant, designers, and company head office, constituting the **preconditions** for site operation. **Outputs** are the measurable results of the site operation, which are chosen to be in this case cost, time, quality, and safety.

The main parts of the model are thus preconditions, the operation process, and results. The preconditions portion comprises the support the site is given from clients, designers, and the head office. The process consists of the management system, work behavior, and leadership. According to Blake and Mouton's (1994) Grid theory, leadership focuses on both production and people. In the model, "production" constitutes the planning and controlling of the management systems box, with "people" covered in the work behavior box, referring to the concrete actions and work on the site. The study focuses on the relationships between results and other elements of the system model, so the relationships between operation process elements remain unspecified at this stage. Results are divided into cost, time, quality, and safety. The feedback has no separate meter but illustrates that the process of using the measurement system includes the feedback also.

The environment of the system consists of elements that can't be directly influenced by project members but do have potential influence on project operation. In the measurement system, the environmental variables are not systematically measured because they are not part of the focus of the study. However, the essential characteristics of the construction sites studied are registered, like the size, contract type, and amount of subcontracting. They can be used to find out whether the measured sites fall into groups on the basis of certain classifying variables, which can influence other measurements in a way that should be taken into consideration in drawing conclusions about the analysis.

The model developed is relatively similar to that of Liu and Walker (1998) (Fig. 16). It too is an input/output model, and the transformation phase is in many ways analogous to the model applied in this study, with its management and behavior components.

These are the elements and interrelationships thereof that together form the model for developing the measurement system for this study and a hypothesis for testing the interrelationships of the performance elements in the analysis. The next step was to develop the actual meters and therefore create a more detailed list of the variables involved for each of the system components.

5 DEVELOPING THE CONSTRUCTION SITE PERFORMANCE MEASUREMENT SYSTEM

5.1 THE PRACTICAL DEVELOPMENT OF THE MEASUREMENT SYSTEM AND METHODS

The construction site system model was developed by combining the knowledge gained from performance measurement and organization theories with the results of previous studies. However, the participating companies were the clients where the study was concerned, and they expected practical solutions to their problem of performance measurement. Therefore, the companies' commitment and acceptance of the solution had to be ensured. The development process was implemented in such a manner that in parallel with the theoretical study, a practical development process was conducted in cooperation with the companies. Although the field research in the companies concentrated mainly on developing the individual measurement methods, also the construction site system model was put to a "practical test" in the company context. The practical applicability of the model was discussed with project managers and other company personnel, and the development of the measurement methods started only after the companies had accepted the system model and its main elements.

A systematic procedure for the practical development of the construction site performance measurement system was used, where the ideas from the performance management systems presented in Section 2.6 were applied for the purpose of this study. It included six phases, which together describe the step-by-step process of developing the practical measurement system. Also, all the main principles of a constructivist study method, as presented in Section 1.6, are covered, but it describes the practical development phases in greater detail.

The phases of the development process are listed below.

1. Determination of the organization's task
2. Determination of the organization's structure and stakeholders
3. Analysis of the current performance measurement systems and methods
4. Determination of the purpose and objective of the performance measurement system
5. Design of the performance measurement system:
    - System model
    - Measurement methods
    - Measurement result processing and reporting systems
    - Piloting, testing, and finalizing of the measurement system
6. Use of the measurement system as planned in continuous improvement

Definition of the organization's task proved fairly obvious in this case. The aim of a construction project is successful implementation of the project. A construction project's success was determined in the system model to be a matter of costs, time, quality, and safety.

Identification of the stakeholders of a construction project is important because it describes the functional environment that is the project's setting and sheds light on different angles from which the project is to be considered. Figure 19, which shows participants in a general project, is applicable to construction projects as well. Outside the "core" of the project personnel are parties perhaps not occupied full-time by the project but nevertheless having an influence on it. They include resources from the company, suppliers, the client and users, and others. Moreover a number of "invisible members" may exist, who are specialists, consultants, or support functions used by the project (Briner et al. 1995).

In the case of a construction project, the procurement method and roles of the participants may vary, but as a project organization, they greatly resemble each other. There are clients or consultants who initiate the project, the site management team, company support functions, suppliers and subcontractors, and designers and specialists. When the performance measurement system model was compiled, the perspective chosen was the construction site or construction phase of the project, which is the perspective of the participating construction companies.

The third phase, analysis of the current situation from the performance management angle, has been described in part in Section 3, where a review of construction site performance studies was presented. Another part of the situational analysis is to become familiarized with the measurement systems used in the participating

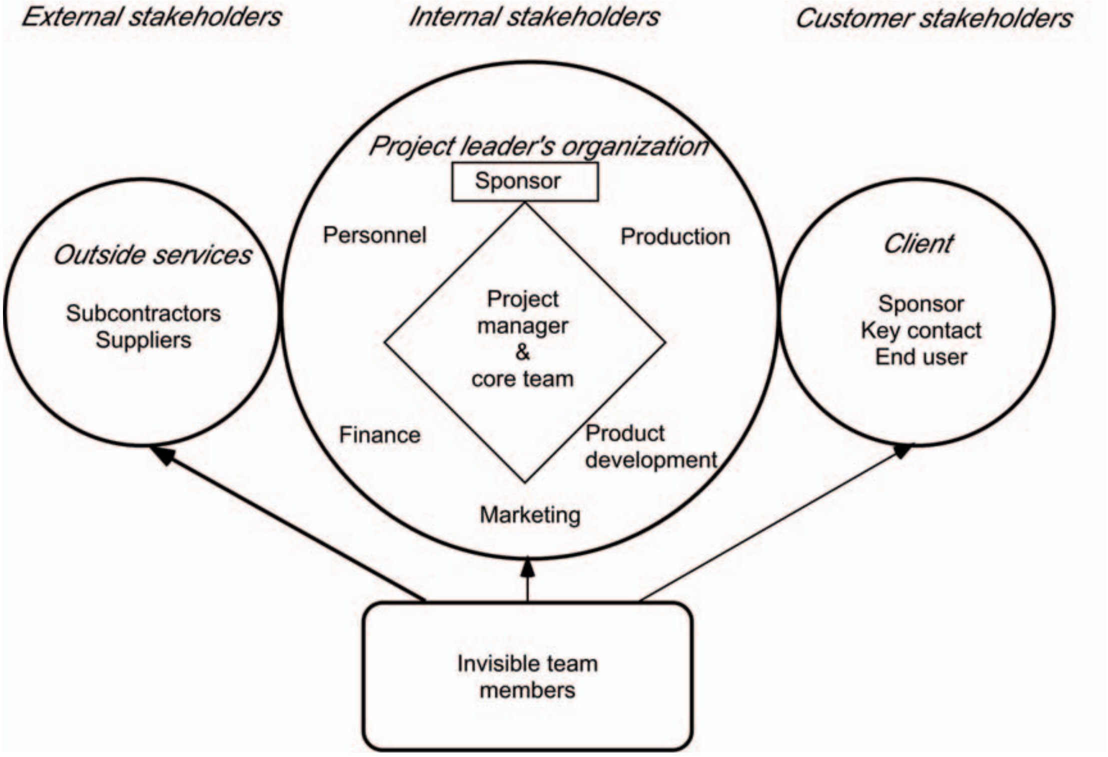


Figure 19. Stakeholders in a project (Briner et al. 1995).

companies. Systems presently in use in companies were used as background material for developing the measurement system whenever it was appropriate. Only in parts of quality auditing systems and quality measurement were remarkable differences between companies observed, but none of the companies had a numerical meter for these ends. Another essential observation on the present meters was that they were not used in a comprehensive way; instead, different meters were used independently of each other, and usually proper feedback was not provided to those whom the measurements concerned.

The intended use of the meter in performance development was determining the performance of individual sites, comparing the results with those of other sites and business units, and using the feedback in developing the operation. Derived from this, the purpose and objective of the measurement system was to measure the essential elements of the construction project operation and its results. The measurement system would include also a method for processing the reports, giving feedback to sites and companies, and suggesting development measures.

Following these considerations, the development of the actual measurement system took place. First, the construction site system model tying together the individual meters was compiled based on the literature review and evaluation. Also, the discussions and workshops in participating companies helped to ensure that the companies and other parties involved in the research considered the model functional.

The measurement system consists of separate meters for every performance element of the construction site system model. Developing each measurement method were, in effect, sub-projects in the research, connected to each other by the system model. The three companies in the study (Salminen 2000a) participated in developing the meters, but the work was divided up so that different companies or cooperating parties concentrated on different areas of the measurement system. However, all meters were also evaluated and accepted in every company. PSYCON Corporation helped with the practical methodology of the organizational behavior measurement tool. The development process involved two or three workshops at every company as well as many interviews and discussions with both project mangers and other experts.

After the first version of the meters was developed, eight sites were measured with it. On the basis of the experiences thus gained, additional adjustments were made to the meters. A spreadsheet-based method was developed for processing the results. An essential element of this was a summary page, a “performance scorecard” where results of all meters were presented along with comparisons to other sites.

Minor changes were made to the meters also during the measurement process. The wording of criteria was corrected to better describe what was intended, and some criteria were removed while others were added. Mostly the changes only improved the clarity of the meters and didn’t change their content, and thus the comparability remained. However, a few additions were made also, and consequently those measurement items were missing in the earlier measurements. In conclusion, the meters evolved to some extent even during the early measurement period, but the changes were small and care was taken that the changes did not have a considerable effect on the results of the meters.

The measurement system includes the construction site system model, the measurement methods for each performance element, and the method for processing the measurements into detailed reports and giving feedback to projects and company units. The measurement system consisted in practice of a folder of forms and sheets for collecting the necessary information from the sites. The measurement forms for the entire measurement system are presented in the first section of Appendix 1 (in their original language), but the principles of each meter are described next, in Section 5.2.

5.2 THE MEASUREMENT METHODS OF THE PERFORMANCE MEASUREMENT SYSTEM

5.2.1 Preconditions

The client/consultant, designers, and construction company headquarters determine the preconditions for a site. The site management team can influence those only to a limited extent, depending on contract type, but these still influence the operation. In evaluating site performance, it is necessary to know something about the operational preconditions, even if they are not part of the operation.

The role of consultants and designers is slightly different depending on the project and contract type. However, there is always someone who is responsible for controlling and supervising the project from the client's perspective: a consultancy company, the client's own organization, or the construction company's developers. As for designers, their role in a construction project is always to draw the designs where the product properties are specified. Although the possibilities for influence may vary according to the contractual arrangements, in the measurement system all forms of contracting are treated equally, while the information on matters such as the contract type etc. is collected so that it can be used to determine if the differences in project types and responsibilities affect performance.

The measurement method consists of a list of duties and tasks of the consultant, designers, and company line managers. It helps to determine how well these tasks are carried out from the construction project perspective. The meter is a standardized interview or questionnaire with a written list of questions for the project manager to answer. It includes a set of criteria related to how well the different parties succeed in creating the preconditions for the site operation.

The benefit of such a list is that one can complete the questionnaire quickly and a large number of items can be covered in a short time. On the other hand, all of the measurement is based on the opinion of one person and is thus subject to bias due to personal focus and values, although this error was minimized by formulating the questions and criteria as unambiguously as possible.

The preconditions meter was developed by compiling job descriptions for the parties and interviewing site managers on their expectations. Consultants' duties have been studied in a project concerning client quality system (Kuoppamäki 1998). The responsibilities of construction company line managers ("middle managers"or project managers responsible for several sites) were examined in a study at the HUT Construction Economics and Management unit concerning the quality of line managers in construction companies (Kolhonen 2001). But the majority of the data consisted of information on the participating companies gathered from the workshops and that gleaned from utilizing the insight of experienced project managers on how it manifests itself when the preconditions for the operation on the site are in good order.

The questions were created by formulating the criteria collected for solid prerequisites for operation as questions about the practical accomplishments of the consultant, designers, and head office. On the questionnaire, the questions were divided into three subject areas, each concerning one of the three parties, and their subcategories (Table 3). The full form is contained in Appendix 1, A1.2.

A four-point scale was used in the preconditions meter, the alternatives being "completely," "moderately," "badly," and "not at all." The omission of a neutral middle alternative was intentional, because without a neutral option respondents had to make the choice between "moderately" and "badly." The choice was forced for practical reasons, to make spotting the problem areas in cooperation easier on a single site in cases where the number of respondents didn't make statistical analysis

Table 3. The subject areas that are part of the metric for preconditions.

Preconditions for a construction site

- **A) Client/consultant**
  - Construction preparations
  - Cooperation during construction
  - Client procurements
- **B) Designers**
  - Main designer / design coordinator
  - Architect
  - Constructor
  - HVAC designers
- **C) Company headquarters**
  - Line manager
  - Cost accounting
  - Procurement
  - Marketing (in property development)

at the single-site level possible. On the other hand, this made the variables behave more like ordinal ones instead of interval-scale variables, which must be taken into consideration in the statistical analysis.

5.2.2 Operation process

5.2.2.1 Management systems

In this study, “management system” means a set of methods, protocols, and tools that assist in planning and controlling the operation so it is guided towards the desired outcomes. The purpose of developing management systems in companies is to find the “best practice” within the company and implement it as widely as possible. A management system for a construction site involves applications of software such as schedules, budgeting, and cost control but also a variety of systematic methods with varying levels of documentation to plan and control site operation, such as meetings and inspections of work.

Management systems have been evaluated in quality audits for years, so the method of checking them with the aid of some kind of checklist is familiar in companies. In this study, a general checklist for best practice for planning and controlling the construction site process would be developed and transformed into an index meter with which an individual construction site’s management system would be evaluated. The first task was to determine best practice for a construction site management system at a general level such that it is applicable to all companies.

One way to conduct project operations in general is described in the Project Management Institute’s *Project Management Body of Knowledge* (PMBOK) handbook. The project process is divided into five phases (PMBOK Guide 2000): initiating, planning, executing project plan, controlling, and closing. Even if the handbook is not intended specifically for construction projects, the phases are certainly analogous to those of construction projects. However, the purpose in this study is to get a snapshot of the management system of a construction project in the middle of the project, so categorizing management tasks according to time-based phases is not the best possible approach.

The project management tasks dealt with in the project management handbooks of Kerzner (1998), Meredith and Mantel (1995), and Lewis (1998) can be summarized as follows:

- organization and resource allocation,
- cost estimation and control,
- scheduling and time management,
- project monitoring and control,
- change management,
- quality management, and
- general management.

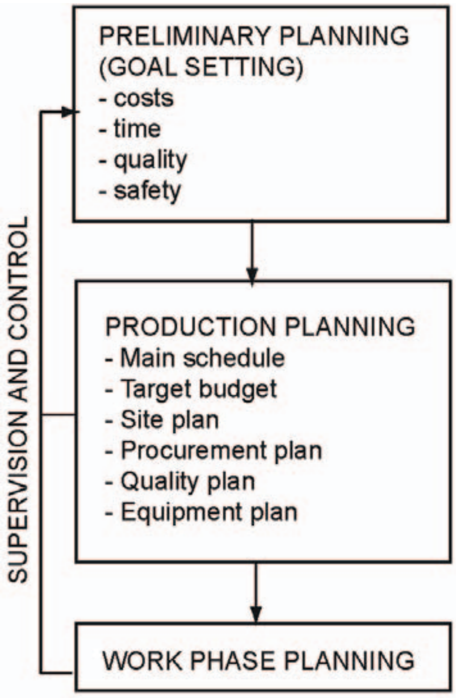


Figure 20. Construction site management model adapted from the RATU 2000 publication, describing general "best practice" in Finnish construction production management (Pussinen et al. 1998).

Naturally, a construction site management system has features specific to construction projects. Construction site management systems are one of the main foci for development at the HUT Laboratory of Construction Economics and Management, and use of the tools developed there has become widespread within the Finnish construction industry. These researchers' view of the ideal project management model has been described in many publications, including the RATU series (Kankainen & Sandvik 1993, Kankainen & Junnonen 1999, Junnonen 1996, Pussinen et al. 1998). In essence, the production planning is based on a work breakdown structure, or WBS (see Kerzner 1998), which is a detailed description of a project's tasks, and the schedules, resources, and costs are planned according to it. Additionally, a construction project has tools for managing procurements and subcontractors, managing quality processes in the various phases of work, and controlling safety and site logistics (Fig. 20).

One source for determining the "best" construction site management system was, naturally, the quality systems of the participating companies. After the quality systems of companies were analyzed, it appeared that they were very similar in their basic approaches and based on the common frameworks widely used in the construction business. This made it easier to find a model for a management system that was approved by all companies.

By using the material from companies, general project management (PMBOK Guide 2000, Kerzner 1998, Meredith & Mantel 1995, Lewis 1998) and construction project handbooks (Kankainen & Sandvik 1993, Kankainen & Junnonen 1999, Junnonen 1996, Pussinen et al. 1998), the structure of the "best" management sys-

Table 4. Parts of construction site management systems covered by the performance meter.

Management systems for a construction site

A) Design control
B) Cost and quantity control
C) Production control
    C1) Quality plan
    C2) Work phase planning
    C3) Schedule and resource planning
    C4) Procurement planning and implementation
D) Organization, cooperation, and communication
E) Logistics, environment, and safety

tem was described with a list of criteria. The system was divided into five main sections, where the "production control" section was further divided into four subsections (Table 4).

The measurement method developed consisted of a list of criteria, a kind of structured interview, which the researcher used in verbally interviewing project managers and engineers. The fulfillment of criteria was judged partly according to the answers of project managers and partly through the documents presented, such as schedules, quality plans, and procurement contracts. A three-point scale was used, where the first option was that the criteria were met "totally," the second "partially," and the third "not at all." The use of just two alternatives would have been simpler, but the middle alternative was added after remarking that it eased the measurement process considerably. Moreover, it helped in pinpointing the result more accurately, because the binary scale was experienced as too coarse for capturing the differences in the management systems.

The first versions of the meter were longer and more detailed, but among the goals was to make the meter compact enough to enable making the measurements within 1,5-2 hours. Some criteria were removed because it was difficult to verify whether they had been fulfilled, and some because the criteria proved to be too easy or too difficult to meet. In addition, some criteria were added after the first tests. The idea was to adjust the meter so that it concentrated on issues causing variation between sites and not on issues for which the criteria were fulfilled or not fulfilled on practically every site, which wouldn't yield any new information in the attempt to uncover the general success factors.

The final meter consisted of 73 measurement criteria that were classified in keeping with the outline presented in Table 4. The measurement form is presented in Appendix 1, Section A1.3.

5.2.2.2 Work behavior and leadership

The construction project system model approaches the human activity in a project from two angles: work behavior and leadership. Work behavior refers to the actions and attitudes of all people on the site and is closely connected to the concepts of atmosphere and culture. Leadership means the leadership style of the project management team, as observed by all site employees. Both aspects are closely interconnected, and as they both were measured with a questionnaire, it was practicable to combine the measurement of the two in the same questionnaire form.

Combining the two meters had several benefits. In trying to keep the measurement system as simple as possible, it is beneficial to have one fewer meter. Additionally, if leadership were to be measured separately, it would bring too much attention to the project managers as persons, which could prove problematic to handle in the feedback meeting. It was considered reasonable by both the researcher and the companies to treat work behavior and leadership as a single entity, in order to simplify the measurement and not to over-emphasize the role in the project of the project manager, who was always in the focus anyway.

A framework or model of work behavior and leadership was needed in order to determine what dimensions would be measured. The framework chosen for organizational behavior was the competing values model of Cameron and Quinn (1999). It combines many organizational typologies (Lansley 1994) and has been applied previously in the construction industry (Handa & Adas 1996, Maloney & Federle 1993). Additionally, the Focus model, which was used in the HUT Laboratory of Work Psychology and Leadership (Järvenpää & Eloranta 1997, Järvenpää & Martinsuo 1997), offered an opportunity to use a tested questionnaire as a starting point for developing the measurement method for construction sites.

In an earlier study (Salminen 1997), a modified version of the Focus questionnaire was used in measuring the culture at seven sites. In the subsequent study (Salminen 2000a), on which this thesis is based, a completely revamped questionnaire was utilized, but with the same competing values framework among its underpinnings. However, the results of both studies indicated that the competing values framework itself needed slight modification before the measurement results could describe the pattern of behavior on a construction site accurately. This issue is addressed in the analysis of the measurement results in Section 7.1.2.2.

As for the leadership element of the questionnaire, the framework used was Blake and Mouton's (1994) Grid theory, where the two dimensions were production- and people-orientation. It is widely used and concentrates on the practical orientation of leadership rather than the personal characteristics of the managers. The focus of the study was to measure performance of a construction site, after all, and avoiding excessive personalization of the questionnaire served the feedback and development process better. At first, only the competing values framework was used and the leadership aspect was integrated with it; the leadership aspect was separated out after proper analysis of the results.

The questionnaire was developed on the basis of the organization atmosphere measurement tool used in PSYCON Corporation. It was a questionnaire with a five-point scale, with questions in groups of about five. It offered a more practical basis for the measuring instrument, has been widely used in many kinds of organizations, and thus saw continuous practical testing and development.

The measurement tool of PSYCON consisted of a list of questions, which were separated into subject areas concerning both the general organizational atmosphere and aspects of leadership. The questionnaire used in this study was developed by picking out subject areas and questions from the question set and formulating a few new ones. Those areas and questions were chosen that were in alignment with the dimensions of the competing values framework. A few questions were added from the previously used Focus questionnaire, which covered subjects not included in some form on the new questionnaire. This produced a questionnaire based on the PSYCON tool, with a few additions from the Focus questionnaire. The question groups of the PSYCON tool remained in parallel with the competing values dimensions, enabling a more accurate division of subject areas.

The first version of the questionnaire consisted of 67 questions and 14 question groups. The reliability of the questionnaire was tested with the data from the measurements of the first eight sites. Cronbach alpha scores were calculated for all dimensions of the measurement method for work behavior and leadership. Based on the Cronbach alpha scores, a few questions that didn’t “belong” to the dimensions were either transferred to a more suitable dimension or discarded. The questions discarded were those that were not understood as intended in the construction site environment and could not be rectified through modification of the wording. Some questions appeared to be measuring practically the same thing. For example, many questions concerning leadership were so similar to each other that a couple of them were removed.

The final questionnaire included 55 questions in the 13 question groups, or sub-dimensions, each of them belonging to one of the four dimension of the competing values framework (Table 5). Even then, not all Cronbach alphas were at a satisfactory level, but the purpose was to perform the final analysis with the complete set of material for 47 sites and then perhaps make additional modifications. Therefore, the groups determined in the preliminary testing were considered to be good enough for the time being, and a more profound analysis was to be made after all measurements were completed.

Although the dimensions of the competing values framework remained the basic assumption for the work behavior and leadership framework, the intention was to test empirically whether the dimensions actually functioned with construction sites. This test was concluded with factor analysis as a part of statistical analysis of the data (Section 7.1.2.2). At this stage, leadership was integrated into the dimensions of Team (leadership) and Firm (management). Therefore, these dimensions had more questions than the other two.

Table 5. The questionnaire's question groups for work behavior and leadership, on both the competing values and the more accurate level, and their Cronbach coefficients.

Group	Cronbach α
Team (leadership)	
WORK SATISFACTION	63,3
PARTICIPATING AND INFLUENCING	68,8
COMMUNITY SPIRIT	72,2
COMMUNICATION	83,8
ENCOURAGEMENT AND FEEDBACK	73,6
RELATIONSHIP WITH THE FOREMAN	80,1
Adhocracy	
DEVELOPMENT AND INNOVATIVENESS	67,9
Hierarchy	
CLARITY OF RESPONSIBILITIES AND INSTRUCTIONS	81,1
COMPLIANCE WITH PLANS AND REGULATIONS	74,9
Firm (management)	
GOAL-ORIENTATION	76,6
CONTROL AND SUPERVISION	54,0
SMOOTH FUNCTIONING OF THE WORKS	61,4
EFFICIENCY	74,1

5.2.3 The results

5.2.3.1 Cost

Evaluating the economic success of a construction site is difficult because there is no objective level of comparison for the price of a building. Many factors affect cost, such as general price level, production technology, and design decisions. There is no "right" price for a building, just the goal that is set at the beginning of the project, which is the "best guess" as to the future cost. However, after the goal is set, it is the accurate, and only, meter of project success from an economic point of view.

The financial goal is actually set with two indicators in construction companies. First, the *target budget* is the reference level for expenses caused by the construction work. It can be used to measure whether the costs materialized according to plan. The *gross margin* is used to measure the profit made by the project, as a percentage. Gross margin is strongly dependent on the business idea or risk level of the project type. Therefore, it would be wrong to compare the performance of projects directly with it. However, the two indicators can be made comparable by using the difference between goal (budget or margin) and result, and by transforming the cost difference as well into a percentage. If used correctly, these two indicators should give the same result.

There are some practical problems connected with the economic key indicators for a construction project. This study focuses on issues that have to do with the activity during the construction phase. Therefore, cost elements that don't describe the efficiency of the construction site, such as the effect of the lot price and costs of design and marketing, should not be included in the construction site performance measurement system. Another issue is that the same items should be included in the target budget and the costs incurred; if, for example, alteration tasks are included in the costs, their value should be added to the target budget as well, for comparability.

Target budget versus costs incurred was decided to be the most appropriate key indicator for the economic success of a project. Another possible key indicator was the target gross margin minus gross margin achieved. However, this was calculated from all costs of the project and thus included more "speculative" sums related to the business idea or risks, which didn't actually describe the performance of the site, and which were more difficult to eliminate from the calculation than they were in the case of just construction costs. The problem with alteration work remained, though, and it had to be taken into consideration in collection of data for calculation of the key indicator.

The key indicator for economic success of the construction site was called **total cost**, meaning the cost difference between target budget and actual cost, expressed as a percentage to make projects comparable. The formula used to calculate the key indicator total cost was

(Target budget – costs) x 100 % / target budget

When cost exceeds target budget, the index is negative. For the sake of clarity, a rule was applied that in the measurement system a negative score always means something "bad," whereas a positive number is "good." For example, in the case of schedules a negative score means that the project is behind schedule, although it could also be understood as indicating that less time has been used than planned.

The effects of alteration work were eliminated by adding income from the alteration work to the target budget. This highlighted the problem that alteration work income too had a profit margin. As the margin was not included in either target budget or costs, it had to be deducted for the alteration work before this work was added to the target budget. As it would have been difficult to find out what the gross margin for alteration work was in each case, the mean gross margin decided upon (10 percent) was deducted from the alteration work income before addition of the work to the target budget. This eliminated most of the bias caused by alteration work.

At the time of the measurement, the total cost of the construction work is, of course, not yet known. It was important nonetheless to have a key indicator to imply the economic situation of the site at that point. At the time of the measurement, the predicted cost was used instead of the final actual cost, which was available only after the project had been completed. The prediction is the best estimate known for the situation, and it was available at the time of the measurement. However, the final total cost indicators were collected afterwards for this study, and the final financial results were used in the analyses, whenever they were available.

In addition to the key indicator of total cost difference, separate key indicators for materials, procurement, and overhead costs were used. This helped to pinpoint the possible problems more accurately for projects in the measurement report. However, in the analyses performed in this study, only the total cost (final) was used, because of the even more complicated comparability problems related to collection of data on the work, materials, procurement, and overhead costs, and due to the fact that further division of the cost component doesn't yield any information that is necessary from the standpoint of this study.

5.2.3.2 Time

The time component in evaluating project success simply refers to the time used in comparison to the amount planned. Time deviation could be expressed in units of time or percentages. In this case, deviation from the original schedule as a number of days was used. The percentage would usually be a very small number, which would not clearly illustrate the importance of the matter. Time deviations were already expressed in days in the construction projects, so it was a familiar measurement, and it was applicable to all projects – for example, a week's delay was equally critical for small and large projects.

The name given to the corresponding key indicator was **schedule deviation**, because it described the practical purpose of the key indicator. Again, the negative figure means that tasks are behind schedule, according to the aforementioned principle that a negative score means something bad.

Even the concept of total time deviation is not self-evident. The full situation cannot be directly derived from comparing the actual status of work phases to the original schedule and calculating a mean. On the schedule, different work phases have different weights, and one minor task, such as turning the heating on, may be on the critical path and delay all others. Different ways to calculate total time deviation as related to individual work phases were tried, but a general formula applicable to all sites was not found. However, a site usually had a clear impression of the situation even if it was more like a rule of thumb, and deviation in days was frequently reported upon to headquarters. The estimation was based on experience and the insight of the project managers, and it was considered to be the best key indicator available.

In addition to the total time deviation, some other key indicators concerning the schedule were compiled to get a more accurate picture of the schedule situation. Deviations of certain individual work phases were presented separately because they were good indicators of how the project was going overall. The tasks chosen were framework structures, roofing, switching on of heating, laying of floor concrete, inside walls, and technical installations tests. The deviation in these work phases tells also whether the deviation is growing or decreasing towards the end of the project. However, in the analysis only the total time deviation was used, because it included the essential information on the deviations of all individual work phases on the site.

5.2.3.3 Quality

The concept of quality varies according to the perspective from which it is considered. From the customer's point of view, quality means above all that the requirements stated in the contract documents are fulfilled without noteworthy deficiencies. Thus, the end product's quality is the most important element from the customer's viewpoint. However, even if the end product fulfils requirements, defects in quality may occur throughout the process, which means ineffectiveness and monetary losses to the company. Thus, to the contractor, quality of and during operations is of equal importance to final product quality. The ideal meter should be able to measure both operational quality throughout the whole process and the quality of the finished product, which is judged in comparison to what is stated in contracts and standards, because both of these depend on the site's operation.

The measurement method was based on research conducted at HUT's Construction Economics and Management unit, where index meters for measuring quality were developed and tested in several projects (Salonvaara 1998, Salminen et al. 1998, Wegelius 1998). These were further developed in this study. The series of meters, were tailored to typical construction work phases. These "quality cards" consisted of a list of criteria specified for each work phase. Every criterion on the lists was given a value of 1 or 0 depending on whether the criterion was met or not. The site's quality index was the index percentage calculated from all quality cards used on the site.

The quality cards were developed in close cooperation with the companies, using the insight of experienced project managers as well as general standards and quality requirements (*Rakennustöiden laatu*, Quality of Construction Works 1995). In the end, quality cards were compiled for 11 typical construction tasks, which were:

- prefabricated unit installation,
- faced brickwork,
- inner wall brickwork,
- covered drains,
- flat roof waterproofing,
- floor surface concrete-laying,
- wet room carpeting,
- dressing with slabs,

- putty and painting,
- (kitchen) fittings, and
- wooden doors and windows.

The criteria on the quality cards were divided into three sections, covering **planning**, **production**, and **finished product** quality. The first part, planning, concerned the work of the foreman, and it consisted of the criteria for planning and preparation for the production, including the procurement functions from the site's perspective. In the second portion were the criteria for implementation of the actual work: work process, environment, and structures to be covered. The third part included the requirements in quality standards and other documents that determined the qualifications that should be met by the finished product (see Appendix 1, A1.5).

Roughly three ongoing phases of work were chosen from every site, and they were measured using the appropriate quality card. The first section of the quality card was filled in by interviewing the foreman and looking up the relevant documents. The second section was completed at the chosen work site with the foreman and the workgroup, and it included the visual checks, measurements, and questions posed to the workers. The third section was filled in at a work site where work had recently finished, by visually checking the quality criteria for the work phase. This was repeated on each of the 2-3 work sites. The most useful measuring sequence was such that the finished product (the third section on the form) was checked earlier and then the work site (section two), because then the feedback from the completed work could be directly delivered to the work group.

5.2.3.4 Safety

Safety level was measured using the TR meter developed by the Finnish Institute of Occupational Safety and Health (Työterveyslaitos) and Finnish safety authorities. The meter had been developed to measure the safety level of a construction site as an index number expressed as a percentage. It was practical to use a ready-made meter suitable for this purpose, one that has been tested in research (Laitinen & Ruohomäki 1994, Laitinen & Ruohomäki 1996) and is widely used in the Finnish construction industry.

The data are collected while the measurers walk through the whole construction site and make observations about passing or failing to meet the safety criteria, which are remarked upon on the measurement sheet. The observations are made on every essential safety matter that has clear criteria for approval, based on safety regulations or general good practice determined by the safety authorities. The observation items are classified in six groups (*TR-mittari* 1994):

1. Working
2. Scaffolds, access bridges, and ladders
3. Devices and auxiliary equipment
4. Fall prevention

5. Electricity and lighting
6. Housekeeping and waste disposal

After walking through the construction site and having made all of the observations, calculated of the index is performed from the sums of “right” and “wrong” remarks, according to the following formula:

$$\frac{\text{“Right” observations [number] x 100 \%}}{\text{Total number of observations [number]}}$$

The TR meter is widely used in Finland, and the completed forms, which are official documents for legislative safety supervision, are preserved at the site. Safety defects that demand immediate correction are written on the sheet. The measurement can be performed fairly quickly; it takes 1-2 hours depending on site size. Thus, the existing, applicable measurement method made it unnecessary to develop a new method just for this study, and the existing meter was used.

5.4 THE PERFORMANCE MEASUREMENT PROCESS

The performance measurement system’s purpose was to be both a development tool and a research instrument. Thus, in parallel with consideration of the substance of the meter, the measurement process was developed. The purpose for standardizing the measurement procedure was to improve the reliability of the measurements, and at the same time to make the performance measurement process support developing operations on the measured construction sites.

The measurement is carried out according to standardized procedure to ensure that it goes smoothly, takes as little time as possible, and generates data that are as faultless and as comparable as possible. Advance information for participants and feedback are also indispensable parts of the measuring process (Table 6).

It is important to give both the line managers and sites advance information on what is going to happen in the performance measurement. This is done with written material that line managers deliver to the sites after they have been briefed themselves at a meeting held in each business unit where the measurements take place. It is necessary to understand that the purpose of the measurement is to develop site operations, not to judge persons or inspect sites for defects. To avoid prejudices, line managers have to emphasize the nature of the performance measurement in comparison to, for example, that of quality audits, where the focus is on finding deviations. It is also important that line managers behave accordingly during the measurement and feedback process and avoid personalization of the defects found.

The measurement was to be performed during the course of one day, and in almost all cases the time allocated sufficed. On a couple of sites, some additional information was gathered afterwards. The expenditure of time is divided among site

Table 6. Phases and time expenditure of the performance measurement and feedback process. All of the measurement took place on a single day, and it consumed about three hours of the project manager's time.

In advance

- Advance information to line management
- Advance information to sites
- Arrangements for the measurement

Measurement implementation

- General information on the site (10 min)
- Preconditions (30 min)
- Management systems (1,5-2 h)
- Work behavior and leadership questionnaire (30 min)
- Key indicators for cost (10 min)
- Schedule deviation (5 min)
- Quality of approx. 3 tasks (1-2 h)
- Safety (1-2 h)

Processing the results

- Processing measurement data and generating a report (1 day/site)
- Processing the questionnaire data (within PSYCON Corporation)

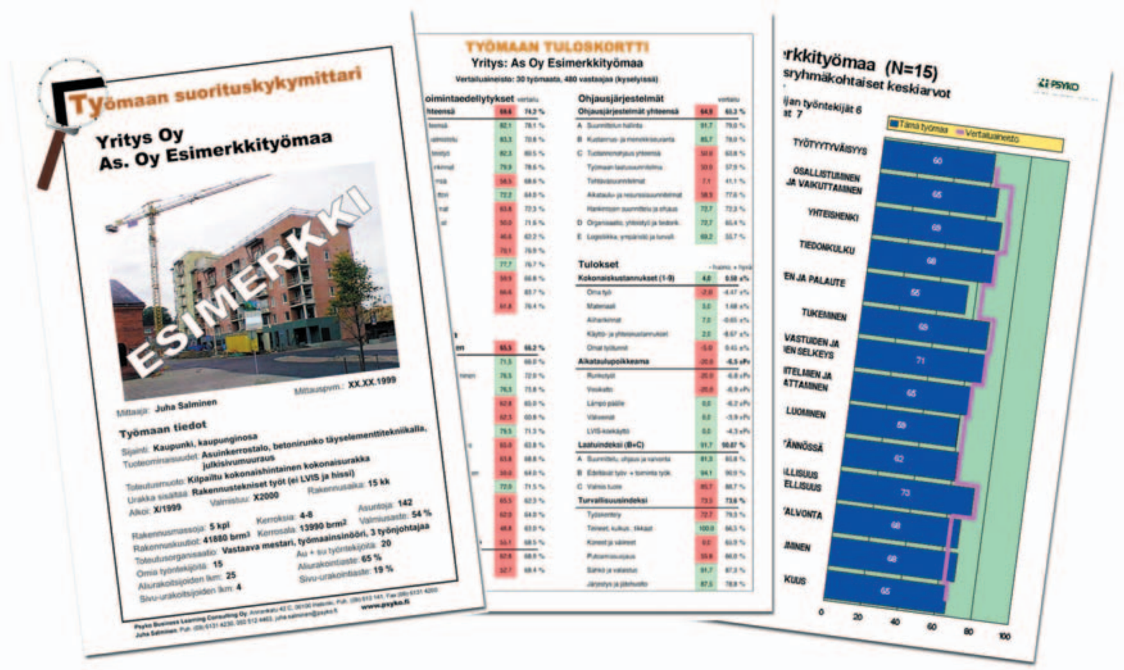
Feedback

- Site: management team, workers (1-2 h per site)
- Business unit and line management (2 h)
- Company management (2 h)

personnel so shouldn't burden anybody excessively. The data about work behavior and leadership measurement are collected from the workers and subcontractors, and the purpose of the measurement can be explained and instructions given at the gathering arranged for the purpose. Completing the questionnaire takes about 30 minutes, and it is convenient to arrange the gathering in the context of a coffee or lunch break. For the sake of reliability, all phases of the measurement process are to be performed as uniformly as possible.

A measurement system includes the data collection and also the procedures for data processing, summarizing, and presentation of the results. In the case of the performance measurements, the results were processed in two phases. First, the results for a single site were compiled in a site report consisting of a summary page and the results of individual meters. Second, the results for business units and companies were summarized at the company level. Companies were not compared directly; the comparison was made against the mean for all sites.

A spreadsheet application was used to summarize all measurement data and to generate the reports. However, the results for work behavior and the leadership



Työmaan suorituskykymittari

Yritys Oy
As. Oy Esimerkkityömaa

ESIMERKKI

Mittauspvm.: XX.XX.1999
Mittaaja: Juha Salminen

Työmaan tiedot
Sijainti: Kaupunki, kaupunginosa
Tuoteominaisuudet: Asuinkerrostalo, betonirunko täyselementtitekniikalla, julkisivumuuraus
Toteutusmuoto: Kilpailtu kokonaishintainen kokonaisurakka
Urakka sisältää: Rakennustekniset työt (ei LVIS ja hissi)
Rakennusaika: 15 kk
Alkoi: X/1999
Valmistuu: X2000
Asuntoja: 142
Rakennusmassoja: 5 kpl
Kerroksia: 4-8
Valmiusaste: 54 %
Rakennuskuutiot: 41880 brm³
Kerrosala: 13990 brm²
Toteutusorganisaatio: Vastaava mestari, työmaainsinööri, 3 työnjohtajaa
Au + su työntekijöitä: 20
Omia työntekijöitä: 15
Aliurakointiaste: 65 %
Aliurakoitsijoiden lkm: 25
Sivu-urakointiaste: 19 %
Sivu-urakoitsijoiden lkm: 4
www.psyko.fi

TYÖMAAN TULOSKORTTI
Yritys: As Oy Esimerkkityömaa
Vertailuaineisto: 30 työmaata, 480 vastaajaa (kyselyissä)

oimintaedellytykset
Ohjausjärjestelmät
Ohjausjärjestelmät yhteensä
Tulokset
Kokonaiskustannukset (1-9)
Aikataulupoikkeama
Laatuindeksi (B+C)
Turvallisuusindeksi

Figure 21. Cover page, summary page, and questionnaire result sheet of the measurement report. The summary page was the "site scorecard," where red and green background colors served as "traffic lights" indicating whether the values were above or below the mean.

questionnaire were summarized at PSYCON Corporation via the company's database tool for this purpose. It produced presentations of the results in graph and table form, and the use of a consultancy company convinced the respondents of the confidentiality of the survey. All data were presented on one summary sheet, where means were calculated and the individual reports were linked (Fig. 21). The data were later transferred from the data sheet and the database of PSYCON. into the statistics program SPSS for statistical analysis in this study.

Every site was given personal feedback. The feedback occurred in two phases: first, the management team was told about the results and the observations based on the measurement. Then, a briefing was arranged for all workers at the site. It focused on the work behavior and leadership questionnaire results, which covered the practical aspects of operation on the site. The result summaries were presented and discussed. Usually, the project manager or line manager presented his or her own conclusions as well. It was imperative that the line manager be present because it was his or her responsibility to ensure that any actions decided upon during the feedback meeting were really implemented. Sometimes the business unit manager was also present.

Business-unit- and company-level feedback concentrated on the summaries and comparisons to other units and the average. The general level of operation was the focus of interest, as were significant deviations in individual sites' results when compared to those of the other sites. Corrective actions were discussed and decided on. Also, the overall situation of individual sites was discussed, and the most attention was focused on problematic projects and corrective measures. The analyses of the operation of individual companies and sites were delivered to participating companies but are not included in this study. The results from the company comparisons cannot be presented here because they were considered confidential and, in any case, are not the focus of this study.

6 MATERIAL, METHODS, AND EXECUTION OF THE ANALYSIS

6.1 COLLECTION AND DESCRIPTION OF RESEARCH MATERIAL

The research material was collected from 47 construction sites of four construction companies operating in Finland, of which two were owned by Swedish companies. As all of the companies operated locally in the Finnish industrial environment, their sites were considered to represent Finnish construction companies. Three of the companies (or their Finnish business units) were the largest in Finland operating nationwide, and one was s medium-sized (on the Finnish scale) construction company. Companies 1-3 participated in the earlier research project (Salminen 2000a), and the measurements in the fourth company were made as a separate development project for the company.

In each of the first three companies, 10 sites were measured, and 17 sites were measured in the fourth company. The companies themselves chose the sites where measurements were to be conducted, with the main criteria in their choice being that the sites were in a convenient phase at the time of the measurement. The most convenient time for the performance measurement is between the late stage of structural frame installation and the early phase of internal work. Most of the sites, 38, were located in the capital region or the county of Uusimaa. Five were in western Finland (the Turku region) and four in southern or central Finland (the Tampere region).

Most of the sites were residential buildings, of which 23 were apartment blocks and seven row houses. Office or commercial buildings accounted for 16 sites, and one was an industrial building. Some of the business units that were selected by the companies to take part in the study specialized in certain product types – for example, residential buildings. Most of the sites were new buildings, but also seven renovation sites were included.

Project type means here the contractual arrangement of the project, or the way the company has acquired the project. Property development projects are financed at the constructor company’s own risk and sold to homebuyers or investors. Competition projects are acquired from official competitions where the main criterion is price. Cooperative agreements are the result of negotiations and a business agreement, where an investor typically finances the building on a lot owned by the contractor. In addition, the project can be in some other way a result of negotiations and a common agreement, where straight price competition is not involved, although at some point at least a limited competition might have been arranged. Management contracting is a cost and fee or target price contract where the contractor gets

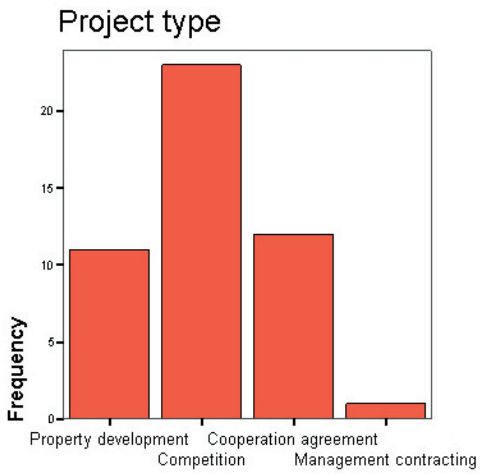


Figure 22. Classification of sites by project type.

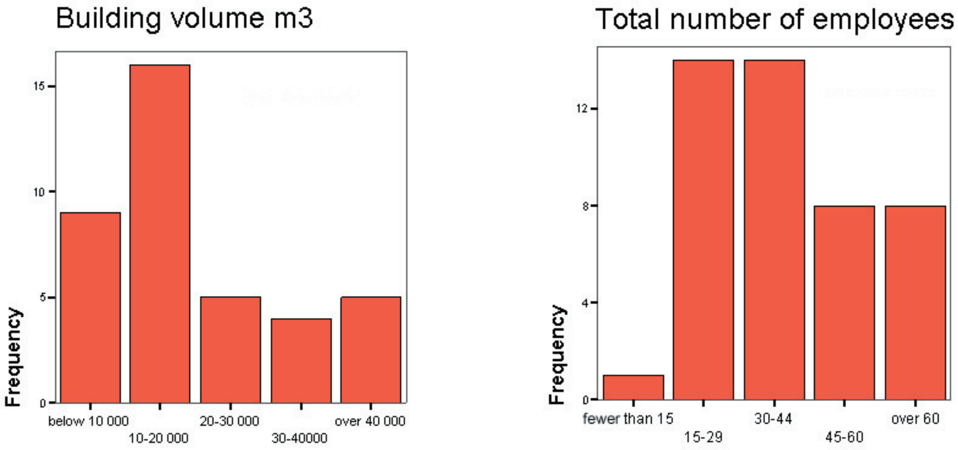


Figure 23. Sites classified according to volume in cubic meters and total number of employees. The number of employees includes all workers and also the site's office

only the agreed profit percentage of the total cost. Competition was the most usual contract type, and only one management contracting project was included in the research material (Fig. 22).

Project size is measured with two variables, building volume in cubic meters and total number of employees on site. A site is classified as falling into one of five categories. The greatest number of sites falls into the 10,000 to 20,000 m^3 category. The "over 40,000 m^3" group includes two projects that are substantially larger than the others: a hotel and a shopping center. The number of employees on site is linked to the volume, of course, but also somewhat to the phase of the project. The largest groups are those of sites with 15-29 and 30-44 employees (Fig. 23).

The amount of subcontracting and work done by subsidiary contractors also illustrates the nature of the project. If the amount of subsidiary contracting is high, a consultant used by the client has great influence and must participate in the coordination of tasks, at least to some extent. The contractor is directly responsible for subcontractors and has greater power to control them than it can exert over subsidiary contractors, but the manner of controlling still differs from the management of direct labor. From time to time, the fragmentation of construction production becomes the subject of discussion, and it is interesting to compare sites according to the extent of subsidiary contracting and subcontracting, to test whether variation in these affects performance.

The extent of subsidiary contracting was calculated from the value of subsidiary contracts in relation to total project value. The extent of subcontracting is the share of procurements in relation to total costs of the contractor. In some cases, these figures could not be acquired in a comparable way because they were not summarized in cost reports and it was difficult to pick them up from individual cost items. Therefore, these key indicators were not available for every site. Both variables are expressed as percentages. Sites are categorized to express the variation as frequencies (Fig. 24).

The extent of subsidiary contracting and subcontracting have been combined for the analysis by calculating the amount of direct labor other than that of the contractor on the site. It is another way to describe the management situation at the site, related to the fragmentation of the project. The variable used is the proportion of subsidiary contractor and subcontractor's workers on the site, expressed as a percentage (Fig. 25). The proportion for various worker groups was available from every site, which made this an even more useful key indicator.

Variation between sites was high where the use of outside contractors and manpower was concerned. At some sites, almost all construction work was done with direct labor, and some sites had practically all of it subcontracted. In general, the amount of subcontracting was higher in the Helsinki region and use of direct labor was favored more in other parts of Finland. At the time the measurements were made, the construction market was growing rapidly in the capital area and skilled workers were hard to come by as well, which added to the tendency to use subcontractors.

The degree of completion is calculated from the actual costs in relation to the total estimated costs. When calculated at the time of the performance measurement, it indicates the phase of the project during which the performance measurement has taken place. This knowledge enables evaluation of whether the time of making the performance measurement influences the measurement results or if the success factors are different in different stages of the project, as indicated by the study of Russell et al. (1977). However, as most of the measurements were made in the middle of the project (Fig. 26), the small number of projects in the early or late phase made it impossible to explore the success factors in different phases of a project further in this study.

The questionnaire concerning work behavior and leadership was conducted at every site. After the preliminary checks, the total number of respondents (n) came to 714. This consisted of three groups: project managers or foremen (n=134), contractor's workers (n=323), and other (subsidiary contractor and subcontractor's) workers (n=257). The contractor's direct labor was thus the largest group.

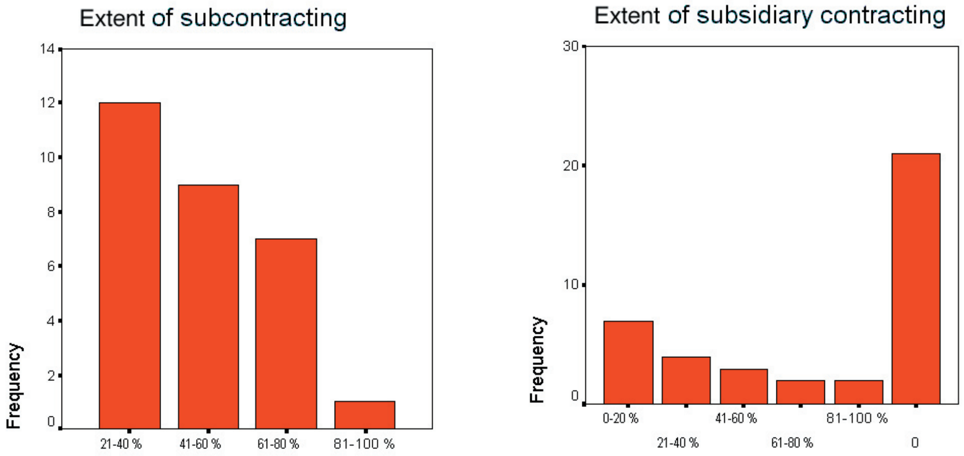


Figure 24. The extent of subsidiary contracting and subcontracting illustrates the management conditions on the site.

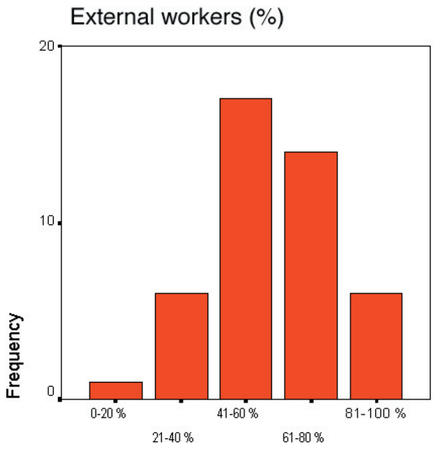


Figure 25. The percentage of external (subsidiary contractor and subcontractor's) workers at the site. This variable describes the nature of the influence the contractor has on work groups.

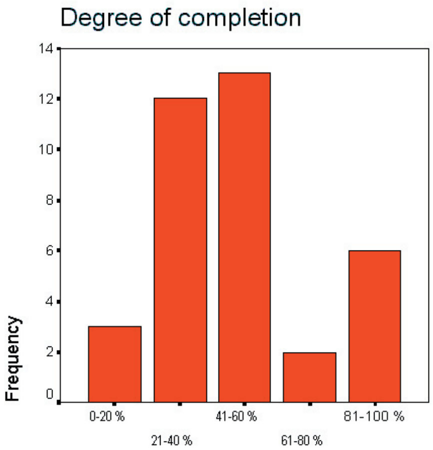


Figure 26. Sites by degree of completion, calculated from the budget used.

Another way the respondents were classified was by age. The age distribution was fairly even. There were 143 respondents below 30 years of age, 199 between 30 and 39, 210 aged 40-49, and 147 over age 50.

The classifications presented are used later as background variables, whose influences on the variables of the performance measurement system are tested. If some of them have a substantial influence on the performance of the project, this should be known and taken into consideration in forming conclusions about the success factors. These influences are tested in the discriminant analysis of Section 7.3.

6.2 THE ANALYSIS PROCEDURE

In this study, the data was acquired from performance measurements for 47 construction sites. The total number of variables is quite high, about 300, and in the background are the structure of the construction site performance system model and the hierarchy of the items within the individual meters.

The aim was to find relationships between the variables related to the results and operation of a construction site. However, in order to accomplish that, some preparatory processing of the data and categorization of the variables are needed.

In the data analysis, the procedure that follows was used.

1. **Preparing and cleaning the data**
   Data were entered in the database; they were checked by calculating frequencies, ranges, etc.; and the necessary definitions of variable were made.

2. **Describing the research material**
   Descriptive statistics were calculated to get overall information about the research material. The results were presented as graphs characterizing the sample of construction sites.

3. **Creating sum variables**
   If all measurement items and key indicators are added up, the data consist of about 300 variables. It was necessary to create sum variables of the measurement items of the preconditions, management systems, work behavior and leadership, quality, and safety meters in order to capture the essential information on the performance elements.

4. **Discriminant analysis of the data**
   One aim of this study is to identify relationships between different elements of construction site operation. All other variation in variables having nothing to do with site operation – connected to, for instance, size, type, company, or location of the site – can distort the findings. Therefore, it is necessary to know how homogeneous the research material is and what groupings of sites exist in the material so that the effect can be taken into consideration in drawing conclusions.

5. **Performance element relationships**
   The relationships between performance system model elements are explored with correlation and regression analyses. The central aim is to discover the relationships between the elements of the operation process and the result elements.

6. The effect of variables within performance elements

To get more accurate information on success factors, correlations between the variables within different meters in the measurement system and result variables are studied to pinpoint the individual measurement items that have the greatest effect on construction site results within each meter.

These steps are explained in detail in the data analysis, and the main results of the analyses are presented in tables and in Appendix 2.

6.3 PREPARING THE DATA FOR ANALYSIS

The construction site performance measurement system consists of seven different meters, of which total cost and schedule deviation are expressed directly by one key indicator, while the other measurement methods consist of a number of individual measurement items from which the higher-level key indicators can be calculated. Every measurement item in the meters produces numerical data, but the scale and format of the data is specific to each meter (Table 7).

Table 7. The types of scales used for the measurement items in the performance measurement system meters.

Meter	Scale	Scale type
Preconditions	4-point	ordinal/interval
Management systems	3-point	ordinal/interval
Work behavior and leadership	5-point	ordinal/interval
Total cost	%	interval
Schedule deviation	%	interval
Quality index	0/1	dichotomous
Safety index	0/1	dichotomous

The scale type for preconditions, management systems, and work behavior and leadership is classified as ordinal/interval because although the scales are in principle interval, the intervals between the points are not necessarily the same, due to the small number of options on the scales. Therefore, the scales should be considered to be ordinal, although both scale types are used in studies for meters having 3-to-5-point scales (Bryman & Cramer 1995).

In addition to the variables acquired from the system model meters, 11 classification variables were collected using the general information form (Table 8). If they didn't originally have a nominal or ordinal scale, they were transformed such that they used one for the analysis. Variables like the location or company were on

Table 8. Classification variables and their descriptive statistics.

	Valid N	Number of classes
Site location	47	3
Extent of subcontracting*	29	5
External workers (%)*	44	5
Building volume m3*	39	5
Extent of subsidiary contracting*	39	6
Payment	47	5
Building type	47	5
Total number of employees*	45	5
Project type	47	4
Degree of completion*	36	5
Valid N (listwise)	20	

* The interval-scale variable has been classified under ordinal scale.

the nominal scale and variables like number of gross cubic meters or number of employees were classified on the ordinal scales by dividing them into categories.

The analyses were performed with the statistics program SPSS. When the data were entered in the database, variables were labeled (given names), and their scale types were determined. Data were checked by calculating the ranges and frequencies, which exposed the potential abnormalities in the material. A few entry errors were found and corrected.

The work behavior and leadership questionnaire results formed a database of their own, because for the questionnaire, the cases were the 714 respondents and not the 47 construction sites. The questionnaire was analyzed in SSPS separately, during examination of the organizational behavior dimensions. However, sum variables of behavior dimensions were moved into the same database as the other measurement system materials in the course of studying the relationships between system elements. The creation of the sum variables is presented in Section 7.1.

Three questionnaire forms were discarded because they obviously were not answered properly, two of them having only “3”s as answers and one only “5”s. Some forms were only partially completed, but there was no evidence that the questions that had been answered were not answered properly, so they remained in the material.

In all analyses, the pairwise method was used in eliminating the effect of missing variables; hence, whole cases were not removed even if a few variables were missing. In the whole database, including all measurement item variables, there were about 300 variables. Later, the database was “condensed” by calculating sum variables including the essential information of the different meters (see Section 7.1).

7 PRELIMINARY PROCESSING OF THE DATA

7.1 COMPOSING SUM VARIABLES

The construction site performance meter is based on the idea that construction site operation can be described with a system model. The measurement system structure is described by the system model and its elements. Each element has also its own structure, where the measurement items measure different aspects of the element. Therefore, it is not necessary to treat every measurement item as a single variable; instead, they can be combined in groups that represent certain entities. In this study, the combining of variables was accomplished by creating sum variables.

The choice of sum variables is based on the structure of meters, and they must be composed in such a way that every sum variable covers the intended subject matter, or series of measurement items tightly bound together (Bryman & Cramer 1995, Heikkilä 1998). When sum variables are correctly composed, they help to encapsulate the essence of the analysis without the loss of any significant information. An additional benefit to using sum variables is that when a sum variable is calculated from several ordinal-scale variables, it is transformed into an interval-scale variable, and then more effective statistical tests can be used to analyze it (Sekaran 2003).

When the essential observations have been made from the sum variables, it is possible also to examine the measurement items individually in seeking answers to specific questions. The method of forming sum variables depends on the characteristics of the meters, and each meter here must be addressed individually.

The sum variables of this study create a hierarchy wherein the level-1 variables are the key indicators for construction site performance system model elements, where all the measurement items in a system element meter are combined into one sum variable, such as the key indicator for variable management systems. The level-2 variables are the sum variables within a system model element, describing the next-level grouping of the measurement items. Examples include the sum variable for logistics, environment, and safety. The level-3 variables are the individual measurement items of the meters, which are not sum variables. Whether all three levels exist in a meter depends on the structure of the meters.

Another principle was that all sum variables were transformed into percentages whenever possible. This makes the variables comparable and more illustrative, because the scale would otherwise be different in every meter and picturing, for example, what the index value “2” means in each case would be difficult.

7.1.1 Preconditions

In the site preconditions meter, the performance of client/consultant, designers, and company headquarters is evaluated. The meter is structured according to the functions of each party. The sum variables can thus be logically built on the basis of the meter structure. Sum variables form a three-level system: the meter as a whole, each group of actors, and the division of their tasks.

Table 9. The preconditions meter's level-1 and level-2 variables. The first number refers to the variable level.

1. **Preconditions**
    - 2.1. Client/consultant
    - 2.2. Designers
    - 2.3. Company headquarters

In the preconditions meter, a project manager evaluated the operation of each party on a four-point scale. The reason to omit the neutral middle alternative was that this made it easier to point out the most problematic areas. There are two ways to calculate the sum variables from the four-point scale. One can use either the total percentage of positive answers (3 or 4) or the mean of all answers. The mean was selected for use because it distinguished sites and reveals deviations better. At many sites, only alternative 1 or 2 was chosen, which would have been given the result value of 100 % with the positive answers method, although it is a significant difference whether most of the answers are 1 or 2.

The preconditions index sum variable was calculated and transformed into a percentage with the following formula:

$$\text{Preconditions index \%} = 100\,(1 \text{ x } N_{completely} + 0{,}67 \text{ x } N_{moderately} + 0{,}33 \text{ x } N_{badly} + 0 \text{ x } N_{not\ at\ all}) \,/\, \text{total number of criteria for which there are responses}$$

7.1.2 Operation process

7.1.2.1 Management systems

The structure of the management systems meter is analogous to that of the preconditions meter. Management systems are outlined in the meter as logical entities that are measured by using a group of criteria as question items. Sum variables can thus be composed on the basis of the structure of the meter. Sum variables form a two-level system: management systems as a whole and the subgroups thereof.

Table 10. The sum variables of the management systems meter, on two levels. The first number refers to the variable level.

1. Management systems
  2.1. Design control
  2.2. Cost and quantity control
  2.3. Quality plan
  2.4. Work phase planning
  2.5. Schedule and resource planning
  2.6. Procurement planning and implementation
  2.7. Organization, cooperation, and communication
  2.8. Logistics, environment, and safety

In the meter, the term "production control" was used to group sum variables 2.3-2.6 together. This was done to clarify the contents of the meter in the measurement phase, but in the analysis phase the sub-items were used directly.

The scale used in the management systems meter was three-point: criteria were fulfilled completely, partially, or not at all. The same problem applies here that was encountered in the case of the preconditions meter, namely that sum variables could be calculated also using the percentage of "completely" or "partially" answers, but the mean was chosen for use here also, for much the same reasons. The sum variables were transformed into percentage indexes with the following formula.

$\textit{Management systems index \%} = 100\ (1 \times N_{completely} + 0{,}5 \times N_{partially} + 0 \times N_{not\ at\ all})\ /$ *total number of criteria for which there are responses*

7.1.2.2 Work behavior and leadership

The work behavior and leadership meter differs from previously mentioned meters because in measuring organizational behavior, the work division or role of different systems doesn't automatically determine the structure in people's minds and consequently the meter structure. The four dimensions of the work behavior and leadership model were, according to the competing values framework, Team, Adhocracy, Hierarchy, and Firm. They were further divided into 13 dimensions, under each of which there were 3-5 questions (see Table 5).

In the measurement reports to sites, the more practical 13 dimensions were used, which was helpful in specifying problematic areas of operation and finding development areas. The functionality of question groups was tested with Cronbach alpha scores when the first eight sites had been measured, and it served the practical measurement purpose well enough.

However, the competing values framework was only a hypothesis, a starting point on which to build the questionnaire structure (see Section 5.2.2.2). When all data had been collected, they were tested. If the logic of the respondents actually corresponded to the logic of the model in all of the material, it would be verified; otherwise, it would be clear that the framework should be developed into one better describing the behavior on a construction site. In other words, the theoretical model is verified or further developed using the empirical data. The dimensions verified would be the sum variables, used in the analysis. Thus, at the same time as the dimensions of construction sites' work behavior and leadership are verified, the final sum variables for corresponding dimensions are determined.

A factor analysis using principal axis factoring and varimax rotation was conducted for the questionnaire data. This produced 10 factors, where most of the questions were divided into factors 1-3 and several factors had only a few questions. The number of factors seemed to be too high and poorly balanced for the intended use. Therefore, the number of factors was forced to be seven. Now the question groups seemed more logical, but still some questions remained that didn't belong to any group.

Finally, a six-factor solution was used, and consequently five questions in total were left out of the dimensions. The structure seemed to be logical and functional, and statistical evidence supported it (see Appendix 2, A2.2). Also, the Cronbach alpha coefficients verified that the new division produced considerably better results than the groups used earlier did, showing that the dimensions functioned well, especially the two including the highest number of questions.

It is evident that the six factors yielded by factor analysis don't fit the competing values framework directly, foremost because the number of factors is six, not four. However, some dimensions carry clear similarity to the dimensions of the competing values framework, and in many ways it supports the more accurate grouping of questions used in the analyses. The questionnaire includes both the managerial and cultural aspects of sites' operation, and when the question groups are examined more closely, it seems that the first two factors concern the actions of site managers and the other dimensions illustrate the general atmosphere and culture at the site.

The first dimension describes the managerial style, where the focus is, above all, on controlling production. This is the "Firm" dimension in the competing values approach to management and is also often called pure "management" in contrast to "leadership," which is the people-focused "Team" dimension in competing values terms (Fig. 9). Question group 2, which focuses on the relationships between the foreman and workers, describes the leadership aspect of the project managers' and foremen's actions. These dimensions describing leadership dimensions are also analogous to the Blake and Mouton (1994) Grid theory.

The other four dimensions fit well with the organizational aspect of the competing values framework. The third dimension includes questions that indicate how satisfied the respondents are with their work and also how they grow and develop

Table 11. The question groups yielded by factor analysis, and their Cronbach alpha coefficients. A title more illustrative for the purpose of this study has been given to every dimension, but the connection to the competing values model is presented in paragraph form. The number before a question is the question number on the questionnaire.

1.	**Management, focus on production** (= “Firm/management”)	alpha = 90,41
17	Clear division of responsibility is followed in decision-making	
19	The site has clear rules of operation	
18	Work goals are clear	
16	Compliance with work specifications and quality requirements is monitored	
23	Division of tasks and duties is clear	
28	People comply with the assigned division of work and duties	
21	People follow the methods and rules set forth for operation	
12	Plans are followed accurately	
22	The quality plan affects site operation	
32	Common goals are clear	
11	The works are organized well	
15	Work results are inspected often	
2.	**Leadership, focus on people** (= “Team/management”)	alpha = 90,46
47	The foreman listens to workers	
48	The foreman encourages workers to participate in planning	
46	The foreman understands workers’ problems	
53	The foreman is willing to try out workers’ ideas	
55	I’m satisfied with my foreman	
51	The foreman treats workers equally	
44	The foreman motivates workers	
50	The foreman explains work methods enough	
52	The foreman’s reaction to mistakes is justified	
43	The foreman justifies decisions	
54	The foreman gives enough feedback on good performance	
49	The foreman supports workers’ efforts to develop themselves	
41	Sharing information with the foreman is useful	
3.	**Satisfaction and growth** (= “Adhocracy/organization”)	alpha = 77,03
3	There are enough new and challenging duties	
1	Work gives satisfaction	
9	Opportunities to develop professionally are good	
8	Being at work is satisfying	
4	Workers have enough influence in decision-making	
24	Autonomous operation is supported	
7	Work endurance is good	
13	Applying new work methods is encouraged	
4.	**Effectiveness and clarity of tasks** (= “Firm/organization”)	alpha = 78,69
10	Work and operating instructions are consistent	
14	The operation process is clear	
40	Lack of information concerning work isn’t a hindrance	
27	Decision-making is fast	
5	Work conditions are good	
20	On site, plenty of results are achieved	
2	The amount of work is steady	
6	Work equipment is appropriate	
25	Problems detected are solved quickly	
5.	**Community spirit** (= “Team/organization”)	alpha = 66,72
34	Community spirit among the nearest co-workers is good	
29	Community spirit on the whole site is good	
30	It is easy to get help from other workers	
33	Conflicts are dealt with and resolved	
6.	**Communication** (= “Hierarchy/organization”)	alpha = 77,62
35	Enough information is given	
36	Information is given openly	
42	Information is given on the results achieved	
37	Information is reliable	
Other questions (not included under the dimensions)		
26	Good performance is rewarded	
31	Workers consider the benefit of the whole site	
39	Feedback is given on achievement of the work results	
38	The amount of work instructions is adequate	
45	The foreman provides enough supervision of the workers	

along with it. The possibility to develop and learn seems to be an element of job satisfaction for construction site workers. Independence, opportunities to have an influence, and chances to learn are typical of an Adhocracy kind of organization, and thus the dimension of satisfaction and growth is an analogous term for it in the construction site context.

The fourth dimension describes how well work is going in practice. Do the workers feel that the site is functioning effectively and systematically? This is analogous to the competing values "Firm" dimension, but as seen from the organization's point of view. It describes how goal-oriented and efficient the production at the site is.

Factor 5 is similar to the competing values dimension "Team": community spirit is high and everybody is helping others, now from the organizational behavior perspective. It has been termed "community spirit" here.

The sixth factor has to do with communication and information flows on the site and is clearly a group of its own. This is the most difficult dimension to fit into the competing values framework, because the only dimension left is that of "Hierarchy." As was already noticed in the earlier study (Salminen 1998b), Hierarchy isn't obviously a very relevant dimension in construction project culture, which is easy to comprehend, in light of the fast-moving project environment.

Five questions obviously didn't belong to any dimension, and they had to be left outside them. It can be concluded that some of the questions can be understood in different ways or have an unintended value loading, such as the one concerning rewards. This doesn't mean that they weren't useful in interpreting the feelings of workers in practical situations, but it does indicate that they cannot be used in the analysis because they describe detached viewpoints and cannot be included in the final model.

These six dimensions were used in the analyses to determine their relationships with other performance system model elements. The values of the sum variables for the six dimensions were calculated as means and transformed into percentage indexes. Thus, the six dimensions form the level-2 variables of the work behavior and leadership meter.

It could also have been possible to separate the results from the questionnaire into two separate sum variables for work behavior **and** leadership, as they are in the system model. However, as the performance elements leadership and work behavior are measured with the same questionnaire, they tend to correlate automatically with each other, because the respondent's attitudes show through in every dimension. In analyses concerning the system model's level-1 variables, separating them wouldn't thus produce additional information. They are therefore treated as one sum variable covering both aspects.

7.1.3 Results

7.1.3.1 Cost

The financial success of a site was evaluated with a key indicator where the difference between target budget and actual end cost was transformed into a percentage index, and hence the relative value of the project was taken into consideration. The key indicator was calculated at the time of the measurement from the predicted cost, and again after the project had been completed, in order to obtain the final result for the project. The predicted cost was used in the measurement report for the site, but in this study the total cost is the key indicator used in the analyses, because it is the economic outcome of the project.

Other financial key indicators were used as well; in addition to total cost, the data needed for calculating the corresponding key indicators for costs of work, materials, procurement, and overhead were also collected. As mentioned earlier, these figures carry even more uncertainty than the total cost, one reason being the effect of alteration or additional work and changes in the previously mentioned cost items, which were not always updated in the budget. In the total cost key indicator, the effect of alteration or additional work was taken into consideration by adding the value of this work to the budget after deducting a 10 % profit margin. This corrective calculation was not usually possible for the cost categories because division between work, materials, etc. was not performed for the cost reports.

Therefore, the final total cost key indicator as a percentage is the best "sum variable" for describing sites' economic success, although it is not in fact a sum of anything but a key indicator of its own. The level-2 key indicators of work, materials, and other costs were not used in the analyses because of the aforementioned unreliability connected with them. The total cost value is 0 when the cost is exactly the same as the target budget; otherwise, it is a positive or negative figure, typically within the range of ±5 %, according to the "negativity" principle, where a negative number means something bad and positive means good (for example, +1,5 % means that the cost is 1,5 % less than the target budget).

Even though the total cost key indicator is theoretically simple, there are some practical problems that have to be taken into consideration. First is the question of the objectivity of the goal setting. The economic result of the project is determined by comparing the total costs (final) to the target budget. But is the target budget set on an equal basis for every project? Often project managers describe the target budget with the words "tight" or "loose" to indicate that sometimes the goal is more and sometimes less challenging. What is the objective price of a building such that the site performance could be compared with it? In this study, the assumption was that there is none. The price is dependent on the cost index of the time; production methods; architectural, structural, and material choices; and so on. There is no objective cost level, and the target budget is always an estimate. But it is the best estimate at hand, and it is the goal that is in place for the project. Project success must be compared against set goals, whatever the goals are, and thus they are in a sense always "correct."

There is one exception, though. It sometimes occurs that there is a clear flaw in the target budget. If, for example, part of the building is forgotten in preparing the cost budget, it is reasonable to assume that the price of the building is erroneous, and it is unjust to evaluate the performance of the site management against the target budget, which is unrealistically "tight." A rule of thumb applied by construction project managers is that when the cost exceeds the budget by more than ±5 %, there is often a major mistake in the target budget, in one direction or the other. If a clear mistake like this is found in the target budget, it must be eliminated by discarding the faulty key indicator.

The second criterion for financial key indicators is that they be calculated correctly. This means that the figures that the percentage index is calculated from must be correct and the target budget and actual cost must include comparable information – otherwise, the total cost key indicator ends up being incorrect. This criterion was easier to fulfil with the predicted cost, because the researcher was present at the site and could either check the numbers from the cost report himself or explain to the site personnel in detail what figures were needed and what they should include.

When the total costs (final) were collected from companies for calculating the total cost key indicator, the situation was more complicated. The data were collected from companies after work on the sites was completed, and were provided by line managers by phone or email. However, in some cases serious concern was aroused that something was wrong with the numbers, because the total cost (final) deviated remarkably from the predicted cost. In some cases, after closer examination, this was indeed found to be the case, but it was not possible to check the numbers thoroughly on all occasions, and some managers were even reluctant to provide the final numbers after their part of the research project was over.

The relationship of predicted cost and total cost (final) is shown in Figure 27. At the time of the measurements, the sites predicted that the financial outcome would be close to the target budget. The total cost (final) figures show much more deviation, which means that the predictions were not very accurate or there is something wrong with one of the two numbers.

Another view on the same issue is given in Figure 28, showing a scatterplot of the predicted costs and total costs (final) of the 36 sites that had total cost (final) figures available. In the scatterplot, it is particularly easy to pinpoint the ones having notably low or high results, or sites that have predicted the result badly. Some of these sites were examined in greater depth by asking the companies for background information.

Where two extremely low values were noted, a calculation mistake was later found in the cost estimate figure, and the fact that the result was predicted at the beginning quite accurately in both cases supported this. A couple of other sites with extremely good total cost values were examined more closely, but no obvious ex-

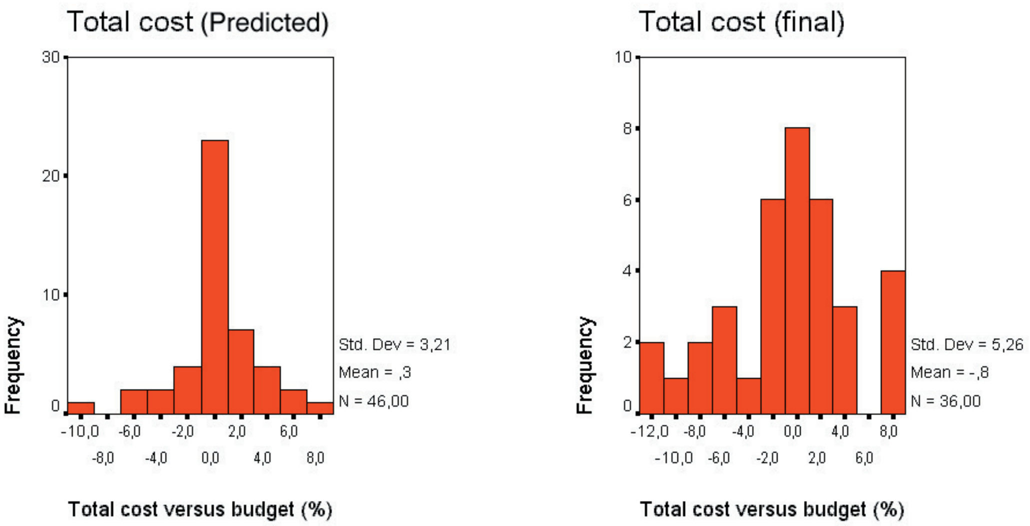


Figure 27. Cost predictions and total cost (final) frequency charts. Total cost (final) was available from only 36 sites. A negative percentage means that the costs exceeded the budget.

planation other than good performance was found, so they were not removed from the material.

Additionally, some of the line managers tended to give a more positive picture of the outcome of sites than matched reality. There were cases where the effect of alteration work was not properly removed from the result figures or other sums, such as the risk provision, were later added to the target budget, making it incomparable to the original goal. In several cases, where the result showed significant improvement over that predicted, there were doubts that the instructions for collecting the result figures were correctly understood or applied. It was not possible to get enough in-depth information on site costs after the research project had ended.

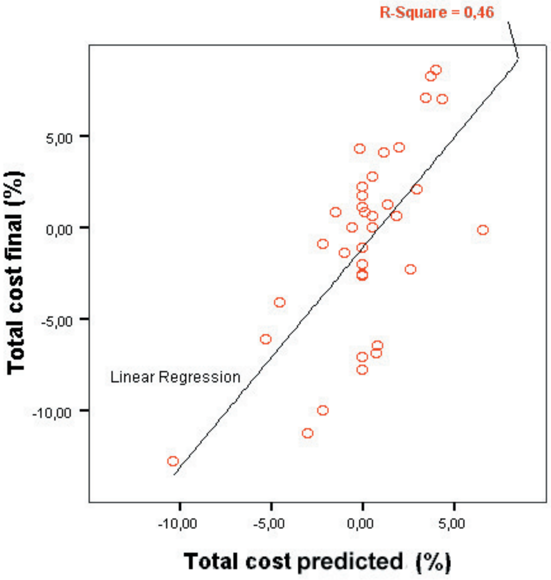


Figure 28. The scatterplot and linear regression curve for total cost (final) and predicted cost (N=36) after erroneous values were removed. The scatterplot was used in finding the extreme values needing closer examination.

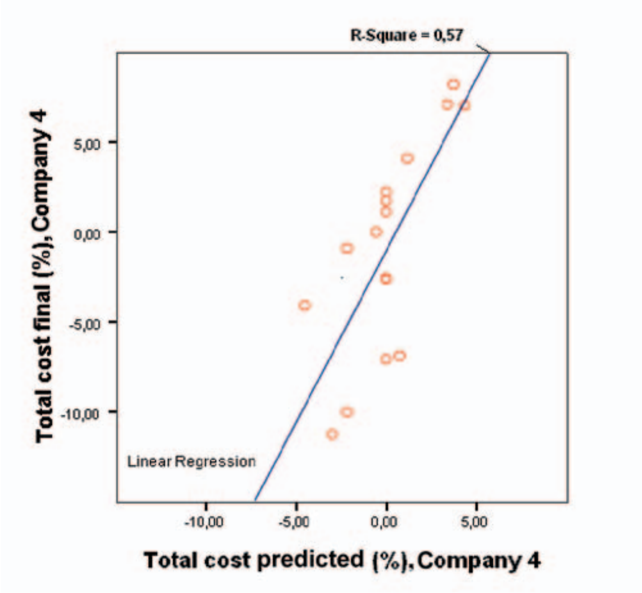


Figure 29. Pearson correlation between predicted and final cost for the sites of Company 4 (N=16).

However, there was one exception. Company 4 became the place of employment for the researcher afterwards, so the cost reports and other necessary data were directly accessible. The number of analyses in Company 4 was 17, and thus the number of reliable cost key indicators was considerable, although the actual number of sites where total cost was calculated was only 16 since a cost and fee contract was in force for one of the sites, which consequently had no target budget at all (Fig. 29).

In principle, the total cost key indicator was relatively clear and applicable for the purpose of this study. However, there were problems with the reliability of the key indicator, because the figures were solicited after work on the sites had finished and the research project was already concluded from the companies' perspective. Therefore, reliable data were difficult to obtain from outside the companies, except for Company 4, and analyses concerning financial results have been conducted for both the whole set of material and the material for only Company 4.

7.1.3.2 Time

The "time" aspect of construction project performance is expressed by the schedule deviation key indicator, which refers to the deviation from the main schedule in days. Schedule deviation information was also collected two times: at the time of the measurement and at project completion. This referred to the deviation at the commencement date.

In contrast to the pattern for the cost key indicator, schedule deviation at the time of the measurement describes the schedule deviation better than that at delivery time does. There were only a few sites where delivery was not made on time. The work usually gets done by the delivery date, even if this means overtime and excessive costs. Therefore, how well the site keeps to schedule during the construction process is a better indicator of the performance and is more important than the final outcome. The schedule deviation in days during production is thus a “sum variable” that is applicable to describe results concerning time.

For schedule deviation, the key indicator is negative when the site is behind schedule, and positive when the site is ahead of schedule, according to the “negativity” principle previously mentioned (Section 5.2.3).

7.1.3.3 Quality

The quality meter consisted of blanket measurements for 13 different, typical work phases (see Appendix 1, A1.5). They all had a common sum variable structure (Table 12), which made it possible to count dimensions of several forms of quality together. The quality key indicator was referred to as the quality index in practice, illustrating the nature of the index meter.

Table 12. The structure of the quality meter.

1. Quality index
    2.1. Planning (not used in analysis)
    2.2. Production
    2.3. Finished product

The first part, planning, had certain similarities to the management systems meter, although the quality meter concentrated on planning and managing a specific phase of work. It was necessary to include the planning phase in the quality index in analyzing and developing the operation of the sites in practice. However, it was a problem from the standpoint of the performance measurement system model used in the study because the planning phase didn’t actually represent results of the operation, unlike the other two items.

Therefore, the planning phase was omitted from the calculation of the quality index. The quality index thus consists only of operation and finished product quality. “Production” and “finished product” could have been used also separately as level-2 variables, but in practice only the level-1 variable of total quality was used, because dividing it further into two dimensions would not have produced any new knowledge.

7.1.3.4 Safety

The result of the TR meter can be used directly as a sum variable of the safety key indicator. The safety index itself is the sum variable for construction site safety, and the dimensions can be used as lower level-2 variables, if necessary. The safety index is expressed as the percentage of criteria met. As with quality, the level-2 variables in the safety meter were not used in the analysis (Table 13).

Table 13. The structure and sum variables for construction site safety.

1. Safety index
- 2.1. Safety precautions at work
- 2.2. Scaffolds, access bridges, and ladders
- 2.3. Devices and auxiliary equipment
- 2.4. Fall prevention
- 2.5. Electricity and lighting
- 2.7. Waste disposal and order at site

Table 14. The level-1 and level-2 variables (level-1 variables in **bold***) and their descriptive statistics. All sum variables are of interval scale.*

	N	Minimum	Maximum	Mean	Std. Deviation
Site preconditions	46	52.39	93.17	72.9343	9.84390
Client/consultant	46	54.71	93.95	77.4047	9.29389
Designers	46	44.72	90.39	66.9489	12.84228
Company headquarters	46	42.06	96.68	75.3753	12.09683
Management systems	47	40.77	93.28	66.7244	11.72375
Design control	47	50.00	100.00	79.7188	13.39137
Cost and quantity control	47	35.71	100.00	80.3445	15.90207
Quality plan	47	.00	100.00	63.2016	26.00541
Work phase planning	47	.00	100.00	42.2872	29.06779
Schedule and resource planning	47	28.57	108.33	71.9352	19.54221
Procurement planning and implementation	47	50.00	95.83	74.3214	10.38321
Organization, co-operation and communication	47	35.00	100.00	65.9155	16.27666
Logistics, environment and safety	47	23.08	100.00	58.7493	16.59105
Human behavior and leadership	47	56.89	81.69	67.2774	5.74745
Focus on production	47	53.63	86.44	67.2014	7.63626
Focus on people	47	57.38	83.41	69.2603	6.68748
Satisfaction and growth	47	54.22	76.93	65.6857	4.82109
Effectiveness and clarity of tasks	47	54.39	80.91	64.3079	6.67647
Community spirit	47	59.38	91.41	77.5793	6.46170
Communication	47	50.90	82.03	66.0908	7.66674
Total cost (final)	36	-12.83	8.60	-.7902	5.26390
Total cost Company 4	16	-11.28	8.19	-.9000	5.97264
Schedule deviation	46	-30	10	-6.65	8.252
Quality	41	71.40	100.00	88.9029	6.60008
Safety	47	55.10	98.20	76.5745	11.09372

7.1.4 Summary of the sum variables

Level-1 variables consist of the system model variables that include the information of a whole meter within the measurement system down to only one variable (Table 14). The level-2 variables constitute the structure of a meter. As level-1 variables aid in understanding the overall dynamics of the measurement system model, level-2 variables give more specific information on which dimensions within a meter are most important.

In the analyses, mainly level-1 and level-2 variables were used, because the aim of this study is to identify the success factors for construction site operation. The measurement items were used in site reports for individual sites, for pinpointing development needs, but also the central observations on the level-3 variables are presented in this study.

7.2 NORMALITY OF SUM VARIABLES

Statistical tests have certain assumptions that must be true if the tests are to function correctly. Different statistical tests are performed on variables with different scales and different distribution types. In this study, it is assumed that the variables are normally distributed. However, the normality of the sum variables was tested to ensure that statistical tests suitable for normally distributed variables could be used.

The test of normality is performed for level-1 and level-2 variables with both Kolmogorov-Smirnov's and Shaphiro-Wilk's test. The latter is more suitable for small bodies of material, approximately 50 or fewer cases, and thus for this study. On the other hand, the number of cases, at 47, is very close to 50, so it is useful to try both tests to get a reliable picture of the situation.

Test results are expressed by statistical significance p (Sig. in Table 15). The H_0 hypothesis is that a variable is normally distributed, and this is not true if the p value is below 0,05. The max p value given to variables in the K-S test is 0,2, so when the p value is higher, it easily passes the normality test.

The only variable having problems passing the test is schedule deviation, the p (Sig.) value being 0,01. For studying this variable more closely, a frequency graph with normal curve and a QQ plot are drawn (Fig. 30). The problem seems to be a few extreme cases exceeding the typical variation in schedule deviation; otherwise, the distribution looks quite normal. In a QQ plot, the variables are normally distributed if they lie close to the dividing line. This seems to apply in this case. The number of cases looks small because they are often on top of each other since the unit is days. From numerical and visual inspection it can be concluded that also the schedule deviation variable is close enough to normal distribution, and thus all level-1 variables are considered to be normally distributed.

Table 15. Test of normality for level-1 variables. Variables are normally distributed if the p (Sig.) value is over 0,05.

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Preconditions	,067	46	,200*	,984	46	,755
Management systems	,060	47	,200*	,986	47	,824
Work behavior and leadership	,110	47	,200*	,967	47	,201
Total cost Company 4	,095	16	,200*	,965	16	,747
Schedule deviation	,181	46	,001	,948	46	,038
Quality	,099	41	,200*	,961	41	,164
Safety	,083	47	,200*	,977	47	,481

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

The K-S and S-W tests are conducted also for level-2 variables, and the results (Table 16) show that some variables are close to the 0,05 p value limit and some are even below it, in both tests. Inspection of charts and plots shows that a couple of variables are close to being not normal. It is concluded that the variables can be considered to be normally distributed for the purpose of this study because the vast majority clearly are so and there are few cases at or exceeding the limit.

An interesting variable is “focus on people” in the work behavior and leadership meter. It seems that opinions are divided in terms of liking or disliking a manager’s leadership style, and thus the variable is more polarized than the criteria for normality allow. The problem with some other variables may be that practices are similar within companies – concerning, for example, cost control – and consequently a variable isn’t as normally distributed as it would be if every site were managed at a more individual level. Although tests assuming that all variables are normally distributed are used in the study, it is useful to know the nature of the variables, especially in the limit cases.

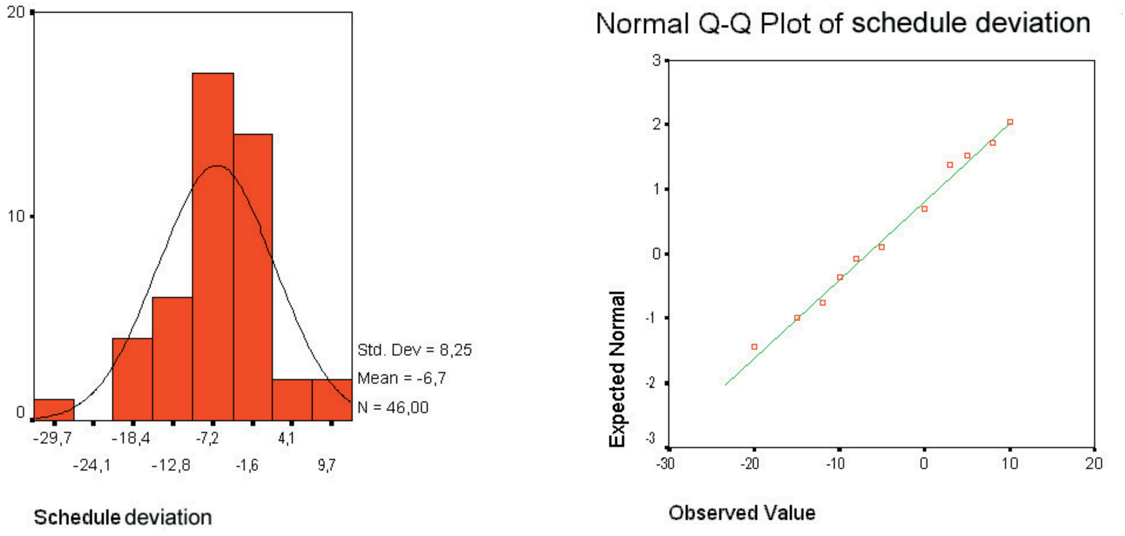


Figure 30. Frequency graph with normal curve and QQ plot for schedule deviation.

Table 16. Kolmogorov-Smirnov and Shapiro-Wilk tests of normality for level-2 variables.

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Client/consultant	,109	46	,200*	,973	46	,367
Designers	,105	46	,200*	,958	46	,098
Company headquarters	,071	46	,200*	,975	46	,415
Design control	,141	47	,020	,941	47	,020
Cost and quantity control	,145	47	,015	,924	47	,005
Production control	,069	47	,200*	,989	47	,939
Quality plan	,156	47	,006	,934	47	,011
Operation plans	,131	47	,041	,932	47	,009
Schedule and resource planning	,082	47	,200*	,973	47	,341
Procurement planning and implementation	,101	47	,200*	,974	47	,379
Organization, co-operation and communication	,099	47	,200*	,978	47	,503
Logistics, environment and safety	,120	47	,088	,978	47	,517
Focus on production	,091	47	,200*	,978	47	,525
Focus on people	,162	47	,003	,959	47	,102
Satisfaction and growth	,090	47	,200*	,986	47	,825
Effectiveness and clarity of tasks	,137	47	,028	,952	47	,053
Community spirit	,104	47	,200*	,978	47	,494
Communication	,081	47	,200*	,983	47	,701

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

7.3 HOMOGENEITY OF THE DATA

In this study, the main interest lies in discovering dependencies and relationships between variables that are part of the construction site system model. All other factors that are not part of the system model can potentially influence the relationships and thus serve as confounding factors, disturbing the analysis.

As mentioned previously, the research material consists of data from construction sites of four companies. Moreover, sites can be classified by contract type, location, building type, and so on. It is possible for sites with certain characteristics to have something in common that affects the variables in the system model. If these regularities don't exist in the material, it can be called homogeneous. If they do exist, this is of course an interesting observation in its own right, but it is important to recognize them also because they can cloud the actual dependencies between variables that are part of the focus of this study.

If the material is not homogeneous, the variation due to the classifying variables should be either eliminated or taken into consideration in forming conclusions. One way to eliminate the variation is to remove some cases or groups of cases from the data, if doing so can be justified. Another way is to divide cases into groups and test them separately.

These regularities in different groups in the data can be tested by discriminant analysis. It reveals whether the material differs systematically depending on the classification variables and gives a comprehensive picture of a large body of material quickly. Discriminant analysis is performed on interval-scale variables with a normal distribution.

Discriminant analysis is performed for level-1 variables. The classification variables tested were those that could potentially influence site operation in some way, and that had information reliably collected for the general information sheet of the performance measurement system. Some classifying variables express practically the same issue, and the analysis was not performed for both of them (for example, extent of subcontracting and proportionof external employees).

The classification variables used were:

- company (differences between companies),
- project type (different starting points for projects),
- building type (type of product),
- proportion of external employees (lack of integration of management environment),
- building volume (size of the site), and
- degree of completion (construction phase at the time of measurement).

In discriminant analysis, one or several variables are independent variables analyzed in relation to one classification variable. The procedure generates a discriminant function, or a set of them, based on the linear combinations of the independent variables that provide the best discrimination between groups.

In this analysis, the total cost variable is not just the total cost (final) key indicator, which was not acquired for all sites, nor is it Company 4 values; instead, it consists of values marked “latest,” which could be the total cost (final), or the latest cost prediction from a site if the financial result was not available. This gives the widest coverage concerning financial results, which is of benefit for this test because the number of cases with calculable variables is increased.

In discriminant analysis, the structure matrix displays the number of discriminant functions found and the correlation of each variable with the function. The higher the correlations in a function are, the better the function discriminates the group from others, and the correlation helps to pinpoint the variables that differ most between the groups. The structure matrices having significant correlations are presented with the text, but he results are also based on the tables presented in Appendix 2, Section A2.2:

- group statistics showing the means of independent variables within each group;
- Wilk’s Lambda test, evaluating the probability with which the functions can discriminate the groups; and
- classification results giving the results of classifications.

Table 17. Discriminant functions of the classification variable "company"; the p value of function 1 is significant at level 0,05.

Structure Matrix

	Function		
	1	2	3
Management systems	,765*	,298	,178
Quality	-,274*	,169	-,109
Safety	,392	-,625*	,156
Work behavior and leadership	,058	,193*	,144
Preconditions	,172	,305	,794*
Schedule deviation	-,109	-,249	,589*
Total cost (latest)	,021	-,043	,286*

Pooled within-groups correlations between discriminating variables and standardized canonical discriminant functions

Variables ordered by absolute size of correlation within function.

*. Largest absolute correlation between each variable and any discriminant function

Discriminant functions of the classification variable "company" – which can have one of four values (number of the company) – are presented in a structure matrix (Table 17 and Appendix 2, A2.2). Three different functions are found. The p value according to the Wilk's Lambda test of function 1 is 0,045, which mean that the function can discriminate groups with probability level 0,05. The p values of the other two functions are not significant (0,183 and 0,264). The variables discriminating the groups especially well are management systems, preconditions, safety, and schedule deviation.

Comparing the means of the variables by group makes the situation clearer (Appendix 2, A2.2). The preconditions level on sites of Company 1 is about 10 % better than in other firms, which explains the high correlation in function 1. As function 2 indicates, management systems in Company 3 are on about a 15 % lower level. Safety levels in companies 1 and 4 are about 10 % better than in the other two companies. For schedule deviation, differences between groups are not significantly high.

The second classification variable is project type (Table 18 and Appendix 2, A2.2). The test produces two discriminant functions, for which the p value of the first is 0,032 and the second 0,096, which is statistically indicatively significant.

Table 18. Discriminant functions of classification variable project type. Only the p value of function 1 is significant at level 0,05.

Structure Matrix

	Function	
	1	2
Safety	,583*	-,226
Total cost (latest)	,427*	,046
Quality	-,359*	-,094
Management systems	,116	,613*
Preconditions	,435	,465*
Work behavior and leadership	-,176	,426*
Schedule deviation	,002	,026*

Pooled within-groups correlations between discriminating variables and standardized canonical discriminant functions

Variables ordered by absolute size of correlation within function.

*. Largest absolute correlation between each variable and any discriminant function

The variables safety, total cost (latest), and management systems have the highest correlations.

From the means of variables within groups, it appears that preconditions form an interesting sequence: the highest level is found for negotiated contract projects, the second highest for property development projects, and the third highest for competition projects. The difference between groups is about 5 %, which is still not remarkably high. Management systems are at a slightly lower level at competition sites, which could be a logical consequence of the fact that Company 3 had many competition sites and the management systems of the company were at a lower level in general. Cooperation agreement projects seem to yield considerably better financial results. Also, safety is at a higher level for cooperation agreement projects, but the work behavior and leadership value is better for property development sites. However, the differences are not very significant.

Discriminant analysis for the classification variable building type produces four functions (Table 19 and Appendix 2, A2.2). Although there are four classes in the material, the industry/warehouse class contains only one site and is not given more in-depth consideration. The p value of function 1 is 0,016, which is statistically significant. The p value of function 2 is 0,213, and the p values of the other two are considerably higher. The safety and preconditions variables show differences; others are not statistically significant.

The group with the most noticeable difference is row houses, which have a 10-15 % worse safety level than the other groups do. Preconditions are at the highest level for apartment buildings, and lowest for public, store, and office buildings. Other variables don't form clear groups. As the differences between groups are relatively small and concern only a few variables, the test lends no support to the idea that the meters should be different for different types of buildings.

Proportion of external employees, which illustrates the amount of work done by subsidiary contractors and subcontractors, produces four discriminant functions, but none of them separate groups at a statistically significant level. The p value of function 1 is 0,288, with the others much higher (Appendix 2, A2.2). Another

Table 19. Discriminant functions of classification variable building type. Only the p value of function 1 is significant at level 0,05.

Structure Matrix

	Function			
	1	2	3	4
Safety	,647*	-,521	,109	-,132
Preconditions	,512*	,306	,051	,500
Total cost (latest)	,220	-,111	,519*	,084
Management systems	,153	,338	,353*	-,225
Work behavior and leadership	,085	,140	,263	,654*
Schedule deviation	-,002	-,404	,503	,639*
Quality	-,260	-,146	-,032	,519*

Pooled within-groups correlations between discriminating variables and standardized canonical discriminant functions

Variables ordered by absolute size of correlation within function.

*. Largest absolute correlation between each variable and any discriminant function

problem in the material is that there are few sites in the smallest and largest site groups, which makes evaluating those groups unreliable. The only variable with some grouping capabilities is management systems. It seems that the number of subsidiary contractors or subcontractors doesn't have a significant effect on variables in the system model.

Also, the classification variable building volume produces four discriminant functions. The best one divides sites into groups at p level 0,120, which is not statistically significant, and other p values are considerably higher. No clear groups can be formed based on the size of sites, which is an interesting observation because size is often also used as an explanation for bad or even good measurement results.

The last of the classification variables tested was the degree of completion, which tells whether the construction phase at the time of the measurement affects the measurement results. The variable has five classes, but only two sites were in the 61-80 % category (see Appendix 2, A2.2). Six sites were nearly completed, in the 81-100 % category. The discriminant functions are not statistically significant; the best of the functions, function 1, separates variables at p level 0,293. No clear groups can be distinguished, and this indicates that construction phase doesn't affect measurements significantly.

Discriminant analysis shows that the research material forms groups only in certain limited respects. The differences concerned only certain variables, and no obvious groups were found that would be totally different from others. The central observations on variables that differ between groups were as follows.

- Company 1 had slightly better preconditions on average, management systems in Company 3 were at a lower level than in other companies, and safety was a little better in companies 1 and 4.
- Project preconditions were best in cooperation agreement projects, second best in property development projects, and third best in competition projects.
- Row houses had a worse safety level than the other building types did.
- Project preconditions were considered to be best in apartment houses and lowest in public, store, and office buildings.
- Proportion of external employees, gross cubic meters, or degree of completion didn't seem to have a significant influence on project performance.

It can be concluded that the material is rather homogeneous, although certain differences in some variables were observed, mainly between companies. The absence of remarkable groups in the system model variables means that construction sites work basically in a very similar way, independent of the type or size of the project. It is not appropriate to divide the material into groups for the analysis because none of the classification variables affected all or even most of the system model variables, which makes the grouping of sites difficult. However, one must be conscious of the fact that certain differences exist in specific aspects of the material, and they should be taken into consideration in forming conclusions on the analyses.

8 RESULTS

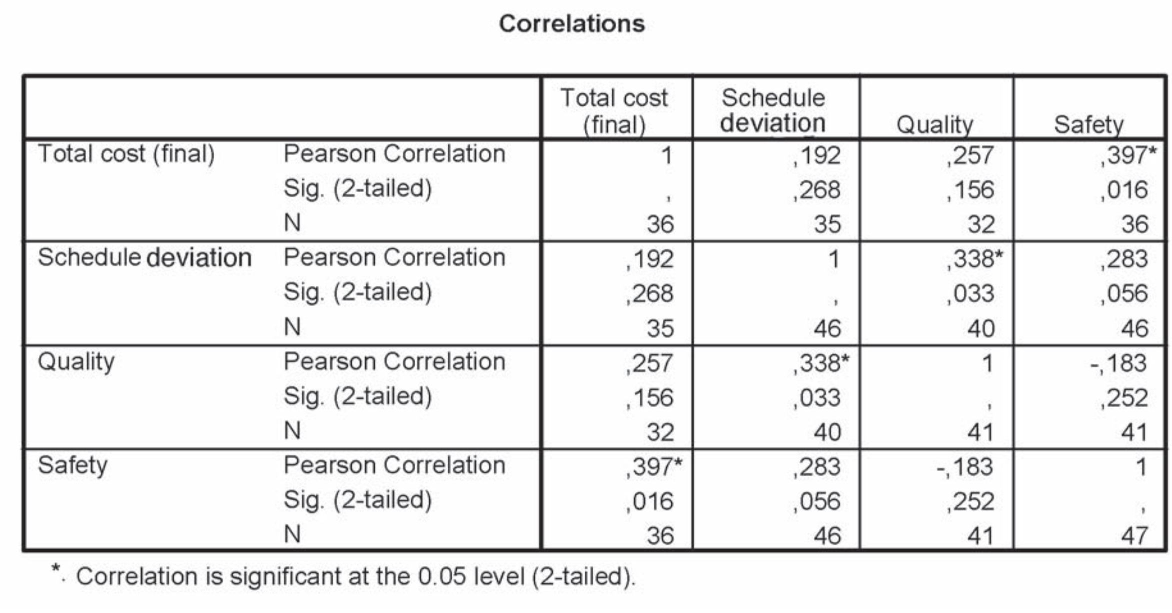
8.1 CONSTRUCTION SITE SUCCESS ELEMENTS

If total cost, schedule deviation, quality, and safety correlated positively, then a site's success in one of these would probably indicate success in others as well. On the other hand, if the result components didn't correlate with each other, it would mean that sites could succeed well with one component and fail with others. This question was concerned with research hypotheses H1 and H2. If the success of a site were one totality, it would be possible to determine which factors are important for the overall success of a site. Otherwise, success factors for the overall success of a construction site could not be determined.

The relationships among result components were studied with Pearson correlations. Correlation matrices were prepared for both the whole body of material (Table 20) and the data for Company 4 (Table 21). Pearson correlations for the whole body of material showed that total cost has a rather high correlation with safety (p=0,016) but no significant correlations with schedule deviation (p=0,268) and quality (p=0,156). In the material for Company 4 alone, the correlations between total cost and the schedule deviation (p=0,03) and safety (p=0,002) were considerably higher, but that with quality was low (p=0,256).

Pearson correlations show also that schedule deviation correlates with safety and quality, but the correlations are stronger in the data for Company 4. Quality correlates somewhat with schedule deviation, but not properly with any other result component. Safety and quality have no positive correlation at all.

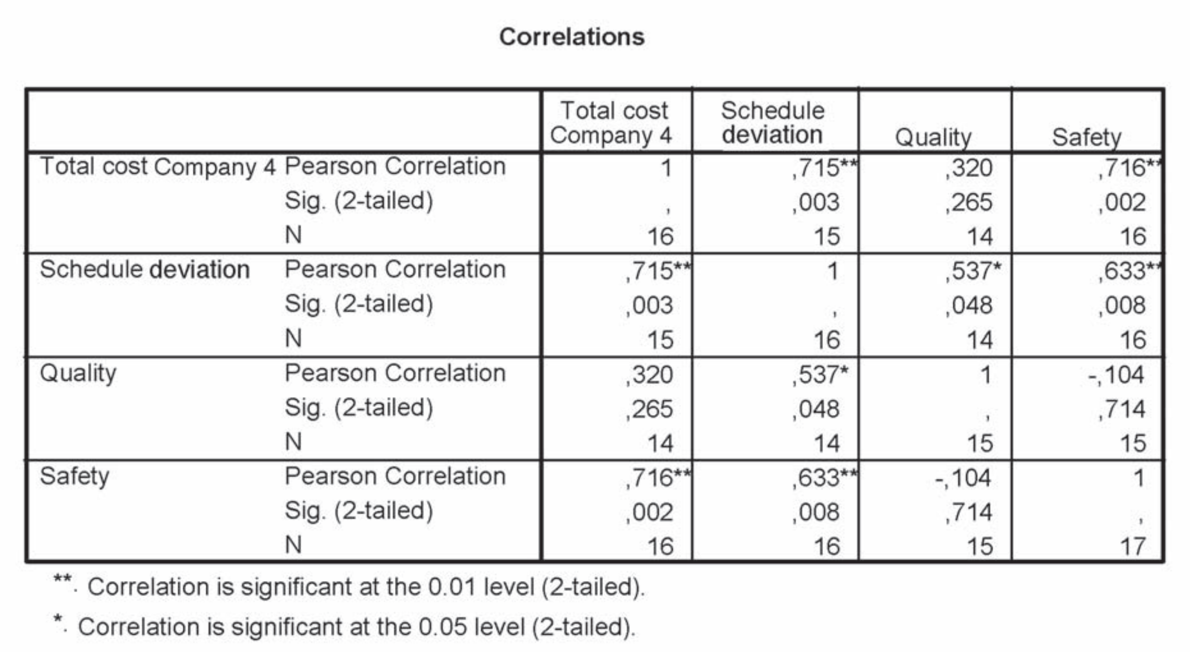
Table 20. Correlation matrix for result components, including all material that has the independent variable measured.



Correlations

		Total cost (final)	Schedule deviation	Quality	Safety
Total cost (final)	Pearson Correlation	1	,192	,257	,397*
	Sig. (2-tailed)	,	,268	,156	,016
	N	36	35	32	36
Schedule deviation	Pearson Correlation	,192	1	,338*	,283
	Sig. (2-tailed)	,268	,	,033	,056
	N	35	46	40	46
Quality	Pearson Correlation	,257	,338*	1	-,183
	Sig. (2-tailed)	,156	,033	,	,252
	N	32	40	41	41
Safety	Pearson Correlation	,397*	,283	-,183	1
	Sig. (2-tailed)	,016	,056	,252	,
	N	36	46	41	47

*. Correlation is significant at the 0.05 level (2-tailed).



Correlations

		Total cost Company 4	Schedule deviation	Quality	Safety
Total cost Company 4	Pearson Correlation	1	,715**	,320	,716**
	Sig. (2-tailed)	,	,003	,265	,002
	N	16	15	14	16
Schedule deviation	Pearson Correlation	,715**	1	,537*	,633**
	Sig. (2-tailed)	,003	,	,048	,008
	N	15	16	14	16
Quality	Pearson Correlation	,320	,537*	1	-,104
	Sig. (2-tailed)	,265	,048	,	,714
	N	14	14	15	15
Safety	Pearson Correlation	,716**	,633**	-,104	1
	Sig. (2-tailed)	,002	,008	,714	,
	N	16	16	15	17

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 21. Correlation matrix showing correlation between result components, including only the material for Company 4.

Total cost seems to correlate most highly with schedule deviation and safety in the data of Company 4, and smaller correlations exist also between some other success components. The situation is summarized in Figure 31, where the strengths of correlations are illustrated by the arrows' thickness.

Total cost correlates most strongly with schedule deviation and safety, but correlations of a certain magnitude appear also with schedule deviation / safety and schedule deviation / quality. This indicates that the result elements are usually interconnected but that they have variation independent of each other as well.

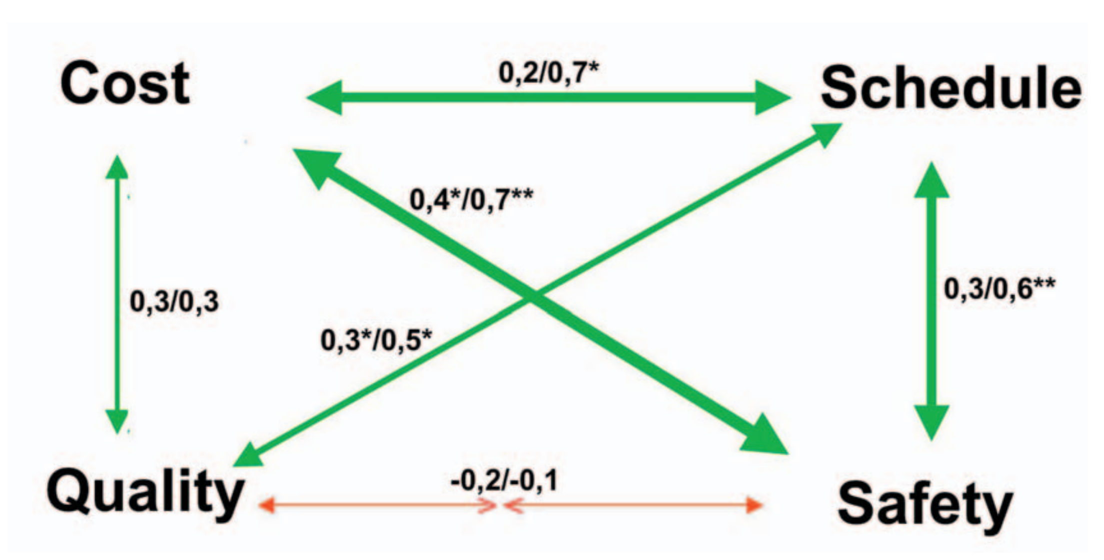


Figure 31. Summary of the correlations between construction site success elements. The use of two stars indicates significant correlation, and one star denotes indicatively significant correlation. The first number refers to correlation over the whole data set, while the second applies to only the data for Company 4.

8.2 CONSTRUCTION SITE SUCCESS FACTORS

8.1.1 Correlations between the performance system model elements

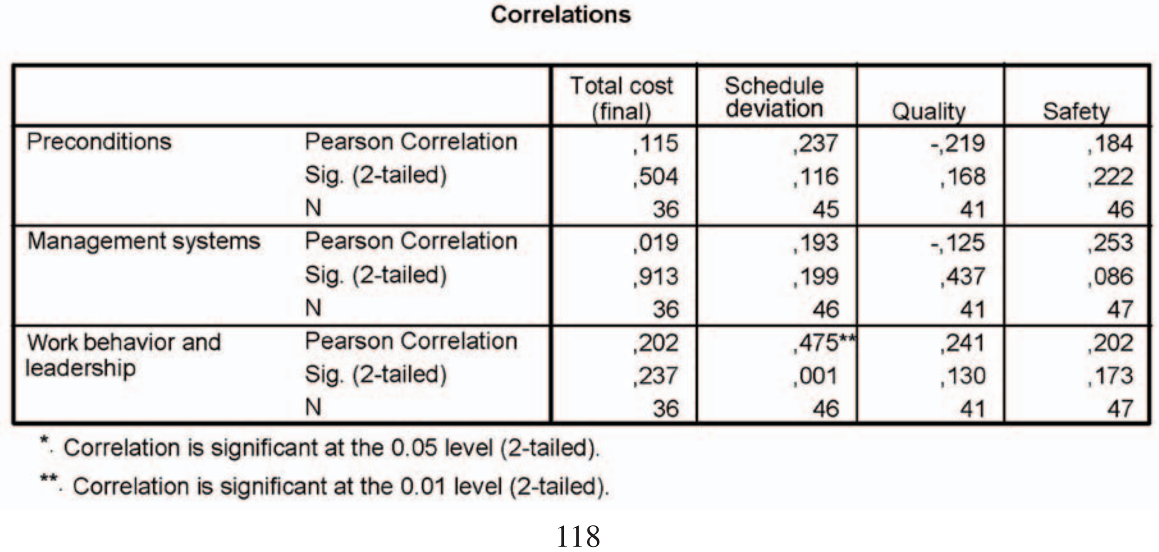
The system model of construction site performance illustrates the hypothetical performance elements and their interaction. The purpose of the analysis is to find out what kinds of relationships are found between the elements and whether they support the system model assumptions and research hypotheses. This issue is addressed in research hypotheses H3 and H4. Can success factors common to all construction sites be determined, or are the sites so different and individual that common factors cannot be found or identified among other influences originating outside the system model?

The relationships between the elements of the performance model can be analyzed on three levels, referring to the variable hierarchy in the measurement system. They are called here level-1, level-2, and level-3 variables, as presented in Section 7.1.4. As a single common variable for describing the overall success of a construction site is not used, dependencies are tested with the success variables total cost, schedule deviation, quality, and safety separately.

To gain a preliminary understanding of relationships between variables, correlation coefficients between the level-1 variables of the system model were calculated. The correlations are calculated for both the whole data set and the data for Company 4, consisting of 17 sites, because of the higher reliability of the latter where the total cost variable is concerned.

First, the correlations between potential success factors and result variables are studied. The correlations shown in the material as a whole between level-1 process and result variables are presented in Table 22. Although positive, the correlations

Table 22. Correlations between success factors and result variables over the whole data set.



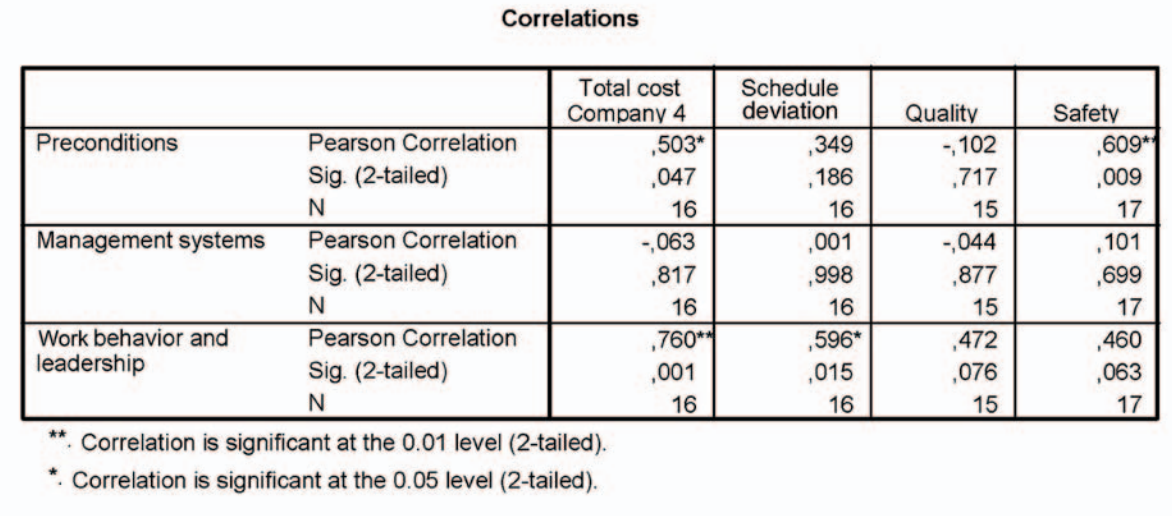
Correlations

		Total cost (final)	Schedule deviation	Quality	Safety
Preconditions	Pearson Correlation	,115	,237	-,219	,184
	Sig. (2-tailed)	,504	,116	,168	,222
	N	36	45	41	46
Management systems	Pearson Correlation	,019	,193	-,125	,253
	Sig. (2-tailed)	,913	,199	,437	,086
	N	36	46	41	47
Work behavior and leadership	Pearson Correlation	,202	,475**	,241	,202
	Sig. (2-tailed)	,237	,001	,130	,173
	N	36	46	41	47

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Table 23. Correlations between process and result variables in the Company 4 data.



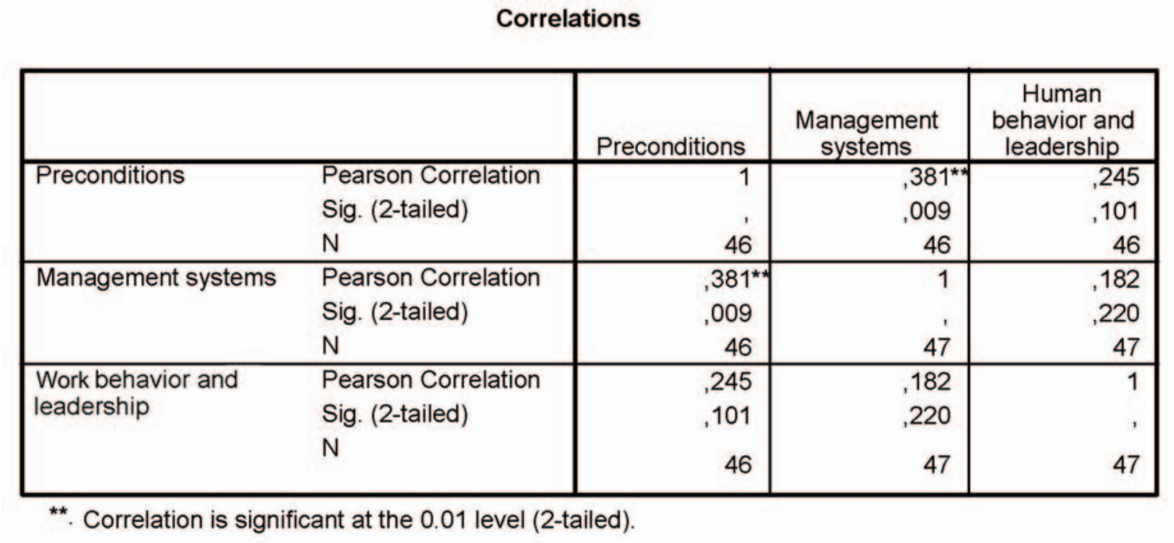
Correlations

		Total cost Company 4	Schedule deviation	Quality	Safety
Preconditions	Pearson Correlation	,503*	,349	-,102	,609**
	Sig. (2-tailed)	,047	,186	,717	,009
	N	16	16	15	17
Management systems	Pearson Correlation	-,063	,001	-,044	,101
	Sig. (2-tailed)	,817	,998	,877	,699
	N	16	16	15	17
Work behavior and leadership	Pearson Correlation	,760**	,596*	,472	,460
	Sig. (2-tailed)	,001	,015	,076	,063
	N	16	16	15	17

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 24. Correlations between preconditions and process variables over the whole data set.

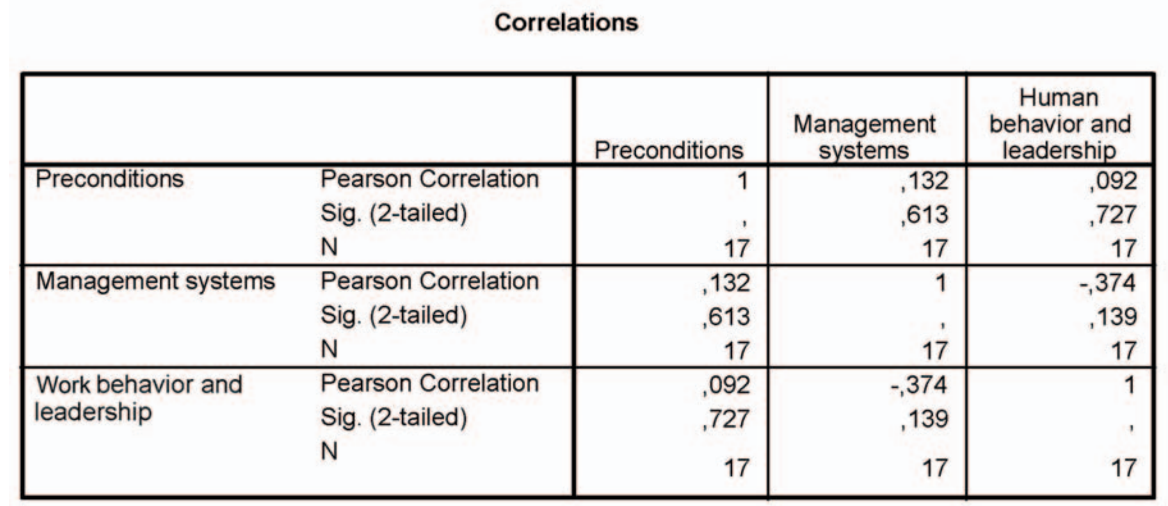


Correlations

		Preconditions	Management systems	Human behavior and leadership
Preconditions	Pearson Correlation	1	,381**	,245
	Sig. (2-tailed)	,	,009	,101
	N	46	46	46
Management systems	Pearson Correlation	,381**	1	,182
	Sig. (2-tailed)	,009	,	,220
	N	46	47	47
Work behavior and leadership	Pearson Correlation	,245	,182	1
	Sig. (2-tailed)	,101	,220	,
	N	46	47	47

**. Correlation is significant at the 0.01 level (2-tailed).

Table 25. Correlations between preconditions and process variables in the Company 4 data.



Correlations

		Preconditions	Management systems	Human behavior and leadership
Preconditions	Pearson Correlation	1	,132	,092
	Sig. (2-tailed)	,	,613	,727
	N	17	17	17
Management systems	Pearson Correlation	,132	1	-,374
	Sig. (2-tailed)	,613	,	,139
	N	17	17	17
Work behavior and leadership	Pearson Correlation	,092	-,374	1
	Sig. (2-tailed)	,727	,139	,
	N	17	17	17

are weak, with the exception of the correlation between work behavior and leadership and the schedule deviation variable (p=0,01). Quality even has negative correlations with process variables.

In the correlation matrix for only Company 4 (Table 23), both the preconditions and the work behavior and leadership variables have strong correlations with total cost and schedule deviation. Management systems still don't correlate with success indicators even in this material, the most homogeneous and reliable data. However, work behavior and leadership correlates with total cost (p=0,001) as well as schedule deviation (p=0,015).

In order to evaluate the system model, also correlations between preconditions and process variables (management systems, work behavior and leadership) are useful. They are also presented in two ways, for the whole body of material and only for Company 4. The matrix for the whole body of material (Table 24) shows that preconditions and management systems correlate highly (p=0,009). With the material of only Company 4 (Table 25), no statistically significant correlations exist.

There seem to be great differences in how the system components correlate with the result variables. Work behavior and leadership have the highest correlations with practically all result components, and management systems correlations with other system model components are weak. The relative importance of the success factors is further studied via regression analysis.

8.1.2 Relative importance of the performance factors

Generally speaking, the purpose of all statistical tests is to study the relationships between variables. Some tests, like correlation analysis, explore relationships between two variables. In regression analysis, the relative influence of several independent variables on one dependent variable, and their relationship, are studied. The simultaneous relationships between many variables can be studied with, for example, structural equation models (Rigdon 1988, Nummenmaa et al. 1997). In structural equation modeling, several statistical techniques – such as path analysis, factor analysis, and regression analysis – are integrated in validating a measurement model and then fitting the best structural model to it.

In this study, only correlation and regression analyses are used in determining the links and causal relationships between system model elements. The aim of the study is to determine the success factors for a construction site, which serves the practical development of construction site operation. The performance measurement system developed is based on the framework of systems thinking, but in this study systems thinking is applied more as a philosophy than as a mechanical tool. Therefore, the focus is not on determining with complete accuracy the actual network of dependencies in system model operation but to find out specifically how the variation in the performance system model elements of preconditions and operation process causes variation in the success elements. The aim is to find out what should be done in planning and managing a site in order to get better results, not to model all possible dependencies, which would produce an imperfect model anyway, considering the complex nature of construction site operation and the influence of factors that are not included in the model.

Multiple regression analysis explores the linear correlation between one dependent variable and the independent variables, and it yields also the relative strength of the relationships through correlation coefficients in the linear equation. The R^2 value of the regression model expresses the degree of variation in the dependent variable, which is explained by the equation model. The F-test gives the probability that the model explains the variation in the dependent variable as a p value, where a value below 0,01 is statistically significant.

Assumptions for regression analysis are that variables are of interval scale; they have normal distribution; and independent, explanatory variables don't correlate with each other. The test of normality for the interval-scale sum variables has already been performed (see Section 7.2). If a high correlation exists between independent variables (in this case, preconditions, management systems, and work behavior and leadership), it means that there may be a problem with collinearity. This makes the regression model unreliable because explanatory variables explain each other's variance instead of the dependent variables'. However, when the purpose is only to predict the value of the dependent variable in relation to changes in independent variables, this is not as big a problem (Häkkinen 2001).

According to the correlation matrix of success factors in tables 24 and 25, correlations between explanatory variables are low for the whole set of material, except for that between preconditions and management systems, which makes it necessary to test the effect of collinearity in connection with the analyses. The collinearity test is conducted in connection with the coefficients table, where a collinearity tolerance value close to 0 indicates that a collinearity problem may exist. A collinearity problem didn't appear for the tests including the material for only Company 4, because of the low correlations in Table 25.

The regression analyses are conducted first for all of the material and then for the material for Company 4. The latter analysis has been performed separately because this was the most homogeneous and reliable material – not just because of the possibility of collecting the total cost key indicator data directly but also because in the Company 4 material the influence of differences between companies is eliminated. In studying the relative importance of success factors, it is beneficial for the variation caused by factors not relevant for the research to be eliminated to the greatest extent possible. When both the whole body of material and the Company 4 data are considered, the latter material probably provides the best conception of the situation.

In the analysis, total cost is the dependent variable, and preconditions, management systems, and work behavior and leadership are the independent, predictor variables. The regression models may not explain the dependent variable well, because other factors from outside the model have a greater influence, or due to measurement errors. Or there might simply be no connection between the dependent and predictive variables. The R^2 and p (Sig.) indicators help us to evaluate how good the model is in explaining the dependent variable, and the standardized coefficients indicate the relative weight of each independent variable in the model.

A R^2 value close to 1 means that the model explains the variation of the dependent variable well, and a value close to 0 that it does not explain it. The probability of explaining the variation with the model is given by the p (Sig.) value in the ANOVA table. In the coefficient table, the collinearity tolerance tests the possible problem with collinearity between independent variables, where a value close to 0 implies that a collinearity problem may exist. In addition, the PP plots and scatterplots of the residuals were inspected, although this was relevant only when the model was otherwise good.

First, the model for total cost is calculated for the whole body of material, although the total cost key indicators were highly unreliable for companies other than Company 4. In this case, the key indicator “total cost (latest)” was used, meaning that if the total cost (final) was not available, the predicted cost at the time of the measurement was used. Thus, the number of sites in the analysis was 44; otherwise, it would have been only 36.

The model for “total cost (latest)” is presented in Table 26, and according to the R^2 (0,11) and p (0,92) values, the model does not explain the dependent value in practical terms at all, which confirms the unreliability of cost data for the whole data set. Collinearity and residual tests are in this case irrelevant.

Table 26. Regression analysis of total cost (latest) over the whole data set (N=46).

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,110[a]	,012	-,062	5,20178

a. Predictors: (Constant), Human behavior and leadership, Management systems, Preconditions

b. Dependent Variable: Total cost (latest)

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	13,316	3	4,439	,164	,920[a]
	Residual	1082,340	40	27,058		
	Total	1095,656	43			

a. Predictors: (Constant), Human behavior and leadership, Management systems, Preconditions

b. Dependent Variable: Total cost (latest)

Coefficients[a]

		Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics	
Model		B	Std. Error	Beta	t	Sig.	Tolerance	VIF
1	(Constant)	-6,544	10,169		-,644	,524		
	Preconditions	4,465E-02	,089	,087	,503	,618	,823	1,215
	Management systems	-1,454E-02	,074	-,034	-,198	,844	,846	1,182
	Human behavior and leadership	5,419E-02	,143	,062	,379	,707	,931	1,074

a. Dependent Variable: Total cost (latest)

Table 27. Regression analysis of schedule deviation over the whole data set (N=46).

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,496[a]	,246	,191	7,424

a. Predictors: (Constant), Human behavior and leadership, Management systems, Preconditions

b Dependent Variable: Schedule deviation

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	736,716	3	245,572	4,456	,008[a]
	Residual	2259,621	41	55,113		
	Total	2996,336	44			

a. Predictors: (Constant), Human behavior and leadership, Management systems, Preconditions

b Dependent Variable: Schedule deviation

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	-58,551	14,347		-4,081	,000		
	Preconditions	8,577E-02	,125	,102	,684	,498	,823	1,215
	Management systems	5,241E-02	,104	,074	,505	,616	,846	1,182
	Human behavior and leadership	,626	,202	,436	3,104	,003	,931	1,074

a Dependent Variable: Schedule deviation

Table 28. Regression analysis of quality for the whole data set (N=41).

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,382[a]	,146	,077	6,34212

a. Predictors: (Constant), Human behavior and leadership, Management systems, Preconditions

b. Dependent Variable: Quality

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	254,209	3	84,736	2,107	,116[a]
	Residual	1488,234	37	40,223		
	Total	1742,442	40			

a. Predictors: (Constant), Human behavior and leadership, Management systems, Preconditions

b. Dependent Variable: Quality

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	80,226	12,852		6,242	,000		
	Preconditions	-,179	,112	-,267	-1,592	,120	,823	1,215
	Management systems	-,046	,093	-,082	-,496	,623	,846	1,182
	Human behavior and leadership	,368	,181	,321	2,037	,049	,931	1,074

a. Dependent Variable: Quality

In the regression model for schedule deviation over the whole data set (Table 27), work behavior and leadership has the highest coefficient, while the coefficients of other variables are not significant. The R^2 value of the whole model is 0,25, which means that the model does not explain the variation of schedule deviation very well. The p value of the model is 0,01, which is statistically significant. The collinearity tolerance and residual tests (not included here) show no noteworthy problems concerning collinearity.

Table 29. Regression analysis of safety over the whole data set (N=47).

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,305[a]	,093	,029	10,93418

a. Predictors: (Constant), Human behavior and leadership, Management systems, Preconditions

b. Dependent Variable: Safety

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	516,812	3	172,271	1,441	,244[a]
	Residual	5021,367	42	119,556		
	Total	5538,179	45			

a. Predictors: (Constant), Human behavior and leadership, Management systems, Preconditions

b. Dependent Variable: Safety

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	38,891	20,897		1,861	,070		
	Preconditions	8,102E-02	,183	,072	,444	,659	,823	1,215
	Management systems	,188	,151	,198	1,242	,221	,846	1,182
	Human behavior and leadership	,286	,294	,148	,973	,336	,931	1,074

a. Dependent Variable: Safety

In the regression model for quality, none of the independent variables correlate with quality significantly (Table 28). The R^2 of the model is 0,15, and the F-test p value of is 0,12, which means that the model doesn't explain the relationships between predictor variables and quality as measured by the performance measurement system.

Coefficients in the regression model of safety too are low, and their p values are not significant (Table 29). The R^2 of the model is only 0,09 and p value 0,24, so the model does not explain the variation in safety.

Corresponding tests have been conducted also on the data for only Company 4. In the regression model for total cost for Company 4 (Table 30), the R^2 value is 0,79, implying that only 21 % of the variance is not explained by the three variables. The F-test gives a p value of 0,00, which is statistically significant. In this model, the work behavior and leadership variable has the greatest influence on the dependent variable, and the p of the coefficient also is statistically significant.

With the model of total cost for Company 4, which is the best model so far, also the PP plot and residual scatterplots are presented here in order to evaluate the collinearity problem, if any, in the model (Fig. 32). In the PP plot, residual distribution is at least close to being normal, and no correlation is observable between residuals and predicted values, which means that no visible problem with collinearity exists and the model is reliable from this perspective also.

In the model of schedule deviation for Company 4 (Table 31), the R2 value of the model is 0,48, which means that the model explains about 50 % of the schedule deviation variation. The p value of the model is 0,04, which is indicatively significant. The best explanatory variable is again work behavior and leadership. Although the

Table 30. Regression analysis of total cost for the data for Company 4 (N=16).

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,891[a]	,794	,742	3,03265

a. Predictors: (Constant), Human behavior and leadership, Preconditions, Management systems

b. Dependent Variable: Total cost Company 4

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	424,723	3	141,574	15,394	,000[a]
	Residual	110,364	12	9,197		
	Total	535,087	15			

a. Predictors: (Constant), Human behavior and leadership, Preconditions, Management systems

b. Dependent Variable: Total cost Company 4

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	-88,441	15,025		-5,886	,000		
	Preconditions	,276	,091	,407	3,040	,010	,959	1,042
	Management systems	,123	,099	,179	1,243	,238	,832	1,202
	Human behavior and leadership	,890	,161	,790	5,520	,000	,840	1,191

a. Dependent Variable: Total cost Company 4

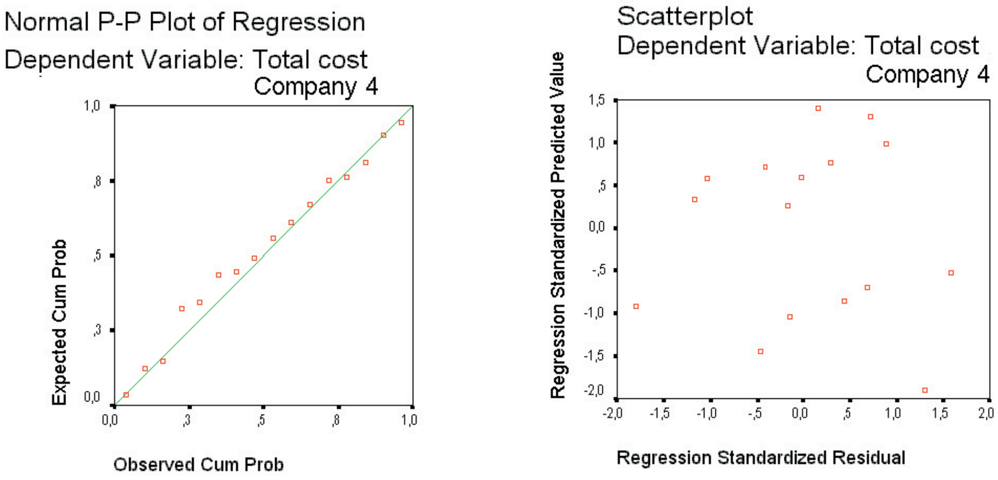


Figure 32. Test for residual normality and correlation between predicted values for the model for total cost, Company 4.

schedule deviation model was better for the whole set of data, the direction of the results is similar to that in the Company 4 model.

The regression model for quality that uses the Company 4 data is not much better than that using the whole body of material (Table 32). The R2 is 0,27 and p 0,30, meaning that the performance measurement system is not capable of explaining the variation in quality meter results. Therefore, not much can be concluded on the relative strengths of the coefficients either.

However, the regression model of safety in the Company 4 (Table 33) data is capable of explaining over 50 % of the material (R2=0,57), and the model is also

Table 31. Regression analysis of schedule deviation, using the data for Company 4 (N=16).

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,692[a]	,479	,349	7,069

a. Predictors: (Constant), Human behavior and leadership, Preconditions, Management systems

b. Dependent Variable: Schedule deviation

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	552,045	3	184,015	3,682	,043[a]
	Residual	599,705	12	49,975		
	Total	1151,750	15			

a. Predictors: (Constant), Human behavior and leadership, Preconditions, Management systems

b. Dependent Variable: Schedule deviation

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics	
		B	Std. Error	Beta	t	Sig.	Tolerance	VIF
1	(Constant)	-111,861	35,025		-3,194	,008		
	Preconditions	,260	,212	,261	1,229	,243	,959	1,042
	Management systems	,212	,231	,209	,917	,377	,832	1,202
	Human behavior and leadership	1,076	,376	,651	2,863	,014	,840	1,191

a. Dependent Variable: Schedule deviation

Table 32. Regression analysis of quality in the data for Company 4 (N=15).

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,523[a]	,274	,076	7,62930

a. Predictors: (Constant), Human behavior and leadership, Preconditions, Management systems

b. Dependent Variable: Quality

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	241,306	3	80,435	1,382	,300[a]
	Residual	640,269	11	58,206		
	Total	881,575	14			

a. Predictors: (Constant), Human behavior and leadership, Preconditions, Management systems

b. Dependent Variable: Quality

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics	
		B	Std. Error	Beta	t	Sig.	Tolerance	VIF
1	(Constant)	30,096	39,122		,769	,458		
	Preconditions	-,161	,237	-,178	-,679	,511	,959	1,042
	Management systems	,173	,259	,189	,670	,516	,832	1,202
	Human behavior and leadership	,837	,420	,559	1,993	,072	,840	1,191

a. Dependent Variable: Quality

Table 33. Regression analysis of safety for the data for Company 4 (N=17).

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,758[a]	,574	,476	8,01336

a. Predictors: (Constant), Human behavior and leadership, Preconditions, Management systems

b. Dependent Variable: Safety

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1125,469	3	375,156	5,842	,009[a]
	Residual	834,780	13	64,214		
	Total	1960,249	16			

a. Predictors: (Constant), Human behavior and leadership, Preconditions, Management systems

b. Dependent Variable: Safety

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	-52,877	38,444		-1,375	,192		
	Preconditions	,674	,232	,536	2,900	,012	,959	1,042
	Management systems	,274	,254	,214	1,079	,300	,832	1,202
	Human behavior and leadership	1,026	,412	,491	2,487	,027	,840	1,191

a. Dependent Variable: Safety

statistically significant (p=0,01). According to the discriminant analysis (Section 7.3), the safety level was systematically better in two of the companies, which may explain why the model for the whole body of material was worse than the model concerning only Company 4.

The regression models explaining the dependent variables best were the total cost, for the material for only Company 4; schedule deviation for the whole body of material; and safety in Company 4. The models of quality had low capability in explaining the variation, but through combining the information in the models of other success elements, one can detect a pattern of influences.

A summary of the regression analysis results is presented in Table 34, where the relative weights of the predictor variables are expressed as percentages. The regression analysis gives the relative weights of the variables as standardized coefficients (“beta values”) of the linear regression equation. How well the equation explains the variation in the dependent variable is given as an R^2 value. Therefore, the value $1\text{-}R^2$ gives the degree of variation that must be explained by factors apart from model measurement errors and so forth. In calculating the percentages, also the proportions of the $1\text{-}R^2$ values have been taken into account, thus expressing the proportion not explained by the regression models.

Even if the capabilities of explaining the variation in different result elements vary in each equation, the direction of the relative weights of the independent variables is the same. The influence of work behavior and leadership is the strongest affecting the success elements, and after that comes the influence of preconditions, at least in the cases of total cost and safety. The influence of management systems on site success is surprisingly weak in all models.

Table 34. Summary of the standardized coefficients in the regression models of the success elements, and their weights expressed as percentages. The below 0 values of coefficients have been changed to 0 for simplicity.

Total cost	**All companies**		**Company 4****	
	Stand. coeff.	**%**	**Stand. coeff.**	**%**
Model does not explain (1-R^2)	0,89	89	0,21	21
Preconditions	0,09	11	0,41	23
Management systems	0,00	0	0,18	10
Work behavior and leadership	0,00	0	0,79	45
	0,09	100	1,38	100

Schedule keeping	**All companies****		**Company 4***	
	Stand. coeff.	**%**	**Stand. coeff.**	**%**
Model does not explain (1-R^2)	0,75	75	0,52	52
Preconditions	0,10	4	0,26	11
Management systems	0,07	3	0,21	9
Work behavior and leadership	0,43	18	0,65	28
	0,60	100	1,12	100

Quality	**All companies**		**Company 4**	
	Stand. coeff.	**%**	**Stand. coeff.**	**%**
Model does not explain (1-R^2)	0,85	85	0,73	73
Preconditions	0,00	0	0,00	0
Management systems	0,00	0	0,19	7
Work behavior and leadership	0,32	15	0,56	20
	0,32	100	0,75	100

Safety	**All companies**		**Company 4****	
	Stand. coeff.	**%**	**Stand. coeff.**	**%**
Model does not explain (1-R^2)	0,91	91	0,43	43
Preconditions	0,07	2	0,54	25
Management systems	0,20	4	0,21	10
Work behavior and leadership	0,15	3	0,49	23
	0,42	100	1,24	100

* The p of the model is indicatively significant (0,01<p<0,05)

** The p of the model is statistically significant (p<0,01)

From the regression analysis, the main observation concerning the facts that the site itself can influence is that the practical behavior of people and the leadership capabilities on the site are the best indicators of economic success and keeping work at the site on schedule, and an advanced management system is not an equally important indicator of success in those respects. The regression analysis does not give as reliable information on which factors promote quality and safety, but a tentative conclusion can be drawn that the relative influence of the variables is similar to a great extent for quality and safety as well.

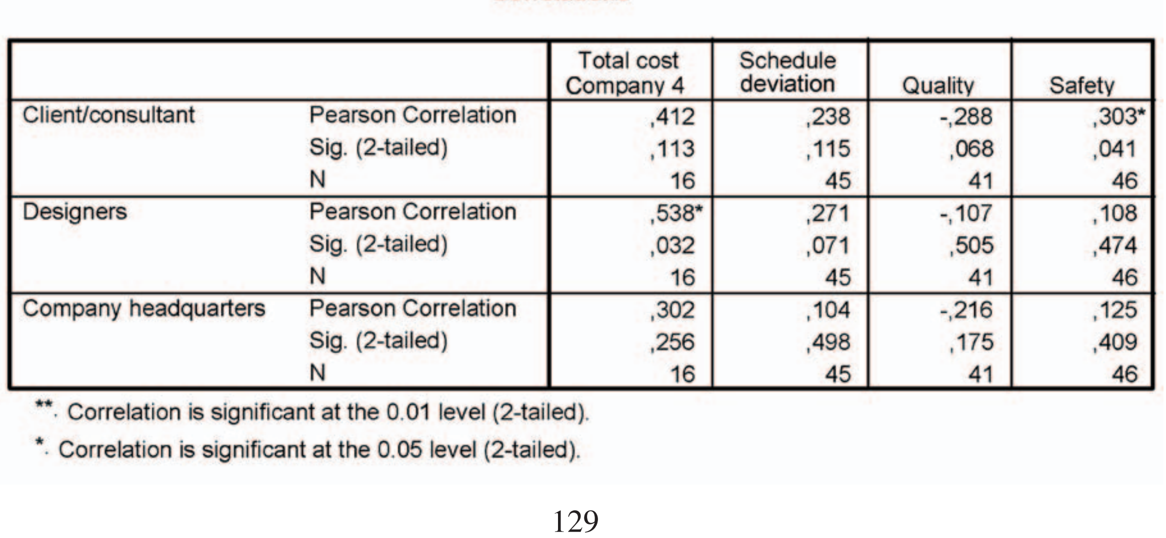
8.3 SUCCESS FACTORS IN THE LEVEL-2 VARIABLES

The sum variables that form the next-level structure or dimensions of the preconditions, management systems, and work behavior and leadership meters are called level-2 variables (see Table 14). The purpose of analyzing level-2 variables is to get more accurate information on the factors affecting success elements within each meter. The level-2 variables constitute the next-level structure, or dimensions, in the measurement methods of the performance measurement system, and they can pinpoint more accurately the areas of operation that affect the success elements the most.

Although the question is again about connections between variables, regression analysis is not the right method to use in this case. The number of variables is too high for them to be included in any useful regression model. A more simple and illustrative method is again the use of correlation. The overall picture of causalities and weights has already been presented on the system model level, and now the intention is to find the most important level-2 sum variables influencing construction site success. The level-2 sum variables of each measurement method have been given in Section 7.1.4, Table 14.

Correlations are first calculated for the three level-2 variables of preconditions (Table 35). The entire body of material is used in the analysis, except that for total cost only Company 4 material is used throughout the analysis, because of the higher reliability of the total cost variable in Company 4 data, as explained in Section 7.1.3.1. All correlations except those concerning quality are positive though not significant, and the statistically almost significant correlations are between designers and total cost for Company 4 (p=0,32) and between client/consultant and safety (p=0,41).

Table 35. Correlations between level-2 variables of preconditions and success elements.



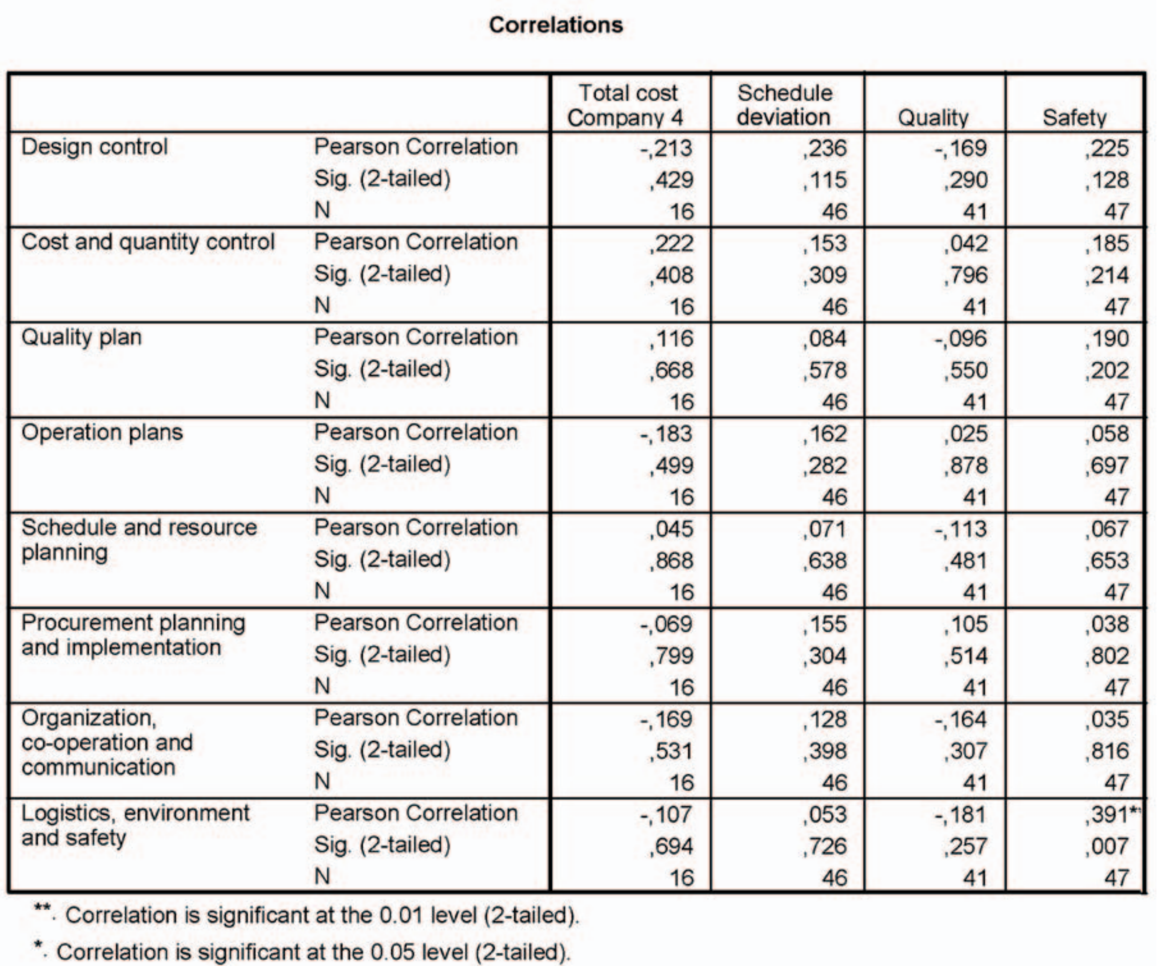
Correlations

		Total cost Company 4	Schedule deviation	Quality	Safety
Client/consultant	Pearson Correlation	,412	,238	-,288	,303*
	Sig. (2-tailed)	,113	,115	,068	,041
	N	16	45	41	46
Designers	Pearson Correlation	,538*	,271	-,107	,108
	Sig. (2-tailed)	,032	,071	,505	,474
	N	16	45	41	46
Company headquarters	Pearson Correlation	,302	,104	-,216	,125
	Sig. (2-tailed)	,256	,498	,175	,409
	N	16	45	41	46

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 36. Correlations between level-2 variables of management systems and success elements.



Correlations

		Total cost Company 4	Schedule deviation	Quality	Safety
Design control	Pearson Correlation	-,213	,236	-,169	,225
	Sig. (2-tailed)	,429	,115	,290	,128
	N	16	46	41	47
Cost and quantity control	Pearson Correlation	,222	,153	,042	,185
	Sig. (2-tailed)	,408	,309	,796	,214
	N	16	46	41	47
Quality plan	Pearson Correlation	,116	,084	-,096	,190
	Sig. (2-tailed)	,668	,578	,550	,202
	N	16	46	41	47
Operation plans	Pearson Correlation	-,183	,162	,025	,058
	Sig. (2-tailed)	,499	,282	,878	,697
	N	16	46	41	47
Schedule and resource planning	Pearson Correlation	,045	,071	-,113	,067
	Sig. (2-tailed)	,868	,638	,481	,653
	N	16	46	41	47
Procurement planning and implementation	Pearson Correlation	-,069	,155	,105	,038
	Sig. (2-tailed)	,799	,304	,514	,802
	N	16	46	41	47
Organization, co-operation and communication	Pearson Correlation	-,169	,128	-,164	,035
	Sig. (2-tailed)	,531	,398	,307	,816
	N	16	46	41	47
Logistics, environment and safety	Pearson Correlation	-,107	,053	-,181	,391**
	Sig. (2-tailed)	,694	,726	,257	,007
	N	16	46	41	47

**. Correlation is significant at the 0.01 level (2-tailed).

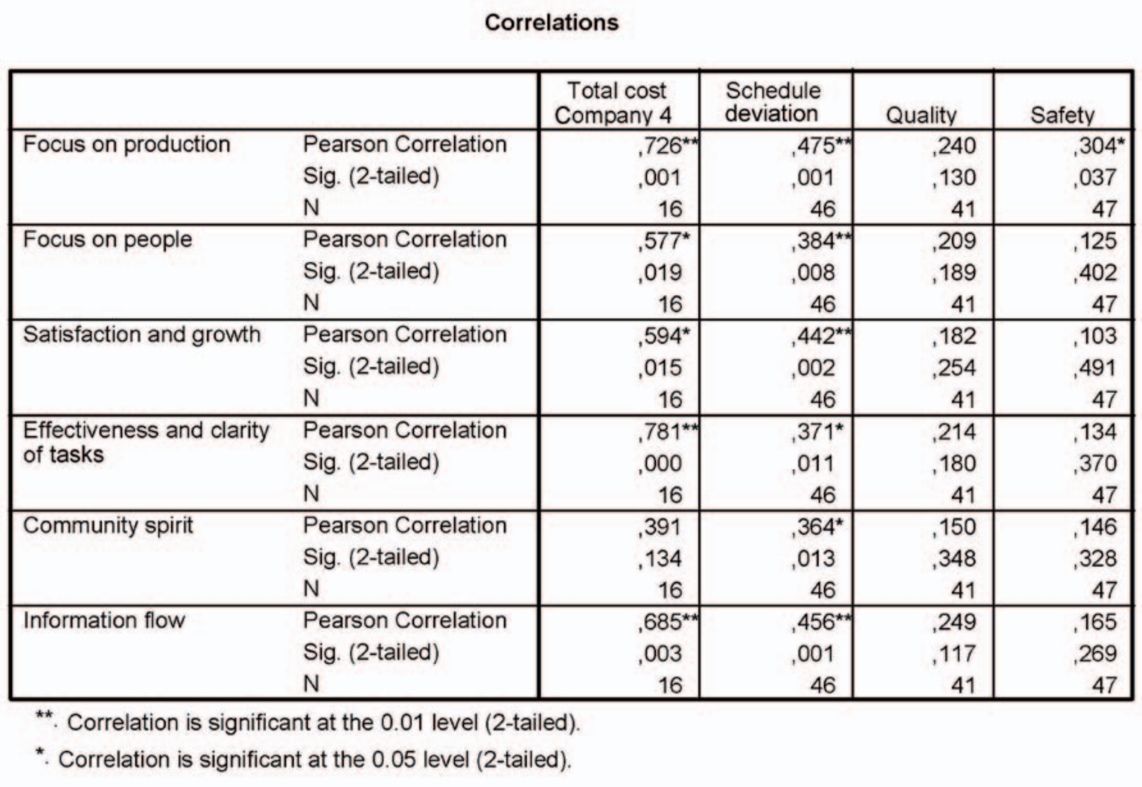
*. Correlation is significant at the 0.05 level (2-tailed).

The management systems element has eight level-2 dimensions, and the correlations are presented in Table 36. The correlations between management systems level-2 variables and success elements are low, the only almost statistically significant one being between safety and the logistics, environment, and safety (p=0,007) variable. The result is a logical one because the management systems did not correlate with the success elements as a whole either.

The six dimensions of work behavior and leadership have considerably higher correlations with success elements, as is expected on the basis of the analyses of the level-1 variables (Table 37). Focus on production correlates significantly with total cost for Company 4 (p=0,001) and schedule deviation (p=0,001). Focus on people correlates significantly with schedule deviation (p=0,008), and so does satisfaction and growth (p=0,002). Effectiveness and clarity of tasks correlates significantly with total cost for Company 4 (p=0,000), and communication correlates significantly with total cost for Company 4 (p=0,003) and schedule deviation (p=0,001).

Generally, the work behavior and leadership dimensions correlate the most with total cost for Company 4 and schedule deviation. All correlations between work behavior and leadership dimensions and the success elements are positive, even with quality and safety. The level-2 dimensions correlating the least with success elements are those related to community spirit.

Table 40. Correlations between level-2 success elements and work behavior and leadership dimensions.



Correlations

		Total cost Company 4	Schedule deviation	Quality	Safety
Focus on production	Pearson Correlation	,726**	,475**	,240	,304*
	Sig. (2-tailed)	,001	,001	,130	,037
	N	16	46	41	47
Focus on people	Pearson Correlation	,577*	,384**	,209	,125
	Sig. (2-tailed)	,019	,008	,189	,402
	N	16	46	41	47
Satisfaction and growth	Pearson Correlation	,594*	,442**	,182	,103
	Sig. (2-tailed)	,015	,002	,254	,491
	N	16	46	41	47
Effectiveness and clarity of tasks	Pearson Correlation	,781**	,371*	,214	,134
	Sig. (2-tailed)	,000	,011	,180	,370
	N	16	46	41	47
Community spirit	Pearson Correlation	,391	,364*	,150	,146
	Sig. (2-tailed)	,134	,013	,348	,328
	N	16	46	41	47
Information flow	Pearson Correlation	,685**	,456**	,249	,165
	Sig. (2-tailed)	,003	,001	,117	,269
	N	16	46	41	47

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Although the analysis of the level-2 variables does not increase knowledge of the interaction between construction site performance system elements, it does provide practical information on which elements within the measurement methods of the measurement system might be important in developing operations. However, the portion dealing with work behavior and leadership is essential to this study in determining the recommended model of organizational behavior on a construction site, which is the subject of research hypotheses H5 and H6.

8.4 SUCCESS FACTORS IN THE LEVEL-3 VARIABLES

Level-3 variables, which are the actual meter items in the system, were also analyzed with correlation matrices indicating their relationships with result variables (Appendix 2, A2.3). Spearman's Rho was used as the correlation method for the ordinal-scale level-3 variables in the preconditions, management systems, and work behavior and leadership meters in place of Pearson correlation, which was used earlier to analyze level-2 interval-scale sum variables.

The level-3 items that correlated highly with result variables are listed below. The result elements with which variables correlated, and Spearman's correlation coefficients and probability levels, are presented in paragraph form.

Preconditions

- Decisions and acceptances have been received quickly from the consultant, causing no delays in work *(total cost C4, r=0,53, p=0,04)*.
- The client/consultant's decisions have been unambiguous *(total cost C4, r=0,5, p=0,05; safety, r = 0,3, p=0,03)*.
- Designs have been systematically organized and indexed *(schedule deviation, r=0,38, p=0,01)*.
- The site has received designs on time *(schedule deviation, r=0,3, p=0,05)*.
- The construction designer has taken the suggestions from the site into account *(total cost C4, r=0,5, p=0,05; schedule deviation, r=0,4, p=0,02)*.
- Inner roofing hasn't been dismantled due to design faults *(total cost C4, r=0,7, p= 0,03)*.
- Concerning the actions of the line manager, there are:
  - appropriate site organization *(total cost C4, r=0,7, p=0,01),*
  - adequate resources *(total cost C4, r=0,8, p=0,00),*
  - preparation of procurements *(total cost C4, r=0,5, p=0,03),*
  - support in compiling subcontracts *(total cost C4, r=0,6, p=0,01), and*
  - general support and motivation *(total cost C4, r=0,6, p=0,02)*.

Management systems

- The site has received all designs on time for production *(total cost C4, r=0,5, p=0,05)*.
- The work phase operation plan includes risk analysis *(safety, r=0,3, p=0,02)*.
- Separate meetings with work groups are held prior to work phase commencement *(schedule deviation, r=0,4, p=0,00)*.
- There are a safety plan *(safety, r=0,3, p=0,02),* environment plan *(safety, r=0,3, p=0,04)*, and waste disposal plan *(safety, r=0,4, p=0,01)*.

Work behavior and leadership

(the questions that correlated statistically significantly at level 0,01)

- Work and operating instructions are consistent *(total cost C4, r=0,7, p=0,00)*.
- The works are organized well *(total cost C4, r=0,7, p=0,00; schedule deviation, r=0,6, p=0,00)*.
- Plans are followed accurately *(total cost C4, r=0,6, p=0,01; schedule deviation, r=0,4, p=0,01)*.
- Compliance with work specifications and quality requirements is monitored *(schedule deviation, r=0,5, p=0,00)*.
- Clear division of responsibility is followed in decision-making *(schedule deviation, r=0,4, p=0,00)*.
- Work goals are clear *(total cost C4, r=0,7, p=0,00; schedule deviation, r=0,5, p=0,00)*.

- The site has clear rules of operation *(total cost C4, r=08, p=0,00; schedule deviation, r=0,4, p=0,00)*.
- On site, plenty of results are achieved *(schedule deviation, r=0,5, p=0,00)*.
- The quality plan affects site operation *(schedule deviation, r=0,5, p=0,00)*.
- Good performance is rewarded *(total cost C4, r=0,7, p=0,00)*.
- Common goals are clear *(schedule deviation, r=0,4, p=0,01)*.
- Conflicts are dealt with and resolved *(schedule deviation, r=0,4, p=0,00)*.
- Enough information is given *(schedule deviation, r=0,5, p=0,00)*.
- Information is given openly *(total cost C4, r=0,7, p=0,00; schedule deviation, r=0,06, p=0,00)*.
- Sharing information with the foreman is useful *(total cost C4, r=0,7, p=0,01; safety, r=0,4, p=0,00)*.
- The foreman provides enough supervision of the workers *(schedule deviation, r=0,5, p=0,00; safety, r=0,4, p=0,00)*.
- The foreman treats workers equally *(total cost C4, r=0,6, p=0,01)*.
- The foreman is willing to try out workers' ideas *(schedule deviation, r=0,4, p=0,01)*.
- I'm satisfied with my foreman *(schedule deviation, r=0,5, p=0,00)*.

As expected from the results concerning sum variable dependencies, only a few management system items correlate clearly with result variables, and, again, many work behavior and leadership questions correlate highly with results. Usually, the correlations with total cost and schedule deviation are in the same direction, and often the same is true for safety. Quality gives even relatively high negative correlations, but the variation seems to be so irregular that any serious conclusions about relationships with quality and other variables are difficult to make.

9 DISCUSSION

9.1 BACKGROUND FOR DISCUSSING THE RESULTS OF THE STUDY

9.1.1 Aim, research questions, and hypotheses

The aim of the study was twofold: to develop a system for measuring construction site performance and to use it in determining the success factors of a construction site. The aim was further specified by the four research questions, of which the first two concern the developing of the measurement system and the last two are about determining the relationships between performance elements, focusing on the factors influencing the success of a site.

1. What are the elements of construction site performance?
2. How can the performance elements be measured?
3. How are the performance elements related, and how can they be integrated in a measurement system model?
4. What are the most important success factors in construction site operation?

On the basis of the research questions, the results of the study are:

- identification of the central performance elements for a construction site,
- methods for measuring each of these elements,
- an integrated performance measurement system for a construction site, and
- the central success factors in construction site operation according to the data analysis.

Additionally, six research hypotheses were established for helping to focus the statistical analysis of the research data. They determined more accurately the practical steps applied in answering research question 4, concerning the success factors of a site. The research hypotheses were presented in three pairs, where the hypotheses in each pair presented opposing alternatives. If the "positive" alternatives in the three pairs were found to be true, this would suggest that:

1. If a construction project is successful in one respect, it is probably successful in others as well.
2. A group of common factors influencing construction site success exists and their influence can be identified from other project-specific factors.
3. A generally recommended relative strength of the dimensions of organizational behavior in the construction site context can be determined.

The research questions describe the original progression of the study, where the measurement system had to be developed first and this information was analyzed after the research data had been collected. In this section, the results are presented and discussed in the “reverse” order: first, the results of the analysis are presented and discussed using the framework of the research hypotheses (Section 9.2). Later in the same section, the analysis results are then used to evaluate the measurement system, system model, and research material.

9.1.2 Use of the research approaches in discussing the results

The study was conducted according to the principles of a rational study. Although the development included some empirical development phases also, nearly in determining the dimensions of the organizational behavior accurately, the basic approach of developing the performance measurement system and analyzing the data collected is rational. This means that the measurement system was first developed on grounds of rational deduction, and then it was tested and verified with the research data. The measurement system was then used as a research instrument in gaining new knowledge of construction site operation. When the research data have been collected and analyzed, the rational model of the performance measurement system is evaluated with the experience and results from the research process.

The results concerning the analysis section of the study are discussed from the perspective of a success factor study. In success factor studies, the approach is practical and the intention is to find the important issues in the operation of the subject organization that should be focused on for achieving the desired results. The verification and generalization of the study is done by comparing the results to those of other studies, which are in this case other construction site success factor studies.

In the methodology section (1.6), the contingency approach was also mentioned. In contingency studies, the greatest compatibility between organization characteristics and its environment is sought. In this case, the environment is the Finnish construction industry. As the study has yielded the characteristics of a successful construction site, or success factors, in this particular environment, it could be considered as a contingency study also. However, the study did not involve analysis of the environment where construction sites operate, or comparisons to other environments, and thus it is not actually a contingency study. Regardless, the contingency approach was mentioned to point out that the measurement system could also be used in contingency studies, if used for construction sites in different environments.

As described in the methodology section (Section 1.6), the development of the measurement system as a tool for improving construction site performance can also be considered a constructivist study. In Section 9.3.5, the practical applicability of the solution model that was developed, the performance measurement system, is evaluated according to the criteria for a constructivist study.

9.2 DISCUSSION OF THE RESULTS CONCERNING THE SUCCESS FACTORS

9.2.1 Interaction of construction site success elements

The results of the analysis, where the purpose was to answer research question 4 concerning the success factors, are evaluated against the six research hypotheses set forth in Section 1.3. The first research hypothesis pair was formulated to test whether the construction project success elements are connected to each other.

Construction site success
H1: If a construction site is successful in one respect, this doesn't mean that it is successful in every respect.
H2: If a construction site is successful in one respect, it is probably successful in others as well.

The hypotheses refer to a conception that construction site success is one entity having several aligned components. If success indeed is one entity, then the components ought to correlate significantly with each other. Otherwise, success could not be treated as one entity but merely a group of individual construction site result areas.

The issue was explored in Section 8.1, and the correlations found were summarized in Figure 31. The statistically significant correlations were between total cost for Company 4 and both schedule deviation and safety. Schedule deviation correlated also almost significantly with quality over the whole body of material. Thus, evidence exists that the result elements are interconnected, but it seems that there are also exceptions, at least in the cases of quality and safety.

Although the situation is not totally unambiguous, the results support hypothesis H2 sooner than they do H1. Therefore, a construction site is usually successful simultaneously in many respects, and failing in one area means usually failing in others as well. In particular, cost, time, and safety were closely connected in the most reliable material, that for Company 4. Although quality was not as clearly connected to the other elements, which can also indicate that there were problems with the measurement method, it would be safe to assume that good quality at least doesn't prevent a project from being successful.

Even though the result areas are connected, it would be inaccurate to speak of construction site success as a single integrated entity. It is probably more useful to acknowledge that a site's success consists of several elements, which also support each other. Additionally, targets should be set for all areas separately in project plans, depending on the characteristics of the projects and relative importance of the different result areas in each case.

9.2.2 Successful construction site operation

The second phase in answering research question 4, about the success factors of a construction site, was to study the elements in site operation influencing the success elements. Research hypotheses H3 and H4 were formulated to emphasize the problem of separating the common success factors in the operation of all sites from the variation in result elements caused by factors outside the system model and other site-specific characteristics.

Construction site success factors

H3: Many factors influence construction site success, and factors the site can influence and that are common to all construction sites cannot be identified.

H4: A group of common success factors that the site can influence exists and can be identified from other, confounding factors.

The relationships between potential success factors and success elements were studied by examining correlations and using multiple regression analyses. Correlation analyses indicated which variables were somehow connected, and regression analysis gave the relative strength of the connection between the predictor variables (preconditions, management systems, work behavior and leadership) and the success elements (cost, schedule deviation, quality, safety). Correlation and regression analyses explore whether a relationship between the variables exists. However, they don't automatically indicate the direction of causality between them. In success factor studies, the purpose is to find the factors that cause the desired results, and therefore the causal relationship between the variables should be known.

Causality means that variation in one variable causes variation in another variable. Causality exists if three criteria are fulfilled. There must be apparent relationship between variables, the relationship must not be caused by a third variable that affects both, and the chronological order of variables must be such that cause precedes effect (Bryman & Cramer 1995).

The connection between the variables has been proved to exist in analysis, although the strength of it varies with different process and result components. Whether the variation is caused by a third variable that is not included in the model is more difficult to determine, because variables outside the model were not included in this study. However, it is recognized in situating the study that other factors outside the performance system model influence site success, while only those factors in the construction site sphere of influence are relevant for this study. Therefore, according to the soft systems thinking principle, it is not necessary to know all possible variations in and outside the system model; it is enough to know how the variables that are dealt with in the study influence the outputs of a system.

The third requirement for existence of causality, correct time order, is easy to fulfil in project operation. Projects advance in chronological sequence, and results are created by the actions of the project participants. Time order is also integrated into the system model in the input–process–output principle. Therefore, the preconditions and process operation elements must exist before the expected results are produced, and the relationships found between success factors and success elements must indicate a causal relationship between them, even if it in fact was implemented through a third element not included in the model.

The correlation analyses revealed significant correlations both in the whole data set and in the Company 4 data, which were tested in parallel with the whole body of material because the total cost key indicator for the latter was considered more reliable and with this material the differences between companies didn't interfere with the variables' relationships. The general direction of correlations was positive for both sets of material, indicating that a positive connection of some degree existed between the result and other system model elements. The only exception was quality, whose variation seemed independent of preconditions, management systems, and work behavior and leadership.

The conclusion of the regression analysis is presented as percentages in Figure 33, as adapted from the better of the two models of the whole body of material or Company 4 data. The percentages express the relative influence of the system com-

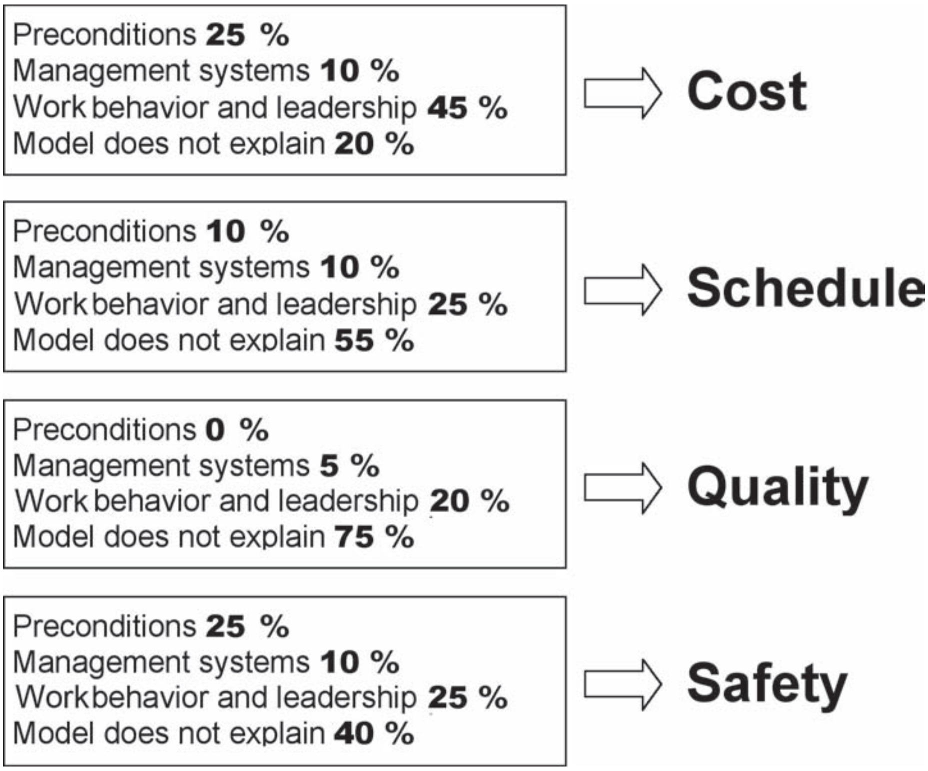


Figure 33. The relative influences of the predictor variables on construction site success elements, expressed as percentages. The figures are adapted from the regression equation coefficients and rounded to the nearest 5 to underscore that they are rough estimates. The coefficients for schedule deviation are from the whole data set, and the other coefficients are from the data for Company 4. The best regression models from Table 37 were chosen for the summary.

ponents on each result element, and also the partition of the variation, which the model didn't explain, according to the R^2 indicator. The figure presents the relative importance of the success factors studied, for each result element.

The most influential element in the system model was work behavior and leadership, whereas the effect of management systems on project results was remarkably low. However, it seemed that the independent variables have almost no effect on quality, or the quality measurement is otherwise problematic. The model for safety does either explain variation very strongly, but the relative weights of factors seem much analogous with the models of other dependent variables.

Although other variables from outside the system model seem to have a strong influence on sites' success, the system model elements studied were capable of explaining variation in construction sites' success elements as well. Even if the capability to explain the variation in different regression models is not equally strong, the central observation is that work behavior and leadership explain most of the variation and the effect of management systems is almost nonexistent. However, the situation is not necessarily as straightforward as this in reality, and the issue is discussed further in Section 9.3, where the measurement system that has been developed is evaluated.

The result of the regression analysis can be further summarized in a figure where all success elements have been integrated into one result totality (Fig. 34). In the integrated model, the results have been roughly estimated from various sets of percentages to give a general impression of the amplitudes of the influences of the

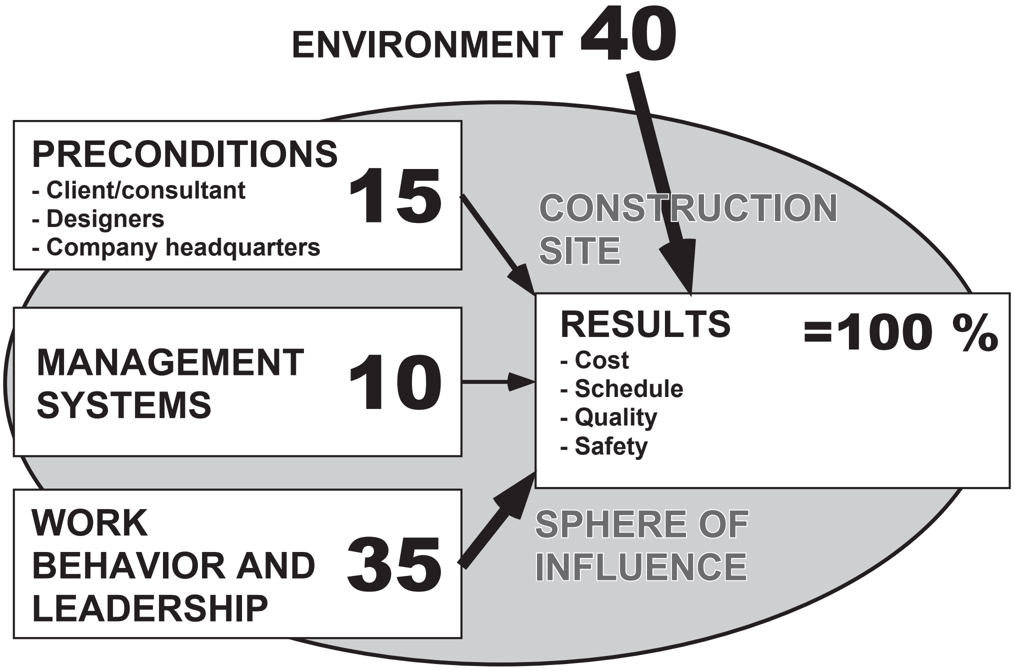


Figure 34. Factors affecting construction site results and their relative proportions as percentages. In the outside sphere are some potential factors affecting site results from outside the model, and their relative influence in percentage terms, summarized from the regression models.

system model elements. The illustration of the influences contains also the environment element, which in fact includes all other factors affecting the dependencies, like measurement errors and characteristics of the research material.

Research hypotheses H3 and H4 concerned the possibility of separating the common success factors of all sites from the situational or site-specific factors influencing project success. Although the dependencies between success factors and success elements could have been stronger, certain dependencies were found and the general direction of the dependencies was clear. Thus, evidence indicates that success factors applicable to all construction sites exist, although they are not easy to distinguish among other disturbances in the project environment and measurement errors. Hypothesis 4 can be determined to have a high probability of being true; at least the organizational behavior at a construction site is a strong indicator of success.

Also, the correlations between the system model element level-2 and level-3 variables and the success elements were explored to gain knowledge of the precise areas of the system model elements that influence site results most. Work behavior and leadership dimensions are addressed in the next section in the course of answering to the presumptions made in hypotheses H5 and H6. Although the influence of preconditions and management systems on construction site success was not as great, the results of the analysis lead to interesting discussion.

Preconditions refer to the quality of support that the client/consultant, designers, and company headquarters give to a construction site. The construction site management team often sees the cause of its problems as lying in the preconditions. An interesting question in the analysis was to find out whether the preconditions really are as strong a success factor as is often claimed and which are the most influential dimensions of preconditions.

The analysis shows that preconditions have only a limited connection to site success. The influence on costs and safety was the strongest, but only in the data for Company 4. On the other hand, the effects of sites' own efforts on results were much greater than the potential influence of preconditions. Therefore, it does not seem credible for a site management team to blame all its problems on preconditions, although these can have some effect on site operation.

The **management systems** meter measured the extent of planning and documentation of site operations. It evaluates the principles and methods of operation and documentation, much the same way as in quality audits, for which purpose similar kinds of checklists had been used before in the companies. It shows how things are done in principle, but not necessarily in practice, as can be clearly concluded from the results of the analysis.

That the level of the management systems had practically no correlations with any other parts of the system model is one of the biggest surprises in this study. When one considers that quality systems are the area where construction companies have traditionally invested most of their development contribution, the result is remarkable. It raises the question of whether all the effort of developing management systems in companies has been worthwhile, and whether the management systems meter is necessary in the measurement system at all.

However, it would be premature to remove the management systems meter component from the measurement system. The companies participating in this research were the biggest construction companies in Finland. They have strong system support and highly professional project managers. Every project had schedules, budgets, and the basic planning and control systems in place. The results indicate that when the basic systems are in order, it doesn't make much difference if the latest advances in management techniques are in use. If more varied sizes and types of companies were included in the research material, the result could be different, because the variation in management system level would be greater. When a certain level of systematic operation is achieved, other factors influence the final success more, and an additional input at the management systems level doesn't necessarily bring the desired results.

9.2.3 Organizational behavior in a successful construction site operation

All analyses indicated that work behavior and leadership was the most outstanding success factor for a construction site. The relationship was strongest with total cost for Company 4 and schedule deviation, but positive connections to safety and even quality were also found. This means that people working on the site have a good conception of the overall situation of the project. People may even detect signs of problems before official monitoring systems like schedule and cost follow-up expose them. Research hypotheses H5 and H6 concerned work behavior and leadership on a construction site.

Work behavior and leadership on site

H5: No optimal relative strength of the dimensions of organizational behavior on construction sites exists; successful behavior depends on situational factors.

H6: A generally recommended relative strength of the dimensions of organizational behavior at construction sites can be determined.

The factor analysis gave the empirical dimensions for organizational behavior on a construction site. The factor analysis separated questions connected with leadership from those dealing with general work behavior. Both have, however, been treated as a single area in the analyses, because they are measured with the same instrument and it would have been inappropriate to separate then artificially. However, at this stage leadership can be separated from the general work behavior concept for forming conclusions on both separately. The leadership dimensions were focus on people and focus on production, which have echoes in Blake and Mouton's (1994) grid. The work behavior dimensions were modified from Quinn's (1998) competing values model (see Section 7.1.2.2).

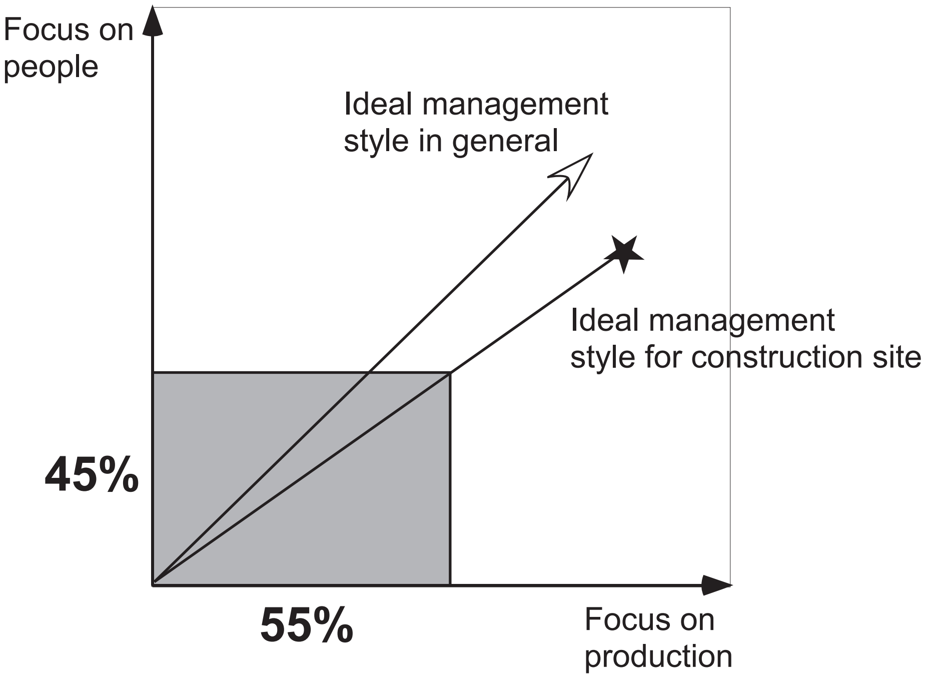


Figure 35. The best leadership style on a construction site compared to the general 50/50 model of Blake and Mouton's management grid (1994).

The correlation of "focus on production" with the result elements is slightly higher than that "focus on people" had with them (Tables 37). Therefore, a leadership style that concentrates a little more on production than people seems to be the most efficient on a construction site. However, the simultaneous use of people-oriented leadership skills is not in contradiction with this principle, as the original Grid theory model emphasizes. Although both aspects of leadership are important, it can be concluded that the most suitable management style for a construction site is weighted a bit more heavily toward a production-oriented approach (Fig. 35).

The work behavior dimensions were constructed based on the organizational culture framework of competing values (Quinn 1998). After the empirical testing of the framework, it was modified into an even more suitable model for construction sites. Namely, the competing values dimension "hierarchy" was replaced by the new dimension "communication." Although the names of the other dimensions were also changed for greater suitability for the construction business environment, the content of the dimensions remained analogous with the competing values framework. The resulting dimensions were "community spirit," "satisfaction and growth," "communication," and "effectiveness and clarity of tasks."

The relative importance of the work behavior dimensions, based on the correlation analysis of level-2 variables in Table 37, is presented in Figure 36. The gray square illustrates the proportion of each dimension in the optimal behavior pattern. The position of the square is biased slightly such that the areas for the dimensions "communication" and "effectiveness and clarity of tasks" are a little larger than those for other dimensions, illustrating the relative importance of the dimensions

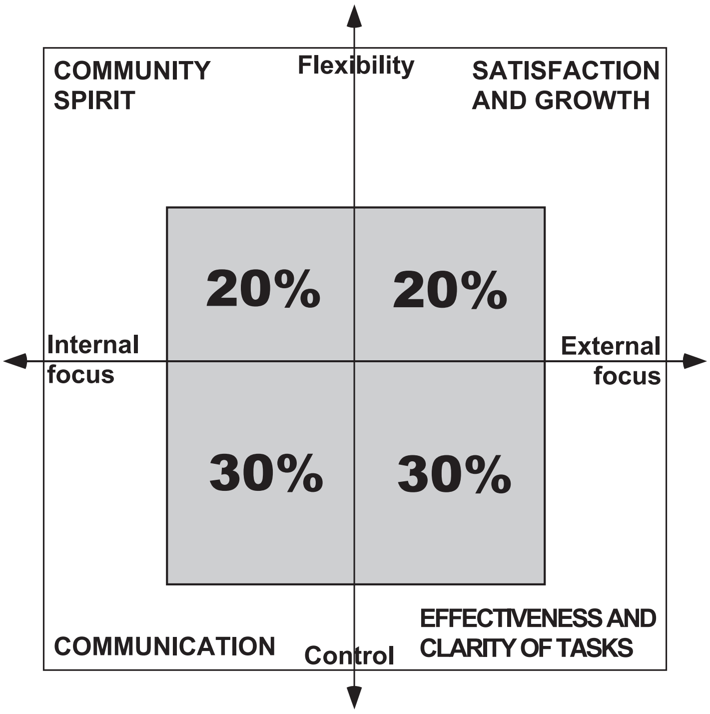


Figure 36. Dimensions of work behavior at a construction site and their relative importance. The model is a modification of the competing values framework (Quinn 1988).

on the basis of the correlation analysis. This illustrates that the ideal balance in actions and attitudes of people is closer to the control end of the spectrum than to the flexibility end, related to community spirit and work satisfaction, although the latter do have a beneficial influence on construction site success. According to Quinn (1988), not all dimensions need be equally strong, but failing completely in any of them is not permissible. It is probable that even if some of the dimensions are more beneficial than others, all must remain at a substantial level.

Although strong community spirit and work satisfaction benefit construction work, the most beneficial work behavior is oriented toward effective production and communication. In other words, objectives are communicated and they are pursued effectively, even if the result sometimes isn’t so satisfactory. Top performance means that information and process flows are top priorities, and good community spirit and preconditions for personal growth are built upon this foundation.

An interesting observation is that even if the role of management systems is –according to the findings of this study – relatively unimportant for construction project success, the results emphasize a management style that is oriented toward effective and systematic management and information sharing. The seemingly contradictory result indicates that advanced management systems and systematic leadership are two different things. The fact that management systems are advanced and documented well doesn’t necessarily mean that the site is managed effectively. This verifies that the management systems and the behavior of project management should be considered as two separate issues, as is done in the performance measurement system.

9.2.4 Evaluation of the results in light of other studies

The main result of this study, the determination of construction site success factors, was based on research question 4 and divided into three sub-problems covered by the research hypotheses. The results were presented in three phases, which are evaluated here against the backdrop of the literature review of Section 3:

1. Relations between result components.
2. Factors affecting project success on the system model level.
3. The foremost success factors in level-2 variables, especially from the work behavior and leadership angle.

The relationships between the result components cost, schedule deviation, quality, and safety have been the subject of surprisingly little research. The starting point in most studies is that cost, schedule, and quality are the self-evident outcomes of a project, and that the interesting thing is to know the factors affecting them and not how they affect each other. At least the connection between cost and schedule is considered so obvious that it is not even questioned. As for the quality of construction site operations, not even a practical means of measuring it has been presented, so not much can be said about its connection to other result elements.

On the other hand, some studies have been conducted in Finland to test the connection between safety and cost or productivity (Hyödynmaa et al. 1986, Hyttinen et al. 1993, Mattila et al. 1994a & 1994b, Kemppilä et al. 2002). However, these had difficulties in verifying connections between safety and the other result areas. On the other hand, methods for measuring safety were not used in the international studies encountered, so at least no studies contradicting the conclusion as to the positive connection between safety and cost were found.

Factors affecting construction site success, by contrast, have been studied in greater depth. The studies presented in Section 3.3 typically focused either on only one or a few components of operation or on a larger range of variables affecting the whole project and its environment, rather than on just the production phase. In general, studies concentrated on “hard” management and contractual issues or “soft” leadership issues but didn’t cover both at the same time. Nonetheless, many studies emphasize the importance of leadership issues in construction project success – for example, “experience” (Sanvido et al. 1992), “project management” (Chua et al. 1999), “project team commitment” (Chan et al. 2001), and “effectivity of management team” (Walker 1995). Arditi and Gunaydin (1998) found the factors influencing project quality the most to be “clarity of specifications” and “efficient supervision,” which are fairly similar to the “communication” and “effectiveness and clarity of tasks” angles in this study. Also, Jennings and Kenley (1996) emphasized the importance of “integration management” in a project, which supports the findings of this study.

The effect of communication has been covered in some studies (Thomas et al. 1998, Pocock et al. 1996 & 1997, Moshini & Davidson 1992). They all conclude that communication and information is of central importance to a construction project, and Konchar and Sanvido (1998) end up favoring design-and-build implementation of a project because of better project integration and therefore communication. Also, the importance of the client's actions is emphasized in some studies (Walker 1995, Russell 1997, Chan et al. 2001). As the cooperation agreement contract sites were better than average when it comes to preconditions, total costs, and safety, the results of this study support the suggestion that integrated contract models are advantageous at least to the contractor.

An argument presented by Sidwell (1990) and by Pinto and Slevin (1998) is that there are different success factors in different phases of the project. This doesn't get support in this study concerning construction projects, because the degree of completion didn't have any remarkable influence on meter variables However, only a few of the sites were in the early or late phase of the project, so the sample is not very representative.

Even if the importance of the project manager's actions was recognized in several studies, few studies were found that dealt more closely with the leadership or work behavior dimensions of a construction site. In some studies, the project manager's capacity to plan and manage the site is emphasized (Walker 1995, Walker & Shen 2002, Turner 1993, Ardati & Gunaydin 1998), which supports the result of this study concerning production-oriented leadership. On the other hand, some studies contradict the results of this study by claiming that s people-oriented leadership style is more successful (Briner et al. 1995, Rowlinson et al. 1993, Hyttinen 1994). However, the studies are difficult to compare because the dimensions used for organizational behavior were not the same and the studies didn't measure a construction organization's success in a valid way. For example, the result of the study by Hyttinen (1994) indicating that the best foremen were people-oriented is based mainly on evaluation of a foreman's success via a questionnaire administered to workers.

The general observation about studies concerning construction site success factors or elements is that in many cases they even go so far as to produce a theoretical model of construction site performance (Liu & Walker 1998, Fryer 1990, Stewart & Fortune 1995) or describe a possible way of measuring it (Jokiniemi 1993, Kagioglou et al. 2001, Yasamis et al. 2002, Herbsman & Ellis 1990) but don't actually verify the model in any way or apply the measurement system in practice. In most cases, the success factor studies are based on questionnaires administered to project managers etc. but don't use any objective methods for measuring success. Therefore, a major contribution of this study is in creating a practically applicable model for measuring and developing construction site performance and using it to produce data from various perspectives on construction site operation and results, which can be used in studying the performance elements.

None of the studies clearly contradicts the findings of this study, but the importance of work behavior and leadership at the expense of management systems is perhaps one surprising finding contrasting with the results of other studies. Also, the role of the project manager's leadership skills is emphasized in many studies but seldom presented in numerical, proportional terms. However, as the companies participating in the study were large, at least by Finnish standards, generalization of the results to the whole construction business would demand measurements in a larger population with different kinds of companies. As mentioned in connection with the discussion of the contingency approach, the fact that the success factors found do work in the Finnish construction industry environment doesn't necessarily mean that they work in other countries, let alone apply in other types of project work.

9.3 DISCUSSION OF THE DEVELOPMENT AND USE OF THE PERFORMANCE MEASUREMENT SYSTEM

9.3.1 Determination of the success model's elements

The result of the study concerning research question 4, success factors of a construction site, has been given in the previous section (9.2). The results of a study are, however, only as reliable and generally acceptable as are the research material and the research instrument. Therefore, in Section 9.3, the first three research questions concerning the development and use of the construction site performance measurement system are discussed. Research question 4 was deemed worthy of discussing first because interpretation of the analysis results was a precondition for evaluating the measurement system and the system model on which it is based.

The evaluation of the performance measurement system in terms of a rational study follows the logic of the first three research questions. The first research question was about determining the construction site performance elements. This was based on both the general performance management literature and studies concerning construction site performance. In this first section, 9.3.1, the method of literature review utilized is discussed.

The general literature helped to define the concept of performance and understand its multidisciplinary framework. However, the dearth of performance-related literature with a particular focus on the project environment was a surprise. The contribution of the general performance literature was in putting the main components of performance in place and including both the process and result elements in the same model. The idea of performance management helped also to develop the construction site performance measurement system into a tool for developing performance rather than only measuring it.

One major observation in the beginning stages of the study was that the human side of an organization must be included in the performance measurement system, which led to the need to understand organizational behavior better. This area has been covered rather extensively in this study, compared to, e.g., construction site production control methods. The reason for this was that the production control systems applied in construction projects are the core competence of the HUT Construction Economics and Management unit and it was not necessary to describe in great depth issues familiar to the main target group of the study. By contrast, organizational behavior is a research area less familiar to the intended audience, and thus it was covered more throughout. This was also why the research methods of the social and psychological sciences, such as questionnaires and data analysis, were introduced in more detail than is used in studies conducted in those disciplines.

The literature review concerning construction business performance studies helped in applying the concept of general performance to the construction site environment. As the general performance literature approached performance from the whole company or organization's point of view, the purpose was to ascertain which performance elements it was necessary to cover in the construction site performance system model. Construction site performance studies provided ideas concerning measurement methods that could be utilized in the measurement system as well, although the only meter that could be used directly was the safety meter and others had to be developed.

As was mentioned in Section 4.4, the elements that should perhaps be included in the measurement system but were left out for practical reasons were customer satisfaction and environmental influence. Other potential elements, like organization structure or technical considerations, were omitted intentionally for reasons derived from the aims and focus of this study. Other relevant elements found in the literature and considered important were included in the model. Therefore, the measurement system can be considered to include the essential elements for the purpose of this study.

9.3.2 Validity and reliability of the meters

The second research question concerned the development of the measurement methods for the chosen performance elements. The meters were developed individually for each performance element by relying on both the literature and field research, where the latter refers to workshops, interviews, and discussions in companies. The quality of the measurement system depends on the characteristics of the meters within it, and so does the quality of the results of the analysis. Therefore, it is necessary to evaluate the characteristics of a meter in order to evaluate the results of a study.

A meter is usually evaluated in terms of validity and reliability. Validity is related to the meter measuring what it is intended to measure or serving the purpose for which it was developed. Reliability means that the meter measures accurately, without any deviation on account of the meter itself, the measurement situation, or other disturbances influencing the variation of the variables measured. In evaluating reliability, a criterion for meter accuracy can be set: for example, that variation due to measurement errors remain within certain limits (Bryman & Cramer 1995).

The performance measurement system consists of many individual meters with their typical characteristics. In the material that follows, each is considered from the standpoint of validity and reliability.

The **preconditions** meter consists of the detailed work descriptions of parties whose operation it is meant to measure, according to the insight of specialists and project managers. As the criteria used as measurement items were mostly based on the fieldwork done in the companies, the meter includes the issues that the sites themselves consider important, and thus can be considered to be fairly valid in measuring site preconditions. However, where reliability is concerned, the problem is that the preconditions meter is based on the opinion of usually only one person: the site manager. Given that every person has an internal scale of his or her own when answering questions, a meter based on the opinions of only one person cannot be considered the most reliable one.

The reliability of the preconditions meter could be improved by asking the same questions of a larger group of people – the line manager, site engineers, etc. – which indeed was done at some sites where possible. However, the number of respondents was in every case small, and although the questions were compiled with the intention that they be as accurate and unambiguous as possible, the problem remains.

The **management systems** meter was a central part of the system, and more time was taken with it in the measurement process than with any other meter. The meter was developed using the latest knowledge on construction management system best practice in the HUT Construction Economics and Management unit, with the material and expertise of the companies also utilized. Therefore, the validity of the meter depends on the capability to encapsulate the acquired knowledge in clear and unambiguous criteria. The meter included only criteria that had variation, and the obvious issues were left out, which aided in separating the more advanced management systems from the less advantageous ones. Although a meter of this kind is never perfect and should be continuously improved, the anecdotal evidence from companies indicated that it was fairly valid in describing the characteristics of the management systems of different construction sites.

The researcher entered the results on the measurement form on the basis of the interview data and inspection of documents on the site. In this case, it was advantageous from the reliability standpoint that the same person performed all measurements, because this ensured that interpretation of the criteria was more consistent. Thus, the reliability of the management systems meter can be considered better than, for example, that of the preconditions meter; therefore, the low correlations with other system model elements cannot be completely explained by meter properties.

The **work behavior and leadership** questionnaire was statistically tested both with the first eight sites and when all of the material was available. The final question groups were compiled empirically with factor analysis, and the internal consistency of the final dimensions was, according to the Cronbach alpha tests, at a good or acceptable level. Therefore, the validity of the questionnaire to measure the intended subjects (dimensions) was good. In order to minimize the effect of situational conditions on the reliability, all occasions for completing the questionnaires were arranged in the same way, in connection with a lunch or coffee break, where the purpose of the questionnaire was explained, answering advice was given, and the questionnaire forms were filled in and collected.

Of the results meters, the key indicators **total cost** and **schedule deviation** were as good as the information received from the sites. Both meters are central indicators of construction project success and are used constantly in companies, and thus they are in theory valid and measure the issues they are intended to. The problem with total cost concerned the reliability of the final results, or the possibility of ensuring that the figures were correct when the original cost reports were not available to the researcher. The problem was partially solved by testing the Company 4 material separately, because at Company 4 the result figures were directly available, as the company was the researcher's employer. The schedule deviation key indicator was based on the daily schedule control of sites, and although no universal formula for calculating it was found, the insight of the site personnel could be used and can be considered fairly reliable given the accuracy level of the key indicator (days).

Quality measurement was developed to measure the quality of one individual work phase at a time. Although it may have succeeded in doing so fairly reliably, in measuring the quality level of an entire site it had a serious validity problem. A valid measurement of site-level quality would have demanded many more measurements per site. With only a few work phases, the result was too dependent on the characteristics of individual work groups and the work conditions on the day in question. Therefore, the meter measured quality of single work phases but not necessarily the whole site. If the use of a second day for the measurements had been possible, the result could have better described the quality of the whole site, but there simply were not enough resources for that in the study. A method for measuring quality at a construction site was developed in principle, but to really test it and analyze the results would have required a study of its own.

The TR meter for measuring **safety** was developed in an earlier research project (Laitinen & Ruohomäki 1994, 1996). The validity of the meter is based on the expertise of safety authorities, companies participating in the development, and the researchers, and the meter was developed to measure both compliance with safety regulations and best practice regarding safety at sites, as determined by common workshops. The meter has been tested for reliability through multiple, parallel measurements. Many safety inspectors conducted measurements for the same construction site at the same time, and the variation of results was less than 10 %, which was the acceptance criterion set for the meter. In this study, the same researcher made all measurements, so also variation due to the interpretations of different measurers was avoided.

The discussion concerning meter characteristics indicates that the most unreliable meters are the preconditions and quality meters. The problem with the preconditions meter was that it was a sort of questionnaire, with the result based often on the opinions of a single respondent. With the quality meter, the measurement of the quality of a whole site was based on only a few phases of work. The other meters can be considered more reliable and valid for the intended purpose, although data collected from construction sites can never be compared to measurements made in controlled conditions, where confounding factors can be minimized.

The measurement system and its meters were developed for two purposes. First, it was a practical development tool, and, second, it was a research instrument used for data collection. This explains some of the choices and compromises made for the practical applicability of the meter at the expense of scientific accuracy. The measurement errors can easily explain some of the low correlations, especially with preconditions and quality. The lower correlations make it harder to shed light on the phenomena under study. Thus, it is even more probable that the conclusions about the success factors and other relationships are based on a real phenomenon and that they are cautious enough. The fact that clear and logical indications of the relationships between system model elements were found convinces one of the usability of the measurement system also as a research instrument.

9.3.3 The applicability of the system model and systems thinking

In answering research questions 1 and 2, the performance elements have been determined and the corresponding meters developed. The third research question was about determining the central relationships between the performance elements and thus creating a system model in which the elements are integrated. In other words, the measurement system that was developed was expected to form an integrated system model illustrating how the elements of the model influence each other. The framework for integrating the measurement system was systems thinking, which has been suggested in several studies concerning construction projects (Hughes 1989, Rwelamila & Hall 1995, Stewart & Fortune 1995, Jennings & Kenley 1996).

Systems thinking functioned more as the basic philosophy for using the performance system model, not as a mechanical, accurate model of the elements and their detailed relationships. Systems thinking was used to emphasize the system nature of the model and the way the measurement results were interpreted. In determining the success factors, it was not necessary to know every relationship between variables; rather, the goal was to discover how the variation of predictor variables and that of result variables are connected. From this perspective, systems thinking served well as a framework for using the performance measurement system and interpreting its results for the companies.

The resulting performance system model was presented in Figure 18. It is an input/output system resembling the construction project operation models of Fryer (1990) and Liu and Walker (1998). The parts of the system were labeled preconditions, operation process, and results. In the model, the dependencies between elements within each part of the model were left open, with the essential point being to understand in which part of the system model the elements belonged. After the measurement results are analyzed, the usability of the model can be evaluated.

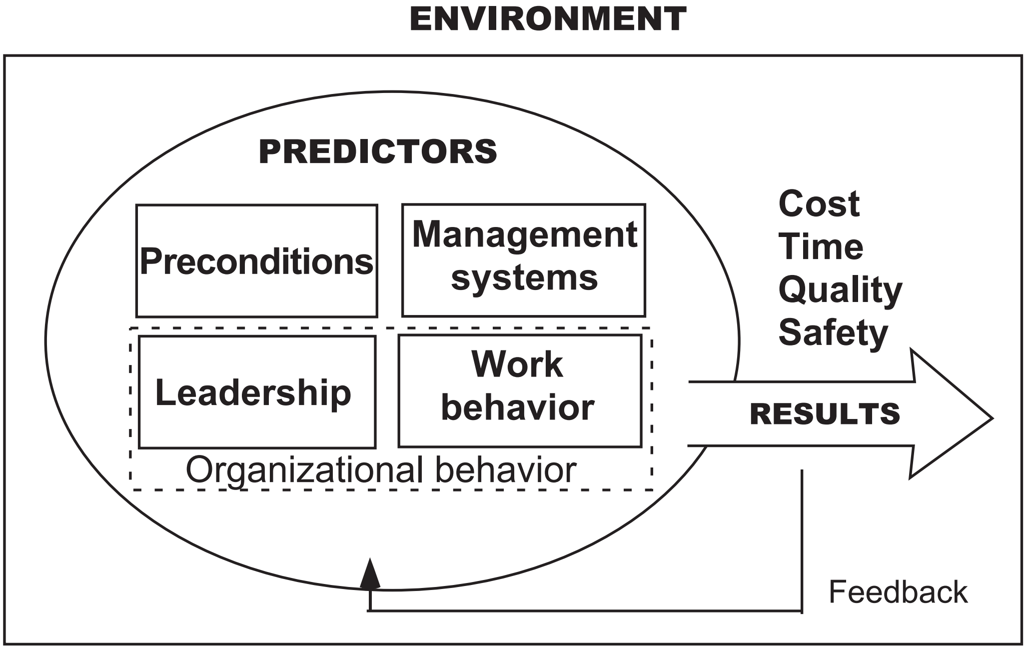


Figure 37. The performance measurement system model for a construction site, updated in keeping with the success factor analysis.

In the study, the dependencies between system model elements were determined via correlation and regression analyses. The results supported to some extent the idea that preconditions and operation process influence a construction site's results. However, the chain of influences doesn't necessarily follow the description applied in the system model, because the correlations between the preconditions and operation process elements were low, especially in the most reliable and homogeneous material, that for Company 4 (tables 24 and 25). Although the idea of the model is logical, it gives a slightly deceptive picture of the actual relationships.

The original model can still be used to illustrate the basic idea of construction site operation and was found to be an illustrative and logical way to describe the functioning of the integrated measurement system. However, an alternative – and, according to the results of the analysis, a more correct – way of describing the measurement system's operation would be to simplify the model so that it has only two main parts: predictors, including both the preconditions and operation process elements, and results (Figure 37).

Another question concerning the final model is that of whether management systems should be included at all, because this element had very low correlations with all other parts of the system model. Removing it altogether from a construction site performance measurement system would be a radical step, because the main effort in developing construction site performance has been focused on management systems in companies. Therefore, management systems remain in the performance system model, with a reminder that the role and significance of management systems should be studied further.

In the model, the close connection between work behavior and leadership is made visible by a dashed line, and the fact that they are two aspects of organizational behavior is made clear. With these changes and additions, the final, simplified model corresponds better to the results and conclusions of the analysis.

One further suggestion for future use of the performance measurement system could be that the results of the success factor analysis be taken into consideration by using weight coefficients for the predictor variables. If the influence of the factors external to the model was eliminated, because the attention should be focused on the known factors that a construction site can influence, the weight coefficients could be as suggested in Figure 38.

The general idea of systems thinking can still be applied to the construction site performance measurement system, although not necessarily in the form of the original input–process–output scheme. The simplified model describes the functioning of the system model accurately enough for success factor studies. However, if the use of a system model would be expanded to analyzing other relationships between system model elements, methods of analysis would be required that can examine the dependencies between many variables simultaneously, such as the use of structural equation models.

The performance measurement system has been tested in four construction companies and at different types of construction sites in Finland. It is probable that it applies equally well to other large or mid-sized Finnish construction companies. Small companies with only a couple of sites active at a time might be so different that the measurement system doesn't apply to them directly. Also, companies in different countries may differ from Finnish ones from, for example, the management systems angle so much that the same meter can't be applied. It would be interesting to try out the measurement system with different company sizes and countries, but for the intended development and measurement purpose, the meter is

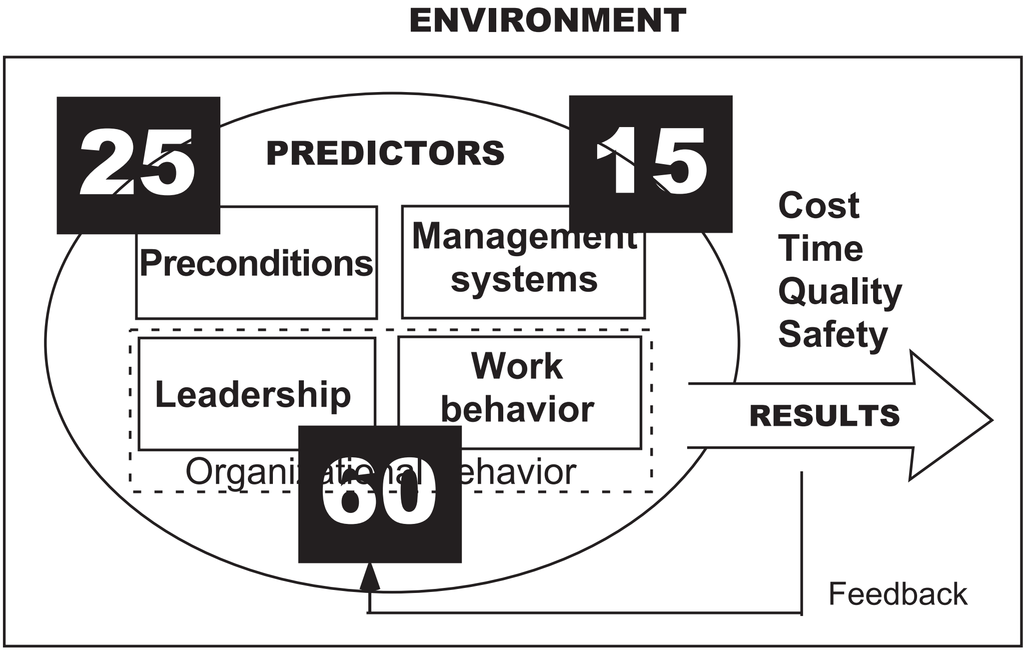


Figure 38. The final performance measurement system model for a construction site, with the suggested weight coefficients of the predictor meters as percentages.

probably not directly applicable and should be “adjusted” to the various different circumstances.

9.3.4 Evaluation of the research material

After the construction site performance measurement system had been developed, it was used as a research instrument for collecting data. The research material has already been presented in detail in Section 6.1, but the research material is discussed in the present section to evaluate what effect the characteristics of the research material could have on results and the conclusions drawn on the basis thereof.

The number of construction sites, 47, can be considered to be a fairly representative sample of typical construction sites of the larger construction companies. The sites were not chosen using any sampling technique; rather, the companies chose suitable sites themselves. The main reason for picking the specific sites was that they were in a convenient phase for the measurement.

The fact that the material covers sites of four companies adds to its representativeness, but the consequent heterogeneity of the material adds other problems to the analysis, because some differences between companies were detected. On one hand, it was beneficial to have diversity in the material to test whether the same meter can be applied to different companies having different management systems, but at the same time the consequent variation might have hidden from view some weak dependencies that would have been observable in more homogeneous material.

In developing the construction site performance measurement system, the aim was to determine the factors in site operation and results that the project management team can influence. Other factors derived from the environment and project characteristics influence project operation also. For the purpose of this study, their influence was to be separated from the influences caused by site personnel. Information on some aspects of project characteristics was collected as classifying variables, in connection with the measurements (Table 8). Factors from the project environment were not analyzed in this study; these may include issues like weather conditions, the actions of authorities, and problems with suppliers. As it is difficult to gain a comprehensive picture of these environmental factors, all influences external to the model were considered to be “random” variation and described in the regression analyses as “factors the regression model can’t explain.”

However, the influence of the classifying variables for which information was collected was explored in the discriminant analysis of Section 7.3. The analysis revealed whether the material included systematic, different groups that could cause problems in finding the relevant dependencies.

According to the discriminant analysis, none of the classifying variables separated groups systematically from others in many respects. Although some differences were discovered, differences between groups with respect to the variables were only 10 % at most. The most discriminating factor was company, which could influence the results to some extent. This was taken into consideration by conducting the central tests for both the whole body of material and the Company 4 data separately.

When forming conclusions on individual sites, one must continuously be aware of possible factors from outside the model that may have a greater effect on performance than the factors covered by the measurement system. The reliability of analyses and conclusions grows when the body of research material is large enough to reduce the effect of individual cases or variables. In this study, the research data are influenced by site characteristics, disturbances from outside the model, and measurement errors, but if the analysis still indicates that there are statistically significant relationships between the measured variables, the probability is high that this is a sign of a real connection between variables.

9.3.5 Applicability of the performance measurement system as a performance development tool

In this study, the performance measurement system was applied foremost as a research instrument for collecting data. The other intended use for the measurement system was, however, to serve as a development tool for companies to use in improving their performance. The development of a practical tool as a solution to a concrete business management problem can be considered part of a constructivist study. Therefore, the performance measurement system development part of the study can be evaluated using the criteria for a constructivist study.

The study has been conducted according to the basic phases of a constructivist study (Section 1.6). The solution model developed is the construction site performance measurement system. The usability of the solution has been tested with the measurements, which ensured that it is functional at least in its measurement aim, although some of the meters worked better than others did. In the discussion of this study, the measurement system and the results achieved with it have been connected to the pre-existing knowledge.

The success of a constructivist study is also evaluated with weak and strong market tests (Kasanen et al. 1991). The weak market test is passed if the solution is brought into use, and the strong market test is passed if the solution produces measurable advantage to the subject organization, meaning either increased income or decreased costs.

During the study, the meter was already being used as a measurement tool, and, according to anecdotal evidence, it was considered interesting and useful. The measurement reports were considered to describe the site operation well, and the atmosphere in the feedback gatherings was positive. The reports were used both at the site and business unit level, and they suggested concrete development actions. The reports also functioned as personal evaluations for the project managers, and as one project manager put it, “It is good to look in the mirror sometimes, although it can hurt.”

After the study was concluded, the measurement system entered into use and was further developed, at least in Company 4. The other companies adapted parts of the system in their operations, but the whole system was not systematically used. The central reason for this may have been that the measurements demanded resources and competencies that the companies didn’t possess at the time. The researcher continued to implement the measurement system in Company 4, because it became his employer.

As for the strong market test, it is difficult to measure what role the performance measurement process had in the improvement of results for a single site, because projects are difficult to compare and the influence of the measurement process is impossible to separate from other factors reliably. However, the measurement system has been in use for three years at Company 4, and in the business units where it is used, the managers consider it a central operation development tool and information source about the development of performance. With all probability, the “what you measure you get” adage should apply in this case also, with the result of the improved performance becoming observable over time.

The greatest difficulty in adapting the performance measurement system for continuous use seems to be the understanding of the nature of a measurement in comparison to what is done in the traditional quality audits. People in construction companies have become used to quality audits and evaluating an operation with checklists. In quality audits, the idea is to find deviations of the operation from the quality system guidelines, and then correct them. With a measurement system, the sites get scores and are encouraged to improve their operation in those areas that are most critical. However, the fact that a site doesn’t necessarily get top scores even when the operation fulfils the traditional standards is sometimes confusing. Getting accustomed to new tools takes time, and the feedback gatherings are helping those involved to understand the measurement philosophy.

In conclusion, the performance measurement system that has been developed can be considered to pass the weak market test, and perhaps in the future the passing of the strong market test as well is going to be observable. The performance measurement system seems to be a tool applicable for performance improvement, at least within Company 4, but the competencies and resources it demands make the practical use of it a challenge. If the benefits of using the meter become evident, the necessary input in bringing the measurement system into use on a larger scale may become a relevant concern and be actualized.

10 SUMMARY OF THE STUDY’S CONTRIBUTION AND SUGGESTIONS FOR FURTHER RESEARCH

10.1 THE NEW KNOWLEDGE PRODUCED AND PRACTICAL IMPLICATIONS

The aims of the study were to develop a system for measuring construction site performance and use it to determine the success factors of a construction site. This was done by using the four research questions as a guide, and the results are the new knowledge about the construction site success factors and the system itself as a development and research instrument. The measurement system represents a relatively new idea of integrating a group of meters together with a system model. Also most of the used meters have been developed and tested in the study for the first time.

The results of the study emphasize the significance of a project manager’s leadership skills and work behavior in successful project implementation. They show that the formal management system on which the development of construction companies has traditionally focused does not necessary reflect how well a site is managed in practice. However, when it comes to the most efficient leadership style, the focus is on controlling the operations, planning, setting goals, and communicating them to the workers systematically. This apparent contradiction has led to the conclusion that efficient management and the management systems are two different things, which are not necessarily linked directly in practice.

This means that top performance cannot be achieved by developing management systems only, and that more weight should be placed on how they are actually used in controlling the operation. Although it is evident that management systems must not be underrated either, the results indicate a need for caution that they not be the only focus of development. Functioning management systems probably create preconditions for systematic operation and help managers, but they do not by themselves guarantee systematic and efficient operation. Today, the linkage between management systems and management in practice doesn’t function well enough.

Although the most efficient leadership style and work behavior was focused on production, good community spirit and work satisfaction too are beneficial for solid operation, and probably even more beneficial in the longer term than they are during just the operation at one site. But if the planning and controlling side of things is neglected, skills in people-oriented leadership don’t necessarily suffice for the overall success of a site. If the production goes smoothly, conditions are better for building community spirit as well. More emphasis should be put on management systems and measures that support the beneficial aspects of leadership and work behavior simultaneously.

A detail supporting this suggestion is that one of the few items among the management system criteria having a significant positive correlation with success elements was “Does project management have informative meetings with work groups prior to commencement of each phase of the project?” An answer in the affirmative means that workers are systematically provided with information on the content, goals, and quality specifications for a phase of work. Informational meetings addressing these matters can be integrated into the management systems to support both production control and effective work behavior.

Another central observation was that the connection between the success elements was evident, with the exception of quality, which can be explained by the poor validity of the meter. This means in practice that a construction site should concern itself with cost, schedule, and safety (and quality) equally and that failing in one of these respects means the risk of failing in others as well. As has been noted previously, it is possible for a site to be successful in, e.g., economic terms even when it has problems with other success elements, but this involves taking great risks. According to this study, also the safety level and economic success were closely related, which supports emphasizing compliance with the safety regulations for construction sites.

When it comes to preconditions, the contribution of designers was the most important. Designs should form a logical, well-organized entity that is easy to use in practice, and they should be delivered to the site in time. One thing expected from a client/consultant was the ability to make clear and reliable decisions. Support from within the company was expected mostly from the line manager.

A relatively new idea advanced by the performance meter is systems thinking. The paradox with systems thinking is that it is often considered to be highly theoretical and complex even if, as explained in connection with the soft systems methodology, it actually aims to simplify things. However, the performance measurement system can be used even if the users don’t recognize the systems thinking philosophy behind it. As the tool becomes established, the understanding of its theoretical underpinnings can be deepened and the utilization of the meter as an analytical tool can be expanded.

The other main result of the study was the performance measurement system. Although, naturally, it needs further development, it is a first step toward creating a new generation of performance development tool for construction sites. The central approach to developing site operations has been the quality system, which is implemented via quality audits. Although describing and standardizing “best practice” in operations has undoubtedly been beneficial, it has not been the breakthrough tool for quality and performance improvement that it was perhaps expected to be. Additionally, as quality systems have now been implemented in nearly every company, having one doesn’t establish a competitive advantage anymore.

Although meters have been used before, the use of a comprehensive measurement system where the role of the various meters is described with a system model is new, as is the systematic development process related to the continuous use of the measurement system. A meter is a more effective development tool than a checklist, as has been demonstrated by, for example, the TR meter used as part of the measurement system of this study. The improvement in safety level and accident rates has been remarkable following the introduction of safety measurement, as opposed to simple monitoring (this is a well-known fact in the Finnish construction industry – see, for example, an article in the 25 November 2004 edition of *Rakennuslehti*, (*"EU palkitsi työturvallisuusmittarit,"* EU rewarded safety meters). If the same effect is achieved with the entire construction site operation, the effect is huge, especially in light of the significance of the construction industry to the whole economy. The use of a more efficient performance measurement and development tool is thus a major opportunity for the construction industry.

10.2 SUGGESTIONS FOR FUTURE USE, DEVELOPMENT, AND RESEARCH

The suggestions for future research can be split into two groups: those concerning the use of the data acquired from the measurements in producing new knowledge of site operations and those concerning the use of the measurement system as a performance development tool.

Below are listed some potential ideas for future research using the performance measurement system

- Testing the conclusions of this study on a larger number of sites and in different companies, perhaps in different countries.
- Expanding the study's scope to encompass the environmental factors and performing a proper contingency study by determining the ideal relationship between site characteristics and environment.
- Determining the "critical" level for management systems, safety, and quality as well as finding the point at which improving meter results has the most positive influence on overall success.
- Using multi-variable analyses, such as structural equation models, to calculate accurately the relationships between system model elements.
- Constantly seeking the factors affecting construction site success most and then focusing measurement on the important matters while decreasing the weight of items that don't seem to have an effect on success.

Also, the measurement system and the performance management process connected to it need further development.

- The role of preconditions and quality must be critically considered. Either a better measurement method needs to be developed or more resources should be invested in the measurement process.
- New meters should be developed when seen as appropriate – for example, concerning customer satisfaction and environmental impact.

- Using an objective comparison level for cost and schedule goals, namely a “standardized estimate” to which the target budget and schedule of a site could be compared, would remove the effect of “looseness” or “tightness” of goals on the evaluation of a site’s success.
- It would be of use to add hypothetical cost estimation to the meter, based on the predictive variables.
- There is a need for developing a database application for processing the data, reports, and summaries as effortlessly as possible.
- It is important to establish a continuous performance development process by integrating the performance measurement process into company management systems.

As stated in the previous section, the construction site performance meter had been in use at Company 4 for about three years at the time of publishing the thesis, and thus most of the suggested improvements to the measurement system and performance management system have been implemented already. The meter has been used mainly in the southern part of Finland, but its use is being expanded constantly. Use of the meter has been integrated into quality audits at Company 4.

The meter that is currently being used is a further developed version of the meter developed in this research. It includes new key indicators, such as customer satisfaction and environment index. However, preconditions and quality meters have been excluded from the meter and the questionnaire has been simplified by reducing the number of questions to 20. A database application has been developed to rationalize data handling and the processing of reports and summaries. The systems for reporting and feedback are an essential part of the measurement and development process, and a yearly quality competition is arranged for all sites involved in the measurement process.

The meter now provides cost estimation of its own by using the estimation of the site as a starting point and adjusting it in a positive or negative direction depending on the result of other meters. Meter results are weighed according to the observations in this study on how well they indicate a site’s results. The meter’s forecast has already been found to predict the final result for a site better on average than the site management in official estimations. A significant negative deviation of the measurement system’s estimate is a clear signal for the business unit management that the site involves risks and must be examined more closely.

The performance measurement system has been integrated into the strategy cycle, when the results for the previous year are summarized and goals for the next year are determined. It also includes regular analyses of the data collected. This means that new data are accumulating quickly and the results of this study can be tested with a larger set of material.

Also some hindrances for fast expansion of the use of the measurement system has been discovered. One is the higher demand of competence for quality auditors; the measurement system forces to perform a more comprehensive analysis of the site operation than the traditional, more inexact checklists. This raises a recource and, sometimes, an attitude problem. Another difficulty is to understand the nature of a meter compared to a checklist, where only deviations from a standard is sought. In a meter, the fact that an average performance yields average scores, is confusing when traditionally the average performance have yielded top scores (=compliance with standards). These are however problems that are always confronted when new methods are impelemented and learning new practices takes time.

The use of a performance meter opens up many possibilities for developing and controlling construction project activities. The increasing knowledge of the elements and relationships involved in construction site performance means that development efforts can be focused on the most important issues. The performance improvement calls also for a change in attitudes toward measurement and an advanced organizational culture where the measurement results are used for continuous improvement and not for personalization and blaming individuals. The experience of using the measurement system in this study demonstrates that both need and willingness to use more advanced tools for performance improvement exist.

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APPENDICES

APPENDIX 1: THE PERFORMANCE METER

A1.1 General information form

A1.2 Preconditions

A1.3 Management systems

A1.4 Work behavior and leadership

A1.5 Quality indexes (4 examples from the 11 forms)

A1.6 TR index

A1.7 Key indicator calculation form

A1.8 Front page of the site report (example)

A1.9 Summary page of the site report (example)

APPENDIX 2: RESULTS FROM THE STATISTICAL ANALYSIS

A2.1 Work behavior and leadership factor analysis

A2.2 Discriminant analysis

A2.3 Level-3 variable correlations

(The forms for the performance measurement system are presented in their original language because it serves the Finnish audience best. If necessary, English versions of the forms may be obtained from the author.)

APPENDIX A1.1.

TYÖMAAN YLEISTIEDOT

Täyttäjä: Pvm:

KOHDETIEDOT

Päätoteuttaja (yritys):	**Työmaa:**
Pääkonttorin/alueyksikön osoite	Työmaan osoite
Puhelin Fax	Puhelin Fax
Tilaaja	Vastaava mestari
Rakennuttaja	Yhteyshenkilö (jos ei vm)

KOHTEEN OMINAISUUDET

Aloitusajankohta	Valmistumisaika	
Urakka sisältää (esim. rakennustekniset työt)		
Rakennusmassoja (kpl)	Kerrosten lkm	Asuntojen määrä
Toteutusorganisaatio	VM/Projektipääll. ☐	Työnjohtajia: kpl ☐
Toimihenkilöitä yht.	Työmaainsinööri ☐	Hankintamies ☐
Aliurakoits. lkm	Sivu-ur. lkm	
Omien työnt. määrä mittaushetkellä	Muiden työnt. määrä mittaushetkellä	

TOTEUTUSMUOTO

PROJEKTITYYPPI		MAKSUTAPA	
Perustajaurakointi	☐	Kokonaishinta	☐
Kilpailtu urakka	☐	Yksikköhinta	☐
Neuvottelu/yhteistoimintaurakka	☐	Laskutyö	☐
Projektinjohtourakka	☐	Tavoitehinta	☐

SUORITUSVELVOLLISUUS

Design&Build ☐ Kokonaisurakka ☐ Jaettu /osaurakka ☐

RAKENNUS

TUOTE		RAKENNUSTYYPPI	
Pientalo, rivitalo	☐	Uudisrakennus	☐
Asuinkerrostalo	☐	Korjaustyömaa	☐
Julkinen, liike, toimisto	☐		
Teollisuus, varasto	☐	TUOTANTOTEKNIIKKA (kts. liite)	
Muu	☐	Rationaalinen täyselementtitekniikka	☐
		Täyselementtitekniikka	☐
KANTAVAN RUNGON MATERIAALI		Rationaalinen osaelementtitekniikka	☐
Betoni	☐	Osaelementtitekniikka	☐
Teräs	☐	Osittainen paikallarakentaminen	☐
Betoni + teräs	☐	Rationaalinen paikallarakentaminen	☐
Puu	☐	Paikallarakentaminen	☐

1. TYÖMAAN TOIMINTAEDELLYTYKSET

Työmaa: ____________________ Pvm _______
Vastaaja: ____________________

Rasti kohtaan, jolla tasolla olet valmis hyväksymään väittämän.

HUOM! Vasen laita on "myönteinen"

A) RAKENNUTTAJA	Pitää paikkansa	täysin	kohtalaisesti	huonosti	ei lainkaan
RAKENTAMISEN VALMISTELU					
1	Tarjouspyyntösuunnitelmien suunnitelmakatselmus on pidetty (ennen aloitusta)	☐	☐	☐	☐
2	Detaljien suunnitelmakatselmus on pidetty (työmaan alussa)	☐	☐	☐	☐
3	Rakennuttaja on tarkastanut suunnitelmien toteuttamiskelpoisuuden	☐	☐	☐	☐
4	Aikataulu ja välitavoitteet ovat realistisia ja toteutettavissa olevia	☐	☐	☐	☐
5	Rakennuttaja on antanut urakoitsijan tarvitsemat tiedot	☐	☐	☐	☐
6	Rakennuttaja on laatinut kohteesta turvallisuusasiakirjan	☐	☐	☐	☐
		☐	☐	☐	☐
TYÖNAIKAINEN YHTEISTYÖ					
7	Päätöksentekovastuista on selkeästi sovittu osapuolten kesken (til/rak/suunn/työm)	☐	☐	☐	☐
8	On sovittu ja kaikkien tiedossa, milloin päätökset ovat virallisia	☐	☐	☐	☐
9	Päätökset ja hyväksymiset on saatu tarvittaessa nopeasti (ei katkoksia työssä)	☐	☐	☐	☐
10	Päätökset ja ohjeet ovat olleet yksiselitteisiä	☐	☐	☐	☐
11	Päätöksistä on pidetty kiinni ja sovitun mukaan toimittu	☐	☐	☐	☐
12	Suunnitelmat on hyväksytty ajallaan	☐	☐	☐	☐
13	Laskut on hyväksytty ajallaan	☐	☐	☐	☐
14	Työmaakokouksia on ollut sopiva määrä (ei liikaa/liian vähän)	☐	☐	☐	☐
15	Työmaakokoukset ovat edenneet tehokkaasti ja esityslistan mukaisesti	☐	☐	☐	☐
16	Työmaakokoukset ovat olleet tarkoituksenmukaisia ja hyödyllisiä	☐	☐	☐	☐
17	Urakoitsijapalavereita on ollut sopiva määrä (ei liikaa/liian vähän)	☐	☐	☐	☐
18	Urakoitsijapalaverit ovat edenneet tehokkaasti ja esityslistan mukaisesti	☐	☐	☐	☐
19	Urakoitsijapalaverit ovat olleet tarkoituksenmukaisia ja hyödyllisiä	☐	☐	☐	☐
20	Rakennuttaja on ottanut huomioon urakoitsijan ehdotukset	☐	☐	☐	☐
21	Rakennuttajan edustaja on ollut tavoitettavissa ja saatavissa työmaalle tarvittaessa	☐	☐	☐	☐
22	Katselmuksissa on voitu tehdä päätökset heti (päättävä taho mukana)	☐	☐	☐	☐
23	Katselmusten tulos on ilmaistu ja dokumentoitu selkeästi	☐	☐	☐	☐
		☐	☐	☐	☐
RAKENNUTTAJAN HANKINNAT					
24	Rakennuttajan kanssa on tarkastettu yhteistoimintakokouksissa: – urakkarajat	☐	☐	☐	☐
25	– aikataulu	☐	☐	☐	☐
26	– tekninen yhteens.	☐	☐	☐	☐
27	Sivu-urakoissa on mukana omien töiden johtovelvoite	☐	☐	☐	☐
28	Sivu-urakoiden työnjohto on ollut tarvittaessa tavoitettavissa	☐	☐	☐	☐
		☐	☐	☐	☐
		☐	☐	☐	☐

OSAINDEKSI (%) ☐

B) SUUNNITTELIJAT	Pitää paikkansa	täysin	kohtalaisesti	huonosti	ei lainkaan
PÄÄSUUNNITTELIJA/SUUNNITTELUN KOORDINAATTORI					
29	Suunnitelmat on jäsennetty selkeän hierarkian ja sisällysluettelon mukaan				
30	Tieto on kulkenut hyvin eri suunnittelijoiden välillä (suunn. kierto, risteilypalaverit)				
31	Suunnitelmat on tehty samoille, ajan tasalla oleville pohjille				
32	Suunnitelmat ovat keskenään yhteensopivia ja vertailtu toisiinsa jo etukäteen				
33	Suunnitelmat on saatu työmaalle suunn. aikataulun mukaisesti (ei katkoksia töissä)				
34	Muutokset on merkitty kansilehden lisäksi myös kuvaan				
ARKKITEHTISUUNNITELMAT					
35	Suunnitelmien toteutettavuus on otettu huomioon (tekotapa, materiaalien saatavuus)				
36	Suunnitelmissa on esitetty tarvittavat detaljit ja leikkaukset				
37	Suunnitelmissa on esitetty tarvittavat mitat				
38	Suunnitelmista löytyvät kaikki värit tai niistä on saatu päätökset ajallaan				
39	Suunnitelmista löytyvät kaikki pintamateriaalit				
40	Lattioiden korkoja ei ole jouduttu muuttamaan				
41	Väliseinien paikkoja ei ole jouduttu muuttamaan				
42	Suunnittelijaa ei ole tarvittu pyytää työmaalle suunnitelmaepäselvyyksien takia				
43	Suunnittelija on tarvittaessa tullut työmaalle				
44	Arkkitehti on ottanut huomioon työmaan ehdotukset				
45	Työmaalla sovitut muutokset on viety nopeasti suunnitelmiin				
46	Töiden etenemisessä ei ole ollut katkoja suunnitelmapuutteiden tai -virheiden takia				
RAKENNESUUNNITELMAT					
47	Toteutustapa on tarvittaessa suunniteltu				
48	Turvallisuus on otettu huomioon suunnitelmissa (esim. elem. koko, kaiteet, sähkövedot)				
49	Suunnitelmissa on esitetty tarvittavat detaljit ja leikkaukset				
50	Suunnitelmissa on esitetty tarvittavat mitat				
51	Suunnittelijaa ei ole tarvittu pyytää työmaalle suunnitelmaepäselvyyksien takia				
52	Suunnitelmia ei ole tarvittu toimittaa työmaalle faksilla				
53	Suunnittelija on tarvittaessa tullut työmaalle				
54	Rakennesuunnittelija on ottanut huomioon työmaan ehdotukset				
55	Työmaalla sovitut muutokset on viety nopeasti suunnitelmiin				
56	Töiden etenemisessä ei ole ollut katkoja suunnitelmapuutteiden tai -virheiden takia				
LVIS -SUUNNITELMAT					
57	Reikäkuvat ovat olleet työmaalla käytettävissä riittävän ajoissa				
58	Reikiä, joita ei esiinny reikäkuvissa, ei ole jouduttu tekemään				
59	Tarvittavat leikkauskuvat on piirretty				
60	Töiden etenemisessä ei ole ollut katkoja suunnitelmapuutteiden tai -virheiden takia				
61	Väliseiniä ei ole jouduttu purkamaan tai piikkaamaan suunnitteluvirheiden takia				
62	Valaisimet ovat sopineet alakattoihin				
63	Alakattojen korkoja ei ole jouduttu muuttamaan				
64	Alakattoja ei ole jouduttu purkamaan				

OSAINDEKSI (%)

C) OMA YRITYS Pitää paikkansa	täysin	kohtalaisesti	huonosti	ei lainkaan
YRITYKSEN LINJAJOHTO (esim. työpäällikkö)				
65 Työmaan tavoitebudjetti ja aikataulu ovat selkeät				
66 Työmaan toteutusorganisaatio on tarkoituksenmukainen				
67 Vastuunjako linjajohdon ja työmaan välillä on selkeä ja toimiva				
68 Työmaalla on ollut käytettävissään tarvittavat henkilö- ja kalustoresurssit				
69 Työmaa-aluetta koskevat suunnitelmat (työmaatilat, nosturit, kulkutiet jne.) ovat toimivat				
70 Työmaan viranomaissuhteiden kanssa ei ole ollut ongelmia (rak.tarkastus, luvat)				
71 Tärkeimmät hankinnat on valmisteltu hyvin (onnistuvat käytännössä)				
72 Seurantapalavereita on ollut riittävän usein ja ne ovat olleet hyödyllisiä				
73 Sopimusten laatimiseen on ollut käytettävissä tarvittava tuki				
74 Vaihtoehtoratkaisujen valitsemiseen on saatu tarvittava tuki ja päätökset				
75 Työmaan ongelmatilanteiden ratkaisemiseen on saatu tarvittava tuki				
76 Työmaa on saanut tukea ja kannustusta toimintansa kehittämiseen				
77 Linjajohto edistää työmaiden välistä yhteistyötä				
78 Linjajohto on ollut riittävästi läsnä tarkastuksissa ja katselmuksissa				
79 Tieto työmaan ja linjajohdon välillä on kulkenut (lisä- ja muutostyöt, reklamaatiot jne.)				
80 Yrityksen arvot ja toimintaperiaattet ovat välittyneet työmaalle				
81 Työmaan johdon palkkaus koetaan oikeudenmukaiseksi				
82 Työmaan palkkiojärjestelmä on selkeä, kannustava ja oikeudenmukainen				
LASKENTATOIMI				
83 Kustannusarviossa ei ole ollut merkitäviä virheitä				
84 Urakkarajat on määritetty laskentav. toteutussuunnitelmassa oikein ja yksiselitteisesti				
85 Laskentavaiheessa valitut tuotantomenetelmät ovat olleet toteutuskelpoisia				
86 Laskentaosastolta on saatu tarvittaessa toteutumatietoja				
87 Laskenta ylläpitää jälkilaskentatiedostoja tuotantosuunnittelun avuksi				
HANKINTATOIMI				
88 Hankintaosaston ja työmaan välinen työnjako on selkeä ja tarkoituksenmukainen				
89 Työmaa on voinut vaikuttaa riittävästi hankintapäätöksiin ja sopimusten sisältöihin				
90 Tarjouspyynnöt ovat yksiselitteisiä ja tuotantoon sopivia				
91 Hankintaosaston tekemät sopimukset ovat yksiselitteisiä ja tuotantoon sopivia				
92 Hankinnat ovat toteutuneet aikataulullisesti työmaan tarpeiden mukaisesti				
93 Hankinnasta on saatavissa tarvittavat toiminta- ja sopimusmallit				
94 Hankinta ylläpitää urakoitsijarekisteriä hankintapäätösten tueksi				
95 Hankinta ylläpitää urakkahintatiedostoja työmaan käytettäväksi				
MARKKINOINTI (perustajaurakoinnissa)				
96 Markkinointiosaston ja työmaan välinen työnjako on selkeä ja tarkoituksenmukainen				
97 Työmaa on saanut tiedon muutostöistä riittävän ajoissa				
98 Sovitut muutostyöt ovat olleet selkeitä ja toteutettavia				
99 Sovitut muutostyöt ovat olleet hinnaltan oikeita				
100 Markkinointiosasto on tiedottanut asiakkaita riittävästi (ei turhia kyselyjä työmaalle)				
101 Työmaakäynnit on järjestetty työmaan toimintaa häiritsemättä				
102 Työmaa on saanut tiedon asiakaspalautteesta				

OSAINDEKSI (%)	
INDEKSI (%)	

2. TYÖMAAN OHJAUSJÄRJESTELMÄT

Työmaa: Pvm:

YHTEENVETO

	pist.	max.	%
A. Suunnittelun hallinta			
B. Kustannus- ja menekkiseuranta			
C. Tuotannonohjaus			
C1. Työmaan laatusuunnitelma			
C2. Tehtäväsuunnitelmat			
C3. Aikataulu- ja resurssisuunnitelmat			
C4. Hankintojen suunnittelu ja ohjaus			
D. Organisaatio, yhteistyö ja tiedonkulku			
E. Logistiikka, ympäristö ja turvallisuus			
Yhteensä (1xOn + 0,5 x Osittain)			

A Suunnittelun hallinta

		On	Osittain	Ei	**Huomautukset**
1	Erilliset suunnitelmakatselmukset on pidetty perustus-, runko- ja sisävaiheen suunnitelmista				
2	Piirustusaikataulussa on esitetty kaikkien suunnitelmien tarve ja sitä on valvottu				
3	Tietojen riittävyyden, toteutuskelpoisuuden ja urakkasopimuksen mukaisuuden tarkastamiseen on sovittu vastuut ja menettelyt				
4	Suunnitelmista tarkastetaan em. asiat heti niiden saavuttua työmaalle.				
5	Suunnitelmien laatua valvotaan ja ristiriitaisuuksia poistetaan ennakolta suunnitelmien kierron, suunnittelu- ja risteilypalaverien avulla				
6	Työmaalla on käytössään kaikki mittaushetkellä tarvittavat suunnitelmat				
7	Mahdollisista puutteista ja viivästymisistä on reklamoitu dokumentoidusti				
8	Suunnitelmapuutteista tai -virheistä aiheutuvista lisätöistä pidetään kirjaa				

B Kustannus- ja menekkiseuranta

		On	Osittain	Ei	**Huomautukset**
1	Työmaalla on reaaliaikainen kustannus- ja menekkiseuranta				
2	Kustannusraporteissa on tehtävittäin tavoitearvio, toteutuneet kustannukset ja ennusteet, sekä yhteenvedot litteraryhmittäin ja kustannuslajeittain.				
3	Ennusteet päivitetään vähintään kerran kuukaudessa				
4	Muutokset omien töiden ja aliurakoiden välillä on päivitetty tavoitearvioon tai kirjattu erikseen muistiin.				
5	Muutostöistä aiheutuvat kustannukset on erotettu muista kustannuksista kustannusraportissa				
6	Seurantapalavereja pidetään noin 1 kk välein työmaan linjajohdon kanssa				
7	Kustannustavoitteet ja niiden toteutuminen ovat tehtävistä vastaavien työnjohtajien tiedossa				

C	**Tuotannonohjaus**	On	Osit-tain	Ei	**Huomautukset**
C1	**Työmaan laatusuunnitelma**				
1	Työmaasta on tehty laatusuunnitelma, jossa on esitetty tehtäväkohtaiset laadunvarmistustoimenpiteet (esim. laadunvarmistusmatriisi)				
2	Työmaasta on tehty riskianalyysi (POA)				
3	Riskianalyysissa esiintulleiden ongelmien varalta on tehty suunnitelmat				
4	Työmaalla on pidetty dokumentoidusti nk. ensimmäisen mestan katselmuksia				
5	Työvaiheiden laadunvarmistusta toteutetaan dokumentoidusti tehtäväkorttien tms.työkohdekohtaisten tarkastuslistojen avulla				
6	Laatusuunnitelmassa määritetyt toimenpiteet on tehty				
7	Laatusuunnitelmaa valvotaan ja päivitetään tarvittaessa				
C2	**Tehtäväsuunnitelmat**				
1	Vähintään kolmesta työvaiheesta on tehty tehtävä- tai laatusuunnitelma				
2	Tehtäväsuunnitelmat sisältävät: • kustannustavoitteen				
3	• aikataulutavoitteen välitavoitteineen				
4	• riskianalyysin/POAn				
5	• laadunvarmistustoimenpiteet ja laatuvaatimukset selkokielisenä				
6	• tuotantosuunnitelman, jossa on huomioitu materiaalisiirrot ja turvallisuus				
7	Tehtäväsuunnitelmien aikataulutavoitteet ovat yhtenevät yleisaikataulun kanssa				
8	Tehtäväsuunnitelmien sisältö on saatettu työntekijöiden tietoon esim. aloituspalavereissa, jotka on dokumentoitu				
C3	**Aikataulu- ja resurssisuunnitelmat**				
1	Työmaasta on tehty yleisaikataulu paikka-aikakaavion muotoon				
2	Työmaasta on tehty tarvittavat rakentamisvaiheaikataulut ja LVIS -aikataulu, joissa esitetään töiden eteneminen työkohteittain				
3	Tehtävät ja resurssit sisältävät viikkosuunnitelmat on tehty muiden aikataulujen pohjalta				
4	Aikatauluun on varattu häiriöpelivaraa ja luovutusaikaa riittävästi.				
5	Välitavoitteet, tahdistavat aikataulutehtävät ja riippuvuudet on merkitty selvästi				
6	Aikatauluun on piirretty toteuma viikottain				
7	Alkuperäistä aikataulua ei ole tarvinnut muuttaa (miksi muutettu?)				

C4	**Hankintojen suunnittelu ja ohjaus**				
1	Hankintasuunnitelmaa on valvottu (toteutumat merkitty)				
2	Hankinta- ja yleisaikataulu on onnistuneesti yhteensovitettu				
3	Puutteista toimituksissa on reklamoitu kirjallisesti				
4	Työmaalla on käytettävissä toimittajarekisteri, ja aliurakoitsijat ovat siinä hyväksyttyjä				
5	Aliurakkasopimukset ovat olleet työmaalla käytettävissä ennen töiden alkamista				
6	Aliurakkasopimuksissa on esitetty selvästi: • urakan sisältö ja rajat (myös työturvallisuus)				
7	• aikataulu välitavoitteineen (myös sakot määrätty tarvittaessa)				
8	• työnjohtovelvoite ja työvoiman pysyvyys				
9	• laatuvaatimukset auki kirjoitettuna				
10	Havaitut (laatu- ja tehtäväsuunnitelmissa esitetyt) potentiaaliset ongelmat on otettu huomioon aliurakkasopimuksissa				
11	Aliurakoitsijoiden työryhmän/nokkamiehen kanssa on pidetty aloituspalaveri tms. perehdytys				
12	Aliurakoitsijoiden aikataulutilannetta seurataan systemaattisesti (esim. urakkapalverit, säännöllinen raportointi)				

D	**Organisaatio, yhteistyö ja tiedonkulku**	On	Osit-tain	Ei	**Huomautukset**
1	Työmaaorganisaation tehtävät on määritetty kirjallisesti, ja ovat ajan tasalla				
2	Työmaan sisäisiä mestaripalavereja pidetään säännöllisesti ja dokumentoidusti				
3	Uudet työntekijät perehdytetään systemaattisen menettelyn mukaisesti				
4	Työmaalla järjestetään säännöllisesti tiedotustilaisuuksia kaikille työntekijöille				
5	Tiedotuksessa käytetään hyväksi kirjallista materiaalia (ilmoitustaulut, tiedotteet)				
6	Työmaalla pidetään yhteistyöpalavereja työryhmien nokkamiesten kesken.				
7	Työmaiden väliseen yhteistyöhön on sovittu menettelyt (missä asioissa, miten)				
8	Työmaalla hyödynnetään yrityksessä ylläpidettyjä tiedostoja: • yleisimmät laatuvirheet (vuosikorjaukset ym.)				
9	• materiaali- ja urakkahintatiedostoja				
10	• yleistä ja kohdekohtaista asiakaspalautetta				
11	Yhteydenpidosta tilaajan tai asukkaiden kanssa on sovittu talon sisällä vastuut ja menettelytavat (esim. muutostöistä sopiminen ja tiedottaminen)				

E Logistiikka, ympäristö ja turvallisuus

		On	Osit-tain	Ei	Huomautukset
1	Työmaasuunnitelma tehty rakennusvaiheittain ja siihen on merkitty kulkutiet, nosturit + säteet, varastopaikat ja jätelavat				
2	Tilanne työmaalla vastaa työmaasuunnitelmaa				
3	Materiaalin vastaanottoa, varastointia ja siirtoja varten on tehty erillinen logistiikkasuunnitelma (tai varastointisuunnitelma)				
4	Työntekijöille on jaettu kulkuluvat ja niistä pidetään luetteloa				
5	Työmaalla on ympäristösuunnitelma				
6	Työmaalla on jätehuoltosuunnitelma, jonka mukaan toimitaan (esim. lajittelu)				
7	Työmaan ympäristöön aiheutuvat häiriöt ja päästöt pyritään minimoimaan suunnitelmallisesti (liikenne, pöly, melu tms.)				
8	Työmaalle on laadittu yhteiset toimintatavat, ns. pelisäännöt, jotka on asetettu näkyville				
9	Tarpeelliset turvallisuussuunnitelmat, kuten putoamissuojaus-, purkutyö-, nostotyö- ja telinesuunnitelmat on tehty				
10	Nosturien ja telineiden käyttöönottotarkastuksista on sovittu menettelyt ja vastuut				
11	Työsuojelukierrokset on tehty ja pöytäkirjat on täytetty korjausmerkintöineen				
12	Työmaalla sovelletaan turvallisuusmittausta (esim. TR-mittari)				
13	Työmaalla on vaarallisista aineista käyttöturvallisuustiedotteet				

Työmaan numero ☐

3.1. TYÖMAAN TOIMIVUUS JA JOHTAMINEN

Vastaamisohjeet

***Vastaaminen** tapahtuu tekemällä rasti 5-luokkaiselle asteikolle seuraavien periaatteiden mukaan: Jos jompikumpi annetuista vaihtoehdoista kuvaa hyvin mielipidettäsi, tee rasti sitä lähinnä olevaan kohtaan. Esim. jos pidät työtäsi vaikeana, tee rasti äärimmäisenä vasemmalla olevaan ruutuun.*

Esimerkki: **Työni on vaikeaa** → ☐☐☐☐☐ ← **työni on helppoa**

melko vaikeaa ***melko helppoa***

Jos pidät työtäsi <u>melko</u> vaikeana, jolloin "vaikea" tuntuu liian voimakkaalta ilmaisulta, voit valita lievemmän vaihtoehdon rastittamalla toisen vaihtoehdon vasemmalta katsoen.

Pyri kuitenkin ottamaan kantaa eli käytä asteikkoa koko "leveydeltään".

***Myönteisen ja kielteisen vaihtoehdon paikka** vaihtelee täysin sattumanvaraisesti. Myönteinen vaihtoehto voi siten olla joko oikealla tai vasemmalla puolella asteikkoa.*

***<u>Kysely koskee sitä rakennustyömaata, jossa nyt työskentelet</u>**. Vastausten tulee perustua siihen, millaisena näet toiminnan tällä työmaalla verrattuna muihin työmaihin, joissa olet työskennellyt. Myös aliurakoitsijoiden vastaukset kuvaavat tätä työmaata, eivätkä esim. omaa työnantajaansa.*

*Vastaukset ovat **luottamuksellisia** eikä yhteenvedoista käy selville yksittäisen vastaajan mielipide. Kaikki tulokset esitetään ryhmiä kuvaavina tunnuslukuina ja jakaumina. Täytetyt lomakkeet jäävät tutkijalle.*

TAUSTA-TIEDOT Rengasta oman henkilöstö- ja ikäryhmäsi edessä oleva numero. Taustatietojen avulla vastaukset voidaan liittää oikeaan ryhmään ja tuloksia voidaan verrata ulkopuoliseen aineistoon.

TYÖNANTAJASI

1. Pääurakoitsija tai päätoteuttaja
2. Ali- tai sivu-urakoitsija

ASEMASI

1. Työnjohtaja tai esimies
2. Työntekijä

IKÄRYHMÄSI

1. Alle 30 vuotta
2. 30 - 39 vuotta
3. 40 - 49 vuotta
4. 50 vuotta tai enemmän

AMMATTINIMIKKEESI

ORGANISAATION TOIMINTA	Arvioi työmaan toimintatapaa verrattuna muihin työmaihin, joilla olet työskennellyt. Arvioinnin kohteena on **tämä työmaa**, ei koko yritys tai muu työnantaja.

Omalle työlleni on ominaista:

1	Työni antaa runsaasti tyydytystä	☐☐☐☐☐	on täysin epätyydyttävää
2	Työmäärä vaihtelee liikaa	☐☐☐☐☐	on sopivan tasaista
3	Saan uusia ja haasteellisia työtehtäviä tarpeeksi	☐☐☐☐☐	liian vähän
4	Päätösvaltaa omaan työhöni liittyvissä ratkaisuissa on riittävästi	☐☐☐☐☐	liian vähän
5	Työskentelyolosuhteet ovat hyvät	☐☐☐☐☐	huonot
6	Työvälineet ovat epätarkoituksenmukaiset	☐☐☐☐☐	tarkoituksenmukaiset
7	Tunnen jaksavani työssäni erinomaisesti	☐☐☐☐☐	tunnen itseni hyvin usein uupuneeksi työssäni
8	Viihdyn työssäni huonosti	☐☐☐☐☐	erinomaisesti
9	Ammatilliset kehittymismahdollisuuteni työmaalla ovat hyvät	☐☐☐☐☐	huonot

Työmaan toiminnalle on ominaista:

10	Työ- ja toimintaohjeet ovat ristiriitaisia	☐☐☐☐☐	johdonmukaisia
11	Työt järjestellään hyvin	☐☐☐☐☐	huonosti
12	Suunnitelmia noudatetaan tarkasti	☐☐☐☐☐	ei noudateta kovinkaan tarkasti
13	Uusiin työtapoihin suhtaudutaan epäluuloisesti	☐☐☐☐☐	uudistuksiin pyritään
14	Toiminta on sekavaa	☐☐☐☐☐	toiminta selkeätä
15	Työtuloksia tarkastetaan usein	☐☐☐☐☐	tuloksia ei tarkasteta koskaan
16	Työohjeiden ja laatuvaatimusten noudattamista valvotaan tarkasti	☐☐☐☐☐	valvotaan huonosti
17	Päätöksenteko tapahtuu selvän vastuujaon mukaan	☐☐☐☐☐	päätöksenteon vastuunjako on epäselvä
18	Työtavoitteet ovat selkeitä	☐☐☐☐☐	työtavoitteet heikosti määritelty
19	Työmaalla on selvät toimintatavat ja pelisäännöt	☐☐☐☐☐	ei selviä pelisääntöjä
20	Saadaan aikaan muihin työmaihin verrattuna vähän tuloksia	☐☐☐☐☐	paljon tuloksia
21	Työmaalla noudatetaan sovittuja toimintatapoja ja pelisääntöjä aina	☐☐☐☐☐	sovitusta poiketaan usein
22	Työmaan laatusuunnitelma vaikuttaa toimintaan paljon	☐☐☐☐☐	laatusuunnitelma ei vaikuta toimintaan
23	Työnjako ja vastuualueet ovat selviä	☐☐☐☐☐	työnjako ja vastuualueet epäselviä
24	Itsenäiseen toimintatapaan kannustetaan	☐☐☐☐☐	itsenäisyys tukahdutetaan
25	Havaitut ongelmat selvitetään nopeasti	☐☐☐☐☐	ongelmat jäävät selvittämättä
26	Hyvät suoritukset palkitaan	☐☐☐☐☐	hyviä suorituksia ei palkita
27	Päätöksenteko hidasta	☐☐☐☐☐	päätöksenteko nopeata
28	Työmaalla toimitaan tarkasti määrätyn työn- ja vastuunjaon mukaisesti	☐☐☐☐☐	työn- ja vastuunjakoa ei käytännössä noudateta

YHTEISTYÖ tällä työmaalla

29	Yhteishenki työmaalla on erittäin hyvä	☐☐☐☐☐	yhteishengessä on toivomisen varaa
30	Muilta työntekijöiltä on vaikea saada apua	☐☐☐☐☐	apua on helppo saada
31	Työntekijät näkevät koko työmaan edun	☐☐☐☐☐	työntekijät näkevät vain oman etunsa
32	Työmaan yhteiset tavoitteet ovat erittäin selviä	☐☐☐☐☐	täysin selventämättä
33	Työpaikalla esiintyviä ristiriitoja käsitellään avoimesti ja ne pyritään ratkaisemaan	☐☐☐☐☐	ristiriitoja peitellään
34	Yhteishenki työmaalla lähimpien työtovereitteni keskuudessa on hyvä	☐☐☐☐☐	huono

TIEDONVÄLITYS tällä työmaalla

35	Työmaan tiedottaminen on: erittäin runsasta	☐☐☐☐☐	erittäin vähäistä
36	salailevaa	☐☐☐☐☐	avointa
37	epäluotettavaa	☐☐☐☐☐	luotettavaa
38	Saan työohjeita riittävästi	☐☐☐☐☐	liian vähän
39	Saan tietoa työtuloksistani aivan liian vähän	☐☐☐☐☐	riittävästi
40	Työtä koskevien tietojen puute haittaa työni tekemistä tuskin koskaan	☐☐☐☐☐	erittäin usein
41	Työtä koskevien tietojen vieminen lähimmälle esimiehelleni on täysin hyödytöntä	☐☐☐☐☐	osoittautunut hyödylliseksi
42	Työmaan tavoitteiden saavuttamisesta on tiedotettu riittävästi	☐☐☐☐☐	ei lainkaan

ESIMIEHEN JOHTAMISTAPA

Kysymykset koskevat **tämän työmaan työnjohtajaa tai vastaavaa mestaria**, jonka kanssa olet eniten tekemisissä ja jonka tunnet parhaiten. Myös aliurakoitsijat arvioivat omaa työtänsä ohjaavaa pääurakoitsijan työnjohtajaa eivätkä oman yrityksensä esimiestä.

Minua lähimmän tämän työmaan esimiehen johtamistavalle on ominaista:

43	Toimii perustelematta ratkaisujaan	☐☐☐☐☐	perustelee ratkaisunsa alaisilleen
44	Kannustaa runsaasti työntekijöitä	☐☐☐☐☐	kannustaa aivan liian vähän työntekijöitä
45	Valvoo paljon työntekijöitä	☐☐☐☐☐	valvoo liian vähän työntekijöitä
46	Ymmärtää työntekijöiden henkilökohtaisia ongelmia	☐☐☐☐☐	ei ymmärrä työntekijöiden ongelmia
47	Ehtii kuunnella työntekijöitä	☐☐☐☐☐	vähän aikaa työntekijöille
48	Suosii työntekijöiden osallistumista töiden suunnitteluun ja järjestelyyn	☐☐☐☐☐	ei suosi työntekijöiden osallistumista
49	Ei tue työntekijöiden kehittymispyrkimyksiä	☐☐☐☐☐	tukee työntekijöiden kehittymispyrkimyksiä
50	Selventää työmenetelmiä riittävästi	☐☐☐☐☐	liian vähän
51	,	☐☐☐☐☐	toisia työntekijöitä suosiva
52	Suhtautuu asiallisesti työntekijöiden tekemiin virheisiin	☐☐☐☐☐	ei ymmärrä työntekijöiden virheitä
53	On valmis kokeilemaan työntekijöiden esittämiä uusia ideoita	☐☐☐☐☐	ei huomioi työntekijöiden ideoita
54	Antaa palautetta hyvistä työsuorituksista aivan liian vähän	☐☐☐☐☐	riittävästi
55	Kokonaisuudessaan olen lähimpään esimieheeni erittäin tyytyväinen	☐☐☐☐☐	erittäin tyytymätön

3.1. TYÖMAAN TOIMIVUUS JA JOHTAMINEN

23.9.1999

TYÖTYYTYVÄISYYS

1 Työ antaa tyydytystä
7 Työssä jaksaminen on hyvä
8 Viihtyvyys työssä hyvä

OSALLISTUMINEN JA VAIKUTTAMINEN

4 Päätösvaltaa omissa töissä on riittävästi
24 Itsenäiseen toimintatapaan kannustetaan
41 Työtä koskevien tietojen vieminen työnjohtajalle on hyödyllistä
48 Esimies suosii työntekijöiden osallistumista töiden suunnitteluun

YHTEISHENKI

29 Yhteishenki työmaalla on hyvä
30 Muilta työntekijöiltä on helppo saada apua
31 Työntekijät näkevät koko työmaan edun
33 Ristiriidat käsitellään ja ratkaistaan
34 Yhteishenki lähimpien työtovereiden keskuudessa hyvä

TIEDONKULKU

35 Tiedottaminen on runsasta
36 avointa
37 luotettavaa
40 Työtä koskevien tietojen puute ei haittaa
39 Työtuloksista saadaan riittävästi tietoa
42 Työmaan tavoitteiden saavuttamisesta on tiedotettu

KANNUSTAMINEN JA PALAUTE

26 Hyvät suoritukset palkitaan
43 Esimies perustelee ratkaisunsa
44 Esimies kannustaa runsaasti
52 Esimies suhtautuu virheisiin asiallisesti
54 Esimies antaa hyvistä suorituksista riittävästi palautetta

SUHDE ESIMIEHEEN

46 Esimies ymmärtää työntekijöiden ongelmia
47 Esimies kuuntelee työntekijöitä
51 Esimies on tasapuolinen työntekijöille
55 Tyytyväisyys esimieheen

KEHITTÄMINEN JA INNOVATIIVISUUS

3 Tarpeeksi uusia ja haasteellisia työtehtäviä
9 Ammatilliset kehittymismahdollisuudet ovat hyvät
13 Työtapojen uudistamiseen pyritään
49 Esimies tukee työntekijöiden kehittymispyrkimyksiä
53 Esimies on valmis kokeilemaan työntekijöiden ideoita

VASTUIDEN JA TOIMINTAOHJEIDEN SELKEYS

10 Työ- ja toimintaohjeet ovat johdonmukaisia
17 Päätöksenteon vastuunjako on selvä
19 Toimintatavat ja pelisäännöt ovat selvät
23 Työnjako ja vastuualueet ovat selviä

SUUNNITELMIEN JA OHJEIDEN NOUDATTAMINEN

12 Suunnitelmia noudatetaan tarkasti
21 Sovittuja toimintatapoja ja pelisääntöjä noudatetaan
22 Laatusuunnitelma vaikuttaa työmaan toimintaan
28 Määrätyn työn- ja vastuunjaon mukaan toimitaan

SUUNNITELMALLISUUS JA TAVOITTEELLISUUS

18 Työtavoitteet ovat selkeät
32 Työmaan yhteiset tavoitteet ovat selvät
38 Työhjeiden määrä on riittävä
50 Esimies selventää työmenetelmiä riittävästi

VALVONTA

15 Työtuloksia tarkastetaan usein
16 Työohjeiden ja laatuvaatimusten noudattamista valvotaan
45 Esimies valvoo paljon työntekijöitä

TÖIDEN SUJUMINEN

2 Työmäärä on sopivan tasainen
5 Työskentelyolosuhteet ovat hyvät
6 Työvälineet ovat tarkoituksenmukaiset
14 Toiminta on selkeätä

TOIMINNAN TEHOKKUUS

11 Työt järjestellään hyvin
20 Saadaan aikaan paljon tuloksia
25 Havaitut ongelmat selvitetään nopeasti
27 Päätöksenteko on nopeata

TEHTÄVÄKORTTI

TEHTÄVÄ: **Kalusteasennus**
TYÖMAA: ______________________ Pvm __________
TYÖKOHDE: ______________________ Mittaaja __________

A) Suunnittelu, ohjaus ja valvonta

		Mittaus	Huomautukset
1	Uusimmat hyväksytyt arkkitehtisuunn. ja asukasmuutokset ovat työmaalla käytössä		
2	Suunnitelmat on tarkastettu ja ne sisältävät tarvittavat detaljit ja mitat		
3	Urakkasopimuksessa on määritetty yksiselitteisesti: – urakan sisältö ja rajat		
4	– aikataulu välitavoitteineen		
5	– työvoiman pysyvyys ja työnjohtovelvoite		
6	– laatuvaatimukset (kirjoitettu auki)		
7	Tehtävä- tai työvaihesuunnitelma on tehty		
8	Tehtäväsuunnitelma sisältää: kustannus- ja aikataulutav., POA, laatuv. ja tuotantoslma		
9	Materiaalien vastaanotto on suunniteltu ja varastointi- ja siirtotarve minimoitu		
10	Edeltävien työvaiheiden tarkastamiseen ja hyväksymiseen on menettely		
11	Poikkeamien kirjaamiseen on menettely		
12	Pakkaus- ym. jätteiden keräämiseen ja poiskuljettamiseen on menettely		
13	Suunnitelmat ja laatuvaatimukset on selvitetty työntekijöille esim. aloituspalaverissa		
14	Tehtävä etenee yleisaikataulun mukaisesti (± 3 pv)		
15	Tehtävän tavoitearvio ei ole ylittymässä		
16	Työnjohto tuntee keskeiset ja poikkeavat laatuvaatimukset:		

B0) Edeltävät työvaiheet

1	Edeltävät työvaiheet ovat valmiit, tarkastetut ja hyväksytyt		
2	LVIS -pisteet ovat oikealla paikallaan		
3	Alusta on puhdas, kuiva ja suora		
4	Asennusvarat ovat riittävät		

B) Toiminta työkohteessa

1	Työkohteessa on tarvittavat lähtötiedot (kuvat) ja merkinnät (korot)		
2	Ylä- ja alakaapin välinen etäisyys on laattamiehen tiedossa		
3	Jätteet on kerätty astioihin tai poistettu ja työkohde on siisti		
4	Materiaalit on toimitettu ajallaan (ei häiriöitä työkohteessa)		
5	Materiaaleja ei ole jouduttu siirtelemään tarpeettomasti		
6	Työkohteessa on tarvittava, oikea materiaali (täydellinen toimitus)		
7	Työntekijät tuntevat aikataulun tai etenemisnopeuden		
8	Työntekijät tuntevat keskeiset ja poikkeavat laatuvaatimukset:		

C) Valmis tuote

1	Pinnat ovat ehjiä ja puhtaita		
2	Peite- ja täytelaudat on asennettu siististi ja kiilat on poistettu		
3	Ovien väliset raot ovat tasalevyisiä, eikä ovien välillä ole hammastusta		
4	Ovien käynti on moitteetonta		
5	Kaapit on kiinnitetty lujasti ja oikein paikalleen		
6	Työ- ja pesupöytätasojen saumaus seinäpintaan on siisti ja tiivis		
7	Ovi- ja työpöytälevyjen pinnan tasaisuuspoikkeama on enintään 0,5 mm/200 mm		
8	Ovi- ja työpöytälevyjen suoruus: alle 1,2 m/2,0 mm; yli 1,2 m/3,0 mm		
9	Lävistykset ja peiteprikat ovat sopivat ja oikein asennetut (tiiviit)		
10	Pöytätasot on suojattu		
11	Työvaiheesta aiheutuneet jätteet on poistettu		
12	Kohdekohtaiset laatuvaatimukset:		

LAATUINDEKSI ☐

TEHTÄVÄKORTTI

TEHTÄVÄ: **Laatoitus**
TYÖMAA: ______________________ Pvm __________
TYÖKOHDE: ______________________ Mittaaja __________

A) Suunnittelu, ohjaus ja valvonta

		Mittaus	Huomautukset
1	Uusimmat hyväksytyt arkkitehtisuunn., ja materiaalimäär. ja asukasmuut. ovat käytössä		
2	Suunnitelmat on tarkastettu ja ne sisältävät tarvittavat tiedot		
3	Työmaalla on käytössä tarvittavat valmistajien ohjeet (kosteussulut, versierist., laastit)		
4	Urakkasopimuksessa on määritetty yksiselitteisesti: – urakan sisältö ja rajat		
5	– aikataulu välitavoitteineen		
6	– työvoiman pysyvyys ja työnjohtovelvoite		
7	– laatuvaatimukset (kirjoitettu auki)		
8	Tehtävä- tai työvaihesuunnitelma on tehty		
9	Tehtäväsuunnitelma sisältää: kustannus- ja aikataulutav., POA, laatuv. ja tuotantoslma		
10	Materiaalien vastaanotto on suunniteltu ja varastointi- ja siirtotarve minimoitu		
11	Alustan riittävä kuivuus on todettu mittaamalla		
12	Edeltävien työvaiheiden tarkastamiseen ja hyväksymiseen on menettely		
13	Poikkeamien kirjaamiseen on menettely		
14	Jätteiden keräämiseen ja poiskuljettamiseen on menettely		
15	Suunnitelmat ja laatuvaatimukset on selvitetty työntekijöille esim. aloituspalaverissa		
16	Tehtävä etenee yleisaikataulun mukaisesti (± 3 pv)		
17	Tehtävän tavoitearvio ei ole ylittymässä		
18	Työnjohto tuntee keskeiset ja poikkeavat laatuvaatimukset:		

B0) Edeltävät työvaiheet

1	Edeltävät työvaiheet ovat valmiit, tarkastetut ja hyväksytyt		
2	Lattian korot ja kaadot ovat suunnitelman mukaiset (väh. kaivo 1:50, muualla 1:100)		
3	Lattian ja seinien tasaisuuspoikkeama on enintään ±4 mm/2 m		
4	Alustan kosteus ja asennuslämpötila ovat materiaalitoimittajan ohjeiden mukaiset		
5	Alusta on puhdas		

B) Toiminta työkohteessa

1	Työkohteessa on tarvittavat lähtötiedot (suunnitelmat) ja merkinnät (korot, linjat)		
2	Työkohteessa on tarvittavat tuotekohtaiset ohjeet ja työselostukset (k-sulut, v-er., laastit)		
3	Materiaalit on toimitettu ajallaan (ei häiriöitä työkohteessa)		
4	Materiaaleja ei ole jouduttu siirtelemään turhaan		
5	Työkohde on siisti ja siellä on roska-astia, laastijätettä ei ole päässyt viemäreihin		
6	Samassa tilassa ei tehdä muita töitä		
7	Vedeneristyksen vahvikekangas on tiiviisti kiinni alustassa		
8	Vedeneriste lattiassa nostettu väh. 100 mm seinälle ja se liittyy tiiviisti läpimenoihin		
9	Ruuvin- ja naulankannat ja halkeamat on käsitelty vedeneristemassalla tai -tasoitteella		
10	Levysaumoihin, seinän ja lattian rajaan sekä nurkkiin on asennettu elast. tiivistenauha		
11	Lattiakaivon ympärille on kiinnitetty vedeneristemassalla elastinen tiivistyslaippa		
12	Läpivientien (1,5 m suihkusta) ympärille on asennettu tiivistevaippa tai eristemassa		
13	Suihkun ympärille 1,5 m etäisyydelle on telattu yhtenäinen ja tiivis vedeneriste		
14	Vedeneristeen toinen sively tehdään vasta kun ensimmäinen on täysin kuiva		
15	Kosteussulkukäsittely on yhtenäinen ja ulottuu kaikille seinille (sivelyt: betoni 1, kipsi 2)		
16	Laastit on varastoitu asianmukaisesti, ne ovat kunnossa ja säilyvyysaikaa ei ole ylitetty		
17	Asennettavat laatat ovat kunnoltaan moitteettomia ja tyypiltään oikeita		
18	Käytettävä vatupassi on kunnossa näyttää oikein (tarkastettu työmaan aikana)		
19	Laastia on levitetty koko alueelle oikea määrä (ei pursu reunoilta)		

20	Laattojen tartunta on tarkastettu työn aikana irrottamalla laattoja		
21	Nurkkiin ja laatan ja seinän väliin on jätetty 2-3 mm:n rako, josta laasti on poistettu		
22	Työntekijät tuntevat aikataulun tai etenemisnopeuden		
23	Työntekijät tuntevat keskeiset ja poikkeavat laatuvaatimukset:		

C) Valmis tuote

1	Saumat ovat suoria ja leveydeltään yhtenäisiä		
2	Laattasaumoissa ei ole reikiä		
3	Lattian ja seinien väliset saumat on puhdistettu ja täytetty siististi saniteettisilikonilla		
4	Laatoitetun seinäpinnan tasaisuustoleranssit: ±3 mm/2 m		
5	Laatoissa ei ole häiritsevää hammastusta		
6	Alahelman laatta on kiinnitetty täydellä laastilla, kun tilassa on lattiamatto		
7	Laatoitus on puhdistettu lopulliseen tasoon		
8	Kohde on suojattu ja siellä liikkuminen kuivumisen ajan estetty		
9	Työvaiheesta aiheutuneet jätteet on poistettu		
10	Kohdekohtaiset laatuvaatimukset:		

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TEHTÄVÄKORTTI

TEHTÄVÄ: **Tasakaton vedeneristys**
TYÖMAA: ____________________ Pvm __________
TYÖKOHDE: ____________________ Mittaaja __________

A) Suunnittelu, ohjaus ja valvonta

		Mittaus	Huomautukset
1	Uusimmat hyväksytyt rakenne- ja arkkitehtisuunnitelmat ovat työmaalla käytössä		
2	Suunnitelmat on tarkastettu ja ne sisältävät tarvittavat detaljit ja mitat		
3	Urakkasopimuksessa on määritetty yksiselitteisesti: – urakan sisältö ja rajat		
4	– aikataulu välitavoitteineen		
5	– työvoiman pysyvyys ja työnjohtovelvoite		
6	– laatuvaatimukset (kirjoitettu auki)		
7	Tehtävä- tai työvaihesuunnitelma on tehty		
8	Tehtäväsuunnitelma sisältää: kustannus- ja aikataulutav., POA, laatuv. ja tuotantoslma		
9	Tulityöluvat ovat olemassa		
10	Materiaalien varastointi on suunniteltu ja siirtotarve minimoitu		
11	Edeltävien työvaiheiden tarkastamiseen ja hyväksymiseen on menettely		
12	Poikkeamien kirjaamiseen on menettely		
13	Jätteiden keräämiseen ja poiskuljettamiseen on menettely		
14	Suunnitelmat ja laatuvaatimukset on selvitetty työntekijöille esim. aloituspalaverissa		
15	Takuu on jätetty tilaajalle		
16	Tehtävä etenee yleisaikataulun mukaisesti (± 3 pv)		
17	Tehtävän tavoitearvio ei ole ylittymässä		
18	Työnjohto tuntee keskeiset ja poikkeavat laatuvaatimukset:		

B0) Edeltävät työvaiheet

1	Edeltävät työvaiheet ovat valmiit, tarkastetut ja hyväksytyt (esim. läpiviennit)		
2	Katon kaadot ovat toimivat		
3	Läpimenot eivät ole liian lähekkäin		
4	Väliseinien raot ovat enintään 2 mm		
5	Valmiit rakennusosat on suojattu hyvin (ovet, ikkunat, LVIS-laitteet jne.)		
6	Alustan tasaisuus vastaa puuhierrettyä betonipintaa		

B) Toiminta työkohteessa

1	Työkohteessa on tarvittavat lähtötiedot (kuvat) ja merkinnät (korot, linjat)		
2	Pikipata on ehjä ja toimiva, kansi tiivis, hana ehjä		
3	Pikipadan läheisyydessä ei ole palavia materiaaleja		
4	Tulityölaitteet ovat ehjät ja letkuissa on takaisku- ja takatulisuojat		
5	Työkohteessa on kaksi kunnossa olevaa 12 kg sammutinta (sokka paikallaan, tarkastettu)		
6	Roskat on kerätty nostamista varten esim. säkkeihin lavoille ja kiinnitetty hyvin		
7	Materiaaleja ei säilytetä alle 1 m etäisyydellä katon reunasta		
8	Kaiteet ovat määräysten mukaiset ja aukot peitetty		
9	Materiaalit on toimitettu ajallaan (ei odotusaikoja työkohteessa)		
10	Materiaalit on sijoitettu katolle tarkoituksenmukaisesti (ei turhia siirtoja)		
11	Eristysalustalla ei ole roskia, vettä, lunta tai jäätä		
12	Avoimet räystäsrakenteet on tarvittaessa suojattu esim. muovilla		
13	Eristys on toteutettu yhtäjaksoisesti		
14	Eristystyötä ei tehdä lumi- tai vesisateen aikana		
15	Vedenpitävyyskoe suoritetaan esim. paineistamalla tai "vesialtaalla"		
16	Työntekijät tuntevat aikataulun tai etenemisnopeuden		
17	Työntekijät tuntevat keskeiset ja poikkeavat laatuvaatimukset:		

C) Valmis tuote

1 Eristys on kauttaaltaan ehjä		
2 Eristyksen nostot ovat vähintään 0,3 m ympäröivän tason yläpuolella		
3 Ylösnostot on kiinnitetty hyvin		
4 Työsaumat on kiinnitetty hyvin (eristyshuovat eivät ole irti)		
5 Liittymäkohdat on tiivistetty oikein ja kunnolla (vastaavat eristeet tiiviyttä)		
6 Eristys on ulotettu suojaavien rakennusosien yli riittävän laajalle		
7 Eristys on suojattu riittävän hyvin säältä ja mekaanisilta vaurioilta		
8 Eristyksen päällä ei ole kiviä tai metallinkappaleita		
9 Työvaiheesta aiheutuneet jätteet on poistettu		
10 Kohdekohtaiset laatuvaatimukset:		

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TEHTÄVÄKORTTI

TEHTÄVÄ: **Väliseinämuuraus (tiili, siporex, aco)**
TYÖMAA: ____________________ Pvm __________
TYÖKOHDE: ____________________ Mittaaja __________

A) Suunnittelu, ohjaus ja valvonta

		Mittaus	Huomautukset
1	Uusimmat hyväksytyt rakenne- ja arkkitehtisuunnitelmat työmaalla käytössä		
2	Suunnitelmat on tarkastettu ja ne sisältävät tarvittavat detaljit ja mitat		
2	Urakkasopimuksessa on määritetty yksiselitteisesti: – urakan sisältö ja rajat		
3	– aikataulu välitavoitteineen		
4	– työvoiman pysyvyys ja työnjohtovelvoite		
5	– laatuvaatimukset (kirjoitettu auki)		
6	Tehtävä- tai työvaihesuunnitelma on tehty		
7	Tehtäväsuunnitelma sisältää: kustannus- ja aikataulutav., POA, laatuv. ja tuotantoslma		
8	Materiaalien varastointi ja v-otto on suunniteltu ja varastointi- ja siirtotarve minimoitu		
9	Telinesuunnitelma on tarvittaessa tehty (jos ei standardiratkaisuja)		
10	Edeltävien työvaiheiden tarkastamiseen ja hyväksymiseen on menettely		
11	Poikkeamien kirjaamiseen on menettely		
12	Muurausjätteiden keräämiseen ja poiskuljettamiseen on menettely		
13	Suunnitelmat ja laatuvaatimukset on selvitetty työntekijöille esim. aloituspalaverissa		
14	Tehtävä etenee yleisaikataulun mukaisesti (± 3 pv)		
15	Tehtävän tavoitearvio ei ole ylittymässä		
16	Työnjohto tuntee keskeiset ja poikkeavat laatuvaatimukset:		

B0) Edeltävät työvaiheet

1	Edeltävät työvaiheet ovat valmiit, tarkastetut ja hyväksytyt		
2	Alusta on puhdas ja tasainen		

B) Toiminta työkohteessa

1	Työkohteessa on tarvittavat lähtötiedot (kuvat) ja merkinnät (korot, linjat)		
2	Muurausjätteet on kerätty astioihin tai poistettu ja työkohde on siisti		
3	Telineet ovat määräysten mukaiset (nousu, kaiteet, työtason leveys, rakenne)		
4	Kattoon on piirretty asennuslinja		
5	Rasioiden kolot ja putkivedot ovat paikallaan tai merkitty		
6	Materiaalit on toimitettu ajallaan (ei odotusaikoja työkohteessa)		
7	Materiaaleja ei ole jouduttu siirtelemään tarpeettomasti		
8	Saumat on tehty asennusohjeiden mukaisesti		
9	Aukkojen ylitykset on tehty suunnitelmien mukaisesti		
10	Muurausjätteet ja laastinroiskeet on siivottu ennen laastin kovettumista		
11	Työntekijät tuntevat aikataulun tai etenemisnopeuden		
12	Työntekijät tuntevat keskeiset ja poikkeavat laatuvaatimukset:		

C) Valmis tuote

1 Seinän käyryys on alle ± 3 mm / 1 m		
2 Seinän poikkeama pystysuorasta enintään 8 mm		
3 Sivusijainti perussuorasta enintään ± 8 mm		
4 Hammastus korkeintaan 4 mm		
5 Muuraussaumat ovat täysiä, liimasaumat purseettomia		
6 Puhtaaksimuuratussa seinäpinnassa ei ole tiililohkeamia enempää kuin 5 kpl/m2		
7 Tiilet silmämääräisesti tarkasteltuina ehjiä, ei liikaa rikkoreunaisuutta		
8 Puhtaaksimuurauksen ulkonäkö on hyvä		
9 Seinän yläpään liittyminen kattoon on asennusohjeen mukainen (hormien palomäär.)		
10 Seinän alapään liittyminen lattiaan on asennusohjeen mukainen (hormien palomäär.)		
11 Ovien ja aukkojen paikat ja mitat suunnitelmien mukaiset		
12 Liikuntasaumat tehty suunnitelmien mukaisesti		
13 Työvaiheesta aiheutuneet jätteet on poistettu		
14 Kohdekohtaiset laatuvaatimukset:		

LAATUINDEKSI ☐

APPENDIX 1.6 (1)

TR MITTARI

Rakennustyömaan turvallisuusindeksi

Päivämäärä ______________________

Yritys ______________________

Työmaa ______________________

Mittaaja ______________________

MITTAUSKOHDE	OIKEIN	YHT.	VÄÄRIN	YHT.
TYÖSKENTELY				
TELINEET, KULKUSILLAT JA TIKKAAT				
KONEET JA VÄLINEET				
PUTOAMISSUOJAUS				
SÄHKÖ JA VALAISTUS				
JÄRJESTYS JA JÄTEHUOLTO				
	OIKEIN YHTEENSÄ		VÄÄRIN YHTEENSÄ	

TR-TASO $\frac{\text{OIKEIN (KPL)}}{\text{OIKEIN + VÄÄRIN (KPL)}} \times 100$ $\frac{\quad}{\quad}$ x 100 = ______ %

KORJATTAVAA	VASTUUHENKILÖ	KORJATTU PVM

____

TYÖNANTAJAN EDUSTAJA

____

TYÖNTEKIJÖIDEN EDUSTAJA

TR MITTARI

Rakennustyömaan turvallisuusindeksi

Mittauskohteet	**Havaintojen määrä**	**Hyväksymisperusteet**
TYÖSKENTELY • suojainten käyttö ja riskinotto	• jokaisesta työtä tekevästä työntekijästä	• käyttää tarvittavia suojaimia • ei ota ilmiselvää riskiä (esim. putoamisvaara, koneenkäyttö, sammutusvälineiden puute tulityössä)
TELINEET, KULKUSILLAT, TIKKAAT • rakennusaikaiset kulkusillat ja portaat • liikuteltavat telineet • kiinteät telineet • työpukit ja tikkaat	• jokaisesta erillisestä rakenteesta ja välineestä • kiinteissä telineissä kahden työtason välinen alue muodostaa yhden havaintokohteen	• kulkutie asianmukainen, kaiteet tai käsijohde sekä katos tarvittaessa • telineen perustus ja tuenta riittävät, rakenne rakennusohjeen mukainen (tarkastettu), telineessä nousutie, kunnolliset työtasot ja jalkalistat sekä kaiteet, jos korkeus yli 2 m • työpukit ja tikkaat tukevat ja ehjät
KONEET JA VÄLINEET • rakennussahat, kaasuhitsauslaitteet, lattiahiomakoneet, elementtifakit, betonisiilot, henkilönostimet, ajoneuvonosturit, nostoapuvälineet, betonipumppuautot	• jokaisesta laitteesta	• perustus ja tuenta • sijoituspaikka • rakenne, varustus ja kunto • säädrtyty tarkastukset tehty
PUTOAMISSUOJAUS • tasojen vapaat reunat • portaiden vapaat reunat • aukot • kaivannot	• jokaisesta reunasta tai välistä • jokaisesta jalan mentävästä aukosta • yksi kerroksen portaiden reunoista	• suojakaiteet, 2 johdetta • jalkalistat tarvittaessa • jalanmentävät aukot suojattu • aukkosuojat merkitty ja siirtyminen estetty • kaiteettomat alueet eristetty • kaivannon sortuminen estetty
SÄHKÖ JA VALAISTUS • rakennusaikaiset sähkö keskukset (>16 A) ja kaapelit • alueen yleisvalaistus • työpisteen keinovalaistus	• yksi alueen sähköistyksestä • yksi alueen valaistuksesta • valaistushavaintoa ei tehdä, jos päivänvalo on riittävä	• sähkäkeskukset ja kaapelit on sijoitettu ja suojattu tarkoituksenmukaisesti • valaistus on riittävä turvallisuuden ja työskentelyn kannalta
JÄRJESTYS JA JÄTEHUOLTO • alueen yleisjärjestys • työpisteiden järjestys • jäteastiat	• yksi alueen järjestyksestä • jokaisesta jäteastiasta	• järjestys on hyvä työskentelyn, liikkumisen ja tavaroiden siirron kannalta • päättyneiden työvaiheiden jätteet on karkeasiivottu • jätteet on oikein kuormattu ja lajiteltu, astian ympäristö on siisti

APPENDIX A1.7. (1)

4. RAKENNUSTYÖMAAN TULOSKORTTI

Työmaa: Pvm:

TUNNUSLUKU	LÄHTÖTIEDOT		LUKUARVO	Huomautukset
KUVAILEVAT LUVUT				
Vrt. normaalikestoon	R-kuutiot [brm3]	Teholl. r-aika [kk]	±kk	
Aliurakointiaste	Enn. ah-kust. [tmk]	Enn. kok. kust. [tmk]	%	
Sivu-urakointiaste	Sivu-ur. urs. [mmk]	Urakkas. [mmk]	%	
Hankkeen kalleus	Koko kohde [mmk]	Bruttoala [brm2]	mk/m2	
Lisätöiden osuus	Tot. kust. [tmk]	Muutost. lask. [tmk]	%	
Valmiusaste	Tot. kust. [tmk]	Enn.kok. kust. [tmk]	%	
KUSTANNUKSET				
Kokonaiskustannukset	Enn. kok.kust. [tmk]	Tavoitekust. [tmk]	%	
– oma työ	Enn. ot [tmk]	Tav. ot [h]	%	
– materiaali	Enn. mat.k. [tmk]	Tav. mat.k. [tmk)	%	
– alihankinnat	Enn. hank. [tmk]	Tav. hank. [tmk)	%	
– käyttö- ja yhteisk.	Enn. k- ja y. [tmk]	Tav. k- ja y. [tmk)	%	
Omat työtunnit	Enn. tunnit. [h]	Tav. tunnit [h]	%	
AIKATAULU				
Aikataulupoikkeama			Keskiarvo tv	
Poikkeama, runkotyöt			Keskiarvo tv	
Poikkeama, vesikatto			Keskiarvo tv	
Poikkeama, lämpö päälle			Keskiarvo tv	
Poikkeama, kev. välis.			Keskiarvo tv	
Poikkeama, LVIS -koek.			Keskiarvo tv	
Kiinniottokustannukset	Ylityötunnit [h]	Tot. tunnit [h]	%	
LAATU				
Laatuindeksi (tehtäväkorttien B- ja C- kohdat)			%	
Turvallisuusindeksi (TR-mittaus)			%	

Työmaan suorituskykymittari

Yritys Oy
As. Oy Esimerkkityömaa

Huom! Kuva on eri työmaasta kuin tiedot

Mittaaja: **Juha Salminen** Mittauspvm.: **XX.XX.1999**

Työmaan tiedot

Sijainti: **Kaupunki, kaupunginosa**

Tuoteominaisuudet: **Asuinkerrostalo, betonirunko täyselementtitekniikalla, julkisivumuuraus**

Toteutusmuoto: **Kilpailtu kokonaishintainen kokonaisurakka**

Urakka sisältää: **Rakennustekniset työt (ei LVIS ja hissi)**

Alkoi: **X/1999** Valmistuu: **X2000** Rakennusaika: **15 kk**

Rakennusmassoja: **5 kpl** Kerroksia: **4-8** Asuntoja: **142**

Rakennuskuutiot: **41880 brm^3** Kerrosala: **13990 brm^2** Valmiusaste: **54 %**

Toteutusorganisaatio: **Vastaava mestari, työmaainsinööri, 3 työnjohtajaa**

Omia työntekijöitä: **15** Au + su työntekijöitä: **20**

Aliurakoitsijoiden lkm: **25** Aliurakointiaste: **65 %**

Sivu-urakoitsijoiden lkm: **4** Sivu-urakointiaste: **19 %**

Psyko Business Learning Consulting Oy, Annankatu 42 C, 00100 Helsinki, Puh. (09) 613 141, Fax (09) 6131 4200
Juha Salminen, Puh. (09) 6131 4230, 050 512 4463, juha.salminen@psyko.fi **www.psyko.fi**

Työmaan tuloskortti

Yritys: As Oy Esimerkkityömaa

Vertailuaineisto: 30 työmaata, 480 vastaajaa (kyselyissä)

Huom! Osa-alueiden tulokset eivät ole samalta työmaalta!

Työmaan toimintaedellytykset

		vertailu
Edellytykset yhteensä	**69,6**	**74,2 %**
A) Rakennuttaja yhteensä	82,1	78,1 %
Rakentamisen valmistelu	83,3	70,8 %
Työnaikainen yhteistyö	82,3	80,5 %
Rakennuttajan hankinnat	79,9	78,6 %
B) Suunnittelijat yhteensä	58,5	68,6 %
Suunn. kooordinaattori	72,2	64,0 %
Arkkitehtisuunnitelmat	63,8	72,3 %
Rakennesuunnitelmat	50,0	71,6 %
LVIS -suunnitelmat	46,6	62,2 %
C) Oma yritys yhteensä	70,1	76,9 %
Linjajohto	77,7	76,7 %
Laskentatoimi	59,9	66,8 %
Hankintatoimi	66,6	83,7 %
Markkinointi	61,8	76,4 %

Ihmisten toiminta

Toimivuus ja johtaminen	**65,5**	**66,2 %**
Työtyytyväisyys	71,5	66,0 %
Osallistuminen ja vaikuttaminen	76,5	72,0 %
Yhteishenki	76,3	73,8 %
Tiedonkulku	62,8	65,0 %
Kannustaminen ja palaute	62,3	60,8 %
Suhde esimieheen	79,5	71,3 %
Kehittäminen ja innovatiivisuus	65,0	63,8 %
Vastuiden ja toim. ohj. selkeys	63,8	68,8 %
Suunn. ja ohjeiden noudattaminen	59,0	64,0 %
Suunnitelmall. ja tavoitteell.	72,0	71,5 %
Valvonta	65,5	62,3 %
Töiden sujuminen	62,0	64,0 %
Toiminnan tehokkuus	48,8	63,0 %
Työryhmien välinen yhteistyö	55,1	68,5 %
Pääurakoitsijan saamat arviot	62,8	68,9 %
Aliurak. saamat arviot	52,7	68,4 %

Ohjausjärjestelmät

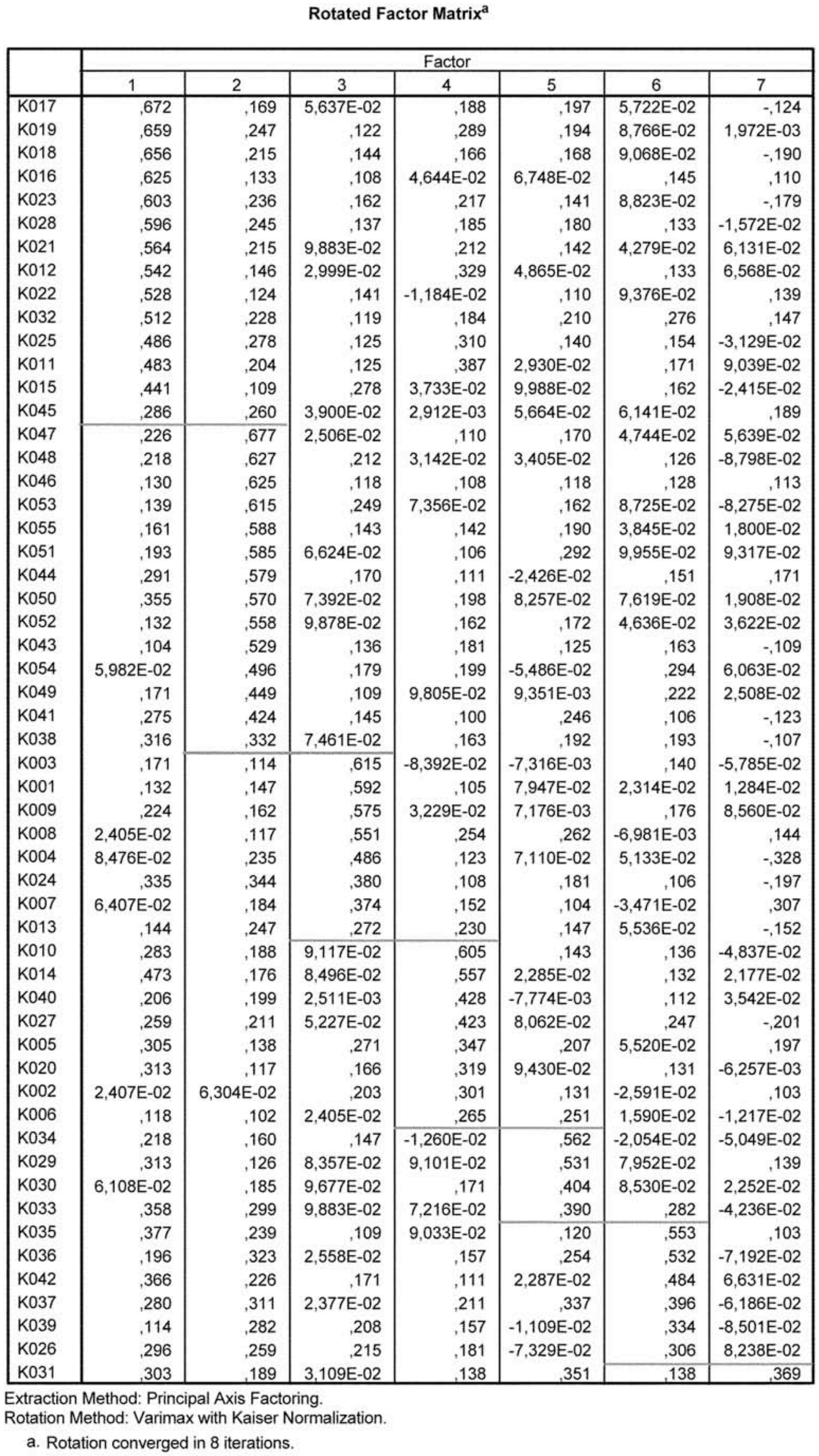
		vertailu
Ohjausjärjestelmät yhteensä	**64,9**	**65,3 %**
A Suunnittelun hallinta	91,7	79,0 %
B Kustannus- ja menekkiseuranta	85,7	78,0 %
C Tuotannonohjaus yhteensä	50,0	63,8 %
Työmaan laatusuunnitelma	50,0	57,9 %
Tehtäväsuunnitelmat	7,1	41,1 %
Aikataulu- ja resurssisuunnitelmat	58,3	77,6 %
Hankintojen suunnittelu ja ohjaus	72,7	72,3 %
D Organisaatio, yhteistyö ja tiedonk.	72,7	65,4 %
E Logistiikka, ympäristö ja turvall.	69,2	55,7 %

Tulokset

		- huono, + hyvä
Kokonaiskustannukset (1-9)	**4,0**	**0,58 ±%**
Oma työ	-2,0	-4,47 ±%
Materiaali	5,0	1,68 ±%
Alihankinnat	7,0	-0,65 ±%
Käyttö- ja yhteiskustannukset	2,0	-8,67 ±%
Omat työtunnit	-5,0	0,45 ±%
Aikataulupoikkeama	-20,0	**-6,5 ±Pv**
Runkotyöt	-20,0	-6,8 ±Pv
Vesikatto	-20,0	-6,9 ±Pv
Lämpö päälle	0,0	-6,2 ±Pv
Väliseinät	0,0	-3,9 ±Pv
LVIS-koekäyttö	0,0	-4,3 ±Pv
Laatuindeksi (B+C)	91,7	**90,07 %**
A Suunnittelu, ohjaus ja valvonta	81,3	65,8 %
B Edeltävät työv. + toiminta työk.	94,1	90,9 %
C Valmis tuote	85,7	88,7 %
Turvallisuusindeksi	73,5	**73,6 %**
Työskentely	72,7	79,3 %
Teineet, kulkus., tikkaat	100,0	66,5 %
Koneet ja välineet	0,0	65,9 %
Putoamissuojaus	55,8	66,0 %
Sähkö ja valaistus	91,7	87,3 %
Järjestys ja jätehuolto	87,5	78,8 %

APPENDIX 2.1. Work behavior and leadership factor analysis

Question numbers are on the left. Dividing lines between factors are drawn in the table.



Rotated Factor Matrix[a]

	Factor						
	1	2	3	4	5	6	7
K017	,672	,169	5,637E-02	,188	,197	5,722E-02	-,124
K019	,659	,247	,122	,289	,194	8,766E-02	1,972E-03
K018	,656	,215	,144	,166	,168	9,068E-02	-,190
K016	,625	,133	,108	4,644E-02	6,748E-02	,145	,110
K023	,603	,236	,162	,217	,141	8,823E-02	-,179
K028	,596	,245	,137	,185	,180	,133	-1,572E-02
K021	,564	,215	9,883E-02	,212	,142	4,279E-02	6,131E-02
K012	,542	,146	2,999E-02	,329	4,865E-02	,133	6,568E-02
K022	,528	,124	,141	-1,184E-02	,110	9,376E-02	,139
K032	,512	,228	,119	,184	,210	,276	,147
K025	,486	,278	,125	,310	,140	,154	-3,129E-02
K011	,483	,204	,125	,387	2,930E-02	,171	9,039E-02
K015	,441	,109	,278	3,733E-02	9,988E-02	,162	-2,415E-02
K045	,286	,260	3,900E-02	2,912E-03	5,664E-02	6,141E-02	,189
K047	,226	,677	2,506E-02	,110	,170	4,744E-02	5,639E-02
K048	,218	,627	,212	3,142E-02	3,405E-02	,126	-8,798E-02
K046	,130	,625	,118	,108	,118	,128	,113
K053	,139	,615	,249	7,356E-02	,162	8,725E-02	-8,275E-02
K055	,161	,588	,143	,142	,190	3,845E-02	1,800E-02
K051	,193	,585	6,624E-02	,106	,292	9,955E-02	9,317E-02
K044	,291	,579	,170	,111	-2,426E-02	,151	,171
K050	,355	,570	7,392E-02	,198	8,257E-02	7,619E-02	1,908E-02
K052	,132	,558	9,878E-02	,162	,172	4,636E-02	3,622E-02
K043	,104	,529	,136	,181	,125	,163	-,109
K054	5,982E-02	,496	,179	,199	-5,486E-02	,294	6,063E-02
K049	,171	,449	,109	9,805E-02	9,351E-03	,222	2,508E-02
K041	,275	,424	,145	,100	,246	,106	-,123
K038	,316	,332	7,461E-02	,163	,192	,193	-,107
K003	,171	,114	,615	-8,392E-02	-7,316E-03	,140	-5,785E-02
K001	,132	,147	,592	,105	7,947E-02	2,314E-02	1,284E-02
K009	,224	,162	,575	3,229E-02	7,176E-03	,176	8,560E-02
K008	2,405E-02	,117	,551	,254	,262	-6,981E-03	,144
K004	8,476E-02	,235	,486	,123	7,110E-02	5,133E-02	-,328
K024	,335	,344	,380	,108	,181	,106	-,197
K007	6,407E-02	,184	,374	,152	,104	-3,471E-02	,307
K013	,144	,247	,272	,230	,147	5,536E-02	-,152
K010	,283	,188	9,117E-02	,605	,143	,136	-4,837E-02
K014	,473	,176	8,496E-02	,557	2,285E-02	,132	2,177E-02
K040	,206	,199	2,511E-03	,428	-7,774E-03	,112	3,542E-02
K027	,259	,211	5,227E-02	,423	8,062E-02	,247	-,201
K005	,305	,138	,271	,347	,207	5,520E-02	,197
K020	,313	,117	,166	,319	9,430E-02	,131	-6,257E-03
K002	2,407E-02	6,304E-02	,203	,301	,131	-2,591E-02	,103
K006	,118	,102	2,405E-02	,265	,251	1,590E-02	-1,217E-02
K034	,218	,160	,147	-1,260E-02	,562	-2,054E-02	-5,049E-02
K029	,313	,126	8,357E-02	9,101E-02	,531	7,952E-02	,139
K030	6,108E-02	,185	9,677E-02	,171	,404	8,530E-02	2,252E-02
K033	,358	,299	9,883E-02	7,216E-02	,390	,282	-4,236E-02
K035	,377	,239	,109	9,033E-02	,120	,553	,103
K036	,196	,323	2,558E-02	,157	,254	,532	-7,192E-02
K042	,366	,226	,171	,111	2,287E-02	,484	6,631E-02
K037	,280	,311	2,377E-02	,211	,337	,396	-6,186E-02
K039	,114	,282	,208	,157	-1,109E-02	,334	-8,501E-02
K026	,296	,259	,215	,181	-7,329E-02	,306	8,238E-02
K031	,303	,189	3,109E-02	,138	,351	,138	,369

Extraction Method: Principal Axis Factoring.
Rotation Method: Varimax with Kaiser Normalization.

[a] Rotation converged in 8 iterations.

A2.2. Discriminant analysis

Company

Group Statistics

Company		Mean	Std. Deviation	Valid N (listwise)	
				Unweighted	Weighted
Company 1	Preconditions	81,2179	9,15386	8	8,000
	Management systems	72,3644	6,34392	8	8,000
	Work behavior and leadership	69,1332	6,92041	8	8,000
	Schedule deviation	-4,0000	7,61577	8	8,000
	Quality	88,3000	6,80021	8	8,000
	Safety	77,6750	10,86354	8	8,000
	Total cost (latest)	,8913	1,21656	8	8,000
Company 2	Preconditions	72,4004	11,87765	10	10,000
	Management systems	67,6352	12,60958	10	10,000
	Work behavior and leadership	68,3425	6,32663	10	10,000
	Schedule deviation	-10,7000	8,96970	10	10,000
	Quality	90,5500	4,56417	10	10,000
	Safety	70,6900	8,19288	10	10,000
	Total cost (latest)	-1,1770	6,38413	10	10,000
Company 3	Preconditions	70,9104	7,30295	7	7,000
	Management systems	55,5004	6,75244	7	7,000
	Work behavior and leadership	66,8990	6,40193	7	7,000
	Schedule deviation	-3,8571	7,47058	7	7,000
	Quality	91,3071	5,36882	7	7,000
	Safety	73,6429	10,08214	7	7,000
	Total cost (latest)	-,1829	4,54816	7	7,000
Company 4	Preconditions	71,5072	8,06697	13	13,000
	Management systems	69,9330	8,16042	13	13,000
	Work behavior and leadership	67,2267	5,52776	13	13,000
	Schedule deviation	-7,4615	9,55349	13	13,000
	Quality	87,6415	7,25267	13	13,000
	Safety	82,7846	11,29202	13	13,000
	Total cost (latest)	-,4392	6,36884	13	13,000
Total	Preconditions	73,6767	9,78577	38	38,000
	Management systems	67,1815	10,46994	38	38,000
	Work behavior and leadership	67,8613	6,00684	38	38,000
	Schedule deviation	-6,9211	8,76227	38	38,000
	Quality	89,2208	6,15715	38	38,000
	Safety	76,8421	11,00981	38	38,000
	Total cost (latest)	-,3061	5,21802	38	38,000

Wilks' Lambda

Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig.
1 through 3	,350	33,106	21	,045
2 through 3	,598	16,176	12	,183
3	,815	6,455	5	,264

Structure Matrix

	Function		
	1	2	3
Management systems	,765(*)	,298	,178
Quality	-,274(*)	,169	-,109
Safety	,392	-,625(*)	,156
Work behavior and leadership	,058	,193(*)	,144
Preconditions	,172	,305	,794(*)
Schedule deviation	-,109	-,249	,589(*)
Total cost (latest)	,021	-,043	,286(*)

Pooled within-groups correlations between discriminating variables and standardized canonical discriminant functions
Variables ordered by absolute size of correlation within function.
* Largest absolute correlation between each variable and any discriminant function

Classification Results(a)

		Company	Predicted Group Membership				Total
			Company 1	Company 2	Company 3	Company 4	
Original	Count	Company 1	7	0	0	3	10
		Company 2	1	7	1	1	10
		Company 3	0	2	8	0	10
		Company 4	2	4	2	9	17
	%	Company 1	70,0	,0	,0	30,0	100,0
		Company 2	10,0	70,0	10,0	10,0	100,0
		Company 3	,0	20,0	80,0	,0	100,0
		Company 4	11,8	23,5	11,8	52,9	100,0

a 66,0% of original grouped cases correctly classified.

Project type

Group Statistics

Project type		Mean	Std. Deviation	Valid N (listwise)	
				Unweighted	Weighted
Property development	Preconditions	75,6761	10,85118	11	11,000
	Management systems	72,0566	8,04299	11	11,000
	Work behavior and leadership	70,5288	5,05301	11	11,000
	Schedule deviation	-6,7273	8,24731	11	11,000
	Quality	89,6736	7,09476	11	11,000
	Safety	72,1818	12,68084	11	11,000
	Total cost (latest)	-1,0545	5,87915	11	11,000
Competition	Preconditions	69,7686	9,14218	18	18,000
	Management systems	63,3400	12,14004	18	18,000
	Work behavior and leadership	66,8696	6,91012	18	18,000
	Schedule deviation	-7,0556	9,37125	18	18,000
	Quality	90,3828	5,39195	18	18,000
	Safety	75,8167	9,49930	18	18,000
	Total cost (latest)	-1,2750	5,27359	18	18,000
Negotiated contract	Preconditions	79,0492	6,76539	9	9,000
	Management systems	68,9061	6,61186	9	9,000
	Work behavior and leadership	66,5844	4,43445	9	9,000
	Schedule deviation	-6,8889	9,13023	9	9,000
	Quality	86,3433	6,16453	9	9,000
	Safety	84,5889	8,25370	9	9,000
	Total cost (latest)	2,5467	3,40393	9	9,000
Total	Preconditions	73,6767	9,78577	38	38,000
	Management systems	67,1815	10,46994	38	38,000
	Work behavior and leadership	67,8613	6,00684	38	38,000
	Schedule deviation	-6,9211	8,76227	38	38,000
	Quality	89,2208	6,15715	38	38,000
	Safety	76,8421	11,00981	38	38,000
	Total cost (latest)	-,3061	5,21802	38	38,000

Wilks' Lambda

Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig.
1 through 2	,453	25,315	14	,032
2	,715	10,756	6	,096

Structure Matrix

	Function	
	1	2
Safety	,583(*)	-,226
Total cost (latest)	,427(*)	,046
Quality	-,359(*)	-,094
Management systems	,116	,613(*)
Preconditions	,435	,465(*)
Work behavior and leadership	-,176	,426(*)
Schedule deviation	,002	,026(*)

Pooled within-groups correlations between discriminating variables and standardized canonical discriminant functions
Variables ordered by absolute size of correlation within function.
* Largest absolute correlation between each variable and any discriminant function

Classification Results(a)

		Project type	Predicted Group Membership			Total
			Property development	Competition	Negotiated contract	
Original	Count	Property development	7	2	2	11
		Competition	4	16	3	23
		Negotiated contract	0	1	11	12
	%	Property development	63,6	18,2	18,2	100,0
		Competition	17,4	69,6	13,0	100,0
		Negotiated contract	,0	8,3	91,7	100,0

a 72,3% of original grouped cases correctly classified.

Building type

Group Statistics

Building type		Mean	Std. Deviation	Valid N (listwise)	
				Unweighted	Weighted
One-family or row house	Preconditions	72,0673	13,47676	7	7,000
	Management systems	69,0376	9,85267	7	7,000
	Work behavior and leadership	68,6564	5,32801	7	7,000
	Schedule deviation	-10,2857	11,49948	7	7,000
	Quality	90,3871	4,54072	7	7,000
	Safety	64,7143	7,37189	7	7,000
	Total cost (latest)	-2,2471	5,90228	7	7,000

Apartment building	Preconditions	78,0435	8,05164	20	20,000
	Management systems	69,2284	8,70204	20	20,000
	Work behavior and leadership	68,4708	6,24160	20	20,000
	Schedule deviation	-6,9500	8,26199	20	20,000
	Quality	87,5845	6,78297	20	20,000
	Safety	82,0500	9,78654	20	20,000
	Total cost (latest)	,9100	4,48157	20	20,000
Public, store, office	Preconditions	65,8757	5,82975	6	6,000
	Management systems	63,8669	14,49329	6	6,000
	Work behavior and leadership	67,4136	6,26143	6	6,000
	Schedule deviation	-,3333	6,53197	6	6,000
	Quality	91,9767	5,21708	6	6,000
	Safety	75,8000	9,56786	6	6,000
	Total cost (latest)	,7283	4,58866	6	6,000
Industry, warehouse	Preconditions	63,9360	,(a)	1	1,000
	Management systems	67,3611	,(a)	1	1,000
	Work behavior and leadership	64,0556	,(a)	1	1,000
	Schedule deviation	-15,0000	,(a)	1	1,000
	Quality	89,2900	,(a)	1	1,000
	Safety	62,7000	,(a)	1	1,000
	Total cost (latest)	-4,1300	,(a)	1	1,000
Rebuilding	Preconditions	68,7955	5,68389	4	4,000
	Management systems	58,6262	13,13746	4	4,000
	Work behavior and leadership	65,0456	7,51076	4	4,000
	Schedule deviation	-8,7500	6,29153	4	4,000
	Quality	91,2100	6,93425	4	4,000
	Safety	77,1250	5,84772	4	4,000
	Total cost (latest)	-3,5850	7,99002	4	4,000
Total	Preconditions	73,6767	9,78577	38	38,000
	Management systems	67,1815	10,46994	38	38,000
	Work behavior and leadership	67,8613	6,00684	38	38,000
	Schedule deviation	-6,9211	8,76227	38	38,000
	Quality	89,2208	6,15715	38	38,000
	Safety	76,8421	11,00981	38	38,000
	Total cost (latest)	-,3061	5,21802	38	38,000

a Insufficient data

Wilks' Lambda

Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig.
1 through 4	,223	46,476	28	,016
2 through 4	,485	22,438	18	,213
3 through 4	,777	7,802	10	,648
4	,982	,577	4	,966

Structure Matrix

	Function			
	1	2	3	4
Safety	,647(*)	-,521	,109	-,132
Preconditions	,512(*)	,306	,051	,500
Total cost (latest)	,220	-,111	,519(*)	,084
Management systems	,153	,338	,353(*)	-,225
Work behavior and leadership	,085	,140	,263	,654(*)
Schedule deviation	-,002	-,404	,503	,639(*)
Quality	-,260	-,146	-,032	,519(*)

Pooled within-groups correlations between discriminating variables and standardized canonical discriminant functions
Variables ordered by absolute size of correlation within function.
* Largest absolute correlation between each variable and any discriminant function

Classification Results(a)

		Building type	Predicted Group Membership					Total
			Row house	Apartment building	Public, store, office	Industry, warehouse	Renovation	
Origina	Count	Row house	4	0	1	2	0	7
		Apartment building	3	15	0	1	2	21
		Public, store, office	0	4	6	0	1	11
		Industry, warehouse	0	0	0	1	0	1
		Rebuilding	1	0	2	0	4	7
	%	Row house	57,1	,0	14,3	28,6	,0	100,0
		Apartment building	14,3	71,4	,0	4,8	9,5	100,0
		Public, store, office	,0	36,4	54,5	,0	9,1	100,0
		Industry, warehouse	,0	,0	,0	100,0	,0	100,0
		Renovation	14,3	,0	28,6	,0	57,1	100,0

a 63,8% of original grouped cases correctly classified.

Proportion of external workers (%)

Group Statistics

Proportion of external workers (%)		Mean	Std. Deviation	Valid N (listwise)	
				Unweighted	Weighted
0-20 %	Preconditions	69,2640	,(a)	1	1,000
	Management systems	64,5833	,(a)	1	1,000
	Work behavior and leadership	71,4643	,(a)	1	1,000
	Schedule deviation	-15,0000	,(a)	1	1,000
	Quality	76,5000	,(a)	1	1,000
	Safety	90,9000	,(a)	1	1,000
	Total cost (latest)	2,1800	,(a)	1	1,000

21-40 %	Preconditions	73,9274	10,09948	6	6,000
	Management systems	69,5425	7,60131	6	6,000
	Work behavior and leadership	67,6438	5,33748	6	6,000
	Schedule deviation	-7,0000	8,24621	6	6,000
	Quality	90,6967	6,47832	6	6,000
	Safety	71,7167	9,85848	6	6,000
	Total cost (latest)	-1,5000	3,44757	6	6,000
41-60 %	Preconditions	77,1285	12,15597	15	15,000
	Management systems	71,4694	9,03617	15	15,000
	Work behavior and leadership	66,9463	6,14304	15	15,000
	Schedule deviation	-8,2667	11,06130	15	15,000
	Quality	88,6827	5,82908	15	15,000
	Safety	75,7667	10,52661	15	15,000
	Total cost (latest)	,7727	6,36994	15	15,000
61-80 %	Preconditions	70,9504	6,20132	12	12,000
	Management systems	65,2125	11,04582	12	12,000
	Work behavior and leadership	67,0861	6,52600	12	12,000
	Schedule deviation	-6,2500	6,07716	12	12,000
	Quality	87,9833	5,35700	12	12,000
	Safety	80,6083	11,37777	12	12,000
	Total cost (latest)	-1,4633	4,78362	12	12,000
81-100 %	Preconditions	70,4209	12,13118	2	2,000
	Management systems	56,0281	10,66782	2	2,000
	Work behavior and leadership	71,7157	6,43329	2	2,000
	Schedule deviation	-5,0000	7,07107	2	2,000
	Quality	96,6650	4,71640	2	2,000
	Safety	83,7000	6,08112	2	2,000
	Total cost (latest)	3,1000	5,57200	2	2,000
Total	Preconditions	73,9445	9,93595	36	36,000
	Management systems	68,0135	9,96327	36	36,000
	Work behavior and leadership	67,4996	5,94897	36	36,000
	Schedule deviation	-7,3889	8,62977	36	36,000
	Quality	88,8903	6,15968	36	36,000
	Safety	77,5667	10,84464	36	36,000
	Total cost (latest)	-,1831	5,29467	36	36,000

a Insufficient data

Wilks' Lambda

Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig.
1 through 4	,336	31,670	28	,288
2 through 4	,554	17,139	18	,514
3 through 4	,816	5,914	10	,822
4	,963	1,079	4	,898

Structure Matrix

	Function			
	1	2	3	4
Management systems	,545(*)	-,065	-,210	-,038
Preconditions	,366(*)	,078	,149	,286
Quality	-,087	,776(*)	,210	,069
Total cost (latest)	,057	-,007	,626(*)	,347
Safety	-,389	-,324	,268	,641(*)
Work behavior and leadership	-,156	-,001	,388	-,398(*)
Schedule deviation	-,117	,214	-,187	,216(*)

Pooled within-groups correlations between discriminating variables and standardized canonical discriminant functions
Variables ordered by absolute size of correlation within function.
* Largest absolute correlation between each variable and any discriminant function

Classification Results(a)

		Proportion of external workers	Predicted Group Membership					Total
			0-20 %	21-40 %	41-60 %	61-80 %	81-100 %	
Original	Count	0-20 %	1	0	0	0	0	1
		21-40 %	0	3	2	1	0	6
		41-60 %	0	4	10	3	0	17
		61-80 %	1	2	2	7	2	14
		81-100 %	1	0	1	2	2	6
		Ungrouped cases	0	0	0	0	3	3
	%	0-20 %	100,0	,0	,0	,0	,0	100,0
		21-40 %	,0	50,0	33,3	16,7	,0	100,0
		41-60 %	,0	23,5	58,8	17,6	,0	100,0
		61-80 %	7,1	14,3	14,3	50,0	14,3	100,0
		81-100 %	16,7	,0	16,7	33,3	33,3	100,0
		Ungrouped cases	,0	,0	,0	,0	100,0	100,0

a 52,3% of original grouped cases correctly classified.

Building volume

Group Statistics

Building volume m3		Mean	Std. Deviation	Valid N (listwise)	
				Unweighted	Weighted
below 10 000	Preconditions	73,9060	9,78972	9	9,000
	Management systems	71,1202	7,51108	9	9,000
	Work behavior and leadership	70,8613	6,66251	9	9,000
	Schedule deviation	-5,2222	8,01214	9	9,000
	Quality	87,3222	6,49382	9	9,000
	Safety	73,6222	14,89125	9	9,000
	Total cost (latest)	-3,1444	4,92285	9	9,000

10-20 000	Preconditions	74,5569	10,27264	14	14,000
	Management systems	65,2931	11,25775	14	14,000
	Work behavior and leadership	69,5677	4,39111	14	14,000
	Schedule deviation	-7,5714	10,73968	14	14,000
	Quality	91,2186	5,32476	14	14,000
	Safety	79,1214	12,55892	14	14,000
	Total cost (latest)	2,1764	4,09949	14	14,000
20-30 000	Preconditions	83,4879	10,58554	4	4,000
	Management systems	73,2408	7,48696	4	4,000
	Work behavior and leadership	62,1612	5,08576	4	4,000
	Schedule deviation	-11,2500	10,30776	4	4,000
	Quality	82,9000	6,13297	4	4,000
	Safety	74,9500	3,55199	4	4,000
	Total cost (latest)	-1,5800	5,66647	4	4,000
30-40000	Preconditions	68,5218	8,48671	4	4,000
	Management systems	68,3313	13,99885	4	4,000
	Work behavior and leadership	65,0151	6,10274	4	4,000
	Schedule deviation	-3,7500	7,50000	4	4,000
	Quality	91,6475	5,84538	4	4,000
	Safety	79,2000	9,13966	4	4,000
	Total cost (latest)	1,1700	5,21148	4	4,000
over 40 000	Preconditions	69,1809	6,95927	3	3,000
	Management systems	65,9732	4,70758	3	3,000
	Work behavior and leadership	66,0480	4,74311	3	3,000
	Schedule deviation	-5,0000	5,00000	3	3,000
	Quality	88,1333	4,80035	3	3,000
	Safety	74,8667	5,23864	3	3,000
	Total cost (latest)	,7267	1,66572	3	3,000
Total	Preconditions	74,2509	10,06003	34	34,000
	Management systems	68,1880	9,86412	34	34,000
	Work behavior and leadership	68,1926	5,85263	34	34,000
	Schedule deviation	-6,7059	9,05716	34	34,000
	Quality	88,9868	6,13175	34	34,000
	Safety	76,8088	11,52342	34	34,000
	Total cost (latest)	,0797	4,82367	34	34,000

Wilks' Lambda

Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig.
1 through 4	,254	36,952	28	,120
2 through 4	,508	18,265	18	,438
3 through 4	,753	7,658	10	,662
4	,970	,815	4	,936

Structure Matrix

	Function			
	1	2	3	4
Total cost (latest)	,385	,478(*)	-,290	-,465
Schedule deviation	,073	-,278(*)	-,248	,195
Work behavior and leadership	,370	-,495	,556(*)	,222
Preconditions	-,235	,338	,552(*)	,096
Management systems	-,296	-,117	,106	,579(*)
Quality	,500	,029	-,291	,504(*)
Safety	,163	,200	-,107	,272(*)

Pooled within-groups correlations between discriminating variables and standardized canonical discriminant functions
Variables ordered by absolute size of correlation within function.
* Largest absolute correlation between each variable and any discriminant function

Classification Results(a)

		Gross cubic meters brm3	Predicted Group Membership					Total
			below 10 000	10-20 000	20-30 000	30-40000	over 40 000	
Original	Count	below 10 000	4	1	0	2	2	9
		10-20 000	2	10	1	1	2	16
		20-30 000	0	0	5	0	0	5
		30-40000	1	0	0	3	0	4
		over 40 000	1	1	0	2	1	5
		Ungrouped cases	1	2	1	4	0	8
	%	below 10 000	44,4	11,1	,0	22,2	22,2	100,0
		10-20 000	12,5	62,5	6,3	6,3	12,5	100,0
		20-30 000	,0	,0	100,0	,0	,0	100,0
		30-40000	25,0	,0	,0	75,0	,0	100,0
		over 40 000	20,0	20,0	,0	40,0	20,0	100,0
		Ungrouped cases	12,5	25,0	12,5	50,0	,0	100,0

a 59,0% of original grouped cases correctly classified.

Degree of completion

Group Statistics

Degree of completion		Mean	Std. Deviation	Valid N (listwise)	
				Unweighted	Weighted
0-20 %	Preconditions	76,4216	6,81108	3	3,000
	Management systems	69,7865	6,35245	3	3,000
	Work behavior and leadership	68,3631	2,68862	3	3,000
	Schedule deviation	-7,3333	9,29157	3	3,000

	Quality	84,0667	6,56227	3	3,000
	Safety	74,3667	17,18323	3	3,000
	Total cost (latest)	2,0433	,76422	3	3,000
21-40 %	Preconditions	75,5326	12,51716	11	11,000
	Management systems	64,7626	13,52383	11	11,000
	Work behavior and leadership	69,5358	5,42287	11	11,000
	Schedule deviation	-4,9091	9,18101	11	11,000
	Quality	90,7764	6,63738	11	11,000
	Safety	79,5273	10,02568	11	11,000
	Total cost (latest)	,3718	5,54786	11	11,000
41-60 %	Preconditions	72,8041	5,83596	10	10,000
	Management systems	69,1520	9,96300	10	10,000
	Work behavior and leadership	67,1006	6,82538	10	10,000
	Schedule deviation	-6,0000	9,36898	10	10,000
	Quality	88,7300	7,05843	10	10,000
	Safety	82,7500	10,62296	10	10,000
	Total cost (latest)	-,0770	4,79157	10	10,000
61-80 %	Preconditions	82,8926	11,91471	2	2,000
	Management systems	69,5896	7,65153	2	2,000
	Work behavior and leadership	68,1583	4,37228	2	2,000
	Schedule deviation	-10,0000	,00000	2	2,000
	Quality	93,3500	4,03051	2	2,000
	Safety	57,1500	2,89914	2	2,000
	Total cost (latest)	-,5500	1,20208	2	2,000
81-100 %	Preconditions	71,4843	12,75367	6	6,000
	Management systems	72,9875	9,76078	6	6,000
	Work behavior and leadership	68,7451	8,36037	6	6,000
	Schedule deviation	-11,1667	11,14301	6	6,000
	Quality	87,6300	4,54020	6	6,000
	Safety	75,2833	4,55430	6	6,000
	Total cost (latest)	-3,4583	7,68500	6	6,000
Total	Preconditions	74,4642	10,10957	32	32,000
	Management systems	68,4491	10,81201	32	32,000
	Work behavior and leadership	68,4305	6,03293	32	32,000
	Schedule deviation	-6,9688	9,17037	32	32,000
	Quality	89,0787	6,35442	32	32,000
	Safety	77,8563	11,25562	32	32,000
	Total cost (latest)	-,3875	5,37015	32	32,000

Wilks' Lambda

Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig.
1 through 4	,283	31,551	28	,293
2 through 4	,531	15,846	18	,603
3 through 4	,743	7,435	10	,684
4	,957	1,109	4	,893

Structure Matrix

	Function			
	1	2	3	4
Safety	-,707(*)	,061	-,032	-,263
Quality	,095	,525(*)	,288	,203
Schedule deviation	-,159	,306(*)	-,226	-,092
Preconditions	,232	,242(*)	-,218	,080
Total cost (latest)	-,046	,231	-,518(*)	,024
Work behavior and leadership	,052	,087	,042	-,715(*)
Management systems	,061	-,407	,153	,457(*)

Pooled within-groups correlations between discriminating variables and standardized canonical discriminant functions
Variables ordered by absolute size of correlation within function.
* Largest absolute correlation between each variable and any discriminant function

Classification Results(a)

		Degree of completion	Predicted Group Membership					Total
			0-20 %	21-40 %	41-60 %	61-80 %	81-100 %	
Original	Count	0-20 %	2	1	0	0	0	3
		21-40 %	1	6	4	0	1	12
		41-60 %	2	4	5	0	2	13
		61-80 %	0	0	0	2	0	2
		81-100 %	0	0	1	0	5	6
		Ungrouped cases	3	4	2	0	2	11
	%	0-20 %	66,7	33,3	,0	,0	,0	100,0
		21-40 %	8,3	50,0	33,3	,0	8,3	100,0
		41-60 %	15,4	30,8	38,5	,0	15,4	100,0
		61-80 %	,0	,0	,0	100,0	,0	100,0
		81-100 %	,0	,0	16,7	,0	83,3	100,0
		Ungrouped cases	27,3	36,4	18,2	,0	18,2	100,0

a 55,6% of original grouped cases correctly classified.

A2.3. Level 3 variable correlations with result components

Correlations Spearman's rho			**Kustannukset C4**	Aikataulupoikkeama (mittaushtekellä)	Laatuindeksi	Turvallisuusindeksi
Edellytykset	Tarjouspyyntösuunnitelmien suunnitelmakatselmus on pidetty	Correlation Coefficient	0,111	0,192	-0,245	0,203
		Sig. (2-tailed)	0,707	0,241	0,156	0,209
		N	14	39	35	40
	Detaljien suunnitelmakatselmus on pidetty (työmaan alussa)	Correlation Coefficient	0,415	0,284	-0,238	0,234
		Sig. (2-tailed)	0,140	0,080	0,169	0,147
		N	14	39	35	40
	Rakennuttaja on tarkastanut suunnitelmien toteuttamiskelpoisuuden	Correlation Coefficient	0,268	-0,022	-0,309	0,199
		Sig. (2-tailed)	0,354	0,895	0,067	0,211
		N	14	40	36	41
	Aikataulu ja välitavoitteet ovat realistisia ja toteutettavissa olevia	Correlation Coefficient	0,196	0,116	-0,249	0,151
		Sig. (2-tailed)	0,483	0,455	0,121	0,323
		N	15	44	40	45
	Rakennuttaja on antanut urakoitsijan tarvitsemat tiedot	Correlation Coefficient	-0,008	-0,096	-0,246	0,053
		Sig. (2-tailed)	0,977	0,534	0,126	0,731
		N	15	44	40	45
	Rakennuttaja on laatinut kohteesta turvallisuusasiakirjan	Correlation Coefficient	-0,533	-0,102	0,227	0,037
		Sig. (2-tailed)	0,041	0,532	0,183	0,820
		N	15	40	36	41
	Päätöksentekovastuista on selkeästi sovittu osapuolten kesken (til/rak/suunn/työm)	Correlation Coefficient	0,014	-0,099	-0,272	0,399
		Sig. (2-tailed)	0,960	0,519	0,086	0,006
		N	16	45	41	46
	On sovittu ja kaikkien tiedossa, milloin päätökset ovat virallisia	Correlation Coefficient	0,122	0,092	-0,154	0,205
		Sig. (2-tailed)	0,652	0,549	0,337	0,171
		N	16	45	41	46
	Päätökset ja hyväksymiset on saatu tarvittaessa nopeasti (ei katkoksia työssä)	Correlation Coefficient	0,530	0,253	-0,245	0,229
		Sig. (2-tailed)	0,042	0,093	0,127	0,131
		N	15	45	40	45
	Päätökset ja ohjeet ovat olleet yksiselitteisiä	Correlation Coefficient	0,506	0,185	-0,103	0,325
		Sig. (2-tailed)	0,046	0,223	0,522	0,028
		N	16	45	41	46
	Päätöksistä on pidetty kiinni ja sovitun mukaan toimittu	Correlation Coefficient	0,203	0,087	-0,239	0,175
		Sig. (2-tailed)	0,450	0,571	0,133	0,246
		N	16	45	41	46
	Suunnitelmat on hyväksytty ajallaan	Correlation Coefficient	0,387	0,257	-0,099	0,026
		Sig. (2-tailed)	0,139	0,093	0,545	0,864
		N	16	44	40	45
	Laskut on hyväksytty ajallaan	Correlation Coefficient	0,501	0,103	-0,060	0,318
		Sig. (2-tailed)	0,057	0,507	0,715	0,034
		N	15	44	40	45
	Työmaakokouksia on ollut sopiva määrä (ei liikaa/liian vähän)	Correlation Coefficient	0,140	0,130	-0,137	0,242
		Sig. (2-tailed)	0,605	0,399	0,401	0,110
		N	16	44	40	45
	Työmaakokoukset ovat edenneet tehokkaasti ja esityslistan mukaisesti	Correlation Coefficient	0,000	0,132	-0,048	-0,123
		Sig. (2-tailed)	1,000	0,395	0,769	0,422
		N	16	44	40	45
	Työmaakokoukset ovat olleet tarkoituksenmukaisia ja hyödyllisiä	Correlation Coefficient	0,068	0,039	0,077	-0,258
		Sig. (2-tailed)	0,801	0,804	0,636	0,087
		N	16	44	40	45
	Urakoitsijapalavereita on ollut sopiva määrä (ei liikaa/liian vähän)	Correlation Coefficient	0,244	-0,043	-0,239	0,188
		Sig. (2-tailed)	0,380	0,787	0,143	0,222
		N	15	43	39	44
	Urakoitsijapalaverit ovat edenneet tehokkaasti ja esityslistan mukaisesti	Correlation Coefficient	0,124	0,093	-0,078	0,001
		Sig. (2-tailed)	0,687	0,564	0,646	0,996
		N	13	41	37	42
	Urakoitsijapalaverit ovat olleet tarkoituksenmukaisia ja hyödyllisiä	Correlation Coefficient	-0,165	-0,013	-0,098	0,001
		Sig. (2-tailed)	0,590	0,934	0,565	0,993
		N	13	41	37	42
	Rakennuttaja on ottanut huomioon urakoitsijan ehdotukset	Correlation Coefficient	0,401	0,235	0,034	-0,147
		Sig. (2-tailed)	0,138	0,155	0,850	0,371
		N	15	38	34	39
	Rakennuttajan edustaja on ollut tavoitettavissa ja saatavissa työmaalle tarvittaessa	Correlation Coefficient	-0,014	0,068	0,041	-0,003
		Sig. (2-tailed)	0,960	0,663	0,802	0,984
		N	16	44	40	45
	Katselmuksissa on voitu tehdä päätökset heti (päättävä taho mukana)	Correlation Coefficient	0,346	0,140	-0,145	0,282
		Sig. (2-tailed)	0,189	0,365	0,373	0,060
		N	16	44	40	45
	Katselmusten tulos on ilmaistu ja dokumentoitu selkeästi	Correlation Coefficient	0,235	0,167	-0,358	0,237
		Sig. (2-tailed)	0,399	0,285	0,025	0,122
		N	15	43	39	44
	Rakennuttajan kanssa on tarkastettu yhteistoimintakokouksissa: — urakkarajat	Correlation Coefficient	0,093	0,045	-0,369	0,197
		Sig. (2-tailed)	0,764	0,808	0,053	0,272
		N	13	32	28	33
	Rakennuttajan kanssa on tarkastettu yhtistoimintakokouksissa: — aikataulu	Correlation Coefficient	0,259	0,009	-0,203	0,177
		Sig. (2-tailed)	0,392	0,960	0,291	0,316
		N	13	33	29	34

APPENDIX 2.3 (2)

Correlations Spearman's rho			Kustannukset C4	Aikataulupoikkeama (mittaushtekellä)	Laatuindeksi	Turvallisuusindeksi
	Rakennuttajan kanssa on tarkastettu yhteistoimintakokouksissa: — tekninen yhteensopivuus	Correlation Coefficient	0,315	0,089	-0,127	0,059
		Sig. (2-tailed)	0,318	0,635	0,520	0,749
		N	12	31	28	32
	Sivu-urakoissa on mukana omien töiden johtovelvoite	Correlation Coefficient	0,284	0,004	0,142	0,429
		Sig. (2-tailed)	0,426	0,986	0,509	0,020
		N	10	28	24	29
	Sivu-urakoiden työnjohto on ollut tarvittaessa tavoitettavissa	Correlation Coefficient	0,059	0,023	-0,192	0,334
		Sig. (2-tailed)	0,871	0,907	0,369	0,077
		N	10	28	24	29
	Suunnitelmat on jäsennetty selkeän hierarkian ja sisällysluettelon mukaan	Correlation Coefficient	0,465	0,384	-0,115	0,088
		Sig. (2-tailed)	0,070	0,010	0,481	0,565
		N	16	44	40	45
	Tieto on kulkenut hyvin eri suunnittelijoiden välillä (suunn. kierto, risteilypalaverit)	Correlation Coefficient	0,143	0,172	-0,043	0,045
		Sig. (2-tailed)	0,597	0,265	0,791	0,769
		N	16	44	40	45
	Suunnitelmat on tehty samoille, ajan tasalla oleville pohjille	Correlation Coefficient	0,287	0,149	-0,103	0,107
		Sig. (2-tailed)	0,281	0,335	0,528	0,484
		N	16	44	40	45
	Suunnitelmat ovat keskenään yhteensopivia ja vertailtu toisiinsa jo etukäteen	Correlation Coefficient	0,269	0,001	-0,253	0,167
		Sig. (2-tailed)	0,314	0,995	0,115	0,274
		N	16	44	40	45
	Suunnitelmat on saatu työmaalle suunn. aikataulun mukaisesti (ei katkoksia töissä)	Correlation Coefficient	0,448	0,311	-0,072	0,133
		Sig. (2-tailed)	0,082	0,047	0,671	0,403
		N	16	41	37	42
	Muutokset on merkitty kansilehden lisäksi myös kuvaan	Correlation Coefficient	0,417	0,271	-0,004	0,102
		Sig. (2-tailed)	0,108	0,075	0,983	0,503
		N	16	44	40	45
	Suunnitelmien toteutettavuus on otettu huomioon (tekotapa, materiaalien saatavuus)	Correlation Coefficient	-0,157	0,077	-0,026	0,007
		Sig. (2-tailed)	0,562	0,615	0,870	0,961
		N	16	45	41	46
	Suunnitelmissa on esitetty tarvittavat detaljit ja leikkaukset	Correlation Coefficient	0,190	0,073	-0,108	0,081
		Sig. (2-tailed)	0,481	0,632	0,501	0,591
		N	16	45	41	46
	Suunnitelmissa on esitetty tarvittavat mitat	Correlation Coefficient	-0,190	-0,191	-0,240	-0,013
		Sig. (2-tailed)	0,480	0,209	0,130	0,932
		N	16	45	41	46
	Suunnitelmista löytyvät kaikki värit tai niistä on saatu päätökset ajallaan	Correlation Coefficient	0,370	0,238	-0,078	0,154
		Sig. (2-tailed)	0,159	0,121	0,633	0,313
		N	16	44	40	45
	Suunnitelmista löytyvät kaikki pintamateriaalit	Correlation Coefficient	0,292	0,170	-0,138	0,217
		Sig. (2-tailed)	0,272	0,270	0,397	0,153
		N	16	44	40	45
	Lattioiden korkoja ei ole jouduttu muuttamaan	Correlation Coefficient	0,303	0,221	-0,001	0,500
		Sig. (2-tailed)	0,273	0,149	0,995	0,000
		N	15	44	41	45
	Väliseinien paikkoja ei ole jouduttu muuttamaan	Correlation Coefficient	0,435	0,180	-0,060	0,252
		Sig. (2-tailed)	0,105	0,242	0,708	0,096
		N	15	44	41	45
	Suunnittelijaa ei ole tarvittu pyytää työmaalle suunnitelmaepäselvyyksien takia	Correlation Coefficient	0,238	0,218	-0,122	0,126
		Sig. (2-tailed)	0,375	0,156	0,455	0,409
		N	16	44	40	45
	Suunnittelija on tarvittaessa tullut työmaalle	Correlation Coefficient	0,278	0,147	-0,197	0,264
		Sig. (2-tailed)	0,297	0,336	0,218	0,076
		N	16	45	41	46
	Arkkitehti on ottanut huomioon työmaan ehdotukset	Correlation Coefficient	0,616	0,327	-0,100	0,224
		Sig. (2-tailed)	0,011	0,042	0,566	0,164
		N	16	39	35	40
	Työmaalla sovitut muutokset on viety nopeasti suunnitelmiin	Correlation Coefficient	0,212	0,039	-0,049	0,048
		Sig. (2-tailed)	0,430	0,800	0,762	0,751
		N	16	45	41	46
	Töiden etenemisessä ei ole ollut katkoja suunnitelmapuutteiden tai -virheiden takia	Correlation Coefficient	0,476	0,165	-0,205	0,134
		Sig. (2-tailed)	0,062	0,283	0,204	0,379
		N	16	44	40	45
	Toteutustapa on tarvittaessa suunniteltu	Correlation Coefficient	0,123	-0,046	-0,311	0,049
		Sig. (2-tailed)	0,650	0,764	0,047	0,748
		N	16	45	41	46
	Turvallisuus on otettu huomioon suunnitelmissa (esim. elem. koko, kaiteet, sähkövedot)	Correlation Coefficient	0,340	0,073	-0,141	-0,106
		Sig. (2-tailed)	0,215	0,642	0,384	0,495
		N	15	43	40	44
	Suunnitelmissa on esitetty tarvittavat detaljit ja leikkaukset	Correlation Coefficient	0,069	0,087	-0,086	-0,124
		Sig. (2-tailed)	0,800	0,570	0,595	0,412
		N	16	45	41	46
	Suunnitelmissa on esitetty tarvittavat mitat	Correlation Coefficient	0,048	0,090	-0,025	-0,043
		Sig. (2-tailed)	0,860	0,557	0,878	0,774
		N	16	45	41	46
	Suunnittelijaa ei ole tarvittu pyytää työmaalle suunnitelmaepäselvyyksien takia	Correlation Coefficient	0,139	0,207	-0,061	-0,043
		Sig. (2-tailed)	0,608	0,173	0,705	0,778
		N	16	45	41	46

Correlations Spearman's rho			Kustannukset C4	Aikataulupoikkeama (mittaushtekellä)	Laatuindeksi	Turvallisuusindeksi
	Suunnitelmia ei ole tarvinnut toimittaa työmaalle faksilla	Correlation Coefficient	0,062	0,245	0,141	-0,116
		Sig. (2-tailed)	0,819	0,177	0,457	0,520
		N	16	32	30	33
	Suunnittelija on tarvittaessa tullut työmaalle	Correlation Coefficient	0,351	0,202	-0,007	0,052
		Sig. (2-tailed)	0,182	0,184	0,966	0,731
		N	16	45	41	46
	Rakennesuunnittelija on ottanut huomioon työmaan ehdotukset	Correlation Coefficient	0,492	0,360	0,171	0,057
		Sig. (2-tailed)	0,053	0,024	0,325	0,726
		N	16	39	35	40
	Työmaalla sovitut muutokset on viety nopeasti suunnitelmiin	Correlation Coefficient	0,103	-0,037	-0,128	-0,064
		Sig. (2-tailed)	0,704	0,811	0,426	0,675
		N	16	45	41	46
	Töiden etenemisessä ei ole ollut katkoja suunnitelmapuutteiden tai -virheiden takia	Correlation Coefficient	0,422	0,244	-0,097	0,070
		Sig. (2-tailed)	0,104	0,106	0,545	0,645
		N	16	45	41	46
	Reikäkuvat ovat olleet työmaalla käytettävissä riittävän ajoissa	Correlation Coefficient	0,248	0,168	0,146	0,009
		Sig. (2-tailed)	0,354	0,286	0,382	0,957
		N	16	42	38	43
	Reikiä, joita ei esiinny reikäkuvissa, ei ole jouduttu tekemään	Correlation Coefficient	-0,065	-0,002	0,199	-0,204
		Sig. (2-tailed)	0,819	0,991	0,218	0,185
		N	15	43	40	44
	Tarvittavat leikkauskuvat on piirretty	Correlation Coefficient	0,284	0,045	-0,017	0,150
		Sig. (2-tailed)	0,306	0,775	0,917	0,332
		N	15	43	39	44
	Töiden etenemisessä ei ole ollut katkoja suunnitelmapuutteiden tai -virheiden takia	Correlation Coefficient	0,289	0,149	-0,162	0,061
		Sig. (2-tailed)	0,278	0,329	0,310	0,690
		N	16	45	41	46
	Väliseiniä ei ole jouduttu purkamaan tai piikkaamaan suunnitteluvirheiden takia	Correlation Coefficient	0,037	0,077	-0,176	-0,088
		Sig. (2-tailed)	0,900	0,623	0,278	0,568
		N	14	43	40	44
	Valaisimet ovat sopineet alakattoihin	Correlation Coefficient	0,657	0,210	-0,220	0,205
		Sig. (2-tailed)	0,109	0,303	0,313	0,314
		N	7	26	23	26
	Alakattojen korkoja ei ole jouduttu muuttamaan	Correlation Coefficient	0,411	-0,011	-0,398	-0,002
		Sig. (2-tailed)	0,184	0,950	0,032	0,993
		N	12	34	29	34
	Alakattoja ei ole jouduttu purkamaan	Correlation Coefficient	0,675	0,142	0,031	0,260
		Sig. (2-tailed)	0,032	0,439	0,875	0,151
		N	10	32	28	32
	Työmaan tavoitebudjetti ja aikataulu ovat selkeät	Correlation Coefficient	0,280	-0,107	-0,353	0,141
		Sig. (2-tailed)	0,293	0,486	0,024	0,349
		N	16	45	41	46
	Työmaan toteutusorganisaatio on tarkoituksenmukainen	Correlation Coefficient	0,651	0,041	-0,080	0,069
		Sig. (2-tailed)	0,006	0,789	0,617	0,648
		N	16	45	41	46
	Vastuunjako linjajohdon ja työmaan välillä on selkeä ja toimiva	Correlation Coefficient	0,205	-0,096	-0,138	-0,067
		Sig. (2-tailed)	0,446	0,535	0,395	0,663
		N	16	44	40	45
	Työmaalla on ollut käytettävissään tarvittavat henkilö- ja kalustoresurssit	Correlation Coefficient	0,834	0,166	0,159	0,100
		Sig. (2-tailed)	0,000	0,275	0,321	0,507
		N	16	45	41	46
	Työmaa-aluetta koskevat suunnitelmat (työmaatilat, nosturit, kulkutiet jne.) ovat toimivat	Correlation Coefficient	0,092	0,163	-0,073	0,139
		Sig. (2-tailed)	0,735	0,284	0,649	0,358
		N	16	45	41	46
	Työmaan viranomaissuhteiden kanssa ei ole ollut ongelmia (rak.tarkastus, luvat)	Correlation Coefficient	0,214	0,090	-0,084	0,120
		Sig. (2-tailed)	0,426	0,557	0,600	0,428
		N	16	45	41	46
	Tärkeimmät hankinnat on valmisteltu hyvin (onnistuvat käytännössä)	Correlation Coefficient	0,541	0,083	-0,258	0,214
		Sig. (2-tailed)	0,030	0,587	0,103	0,153
		N	16	45	41	46
	Seurantapalavereita on ollut riittävän usein ja ne ovat olleet hyödyllisiä	Correlation Coefficient	0,502	0,255	-0,026	0,100
		Sig. (2-tailed)	0,048	0,095	0,875	0,513
		N	16	44	40	45
	Sopimusten laatimiseen on ollut käytettävissä tarvittava tuki	Correlation Coefficient	0,619	0,239	0,021	0,191
		Sig. (2-tailed)	0,014	0,118	0,897	0,209
		N	15	44	41	45
	Vaihtoehtoratkaisujen valitsemiseen on saatu tarvittava tuki ja päätökset	Correlation Coefficient	0,143	0,155	-0,292	0,005
		Sig. (2-tailed)	0,625	0,322	0,067	0,975
		N	14	43	40	44
	Työmaan ongelmatilanteiden ratkaisemiseen on saatu tarvittava tuki	Correlation Coefficient	0,635	0,168	-0,184	0,159
		Sig. (2-tailed)	0,008	0,275	0,256	0,297
		N	16	44	40	45
	Työmaa on saanut tukea ja kannustusta toimintansa kehittämiseen	Correlation Coefficient	0,596	0,243	-0,039	0,213
		Sig. (2-tailed)	0,015	0,107	0,809	0,155
		N	16	45	41	46

APPENDIX 2.3 (4)

Correlations Spearman's rho			Kustannukset C4	Aikataulupoikkeama (mittaushtekellä)	Laatuindeksi	Turvallisuusindeksi
	Linjajohto edistää työmaiden välistä yhteistyötä	Correlation Coefficient	0,147	-0,207	-0,028	-0,176
		Sig. (2-tailed)	0,587	0,172	0,863	0,241
		N	16	45	41	46
	Linjajohto on ollut riittävästi läsnä tarkastuksissa ja katselmuksissa	Correlation Coefficient	0,392	-0,023	-0,180	0,090
		Sig. (2-tailed)	0,133	0,881	0,266	0,557
		N	16	44	40	45
	Tieto työmaan ja linjajohdon välillä on kulkenut (lisä- ja muutostyöt, reklamaatiot jne.)	Correlation Coefficient	-0,307	-0,046	-0,349	0,001
		Sig. (2-tailed)	0,247	0,763	0,025	0,994
		N	16	45	41	46
	Yrityksen arvot ja toimintaperiaattet ovat välittyneet työmaalle	Correlation Coefficient	-0,469	0,047	-0,157	-0,226
		Sig. (2-tailed)	0,067	0,759	0,326	0,130
		N	16	45	41	46
	Työmaan johdon palkkaus koetaan oikeudenmukaiseksi	Correlation Coefficient	0,083	0,138	-0,123	0,209
		Sig. (2-tailed)	0,759	0,376	0,451	0,173
		N	16	43	40	44
	Työmaan palkkiojärjestelmä on selkeä, kannustava ja oikeudenmukainen	Correlation Coefficient	0,099	0,177	0,003	0,264
		Sig. (2-tailed)	0,717	0,245	0,984	0,077
		N	16	45	41	46
	Kustannusarviossa ei ole ollut merkitäviä virheitä	Correlation Coefficient	0,164	-0,076	-0,158	0,166
		Sig. (2-tailed)	0,558	0,622	0,323	0,275
		N	15	44	41	45
	Urakkarajat on määritetty laskentav. toteutussuunnitelmassa oikein ja yksiselitteisesti	Correlation Coefficient	0,095	0,132	-0,220	-0,131
		Sig. (2-tailed)	0,745	0,397	0,173	0,396
		N	14	43	40	44
	Laskentavaiheessa valitut tuotantomenetelmät ovat olleet toteutuskelpoisia	Correlation Coefficient	0,433	0,043	-0,121	0,089
		Sig. (2-tailed)	0,107	0,779	0,451	0,563
		N	15	44	41	45
	Laskentaosastolta on saatu tarvittaessa toteutumatietoja	Correlation Coefficient	-0,098	0,089	-0,123	0,047
		Sig. (2-tailed)	0,728	0,582	0,461	0,767
		N	15	41	38	42
	Laskenta ylläpitää jälkilaskentatiedostoja tuotantosuunnittelun avuksi	Correlation Coefficient	-0,112	-0,151	-0,200	0,046
		Sig. (2-tailed)	0,691	0,345	0,229	0,770
		N	15	41	38	42
	Hankintaosaston ja työmaan välinen työnjako on selkeä ja tarkoituksenmukainen	Correlation Coefficient	-0,220	0,020	-0,315	-0,197
		Sig. (2-tailed)	0,430	0,900	0,047	0,199
		N	15	43	40	44
	Työmaa on voinut vaikuttaa riittävästi hankintapäätöksiin ja sopimusten sisältöihin	Correlation Coefficient	-0,014	0,113	-0,027	-0,113
		Sig. (2-tailed)	0,960	0,461	0,869	0,454
		N	16	45	41	46
	Tarjouspyynnöt ovat yksiselitteisiä ja tuotantoon sopivia	Correlation Coefficient	0,241	0,064	-0,022	0,127
		Sig. (2-tailed)	0,369	0,677	0,889	0,399
		N	16	45	41	46
	Hankintaosaston tekemät sopimukset ovat yksiselitteisiä ja tuotantoon sopivia	Correlation Coefficient	-0,186	-0,096	-0,038	0,049
		Sig. (2-tailed)	0,508	0,541	0,815	0,750
		N	15	43	40	44
	Hankinnat ovat toteutuneet aikataulullisesti työmaan tarpeiden mukaisesti	Correlation Coefficient	0,097	-0,079	-0,161	-0,151
		Sig. (2-tailed)	0,720	0,607	0,315	0,315
		N	16	45	41	46
	Hankinnasta on saatavissa tarvittavat toiminta- ja sopimusmallit	Correlation Coefficient	-0,070	-0,036	-0,062	0,068
		Sig. (2-tailed)	0,804	0,815	0,701	0,655
		N	15	44	41	45
	Hankinta ylläpitää urakoitsijarekisteriä hankintapäätösten tueksi	Correlation Coefficient	-0,098	-0,155	-0,335	0,159
		Sig. (2-tailed)	0,728	0,320	0,034	0,303
		N	15	43	40	44
	Hankinta ylläpitää urakkahintatiedostoja työmaan käytettäväksi	Correlation Coefficient	-0,189	-0,021	-0,099	-0,052
		Sig. (2-tailed)	0,499	0,895	0,556	0,743
		N	15	41	38	42
	Markkinointiosaston ja työmaan välinen työnjako on selkeä ja tarkoituksenmukainen	Correlation Coefficient	0,668	0,169	0,011	0,231
		Sig. (2-tailed)	0,101	0,489	0,964	0,327
		N	7	19	18	20
	Työmaa on saanut tiedon muutostöistä riittävän ajoissa	Correlation Coefficient	0,158	0,311	0,010	-0,085
		Sig. (2-tailed)	0,735	0,196	0,967	0,722
		N	7	19	18	20
	Sovitut muutostyöt ovat olleet selkeitä ja toteutettavia	Correlation Coefficient	.	0,158	0,205	-0,119
		Sig. (2-tailed)	.	0,531	0,430	0,629
		N	6	18	17	19
	Sovitut muutostyöt ovat olleet hinnaltan oikeita	Correlation Coefficient	0,535	0,208	-0,001	0,228
		Sig. (2-tailed)	0,216	0,393	0,996	0,334
		N	7	19	18	20
	Markkinointiosasto on tiedottanut asiakkaita riittävästi (ei turhia kyselyjä työmaalle)	Correlation Coefficient	0,558	0,357	0,008	-0,113
		Sig. (2-tailed)	0,193	0,146	0,975	0,644
		N	7	18	17	19
	Työmaakäynnit on järjestetty työmaan toimintaa häiritsemättä	Correlation Coefficient	-0,158	-0,077	0,096	-0,115
		Sig. (2-tailed)	0,735	0,760	0,713	0,638
		N	7	18	17	19
	Työmaa on saanut tiedon asiakaspalautteesta	Correlation Coefficient	-0,394	0,079	-0,327	0,020
		Sig. (2-tailed)	0,334	0,756	0,201	0,935
		N	8	18	17	19

Correlations Spearman's rho			Kustannukset C4	Aikataulupoikkeama (mittaushtekellä)	Laatuindeksi	Turvallisuusindeksi
Ohjaus-järjestelmät	Erilliset suunnitelmakatselmukset on pidetty perustus-, runko- ja sisävaiheen suunnitelmista	Correlation Coefficient	0,031	-0,155	-0,210	0,222
		Sig. (2-tailed)	0,913	0,308	0,187	0,139
		N	15	45	41	46
	Piirustusaikataulussa on esitetty kaikkien suunnitelmien tarve ja sitä on valvottu	Correlation Coefficient	-0,338	0,290	-0,064	-0,092
		Sig. (2-tailed)	0,259	0,077	0,722	0,576
		N	13	38	33	39
	Tietojen riittävyyden, toteutuskelpoisuuden ja urakkasopimuksen mukaisuuden tarkastamiseen on sovittu vastuut ja menettelyt	Correlation Coefficient	-0,247	0,362	0,050	-0,016
		Sig. (2-tailed)	0,374	0,016	0,760	0,919
		N	15	44	39	45
	Suunnitelmista tarkastetaan em. asiat heti niiden saavuttua työmaalle	Correlation Coefficient	-0,129	0,395	0,233	-0,065
		Sig. (2-tailed)	0,659	0,162	0,444	0,817
		N	14	14	13	15
	Suunnitelmien laatua valvotaan ja ristiriitaisuuksia poistetaan ennakolta suunnitelmien kierron, suunnittelu- ja risteilypalaverien avulla	Correlation Coefficient	-0,092	0,102	-0,064	0,206
		Sig. (2-tailed)	0,734	0,498	0,690	0,165
		N	16	46	41	47
	Työmaalla on käytössään kaikki mittaushetkellä tarvittavat suunnitelmat	Correlation Coefficient	0,492	0,201	-0,030	0,030
		Sig. (2-tailed)	0,053	0,181	0,854	0,840
		N	16	46	41	47
	Mahdollisista puutteista ja viivästymisistä on reklamoitu dokumentoidusti	Correlation Coefficient	-0,078	0,182	0,112	0,047
		Sig. (2-tailed)	0,790	0,260	0,523	0,772
		N	14	40	35	41
	Suunnitelmapuutteista tai -virheistä aiheutuvista lisätöistä pidetään kirjaa	Correlation Coefficient	-0,101	0,068	-0,200	0,205
		Sig. (2-tailed)	0,730	0,683	0,257	0,211
		N	14	38	34	39
	Työmaalla on reaaliaikainen kustannus- ja menekkiseuranta	Correlation Coefficient	-0,196	0,181	-0,069	0,385
		Sig. (2-tailed)	0,467	0,229	0,668	0,007
		N	16	46	41	47
	Kustannusraporteissa on tehtävittäin tavoitearvio, toteutuneet kustannukset ja ennusteet, sekä yhteenvedot litteraryhmittäin ja kustannuslajeittain.	Correlation Coefficient	-0,196	0,000	-0,118	0,180
		Sig. (2-tailed)	0,467	1,000	0,464	0,226
		N	16	46	41	47
	Ennusteet päivitetään vähintään kerran kuukaudessa	Correlation Coefficient	-0,308	-0,068	-0,105	0,075
		Sig. (2-tailed)	0,246	0,653	0,512	0,618
		N	16	46	41	47
	Muutokset omien töiden ja aliurakoiden välillä on päivitetty tavoitearvioon tai kirjattu erikseen muistiin.	Correlation Coefficient	-0,032	0,028	-0,147	0,339
		Sig. (2-tailed)	0,912	0,862	0,377	0,030
		N	14	40	38	41
	Muutostöistä aiheutuvat kustannukset on erotettu muista kustannuksista kustannusraportissa	Correlation Coefficient	0,421	0,297	0,072	0,248
		Sig. (2-tailed)	0,118	0,063	0,676	0,118
		N	15	40	36	41
	Seurantapalavereja pidetään noin 1 kk välein työmaan linjajohdon kanssa	Correlation Coefficient	0,351	0,062	0,284	-0,232
		Sig. (2-tailed)	0,182	0,684	0,072	0,117
		N	16	46	41	47
	Kustannustavoitteet ovat tehtävistä vastaavien työnjohtajien tiedossa	Correlation Coefficient	0,287	0,125	0,168	-0,073
		Sig. (2-tailed)	0,366	0,437	0,319	0,646
		N	12	41	37	42
	Työmaasta on tehty laatusuunnitelma, jossa on esitetty tehtäväkohtaiset laadunvarmistustoimenpiteet (esim. laadunvarmistusmatriisi)	Correlation Coefficient	.	0,025	-0,120	0,271
		Sig. (2-tailed)	.	0,871	0,453	0,066
		N	16	46	41	47
	Työmaasta on tehty riskianalyysi (POA)	Correlation Coefficient	-0,010	0,069	-0,161	0,243
		Sig. (2-tailed)	0,970	0,647	0,316	0,100
		N	16	46	41	47
	Riskianalyysissa esiintulleiden ongelmien varalta on tehty suunnitelmat	Correlation Coefficient	-0,110	0,065	-0,127	0,171
		Sig. (2-tailed)	0,685	0,669	0,428	0,255
		N	16	45	41	46
	Työmaalla on pidetty dokumentoidusti nk. ensimmäisen mestan katselmuksia	Correlation Coefficient	0,075	-0,119	-0,373	0,343
		Sig. (2-tailed)	0,783	0,661	0,171	0,178
		N	16	16	15	17
	Työkohteiden laadunvarmistusta toteutetaan dokumentoidusti tehtäväkorttien tms. tarkastuslistojen avulla	Correlation Coefficient	-0,018	0,178	0,103	-0,005
		Sig. (2-tailed)	0,947	0,236	0,521	0,975
		N	16	46	41	47
	Laatusuunnitelmassa määritetyt toimenpiteet on tehty	Correlation Coefficient	.	-0,062	-0,208	0,389
		Sig. (2-tailed)	.	0,687	0,198	0,007
		N	16	45	40	46
	Laatusuunnitelmaa valvotaan ja päivitetään tarvittaessa	Correlation Coefficient	0,183	0,123	0,093	0,010
		Sig. (2-tailed)	0,497	0,421	0,568	0,946
		N	16	45	40	46
	Vähintään kolmesta työvaiheesta on tehty tehtävä- tai laatusuunnitelma	Correlation Coefficient	-0,008	0,066	0,053	0,085
		Sig. (2-tailed)	0,976	0,662	0,744	0,572
		N	16	46	41	47

Correlations Spearman's rho			Kustannukset C4	Aikataulupoikkeama (mittaushtekellä)	Laatuindeksi	Turvallisuusindeksi
	Vähintään kolmesta työvaiheesta on tehty tehtävä- tai laatusuunnitelma	Correlation Coefficient	-0,406	0,115	-0,079	-0,072
		Sig. (2-tailed)	0,133	0,453	0,626	0,632
		N	15	45	40	46
	"Tehtäväsuunnitelmat sisältävät: • kustannustavoitteen"	Correlation Coefficient	-0,088	0,133	0,139	-0,012
		Sig. (2-tailed)	0,754	0,382	0,392	0,938
		N	15	45	40	46
	• aikataulutavoitteen välitavoitteineen	Correlation Coefficient	0,043	0,237	-0,021	0,100
		Sig. (2-tailed)	0,879	0,118	0,897	0,508
		N	15	45	40	46
	• riskianalyysin/POAn	Correlation Coefficient	0,284	0,217	-0,007	0,349
		Sig. (2-tailed)	0,304	0,153	0,964	0,017
		N	15	45	40	46
	• laatuvaatimukset selkokielisenä	Correlation Coefficient	0,302	0,196	0,067	0,187
		Sig. (2-tailed)	0,275	0,197	0,679	0,213
		N	15	45	40	46
	• tuotantosuunnitelman, jossa on huomioitu materiaalisiirrot ja turvallisuus	Correlation Coefficient	.	0,213	0,073	0,037
		Sig. (2-tailed)	.	0,250	0,719	0,845
		N	12	31	27	31
	Tehtäväsuunnitelmien aikataulutavoitteet ovat yhtenevät yleisaikataulun kanssa	Correlation Coefficient	-0,052	0,171	0,161	-0,044
		Sig. (2-tailed)	0,849	0,274	0,336	0,778
		N	16	43	38	44
	Työmaasta on tehty yleisaikataulu paikka-aikakaavion muotoon	Correlation Coefficient	0,318	-0,031	-0,282	0,054
		Sig. (2-tailed)	0,230	0,838	0,074	0,720
		N	16	46	41	47
	Työmaasta on tehty tarvittavat rakentamisvaiheaikataulut ja LVIS -aikataulu, joissa esitetään töiden eteneminen työkohteittain	Correlation Coefficient	-0,099	-0,074	0,066	0,222
		Sig. (2-tailed)	0,716	0,624	0,683	0,134
		N	16	46	41	47
	Tehtävät ja resurssit sisältävät viikkosuunnitelmat on tehty muiden aikataulujen pohjalta	Correlation Coefficient	0,003	0,159	-0,117	0,185
		Sig. (2-tailed)	0,990	0,290	0,467	0,213
		N	16	46	41	47
	Aikatauluun on varattu häiriöpelivaraa ja luovutusaikaa riittävästi	Correlation Coefficient	0,336	0,120	0,303	-0,011
		Sig. (2-tailed)	0,203	0,426	0,054	0,940
		N	16	46	41	47
	Välitavoitteet ja tahdistavat aikataulutehtävät on merkitty selvästi	Correlation Coefficient	-0,028	0,132	-0,043	-0,196
		Sig. (2-tailed)	0,917	0,380	0,791	0,186
		N	16	46	41	47
	Aikataulun toteutumista on seurattu viikottain (toteuma piirretty)	Correlation Coefficient	-0,370	-0,100	-0,326	0,081
		Sig. (2-tailed)	0,158	0,507	0,038	0,589
		N	16	46	41	47
	Alkuperäistä aikataulua ei ole tarvittu muuttaa (miksi muutettu?)	Correlation Coefficient	0,192	0,065	-0,128	0,127
		Sig. (2-tailed)	0,477	0,779	0,590	0,575
		N	16	21	20	22
	Hankintasuunnitelmaa on valvottu (toteutumat merkitty)	Correlation Coefficient	-0,219	0,062	0,154	-0,059
		Sig. (2-tailed)	0,415	0,681	0,335	0,692
		N	16	46	41	47
	Hankinta- ja yleisaikataulu on onnistuneesti yhteensovitettu	Correlation Coefficient	-0,364	0,000	-0,069	-0,042
		Sig. (2-tailed)	0,166	1,000	0,666	0,778
		N	16	46	41	47
	Puutteista toimituksissa on reklamoitu kirjallisesti	Correlation Coefficient	-0,244	-0,029	0,128	-0,139
		Sig. (2-tailed)	0,422	0,858	0,455	0,385
		N	13	40	36	41
	Työmaalla on käytettävissä toimittajarekisteri, ja aliurakoitsijat ovat siinä hyväksyttyjä	Correlation Coefficient	-0,263	-0,129	-0,167	-0,084
		Sig. (2-tailed)	0,364	0,404	0,309	0,582
		N	14	44	39	45
	Aliurakkasopimukset ovat olleet työmaalla käytettävissä ennen töiden alkamista	Correlation Coefficient	-0,041	-0,067	0,012	0,020
		Sig. (2-tailed)	0,880	0,660	0,941	0,892
		N	16	46	41	47
	"Aliurakkasopimuksissa on esitetty selvästi:	Correlation Coefficient	-0,122	-0,075	0,025	-0,089
		Sig. (2-tailed)	0,654	0,623	0,876	0,551
		N	16	46	41	47
	• urakan sisältö ja rajat (myös työturvallisuus)"	Correlation Coefficient	-0,249	0,230	0,179	-0,096
		Sig. (2-tailed)	0,353	0,124	0,262	0,519
		N	16	46	41	47
	• aikataulu välitavoitteineen (myös sakot määrätty tarvittaessa)	Correlation Coefficient	.	0,047	0,210	-0,026
		Sig. (2-tailed)	.	0,754	0,188	0,864
		N	16	46	41	47
	• työnjohtovelvoite ja työvoiman pysyvyys	Correlation Coefficient	-0,084	-0,063	0,018	0,181
		Sig. (2-tailed)	0,757	0,676	0,909	0,224
		N	16	46	41	47
	• laatuvaatimukset auki kirjoitettuna	Correlation Coefficient	-0,184	0,038	-0,055	0,187
		Sig. (2-tailed)	0,529	0,833	0,770	0,283
		N	14	34	31	35
	Havaitut (laatu- ja tehtäväsuunnitelmissa esitetyt) potentiaaliset ongelmat on otettu huomioon aliurakkasopimuksissa	Correlation Coefficient	0,488	-0,023	-0,122	0,176
		Sig. (2-tailed)	0,065	0,883	0,452	0,241
		N	15	45	40	46
	Aliurakoitsijoiden työryhmän/nokkamiehen kanssa on pidetty aloituspalaveri tms. perehdytys	Correlation Coefficient	0,191	0,424	0,084	0,033
		Sig. (2-tailed)	0,478	0,003	0,601	0,825
		N	16	46	41	47

APPENDIX 2.3 (7)

Correlations Spearman's rho			Kustannukset C4	Aikataulupoikkeama (mittaushtekellä)	Laatuindeksi	Turvallisuusindeksi
	Työmaaorganisaation tehtävät on määritetty kirjallisesti, ja ovat ajan tasalla	Correlation Coefficient	-0,461	-0,203	-0,185	-0,114
		Sig. (2-tailed)	0,072	0,176	0,248	0,446
		N	16	46	41	47
	Työmaan sisäisiä mestaripalavereja pidetään säännöllisesti ja dokumentoidusti	Correlation Coefficient	0,011	0,159	0,062	0,012
		Sig. (2-tailed)	0,971	0,409	0,759	0,950
		N	13	29	27	30
	Uusien työntekijöiden perehdytyksessä käytetään tsekkilistaa ja jaettavaa materiaalia	Correlation Coefficient	-0,226	0,076	-0,010	0,032
		Sig. (2-tailed)	0,400	0,614	0,950	0,829
		N	16	46	41	47
	Työmaalla järjestetään säännöllisesti tiedotustilaisuuksia kaikille työntekijöille	Correlation Coefficient	0,236	-0,064	-0,355	0,130
		Sig. (2-tailed)	0,378	0,672	0,023	0,383
		N	16	46	41	47
	Tiedotuksessa käytetään hyväksi kirjallista materiaalia (ilmoitustaulut, tiedotteet)	Correlation Coefficient	.	-0,066	-0,204	0,177
		Sig. (2-tailed)	.	0,661	0,201	0,233
		N	16	46	41	47
	Pidettävistä suunnittelu-, urakoitsija-, ym. palavereista tehdään muistiot ja ne jaetaan asianosaisille	Correlation Coefficient	.	0,269	-0,016	0,081
		Sig. (2-tailed)	.	0,085	0,927	0,606
		N	15	42	37	43
	Työmaiden väliseen yhteistyöhön on sovittu menettelyt (missä asioissa, miten)	Correlation Coefficient	-0,103	0,141	0,154	-0,253
		Sig. (2-tailed)	0,704	0,350	0,336	0,086
		N	16	46	41	47
	Työmaalla hyödynnetään yrityksessä ylläpidettyjä tiedostoja: • yleisimmät laatuvirheet (vuosikorjaukset ym.)	Correlation Coefficient	-0,028	0,047	-0,153	0,291
		Sig. (2-tailed)	0,918	0,759	0,339	0,047
		N	16	46	41	47
	• materiaali- ja urakkahintatiedostoja	Correlation Coefficient	0,250	0,439	0,217	-0,010
		Sig. (2-tailed)	0,349	0,002	0,172	0,948
		N	16	46	41	47
	• yleistä ja kohdekohtaisia asiakaspalautteita	Correlation Coefficient	-0,106	0,046	-0,018	0,106
		Sig. (2-tailed)	0,697	0,770	0,914	0,495
		N	16	43	39	44
	Yhteydenpidosta tilaajan tai asukkaiden kanssa on sovittu talon sisällä vastuut ja menettelytavat (esim. muutostöistä sopiminen ja tiedottaminen)	Correlation Coefficient	-0,364	-0,051	-0,408	0,033
		Sig. (2-tailed)	0,166	0,761	0,017	0,843
		N	16	38	34	39
	Työmaasuunnitelma tehty rakennusvaiheittain ja siihen on merkitty kulkutiet, nosturit + säteet, varastopaikat ja jätelavat	Correlation Coefficient	-0,308	-0,155	-0,257	0,070
		Sig. (2-tailed)	0,246	0,305	0,105	0,640
		N	16	46	41	47
	Tilanne työmaalla vastaa työmaasuunnitelmaa	Correlation Coefficient	-0,044	0,040	-0,212	0,169
		Sig. (2-tailed)	0,872	0,794	0,183	0,257
		N	16	46	41	47
	Materiaalin vastaanottoa, varastointia ja siirtoja varten on tehty erillinen logistiikkasuunnitelma (tai varastointisuunnitelma)	Correlation Coefficient	0,258	0,130	0,129	0,240
		Sig. (2-tailed)	0,335	0,388	0,420	0,104
		N	16	46	41	47
	Työntekijöille on jaettu kulkuluvat ja niistä pidetään luetteloa	Correlation Coefficient	-0,191	-0,055	-0,030	0,045
		Sig. (2-tailed)	0,480	0,717	0,851	0,766
		N	16	46	41	47
	Työmaalla on ympäristösuunnitelma	Correlation Coefficient	0,026	0,115	-0,041	0,334
		Sig. (2-tailed)	0,925	0,448	0,797	0,022
		N	16	46	41	47
	Työmaalla on jätehuoltosuunnitelma, jonka mukaan toimitaan (esim. lajittelu)	Correlation Coefficient	0,179	-0,024	-0,118	0,307
		Sig. (2-tailed)	0,507	0,874	0,464	0,036
		N	16	46	41	47
	Työmaan ympäristöön aiheutuvat häiriöt ja päästöt pyritään minimoimaan suunnitelmallisesti (liikenne, pöly, melu tms.)	Correlation Coefficient	-0,110	0,017	0,025	0,045
		Sig. (2-tailed)	0,686	0,912	0,876	0,764
		N	16	46	41	47
	Työmaalle on laadittu yhteiset toimintatavat, ns. pelisäännöt, jotka on asetettu näkyville	Correlation Coefficient	-0,028	0,200	0,046	0,286
		Sig. (2-tailed)	0,918	0,182	0,777	0,051
		N	16	46	41	47
	Tarpeelliset turvallisuussuunnitelmat, kuten putoamissuo-jaus-, purkutyö-, nostotyö- ja telinesuunnitelmat on tehty	Correlation Coefficient	0,077	0,005	-0,067	0,372
		Sig. (2-tailed)	0,785	0,973	0,679	0,011
		N	15	45	41	46
	Nosturien ja telineiden käyttöönottotarkastuksista on sovittu menettelyt ja vastuut	Correlation Coefficient	.	-0,058	0,017	0,456
		Sig. (2-tailed)	.	0,708	0,918	0,001
		N	16	45	40	46
	Työsuojelukierrokset on tehty ja pöytäkirjat on täytetty korjausmerkintöineen	Correlation Coefficient	0,161	-0,060	-0,383	0,116
		Sig. (2-tailed)	0,552	0,693	0,015	0,444
		N	16	45	40	46
	Työmaalla sovelletaan turvallisuusmittausta (esim. TR-mittari)	Correlation Coefficient	-0,271	0,053	-0,206	-0,102
		Sig. (2-tailed)	0,310	0,728	0,202	0,498
		N	16	45	40	46
	Työmaalla on vaarallisista aineista käyttöturvallisuustiedotteet	Correlation Coefficient	-0,249	0,040	-0,229	0,106
		Sig. (2-tailed)	0,353	0,791	0,149	0,479
		N	16	46	41	47

APPENDIX 2.3 (8)

Correlations Spearman's rho			Kustannukset NCC	Aikataulupoikkeama (mittaushtekellä)	Laatuindeksi	Turvallisuusindeksi
Toimivuus ja johtaminen	Työni antaa runsaasti tyydytystä	Correlation Coefficient	0,171	0,236	0,033	0,030
		Sig. (2-tailed)	0,526	0,114	0,839	0,844
		N	16	46	41	47
	Työmäärä on sopivan tasainen	Correlation Coefficient	0,331	0,101	0,009	-0,065
		Sig. (2-tailed)	0,210	0,505	0,954	0,667
		N	16	46	41	47
	Saan uusia ja haasteellisia työtehtäviä tarpeeksi	Correlation Coefficient	0,203	0,345	0,185	0,129
		Sig. (2-tailed)	0,451	0,019	0,248	0,389
		N	16	46	41	47
	Päätösvaltaa omaan työhöni on riittävästi	Correlation Coefficient	0,200	0,302	0,166	0,120
		Sig. (2-tailed)	0,457	0,041	0,299	0,423
		N	16	46	41	47
	Työskentelyolosuhteet ovat hyvät	Correlation Coefficient	0,453	0,292	0,070	0,269
		Sig. (2-tailed)	0,078	0,049	0,662	0,067
		N	16	46	41	47
	Työvälineet ovat tarkoituksenmukaiset	Correlation Coefficient	0,265	0,242	-0,077	-0,042
		Sig. (2-tailed)	0,322	0,105	0,632	0,782
		N	16	46	41	47
	Tunnen jaksavani työssäni erinomaisesti	Correlation Coefficient	0,400	0,242	0,100	0,027
		Sig. (2-tailed)	0,124	0,105	0,534	0,859
		N	16	46	41	47
	Viihdyn työssäni erinomaisesti	Correlation Coefficient	0,562	0,262	0,029	0,126
		Sig. (2-tailed)	0,023	0,079	0,856	0,398
		N	16	46	41	47
	Ammatilliset kehittymismahdollisuudet työmaalla ovat hyvät	Correlation Coefficient	0,339	0,310	0,086	0,021
		Sig. (2-tailed)	0,199	0,036	0,595	0,890
		N	16	46	41	47
	Työ- ja toimintaohjeet ovat johdonmukaisia	Correlation Coefficient	0,742	0,324	0,191	0,137
		Sig. (2-tailed)	0,001	0,028	0,231	0,358
		N	16	46	41	47
	Työt järjestellään hyvin	Correlation Coefficient	0,703	0,564	0,309	0,199
		Sig. (2-tailed)	0,002	0,000	0,050	0,180
		N	16	46	41	47
	Suunnitelmia noudatetaan tarkasti	Correlation Coefficient	0,629	0,386	0,166	0,150
		Sig. (2-tailed)	0,009	0,008	0,301	0,313
		N	16	46	41	47
	Työtapojen uudistamiseen pyritään	Correlation Coefficient	0,422	0,196	0,199	0,140
		Sig. (2-tailed)	0,103	0,192	0,213	0,347
		N	16	46	41	47
	Toiminta on selkeätä	Correlation Coefficient	0,571	0,361	0,152	0,165
		Sig. (2-tailed)	0,021	0,014	0,342	0,269
		N	16	46	41	47
	Työtuloksia tarkastetaan usein	Correlation Coefficient	0,363	0,361	0,254	0,359
		Sig. (2-tailed)	0,167	0,014	0,109	0,013
		N	16	46	41	47
	Työohjeiden ja laatuvaatimusten noudattamista valvotaan	Correlation Coefficient	0,518	0,459	0,198	0,341
		Sig. (2-tailed)	0,040	0,001	0,214	0,019
		N	16	46	41	47
	Päätöksenteko tapahtuu selvän vastuujaon mukaan	Correlation Coefficient	0,571	0,413	0,263	0,371
		Sig. (2-tailed)	0,021	0,004	0,096	0,010
		N	16	46	41	47
	Työtavoitteet ovat selkeät	Correlation Coefficient	0,726	0,488	0,171	0,239
		Sig. (2-tailed)	0,001	0,001	0,284	0,106
		N	16	46	41	47
	Työmaalla on selvät toimintatavat ja pelisäännöt	Correlation Coefficient	0,808	0,442	0,200	0,278
		Sig. (2-tailed)	0,000	0,002	0,209	0,059
		N	16	46	41	47
	Saadaan aikaan paljon tuloksia	Correlation Coefficient	0,471	0,488	0,122	0,133
		Sig. (2-tailed)	0,066	0,001	0,448	0,372
		N	16	46	41	47
	Työmaalla noudatetaan toimintatapoja ja pelisääntöjä	Correlation Coefficient	0,661	0,425	0,180	0,181
		Sig. (2-tailed)	0,005	0,003	0,260	0,224
		N	16	46	41	47
	Laatusuunnitelma vaikuttaa työmaan toimintaan	Correlation Coefficient	0,465	0,502	0,105	0,279
		Sig. (2-tailed)	0,070	0,000	0,515	0,058
		N	16	46	41	47
	Työnjako ja vastuualueet ovat selviä	Correlation Coefficient	0,545	0,389	0,177	0,256
		Sig. (2-tailed)	0,029	0,008	0,268	0,082
		N	16	46	41	47
	Itsenäiseen toimintatapaan kannustetaan	Correlation Coefficient	0,485	0,336	0,215	0,130
		Sig. (2-tailed)	0,057	0,022	0,176	0,383
		N	16	46	41	47
	Havaitut ongelmat selvitetään nopeasti	Correlation Coefficient	0,638	0,395	0,181	0,258
		Sig. (2-tailed)	0,008	0,007	0,257	0,080
		N	16	46	41	47
	Hyvät suoritukset palkitaan	Correlation Coefficient	0,743	0,375	0,231	-0,008
		Sig. (2-tailed)	0,001	0,010	0,146	0,956
		N	16	46	41	47
	Päätöksenteko on nopeata	Correlation Coefficient	0,438	0,299	0,268	-0,036
		Sig. (2-tailed)	0,089	0,044	0,090	0,812
		N	16	46	41	47
	Määrättyn työn- ja vastuunjaon mukaan toimitaan	Correlation Coefficient	0,512	0,302	0,222	0,215
		Sig. (2-tailed)	0,043	0,041	0,162	0,147
		N	16	46	41	47
	Yhteishenki työmaalla on hyvä	Correlation Coefficient	0,491	0,321	0,054	0,257
		Sig. (2-tailed)	0,053	0,030	0,735	0,081
		N	16	46	41	47

Correlations Spearman's rho			Kustannukset C4	Aikataulupoikkeama (mittaushtekellä)	Laatuindeksi	Turvallisuusindeksi
	Muilta työntekijöiltä on helppo saada apua	Correlation Coefficient	0,200	0,178	0,116	0,063
		Sig. (2-tailed)	0,458	0,237	0,471	0,673
		N	16	46	41	47
	Työntekijät näkevät koko työmaan edun	Correlation Coefficient	0,482	0,286	0,049	0,286
		Sig. (2-tailed)	0,058	0,054	0,763	0,051
		N	16	46	41	47
	Työmaan yhteiset tavoitteet ovat selvät	Correlation Coefficient	0,369	0,389	0,185	0,181
		Sig. (2-tailed)	0,159	0,008	0,246	0,223
		N	16	46	41	47
	Ristiriidat käsitellään ja ratkaistaan	Correlation Coefficient	0,443	0,443	0,203	0,212
		Sig. (2-tailed)	0,086	0,002	0,202	0,152
		N	16	46	41	47
	Yhteishenki lähimpien työtovereiden keskuudessa hyvä	Correlation Coefficient	0,109	0,128	0,245	-0,026
		Sig. (2-tailed)	0,688	0,398	0,122	0,865
		N	16	46	41	47
	Tiedottaminen on runsasta	Correlation Coefficient	0,570	0,584	0,198	0,274
		Sig. (2-tailed)	0,021	0,000	0,215	0,062
		N	16	46	41	47
	Tiedottaminen on avointa	Correlation Coefficient	0,707	0,577	0,280	0,114
		Sig. (2-tailed)	0,002	0,000	0,076	0,447
		N	16	46	41	47
	Tiedottaminen on luotettavaa	Correlation Coefficient	0,322	0,363	0,231	0,106
		Sig. (2-tailed)	0,224	0,013	0,146	0,476
		N	16	46	41	47
	Työhjeiden määrä on riittävä	Correlation Coefficient	0,480	0,341	0,221	0,224
		Sig. (2-tailed)	0,060	0,020	0,164	0,130
		N	16	46	41	47
	Työtuloksista saadaan riittävästi tietoa	Correlation Coefficient	0,007	0,329	0,443	-0,039
		Sig. (2-tailed)	0,978	0,026	0,004	0,795
		N	16	46	41	47
	Työtä koskevien tietojen puute ei haittaa	Correlation Coefficient	0,566	-0,016	0,115	0,060
		Sig. (2-tailed)	0,022	0,916	0,475	0,687
		N	16	46	41	47
	Tietojen vieminen työnjohtajalle on hyödyllistä	Correlation Coefficient	0,658	0,349	0,021	0,413
		Sig. (2-tailed)	0,006	0,017	0,896	0,004
		N	16	46	41	47
	Työmaan tavoitteiden saavuttamisesta on tiedotettu	Correlation Coefficient	0,562	0,333	0,194	0,176
		Sig. (2-tailed)	0,024	0,024	0,225	0,236
		N	16	46	41	47
	Esimies perustelee ratkaisunsa	Correlation Coefficient	0,470	0,371	0,248	0,059
		Sig. (2-tailed)	0,066	0,011	0,118	0,692
		N	16	46	41	47
	Esimies kannustaa runsaasti	Correlation Coefficient	0,382	0,264	0,245	0,136
		Sig. (2-tailed)	0,145	0,076	0,122	0,364
		N	16	46	41	47
	Esimies valvoo paljon työntekijöitä	Correlation Coefficient	0,351	0,464	0,066	0,429
		Sig. (2-tailed)	0,183	0,001	0,682	0,003
		N	16	46	41	47
	Esimies ymmärtää työntekijöiden ongelmia	Correlation Coefficient	0,424	0,242	0,028	0,059
		Sig. (2-tailed)	0,102	0,105	0,860	0,693
		N	16	46	41	47
	Esimies kuuntelee työntekijöitä	Correlation Coefficient	0,562	0,191	0,054	0,127
		Sig. (2-tailed)	0,024	0,203	0,738	0,396
		N	16	46	41	47
	Esimies suosii osallistumista töiden suunnitteluun	Correlation Coefficient	0,491	0,340	0,159	0,155
		Sig. (2-tailed)	0,053	0,021	0,322	0,299
		N	16	46	41	47
	Esimies tukee työntekijöiden kehittymispyrkimyksiä	Correlation Coefficient	-0,027	0,247	0,196	-0,159
		Sig. (2-tailed)	0,922	0,098	0,220	0,285
		N	16	46	41	47
	Esimies selventää työmenetelmiä riittävästi	Correlation Coefficient	0,237	0,256	0,064	0,152
		Sig. (2-tailed)	0,377	0,086	0,692	0,308
		N	16	46	41	47
	Esimies on tasapuolinen työntekijöille	Correlation Coefficient	0,640	0,299	0,068	0,178
		Sig. (2-tailed)	0,008	0,044	0,671	0,232
		N	16	46	41	47
	Esimies suhtautuu virheisiin asiallisesti	Correlation Coefficient	0,496	0,248	0,155	0,007
		Sig. (2-tailed)	0,051	0,096	0,334	0,963
		N	16	46	41	47
	Esimies on valmis kokeilemaan työntekijöiden ideoita	Correlation Coefficient	0,383	0,386	0,149	0,125
		Sig. (2-tailed)	0,144	0,008	0,353	0,404
		N	16	46	41	47
	Esimies antaa hyvistä suorituksista riittävästi palautetta	Correlation Coefficient	0,237	0,235	0,286	-0,134
		Sig. (2-tailed)	0,377	0,115	0,070	0,369
		N	16	46	41	47
	Kokonaisuudessaan olen esimieheeni tyytyväinen	Correlation Coefficient	0,461	0,488	0,189	0,096
		Sig. (2-tailed)	0,072	0,001	0,237	0,519
		N	16	46	41	47

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

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ISBN 951-22-7493-0
ISBN 951-22-7494-9 (pdf)
ISSN 1795-2700