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STUDY OF EFFICIENCY INDICATORS OF URBAN PUBLIC TRANSPORTATION SYSTEMS

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16. Abstract

This report presents the efforts of a research project on efficiency problems of urban public transportation systems (UPTS). Three test regions were selected in an effort to discover, clarify, and understand the efficiency relationships within UPTS. The test regions vary from a small one-mode region to a large multimode region. The UPTS are first divided into three major system components i.e. primary services, support functions, and the network. Then each system is divided by mode, and each component by each distinct function carried within the system component. The inputs to the system are also divided by type, i.e. labor, capital, and energy, and according to the contributor i.e. the operator, the direct user, the society at large, and the government at all levels. Input units are also traced in terms of money costs (Fiscal Inputs Matrix) and physical units (Physical Inputs Matrix). System outputs are also separated by the receiver and the nature of the outputs.

Efficiency analysis is then explored in a hierarchical manner exploring three types of relationships, i.e. system inputs vs. system outputs; component inputs vs. component inputs; and component outputs vs. component outputs. Efficiency indicators are then discussed as to the type of useful service they may offer in various types of efficiency analysis problems.

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Executive Summary of a Study on Efficiency Indicators of Urban Public Transportation Systems; Primary Services vs. Support Functions

The concept of efficiency is an elusive one in the field of urban public transportation systems (UPTS). Although it essentially focuses on the effectiveness with which inputs of resources are applied to the system in order to produce desirable outputs, the concept of efficiency involves much more than that. An UPTS may easily be seen producing service outputs which are well below desirable levels, well above needed levels or, even producing service outputs greatly different than desired ones. Furthermore, an UPTS may easily be found demonstrating a different level of achievements in one segment of it than in another. It is thus an obvious requirement, established from the outset on any efficiency analysis of UPTS, the need to intergrate with any such analysis important notions of the desirability of service outputs and of the divisibility of the system into several interacting but substantially independently performing system components.

The present study on efficiency indicators of UPTS is based on such an initial set of considerations. In essence it attempts to study the relationship between service outputs of the system and the manner of distribution of input resources into the various primary and secondary functions and components of the system. The objective of the study is clearly methodological, in that it attempts to study the methods, problems and requirements of deriving efficiency indicators of UPTS and not to assess and compare any specific UPTS systems.

For the purposes of this study the UPTS is divided into <u>three</u> major components, i.e. the primary services component, the support functions component and the systems' network component. Input requirements and patterns of distribution within these components were then the primary targets of the project. A secondary target was the measurement of the inputs to an outputs from each system component. The association of these two items and their relative distribution produced the efficiency indicators that the project studied.

An all inclussive approach was also followed in searching for, and counting in, system inputs and outputs. For this purpose <u>four</u> contributors to and/or beneficiaries from the UPTS have been identified and taken into account, the following: (a) the system's <u>operators</u>. Traditionally the operators were in the center of any efficiency studies, and in fact they were almost universally considered to be the only actors concerned with the efficiency of an UPTS. (b) the direct <u>users</u> of the system. This second contributor seems to represent a second, very important aspect of efficiency analysis for UPTS. Obviously, the point of view of the user, and the efficiency of a technological system in meeting his needs constitute important factors in the welfare of that system. (c) similarly the third and the fourth contributors to the UPTS, the <u>society</u> at large and the <u>government</u> at all levels, represent currently important aspects of an efficiency analysis, now when UPTS are so important within urban areas and are so extensively depended upon systematic governmental assistance for their welfare.

The search for efficiency indicators leads into the definition and measurement of three types of such indicators, the following:

(a) Ratios of system inputs to system outputs. This type of indicator is expressing really unit costs of outputs in terms of any predetermined sets of inputs. Labor costs per vehicle mile is just one indicator of this type. They represent convenient, easy to measure and communicable indicators, but are usually very little informative for the analyst as to what is the problem within a particular system;

(b) Ratios between inputs in primary services and inputs in support functions, or more generally, ratios between inputs of the various system components. A ratio of manhours in conducting transportation (primary services) over manhours in repairs and maintenance (support functions) represent an indicator of this type. This type of indicator are primarily technical and primarily technical and therefore present problems in communicating them to the general public. In fact they are difficult, at times, to understand even by professionals, without specific experience. These types of measures are very revealing and instructive in understanding what is the problem in a particular system. Inbalances in resource allocation, waste, and mismanagement can frequently be gauged by just reviewing a set of measures of this type.

(c) Ratios of component inputs to component outputs. For instance a ratio of vehicle miles over labor inputs to only conducting transportation represent one such ratio. Also a ratio of vehicle miles per bus between breakdowns and labor in repairs and maintenance represent another ratio of this type. These types of measures are very revealing of the specific accomplishments of specific efforts, i.e. of the effectiveness with which input resources are carrying out programmed tasks. Managerial shortcomings, supervisory deficiencies, lack of skills, lack of material and many other sources of concern may reveal themselves with the help of such system measures.

The project follows a hierarchial structure in developing efficiency indicators from single functions and tasks to entire system components. By using sequencial elimination and progressive aggregation of data sets the projects derive efficiency indicators of successively larger data basis corresponding to higher levels of managerial responsibility.

Three test regions were used for empirical data ranging from a small region of 0.5 million residents and a single bus system (Wilmington, Delaware) to a large region of 3.5 million residents and five modes of public transportation (the Pennsylvania side of the Delaware Valley). Since the objectives of the study were clearly methodological and not the objectives of a case study, the selection of the three test regions with the variety of circumstances they presented served well the purposes of the study.

The results of the effort can be summarized as follows:

(i) The relationship between inputs to primary services and those to support functions is central to a well planned and managed UPTS.

(ii) Similarly, the distribution of inputs to the various tasks within the support functions is critical in achieving a well performing UPTS.

(iii) The total inputs required for the operation of UPTS far exceed those reported and/or controlled by the operator of the system alone. The contributions of the government to UPTS frequently may equal and even exceed those by the operator. Also, although the "fare" contributions of the direct users frequently cover almost (or only) half of the operator's budget, the total contributions of the direct userare indeed several times greater than the value of the fares. Finally, society at large is found contributing only minor amounts to the operations of UPTS.

(iv) The fares of the direct users are found to cover only about one-third of the out-of-pocket expenditures required for the operation of the larger system studied while they cover more than twice as much the expenditures of the smaller system studied. Although the data basis is not enough to draw a definite relationship between size of the system and proportion of governmental support required, the evidence indicates that as the system grows in size, additional expensive services are required, and greater labor and capital unit costs are occuring for each task performed.

(v) A comparison among UPTS modes reveals that the various modes have different characteristics in the distribution of input resources. For instance bus systems require different levels of support functions than light rail and still different from subway rapid transit. The study of these relationships by each mode seems to be the key in determining optimum level of inputs in each case.

The overall conclusion of the study points clearly towards the significance and the complexity that efficiency studies for UPTS hold. From the limited evidence available, the indications are clear that substantial funds might be wasted annually and even significant operational difficulties might be experienced by an UPTS, simply because of inappropriate allocation of input resources to the various functions and tasks within the system. Efficiency analysis of the operations of UPTS represent the key to better management and planning for such systems. Efficiency analysis of the type suggested in this volume may be directly instrumental in avoiding substantial waste of funds and in achieving a well performing urban public transportation system in any region of the country.

LIST OF ABBREVIATIONS & SYMBOLS
(UPTS VARIABLES)

PRIMARY OPERATOR

(1)	TOE	Total Operating Expenses
(2)	VM	Vehicle Miles Operated
(3)	PM	Passenger Miles
(4)	P	Number of Passengers Carried
(5)	DCCT	Direct Cost of Conducting Transportation
(6)	TLI	Total Primary Manhours
(7)	TLI	Total Primary Labor
(8)	QE	Total Energy Consumed
(9)	UC	Vehicles Used in Base Period
(10)	AC	Vehicles Used in Peak Period
(11)	SM	Seat Miles
(12)	OR	Operating Revenues

PRIMARY USER

(1)	TTC	Total Travel Cost
(2)	DT	Distance Traveled
(3)	TC	Time Cost
(4)	D	Actual Frequency of Departure
(5)	D^*	Demand Frequency of Departure
(6)	AOD	Actual Operating Distance
(7)	MAD	Maximum Acceptable Distance
(8)	FAV	Floor Area of Vehicle
(9)	S	Seats Available

PRIMARY USER -- con'd

(10) NOTA Number of On-Time Movements

(11) NAM Number of all Movements

(12) $\bar{P}$ Average Passengers Carried

(13) NMDP Number of Major Delays

(14) NAS Number of Abandoned Services

(15) NFA Number of Fatalities

(16) NMA Number of Accidents

(17) NATI Crime Incidents

SUPPORT OPERATOR

(1) CSF Total Cost of Support Functions

(2) SLI Support Function Manpower

(3) MH Total System Manpower

(4) TMH Total Primary Services Producing Manpower

(5) CMF Cost of Managerial Function

(6) MLI Manhours in Managerial Functions

(7) MSLI Manpower in Managerial Support Functions

(8) TPT Transportation Employees Trained

(9) TPS Authorized Transportation Manpower

(10) CRF Cost of Repair & Maintenance Function

(11) RLI Manhours of Repair and Maintenance

(12) CRLI Manpower Cost of Repair & Maintenance Functions

(13) VG Number of Vehicles in Garage

(14) V' Vehicles Deployed

(15) V Vehicles in Fleet

(16) DD Average Number of Days in Garage

SUPPORT OPERATOR ---con'd

(17) CIF Cost of Information and Marketing

(18) ILI Manhours in Information and Marketing

(19) PS Parking Spaces Provided

(20) CPF Cost of Physical Facilities

(21) A Assets

(22) FAPF Floor Area of Passenger Support Facilities

SUPPORT GOVERNMENT

(1) CSF* Cost of All Support Functions

(2) RM Route Miles

(3) CPS Policing and Safety Costs

(4) CA Administrative Costs

(5) CTE Traffic Engineering Costs

SUPPORT SOCIETY

(1) SMSF Societal Manpower Devoted to Transportation Support

(2) RMH Total Regional Manpower

(3) SCSF Societal Capital Devoted to Transportation Support

(4) RC Total Regional Capital Investment

(5) SRSF Natural Resources Devoted to Transportation

(6) SISF Total Societal Investment in Transportation Support

(7) RTO Regional Transport Output

NETWORK OPERATOR/USER

(1) MinTOTC:TNFC Minimize Total Travel Costs S.T. Total Network Facility Costs

NETWORK SOCIETY/GOVERNMENT

(1) D_s Density of Access

(2) N^* Operational System Nodes

(3) A_R Area of Region

(4) A_N Area Served by each Node

(5) e Paths in the Network

(6) N^* Nodes in the Network

SYSTEM-WIDE INDICATORS

(1) PT Passengers Marking Transfers

(2) APM Average Trip Length

(3) ARM Average Run Length

(4) ORN Operating Revenue of Access Points

(5) OCN Operating Cost of Access Points

(6) ORF Operating Revnue of Links

(7) OCE Operating Cost of Links

(8) CME Maintenance Costs of Links

(9) MHME Manhours Spent Maintaining Links

(10) CMN Maintenance Cost of Access Points

(11) MHMN Manhours Spent Maintaining Access Points

(12) SM Length of all Links

(13) $\overline{VM}$ Average Vehicle Miles Between Breakdowns

(14) CMRS Cost of Repair and Maintenance of Rolling Stock

Preface

This project was in effect an effort to test with actual data some of the conceptual developments of a previous project sponsored by the University Research Program of the Department of Transportation that focused on the conceptual analysis of Productivity, Efficiency and Quality of Service of the entire complex of an urban transportation system. The previous project was general in its approach and conceptual in nature. Thus the need for the work of the current project, essentially an extension of the previous effort and an actual test of the ideas expressed in the original project. The current project utilizes three test regions and focuses on the public transportation component of the total urban transportation system.

Since the project was to last only 12 months and since its budget did not include funds for any original data collection effort, it was naturally required to use only data already available. This turned out to be an important limitation of the project especially in securing and utilizing the detailed data associated with the various support functions of two of the three test regions. The reader also needs to bear in mind that no quality control could be maintained in any area of the data inputs. Of course, the objectives of the project were not to focus on three specific regions as such, but to utilize data from three test regions in order to demonstrate some central and generally applicable concepts of analysis. This objective can be met even with incomplete or even slightly inaccurate data sets, in terms of detailed breakdowns of aggregate totals. This is exactly what the project, reported in these volumes has tried to do.

The project was assisted by a team of graduate students who worked under the guidance of Dr. Anthony R. Tomazinis, Principal Investigator. Dr. Shiv Gupta, Associate Investigator, served as an advisor and reviewer of the project and contributed in this manner immeasurably to the successful completion of the project. The graduate students who participated in this effort were the following (in alphabetical order): Mr. Steven Beier, Mr. Barton Betz, Mr. Arthur Foran, Mr. Alan Kurtz, Mr. Kamil Siddiqi, Mr. Steven Stryker and Ms. Jeh Wang. In a smaller capacity and shorter duration, the following students also contributed to this project: Mr. Larry Eisenberg, Mr. Howard Evoy, Mr. Barry Owen, Mr. Ramana Rao, Mr. Timothy VanEpp and Mr. Zachary Johnson.

While the contributions by the various members of the team, and those of the Monitoring Officer of DOT, Mr. Douglas Gerleman, are gratefully acknowledged, the responsibility for the remaining shortcomings of this report belongs, of course, to the primary author and Principal Investigator.

Philadelphia, June 1976

Anthony R. Tomazinis
Principal Investigator

ANALYSIS OF INPUTS AND OUTPUTS OF
URBAN PUBLIC TRANSPORTATION SYSTEMS

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CHAPTER I

PROJECT DESCRIPTION

Introduction

This Final Report is the result of a research project on Urban Public Transportation Systems (UPTS) performance indicators, with emphasis on efficiency indicators. The project was sponsored by the U.S. Department of Transportation (US DOT), Office of University Research, and was carried out by a research team at the Transportation Studies Center of the University of Pennsylvania, before its discontinuation in the middle of 1976. The scope of the project was initially somewhat different in terms of where the exact emphasis of the work was to be placed. This is indicated by the initial title of the project, "Primary Services vs. Support Functions in Urban Public Transportation Systems", which clearly suggests a concentration on the relationships between primary services and support functions. The project contemplated, in fact, pursuing these relationships with data from more than twenty UPTS of various sizes and location. This initial intention of work program and project scope was substantially modified as soon as the problems with the required data became evident. In addition, a review of other research activities in the country and within US DOT, plus an articulation of the immediate research needs of various parts of the US DOT, voiced by the project's monitor, suggested a desirable turn in the project's direction. As a result, the emphasis manifest in this Final Report was established bearing two essential characteristics, i.e., first a major concern with data inputs for efficiency studies for UPTS, and second, a direct concern with efficiency indicators only instead of abstract relationships or generalized system performance measures.

A second historical note is pertinent here in terms of the conceptual development of the project. This is, in fact, the second phase of a research effort that started in 1973 on "Productivity, Efficiency and Ouality Studies in Urban Transportation Systems". The first phase of the effort produced directly, a Final Report on October 1974, and indirectly, a major book publication in November 1975.[1,2] During the first phase of the work, the central conceptual issues of productivity and efficiency within UPTS were explored. The need to relate efficiency with quality of service was also noted and a number of general cases were discussed in some detail. Phase One concluded with the establishment of a general theoretical framework for studies in pro productivity, efficiency and quality of service in UPTS. The same study concluded also with a list of problems that productivity and efficiency and quality analyses are bound to face in urban transportation. Among the problems identified were the data availability and reliability problems in determining, in sufficient detail and accuracy, both the inputs to and outputs from an UPTS. This first project concluded with a comprehensive list of productivity, efficiency and quality indicators that would need to be calculated in any specific study in the future.

1/ A.R. Tomazinis, et al, Final Report. Vol. I: Concepts, Issues and Measures in Efficiency Analysis of Urban Transportation Systems. Vol. II: Concepts, Issues and Measures in Productivity Analysis of Urban Transportation Systems. Oct. 1974.

2/ A.R. Tomazinis, Productivity, Efficiency and Quality in Urban Transportation Systems, Lexington Books, D.C. Heath & Co. Lexington, Mass., 1975.

Phase Two of the effort, i.e., the current project, picks up where Phase One has left off and proceeds with a specific test case. For this reason, the essential objective of the current study becomes the test of the feasibility and meaningfulness of the efficiency indicators suggested in the previous project. The test is carved out on the basis of the data available in three test areas, varying in size from 0.5 million to 3.5 million population, and in complexity from a simple small town bus system to a complex, five-mode system of a metropolis. The emphasis in this phase of the work has shifted, of course, from the total urban transportation system to only the public urban transportation system of the three test regions.

1.0 The Basic Approach

The general approach followed in this project is consistent with the conceptual approach developed in the previous phase of the research effort on productivity and efficiency. It essentially includes three important elements as follows: (1) the division of the total UPTS into three fundamental components; (2) the inclusion in the analysis of four actors that interact with the UPTS; and (3) the development of specific rather than generalized input-output relationships by function and system component.

1.1 System Components

The overall UPTS is conceived as being formed by three fundamental components: the network of the systems, the primary services provided over the available network, and the support functions that make the possible functioning of the network and the availability of the primary services.

The allocation of system inputs is based upon activity-specific, or functional and temporal criteria. The expenditure of funds, labor or energy was always associated with one of the system components. Definitionally, each of the components was specified as follows:

Primary Services: Those activities, expenditures and resources that are both necessary and sufficient to produce an optimum travel service.

Support Functions: Those activities, expenditures and resources consumed in the non-daily operation and maintenance of the network and primary facilities, and of the overall system.

Network: Major capital expenditures for fixed assets--links, nodes, stations and terminals.

These definitions are normative and mutually exclusive. According to those definitions, Primary Services include all the services that are performed on the network (links, stations and terminals) as well as all the associated facilities such as rolling stock. Labor devoted to these services plus all directly associated operational and managerial devices are included as inputs to these primary services. The Support Functions include all the supportive facilities, managerial staff and facilities, regulatory provisions, computer controls, repair shops, maintenance facilities, training facilities, etc. The Network includes all the fixed facilities such as links, stations, nodes and terminals.

Questions immediately arise as to passenger stations -- are they network or primary? Also, would a maintenance man involved in the daily care of a revenue vehicle be considered primary service or support function? To resolve these and other definitional problems, the definition of primary services must be detailed so that it is less ambiguous, and thus more clearly includes those activities, expenditures and resources utilized in relations to the direct provision of an optimum transportation service. For this reason, specific definitional determinations were made for each distinctive part and function of the system. Appendix H of this report presents these definitional determinations.

1.2 System Actors

From the outset, the problem of interaction between an UPTS and its environment was conceived as including more actors than simply the operator-supplier of the system. Of course, the important role that the operator plays in all cases is quite obvious and therefore, it seems imperative that any productivity and efficiency study takes, first of all, the concerns of the operator into account in determining efficiency requirements and productivity objectives.

Beyond, however, the role of the operator, the analyst must recognize the role of the direct user of the system in this interaction. It seems quite apparent that the user makes direct inputs to the system from which he needs outputs that meet his needs quantitatively and qualitatively. It seems, therefore, obvious that an efficiency analysis of an UPTS would need to include efficiency measures from the point of view of the user if such an analysis is going to reach any level of completeness.

In addition to these two actors, it seems apparent in today's set of circumstances that an urban public transportation system does not operate within an insulated vacuum that includes only the system's operators and users. In fact, it is quite obvious that society at large has a major concern with regard to these systems. So many essential societal functions depend on a properly functioning UPTS to make such a system an essential concern for the society at large. In this respect society takes the place of a third actor in this complex interaction, which, although it includes the operator and the direct user per se, it encompasses much more than that. In essence, society encompasses all the interest, population groups and objectives that a given region may include.

Finally, in today's realities, in which government at all levels is found directly being involved with urban public transportation systems (controlling them, riding them, and finally, funding them) it seems appropriate to include government as the fourth bona fide actor in the interaction between an UPTS and its environment. Government, acting in the name of society which it serves, takes many direct and indirect actions which involve substantial inputs. For this reason, any reasonable efficiency analysis would need to include the point of view of government in assessing inputs to and outputs from an UPTS, if such analysis is going to reach convincing conclusions.

These four actors together with the three system components form then the "assessment space" within which the present study evolves in exploring efficiency concepts and measures together with all the associated problems and limitations.

1.3 Inputs Outputs Framework of Relationships

The overall methodological approach followed in this can be characterized by three essential concepts that dominated the study, i.e., the structure of inputs and outputs; the relationships between inputs and outputs; and the process of aggregation of inputs and outputs from individual entities into larger aggregates. Each concept needs some more explanation before it is used.

Figure I-1 indicates the inputs-outputs structure or framework for UPTS. As it can be seen, the inputs of each of the four actors enter essentially into each discreet component of the system, i.e., primary services, support functions, and the network. From each component, some internal outputs are then produced that can be combined to effectuate an "operational network" and an "effective service potential". From these two intermediate steps, the internal outputs are then produced in order to effectuate the

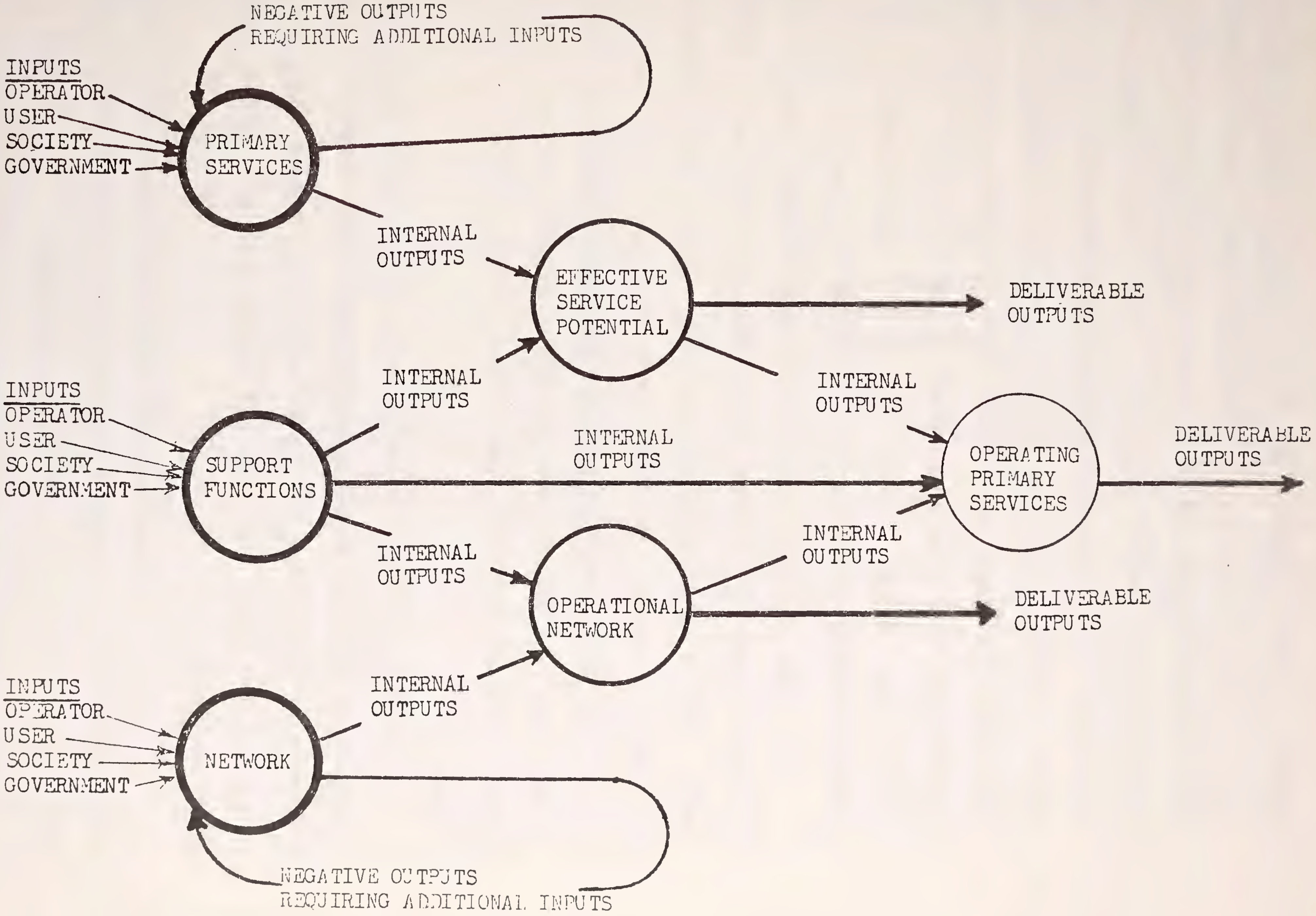


Figure I-1. INPUTS/OUTPUTS FRAMEWORK OF RELATIONSHIPS "operating primary service" of the system. From these last junctions (the effective service potential, the operational network, and the operating primary services) the actual 'deliverable' outputs are more available to all four actors of the system. Of interest is also the fact that both the primary services and the network of an UPTS usually also produce undesirable, negative outputs, i.e., air pollution, environmental degradation, etc. These outputs are taken into account by this structure of inputs outputs by the additional inputs that they require in order to control them and/or ameliorate their negative inputs. This fact is shown in Figure I-1 by the loops that originate from and return to the primary services and the network.

The second essential concept of the methodological approach is shown in Figures I-2 and I-3. Figure I-2 indicates the first set of relationships sought. They are associations between inputs to the system and outputs from the system. The inputs are divided into fiscal and physical inputs while the outputs are divided into total system outputs (products) and only these outputs that have actually been utilized by the users. These relationships need to be traced, of course, for all four actors and for the system-wide totals.

Figure I-3 presents the second set of relationships explored in this study; those involving inputs between various system components. Since the emphasis in this study is on primary services vs. support functions, the input-to-input analysis focuses on the relationships of inputs in those two system components.

While the first set of relationships between outputs and inputs produce essentially a set of unit costs for all the system outputs for each actor, and for all actors put together, the second set of relationships are

INPUTS TO UPTS	OUTPUTS FROM UPTS	
	TOTAL SYSTEM PRODUCTS	UTILIZED SYSTEM PRODUCTS
FISCAL		
PHYSICAL		

Figure I-2. A MATRIX OF INPUTS TO OUTPUTS FOR AN UPTS

INPUTS TO UPTS

INPUTS TO UPTS	PRIMARY													SUPPORT								
	PCI	POE	PLI	PEI	V	DCCT	DCCT	KWH	PUI	F	TT	A&I	PSI	SCI	SOE	SLI	SEI	MA	MA	OCRM	OCRM	KWH
PRIMARY: PCI		*	*	*					*				*									
POE	*		*	*	*				*				*									
PLI	*	*							*				*									
PEI	*	*	*						*				*									
V	*	*	*	*		*	*	*	*			*	*									
DCCTA (hrs)					*																	
DCCT (#)	*				*																	
KWH (tra)																						
PUI	*	*	*	*																		
F																						
TT																						
A&I					*																	
PSI	*	*	*	*	*																	
SUPPORT: SCI	*				*				*				*		*	*	*					
SOE	*	*	*	*	*				*				*	*		*	*					
SLI	*	*	*	*	*				*				*	*	*		*					
SEI		*	*	*	*				*				*	*	*	*						
MA (hrs)					*	*	*															
MA (#)					*	*	*					*										
OCRM (hrs)					*	*	*											*	*		*	
OCRM (#)					*	*	*					*						*	*	*		
KWH (s)								*														

Figure I-3. A MATRIX OF INPUTS TO INPUTS FOR AN UPTS essentially comparisons expressing the relative assistance that each system component receives or requires.

This methodological approach in relating outputs to inputs has also been followed in terms of specific mathematical functions. For instance the function:

$$y = a + bx_1 + cx_2 + dx_3 + ex_4$$

may represent the cost per vehicle-mile (y) in terms of direct labor inputs (x_1), maintenance labor (x_2), managerial labor (x_3) and cost of rolling stock (x_4). The co-efficient a may also represent fixed costs of the system, which the co-efficients b,c,d, and e, would represent to the extent to which the variables x_1, x_2, x_3 and x_4, are important in determining the value of y.

The third essential methodological concept is centered on the aggregation requirements of an efficiency study, Figure I-4 indicates the sequence of aggregations necessary for efficiency studies. As it can be seen, the foundation is established on single element efficiency indicators which focus on single functions within the system and which correspond to the level of responsibility of a single supervisor. A second set of efficiency measures are derivable at the level of a whole sector within a system's component. It corresponds to the level of responsibility of an operations or branch manager, and they can be formed by aggregation of input and output data from the single element to that of a whole sector. A third set of efficiency measures are derivable on the system component level by aggregating all the sector based data sets. This level of efficiency measure may correspond to the level of internal responsibility of Division Head. Finally, a fourth set of efficiency measures is derivable on a system-wide level.

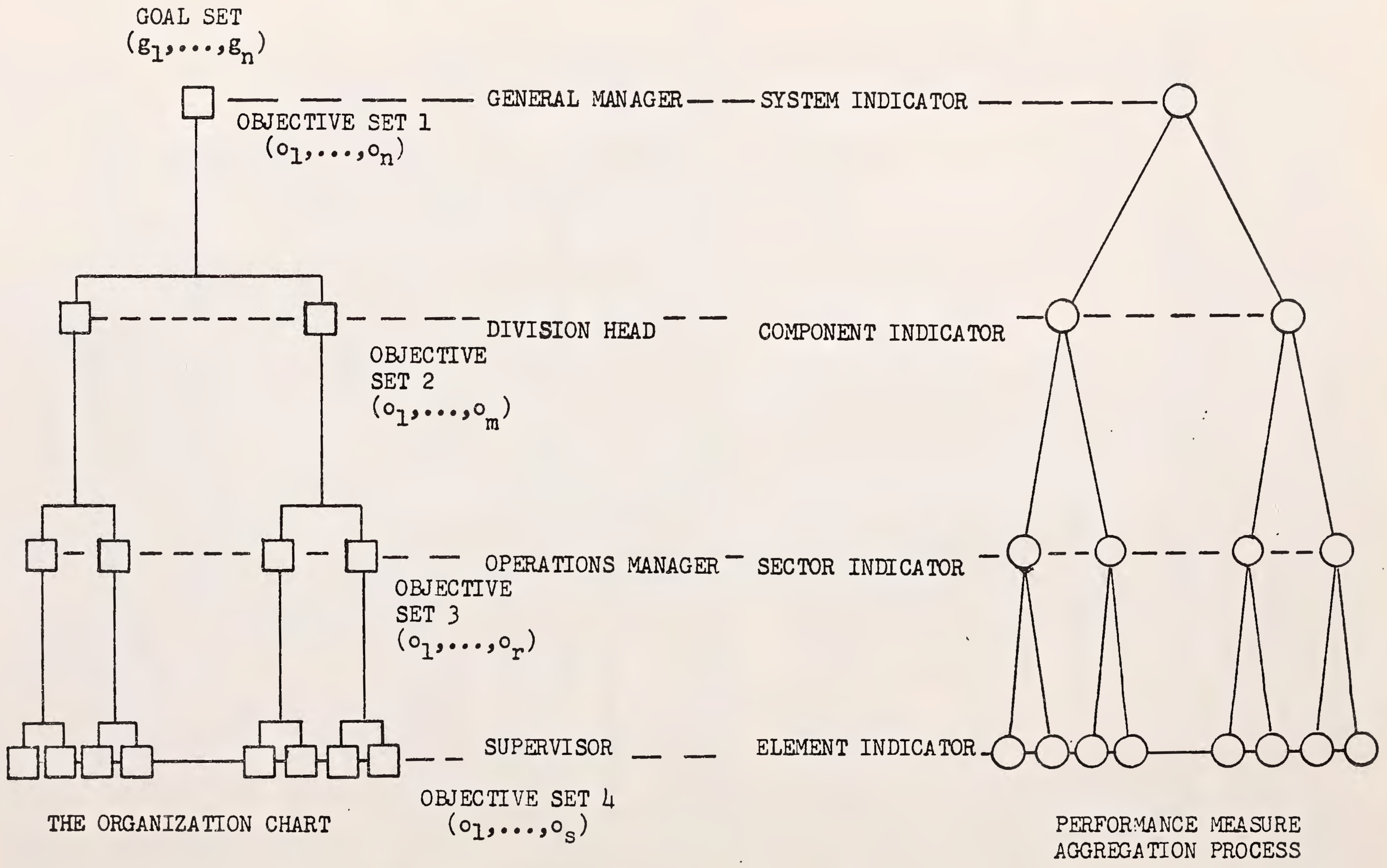


Figure I-4. CORRESPONDENCE BETWEEN EFFICIENCY MEASURES AND MANAGEMENT RESPONSIBILITIES

This can be accomplished by combining data sets from three system components by proper aggregation and elimination. This set of measures corresponds with the general manager level of responsibility and are then addressed to internal and external need, for control and reporting.

2.0 The Three Test Regions

In agreement with the Contracting Officers Technical Representative, the Principal and Co-principal Investigators of this Project, it was decided that three test cases will be used for the purposes of this study. The three test cases involve the selection of three test regions with appropriate urban public transportation systems that can provide the data and the conditions for a promising test. The finally selected three regions (and systems) are the following:

(a) the New Jersey portion of the DVRPC Study Area (NJ Region);

(b) the Pennsylvania portion of the DVRPC Study Area (Pennsylvania Region); and

(c) the Wilmington SMSA (Delaware Region).

The first region is primarily served by PATCO's Lindenwold Line and the bus lines of Transport of New Jersey. Its resident population is about 1.5 million, includes four counties, a central city, and is entirely in one state.

The second region is served by SEPTA (Southeastern Pennsylvania Transportation Authority) as the chief operator in the area with an extensive network of rapid transit, light rail, buses, streetcars and trolley coaches distributed in its region. It is further supported by extensive commuter service largely contracted by SEPTA from Penn Central and Reading Railroads. It includes a resident population of about 3.5 million, five counties, a major central city, and is entirely within one state.

The third region is a bus-oriented region, entirely. Its resident population is about 0.5 million, it includes three counties, a medium size central city, and is spread into three states.

3.0 Data Needs

An efficiency study of this nature is based heavily on the quality of data available. For instance, let us consider the labor aspect of the total urban transportation system and have SEPTA as our frame of reference. SEPTA, as the chief transit operator in the Pennsylvania portion of the Philadelphia region, has three divisions under it. They are City Transit Division (CTD), Red Arrow Division (RAD), and General and Contract Division (GCD).

Two of these divisions have several modes comprising them and serving along different routes and various influence areas. The CTD has rapid transit (subway), light rail (streetcar/trolley/subway-surface car), buses and trolley buses among its multi-modal fleet. The RAD has light-rail as well as buses operating on its various routes. The GCD contracts services from Penn Central and Reading Railroads, which provide transit facilities to the bulk of commuters working in this area. The labor inputs to such a complex system are intricate and quite difficult to measure in all its detailed characteristics.

Also, the labor inputs when examined from the operator's point of view, should again be disaggregated into the various system components. For instance, the support functions would include at least the following:

(1) Managerial functions;

(2) Repair and maintenance functions;

(3) Information and marketing functions; and

(4) Physical facilities functions.

Each of these will have their own subclassifications of labor inputs. For instance, labor input in the managerial functions may be further disaggregated by labor engaged in the following:

(1) Management and administration functions;

(2) Scheduling and dispatching of vehicles;

(3) Personnel and training functions;

(4) Procurement of resources; and

(5) Financial and accounting functions.

Therefore, when examining from a particular point of view, a specific system component and a specific input (such as the labor input), there is a need for extensive disaggregation into very specific classes of that input. Such specific classes of inputs must be defined even further according to the various units of measurement whose quality is equally important. For instance, labor input should be measured in man-days rather than man-years, or even better, man-hours in preference to man-days. On the other hand, a very specific kind of labor input, performing a very specific function, may be further qualified by full-time, part-time or on overtime basis.

Such detailed analysis is required for all the other system inputs that are realized by the different actors. The same is required of outputs, associated with quality measurements, before the analyst undertakes the development of efficiency indicators of the system components and also to evolve measures of total system productivity.

Furthermore, in order to compare and analyze various measures of urban transportation systems productivity and the efficiencies of its various components, it is important to be able to understand such transit operating characteristics as the area and population served, the size of the transit vehicle fleet and the size of operations, operating and capital expenses and revenues, ridership,and other system outputs such as vehicle-or seat-miles. Also, the detailed disaggregation of expenditures incurred in the production of primary services and support functions, the manpower involved in the production of various system components or resources,such as energy consumed at various levels, are vital for arriving at any logical conclusion.

4.0 Study Limitations

There are several limitations or constraints that must be acknowledged from the outset of this study. First, the limitations imposed upon the study by the availability and quality of data have already been referred to earlier. These type of limitations are important indeed for some types of analytical work that the team may desire to undertake. For instance, the fact that the study is essentially an exploratory one, involving only three test regions, precludes any extensive correlation or regression analysis and the establishment of any empirical functions since there can only be at maximum three observation points.

In order to overcome this limitation the study was initially intended to cover five fiscal years for each test region (1970-74). However, it soon became apparent that there hardly was any reliable information available for 1970 and 1971. Beyond even this realization came the fact that the years in the recent past were formative years for all the systems in the three test regions. For the Delaware region DART (Delaware Authority of Regional Transportation) was formed early in the 1970's and it was, then, in its formative years. For the Pennsylvania Region SEPTA (Southeastern Pennsylvania Transit Authority), while it was established on paper in 1963, had its first year of full operations for the CTD division in 1969 and for RAD (Red Arrow Division) in 1972. For the New Jersey Region the TNJ (Transport of New Jersey) faced many adjustments after the construction of the Lindenwold Rapid Transit line (PATCO) in 1969 and after the 1971 agreement for feeder bus lines.

As it was stated earlier, this study is in essence Phase Two of the research effort on productivity, efficiency and quality of urban transportation systems. This sequence of events carries also several implicit limitations for the study. First of all, it becomes deliberately a study that intends to test some specific ideas, developed in some preliminary manner during a previous phase of the research effort. Second, the study limits itself of interest to only the public transportation system of urban areas.

The data limitations, then, together with the subject matter limitations imposed by the sequence of the research efforts, establish for this project its major character. It is for this reason that the emphasis of this research project is essentially twofold:

First: To set up the elements of the problem by collecting the data and forming in all possible detail the matrices for inputs and outputs, including fiscal and physical inputs and outputs as well as direct, estimated and proxy data elements.

Second: To carry out a set of the essential calculations in establishing efficiency measures for three actual test regions, and discover, then, the feasibility and meaningfulness of the actual measures.

5.0 Report Outline

The present report follows a discreet presentation of each subject matter in which the item was handled during the actual work program of the project. Thus Chapter II of this Final Report is focused on the actual derivation of the efficiency measures for the three test regions as discussed earlier in 2.3 of this chapter. Problems and results of this aspect of the effort are presented there. The next Chapter III presents an overview of the set of inputs that enter an UPTS. This chapter is followed by five chapters, all focussed on the inputs of UPTS. Chapter IV deals with the fiscal inputs to the system. Chapter V deals with the physical inputs or the discreet entities of inputs, i.e., labor, land, rolling stock, etc. Chapter VI deals exclusively with the labor inputs in both the physical sense and their fiscal translation. Chapter VII deals with the capital inputs to the system in terms of the fixed assets that the system needs, and in terms of the annual amortization cost that must be considered for each system. Chapter VIII deals with the energy inputs to the system in an ad hoc manner.

Chapter IX deals finally with the outputs of the system, in all their form. This is the only chapter that deals with the system outputs in this project. In this respect an imbalance of effort might be seen but it seems that there was little that this project could add to what this chapter already includes. Chapters X, XI, and XII deal again with inputs but this time from the point of view of strictly each actor, i.e. the user inputs (Chapter X), the inputs that society at large makes for UPTS (Chapter XI). and the inputs that the government makes (Chapter XII). As can be seen no special chapter is devoted to inputs from the point of view of the operator. This is so because essentially this is done in the chapters of fiscal inputs as well as in the chapters on labor and capital inputs.

The final Chapter XIII includes some of the conclusions that were reached by the project.

Finally, nine appendices are included at the end of this volume with additional information pertaining to the discussions and calculations in the preceding chapters.

CHAPTER II

DEVELOPMENT OF EFFICIENCY MEASURES OF UPTS

Introduction

The development of efficiency measures for our urban public transportation system can pose a number of major questions from the outset.

First, the question of what a system measurement is, needs to be answered. An UPTS can be seen as a static composition of parts, or as a dynamic mechanism. Obviously as a static composition of parts, the UPTS would suggest a quite different list of measures than in a dynamic system that requires continuous inputs, carries flexible operations, and produces continuous and variable outputs. For the purposes of this research effort, the UPTS should be seen primarily as a dynamic system that carries out a production process. In this respect measurements need to be developed indicative of the production process that takes place within the UPTS. Furthermore, since the inputs to and outputs from the system produce additional outputs outside the system itself, it seems necessary to develop measurements which are also indicative of or sensitive to the outputs of the system and to its inputs outputs relationships produced in its immediate environment.

The above observation suggests that the traditional benefit-cost analysis (which leads to a ratio between costs and benefits) of urban transportation systems is quite pertinent to the main issue of system measurements.

If benefits are considered all the beneficial outputs of the system, and costs, all the inputs that the system requires, then their relationship would indeed produce a measurement which would be quite indicative of the desirability of the system's performance. Such a measure however bears certain important limitations. First, the costs and benefits would need to be associated with the particular contributor or receiver. Second, the costs and benefits in the traditional application of benefit-cost analysis are usually the increments of an existing or prevailing situation. In this respect, the comprehensive conditions of the system, as already exist, are not really taken into account. Third, a B/C ratio can hardly focus on system components and their specific input output associations. For all these reasons, it seems desirable to develop system measurements which are more comprehensive and more incisive than the typical B/C analysis.

What really is at stake is the measurement of the system in terms of the productivity of the entire system and in terms of the quality of services offered by the system. Although these statements are almost obvious in terms of stating objectives, the problems of how, indeed, efficiency, productivity and quality in UPTS can be measured, remains unsolved. There are, in fact, many problems that reveal themselves as soon as the analyst attempts to initiate such an undertaking. The previous project has belabored on these problems,[1/] and, in essence, has established the central questions that the current project is attempting to answer in an actual situation based on three test regions.

1/ Tomazinis, A.R. op. cit., 1974.

1.0 The Needed Measures of Performance

In terms of further definition of the needed system measurements, the work of this project revealed that such measurements need to be characterized by several features.

First, it seems apparent that each measure must be associated with primarily one of three system performance objectives set forth above. That is, each measure should be indicative of the efficiency or productivity or quality of service of the system. After that association has been established, then, each measurement would need to take the form of an indicator that carries the following four characteristics:

(a) It is expressive of what is measured, and of what contributes in its measurement. In this respect, the indicator should not be an abstract number nor should it be produced indirectly and with data not clearly identifiable.

(b) It is sensitive to the detailed operations of the system and of the environment within which the system operates. In this respect, the indicator should not be a gross number which does not perceptively change when an important change in inputs or outputs has occurred.

(c) It is doable (or calculable) within the typical framework of a well-organized transit system. In this respect, the system indicates what is needed should be derivable with the use of data that can easily be extracted from our UPTS and that can be manipulated. These data inputs should be divisible and additive so that the analyst can trace the corresponding data into smaller or larger aggregations of operations.

(d) It is easily understandable by those individuals that need to make planning or managerial decisions and by those policy makers that need to derive policy directions. In this respect, the needed system indicators should be as direct and as clear as a policy issue usually needs to be for public debate and public scrutiny. If a set of system indicators are going to be used by decision makers (at any level) these indicators need also to be relatively few in number and mutually reinforcing.

2.0 The Methodological Approach

In the previous chapter, the main outline of the methodological approach followed in this research project has been presented. Before the actual use of this approach some additional insights might be helpful.

The essential approach is expressed by the formulation of ratios between (a) inputs and outputs and (b) between inputs into the various system functions.

The first type of ratios, of outputs over inputs, are essentially expressive of unit costs of each type of output. Interestingly enough, by expressing outputs in physical terms (i.e., passenger trips) and inputs in monetary terms, the dollar unit cost of each output is established. Conversely, if the inputs are also expressed in physical terms (i.e., amount of labor), then the functional relationship between outputs and inputs is established. In this project, the reader must notice that no use is made of the monetary revenue of a UPTS as a fiscal output of the system. This is so because of the severe controls that this industry faces, and the peculiar circumstances it encounters. Thus, the fares are almost in all cases set on the basis of political realities or policy directions. In this respect, the revenues produced by the operations of the system can hardly be considered as a satisfactory output measurement for the system. This situation is, of course, peculiar to this system and is in contrast to other industries where the most effective output measure is the revenue produced by the operations.[2]

Another observation with regard to the input output ratios is the fact that both inputs and outputs can be directly related to a particular actor who contributes the inputs or receives the outputs. In this respect, the analyst may also have the opportunity to establish which one of the actors contributes more than he receives, or for the sum of the four actions which system requires more inputs or produces more outputs. And, in the particular case where total fiscal inputs are used together with a fiscal presentation of outputs (i.e., direct user contributions) the analyst can establish, for this case, the extra contribution the system needs in monetary form for its operation (i.e., total operating deficits).

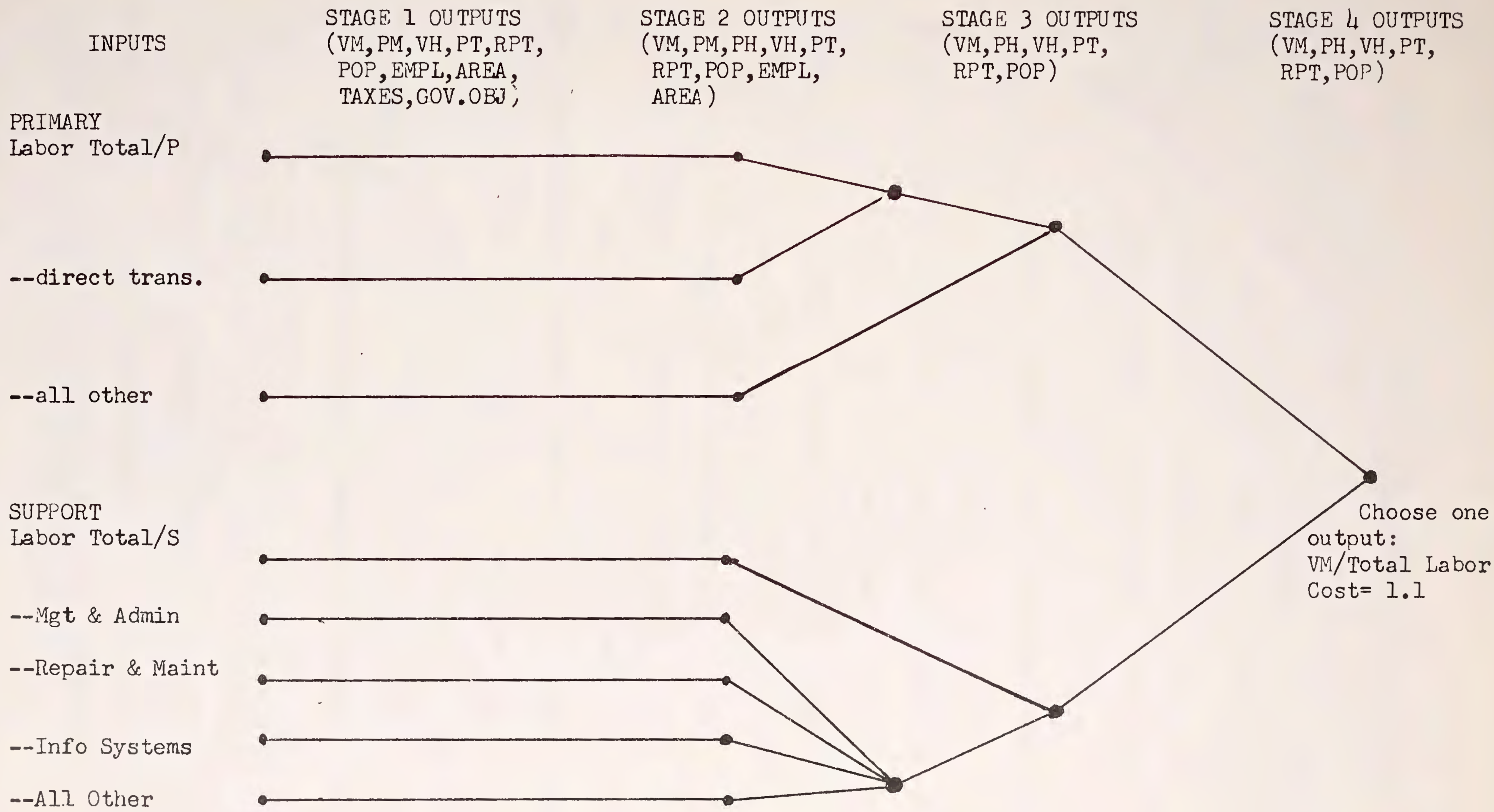
The second type of ratios, of inputs over inputs, has also particular significance. Stating both inputs in fiscal or physical terms the analyst may reveal the proportional support that a particular function receives within the system. This type of analysis is particularly relevant to the initial objectives of this project to explore support functions in comparison with the primary services of a UPTS. The analysis can be carried out in great detail as well as on a total system component basis. Because of this flexibility, the number of input to input ratios can indeed be quite great; at the same time, these ratios can also be directed to various client groups or analysis purposes. As shown in Figure I-3 of the previous chapters, such specific comparisons can be formed within each system component, as well as between system components or specific functions.

2/Provided that the variations in the structure of prices have also been taken into account.

In actually developing a mathematical relationship between amounts of output items and specific sets of inputs, or between unit costs of output items and proportions of contributing partial inputs, it soon became evident that with only three regions, there was not sufficient statistical basis for such an undertaking. For this reason, no mathematical functions were attempted in this project.

The problems of aggregation proved to be more vexing and complex than an initial review may reveal. Figure II-1 indicates the process followed. Combining this figure with Figure I-3 of the previous chapter can assist the analyst to assess the difficulties. The problem is accentuated by the introduction of the requirement, presented earlier in Section 2.0 of this chapter, that system indicators must be easily understandable by decision makers and even the general public. Furthermore, in addition to this requirement, the system indicators should be few in number and mutually supportive. Taking all these aspects of the problem, one can soon realize that any approach followed would be replete with problems. The approach followed in this project was the combinatorial tree analysis with sequential executions of eliminations and combinations. As the process moves from the partial, function-specific ratios to larger entities and broader definitions of functions, many ratios are eliminated as irrelevant or inapplicable. Additionally, many similar sets of data are being combined to produce new sums which then can be used to form new ratios. Finally, combinations can be formed by using multiplications or divisions of previous ratios in order to obtain composite new ratios.

The results of all the above processes and steps are presented in the following section.



NOTE: INDICATOR USED WAS VEHICLE MILES DIVIDED BY TOTAL LABOR COST TNJ (SOUTHERN DIVISION, DURING 1974)

Figure II-1. COMBINATORIAL TREE AGGREGATION(live data)

3.0 Derivation of Measures (Indicators)

The derivation of the actual system measures, with emphasis on the efficiency of the operations, can reasonably well start with a table like Table II-1A and II-1B in which the meaningfulness of each input output relationship is being scrutinized. Table II-1A and II-B include only 130 and 117 relationships that can be considered meaningful in terms of revealing an important condition. This represents a ratio of about 1/3 of the total potential relationships in each of these two tables. Of course, the analyst may also notice that these two tables include only 11 of the 27 output variables included and discussed in Chapter IX of this report (eight in direct outputs, six as estimated outputs, nine as proxy outputs and four as unspecified outputs). Also Table II-1A includes only 33 out of 120 input variables, included in detail in the Fiscal Input Matrix described in Chapter IV of this Report. Correspondingly, Table II-1B includes only 27 input items out of the 45 input variables included in the Physical Inputs Matrix described in Chapter V of this Report. Notice also that the entire discussion is done on the basis of input variables related to the operator only, i.e., a single actor out of the four actors identified already and discussed in detail in Chapters X, XI and XII of this Report. It is clear, therefore, that the analyst needs first to scrutinize the meaningfulness and relevancy of the potential relationships between the pairs of input and output items. Only a very small proportion of the vast number of ratios possible will prove meaningful, and still, a much smaller number of actual ratios should be finally calculated. Thus, the immense data requirements of a complete set of relationships are reduced materially.

From Tables II-1A and II-1B the effort moves to the actual estimation

Table II-1A. MEANINGFULNESS OF INPUT/OUTPUT RATIOS(OPERATOR)

FISCAL ITEMS	MODAL OUTPUTS						SOCIETAL OUTPUTS			GOV'RN. OUTPUTS	
	VM	PM*	PH	VH	PT	RPT	POP	EMPL*	AREA*	TAXES*	GOV'T OBJ.
PRIMARY INPUT											
New Capital T/D#	O	O	O	O	O	O	O	O	O	O	O
<u>Expenses T/D</u>	X	O	O	O	X	X	X	O	O	O	O
-Trans. & Fuel	X	O	O	O	X	X	X	O	O	O	O
-Other#	O	O	O	O	O	O	O	O	O	O	O
<u>Old Capital T/E</u>	X	O	O	O	X	X	X	O	O	O	O
-Old Way	X	O	O	O	X	X	X	O	O	O	O
-Existing Equip.	X	O	O	O	X	X	X	O	O	O	O
<u>Labor Total/E</u>	X	O	X	X	X	X	X	O	O	O	O
-Directions	X	O	X	X	X	X	X	O	O	O	O
-All others	X	O	X	X	X	X	X	O	O	O	O
<u>Energy Total/E</u>	X	O	O	O	X	O	X	O	O	O	O
-Op. stations	X	O	O	O	X	O	X	O	O	O	O
-Daily Maint.	X	O	O	O	X	O	X	O	O	O	O
SUPPORT INPUT											
New Capital T/D#	O	O	O	O	O	O	O	O	O	O	O
<u>Expenses T/D</u>	X	O	O	O	X	X	X	O	O	O	O
-Mgt. & Admin.	X	O	O	O	X	X	X	O	O	O	O
-Repair & Maint.	X	O	O	O	X	X	X	O	O	O	O
-Traffic promo	X	O	O	O	X	X	X	O	O	O	O
-All other	X	O	O	O	X	X	X	O	O	O	O
<u>Labor T/D</u>	X	O	X	X	X	X	X	O	O	O	O
-Mgt. & Admin.	X	O	X	X	X	X	X	O	O	O	O
-Repair & Maint.	X	O	X	X	X	X	X	O	O	O	O
-Info. Systems	X	O	X	X	X	X	X	O	O	O	O
-All other	X	O	X	X	X	X	X	O	O	O	O
NETWORK INPUT											
New Capital T/D#	O	O	O	O	O	O	O	O	O	O	O
<u>Old Capital T/E</u>	X	O	O	O	X	X	X	O	O	O	O
-Existing way	X	O	O	O	X	X	X	O	O	O	O
-Existing Bldgs &Stations	X	O	O	O	X	X	X	O	O	O	O
-Existing Equip.	X	O	O	O	X	X	X	O	O	O	O
<u>SYSTEM-WIDE INPUT</u>					R E T A I N E D I T E M S						
Capital T/D+E	X				X	X	X				
Op. Expense T/D	[X]				[X]	[X]	X				
Labor T/D+E	X		X	X	X	X	X				
Energy T/E	X				X		X				

VM = Vehicle-miles
PM = Passenger-miles
PH = Passenger-hours
VH = Vehicle-hours
PT = Passenger-trips
RPT = Revenue Passenger-trips

POP = Population Served
EMPL = Employment Served
AREA = Geographic Area Served
TAXES = Operator Taxes
GOV'T OBJ. = Achievement of Government Objectives

D = Direct
E = Estimate
X = Meaningful
O = Meaningless
* = Output Eliminated
\# = Input Eliminated
T = Total
□ = Included in Table II-2

NOTE: Underscored items indicate aggregated input item.

Table II-1B. MEANINGFULNESS OF INPUT/OUTPUT RATIOS (OPERATOR)

PHYSICAL ITEMS	MODAL OUTPUTS						SOCIETAL OUTPUTS			GOVERN. OUTPUTS	
	VM	PM*	PH	VH	PT	RPT	POP	EMPL	AREA	TAXES*	GOV'T OBJ.*
PRIMARY INPUT											
Capital											
-T Fleet Size	X	O	O	O	X	X	X	O	O	O	O
-Peak Hr Fleet	X	O	O	O	X	X	X	O	O	O	O
-Vehicles Deployed	X	O	O	O	X	X	X	O	O	O	O
Labor (Direct Trans.)	X		X	X	X	X		X			
-Hours	X	O	X	X	X	X	O	X	O	O	O
-No. Employees	X	O	X	X	X	X	O	X	O	O	O
Energy	X				X	X	X				
-KWH Generated	X	O	O	O	X	X	X	O	O	O	O
SUPPORT INPUT											
Capital											
-Floor Area (Maint. Shops)	X	O	O	O	X	X	O	O	O	O	O
-No. Parking Spaces	X	O	O	O	X	X	O	O	O	O	O
-Ave. No. Vehicles in Garage	X	O	O	O	X	X	O	O	O	O	O
-No. Bus Repair Bays	X	O	O	O	O	O	O	O	O	O	O
Labor											
-Mgt. Employees	X	O	X	X	X	X	O	X	O	O	O
-Mgt. Labor Hrs.	X	O	X	X	X	X	O	X	O	O	O
- Major Repairs Employees	X	O	X	X	X	X	O	X	O	O	O
-Labor Hrs. in Major Repairs	X	O	X	X	X	X	O	X	O	O	O
-Routine Maint. Employees	X	O	X	X	X	X	O	X	O	O	O
-Labor Hrs. in Routine Maint.	X	O	X	X	X	X	O	X	O	O	O
-T Support Empl.	X	O	X	X	X	X	O	X	O	O	O
-T Support Labor Hrs.	X	O	X	X	X	X	O	X	O	O	O
NETWORK INPUT											
- Miles Way Track	X	O	O	O	X	X	X	O	X	O	O
- No. Stations (Stops)	O	O	O	O	X	X	X	O	X	O	O
- No. Stations (Amt. Floor Area)	O	O	O	O	X	X	X	O	X	O	O
- Route Miles (2-way	X	O	O	O	X	X	X	O	X	O	O
SYSTEM-WIDE INPUT											
Network & Capital/T	X				X	X	X		X		
Labor/T	[X]		X	X	[X]	[X]		X			
Energy/T	X				X	X	X				

VM = Vehicle-miles
PM = Passenger-miles
PH = Passenger-hours
VH = Vehicle-hours
PT = Passenger-trips
RPT = Revenue Passenger-trips

POP = Population Served
EMPL = Employment Served
AREA = Geographic Area Served
TAXES = Operator Taxes
GOV'T OBJ. = Achievement of Government Objectives

D = Direct
E = Estimate
X = Meaningful
0 = Meaningless
* = Output Eliminated
# = Input Eliminated
T = Total

of ratios. Tables II-2A and II-2B present a sample of what can be and has been estimated for the purposes of this project. Notice that Tables II-2A and II-2B include ratios of only inputs to outputs, but they include representative ratios for all four actors of the system. However, these two tables include ratios for each one of the transit operators in the three test regions, with subdivisions for inputs and outputs applicable to only the primary services, or the support functions or the entire transit system. Furthermore, each ratio needs to be reviewed carefully because they involve both fiscal and physical units of measurements in a mixed sequence (in contrast to the clarity included in Tables II-1A and II-1B where fiscal input variables are included in one table and physical input variables are included in the other). Finally, the analyst may notice that Tables II-2A and II-2B are for only one year, i.e., 1974.

Obviously a structural presentation of the various ratios between inputs and outputs is absolutely necessary. This is attempted in Tables II-3A, II-3B, II-3C and II-3D. The formation of these tables involve also total system variables and a focus on composite measures of efficiency. Inputs and outputs are also classified by actor so that each measure of efficiency is formulated with a specific actor in mind. Further, the inputs are distinguished as fiscal or physical inputs, while the outputs are classified into total outputs produced by the system and outputs actually utilized by the users of the system.

From the vast number of ratios that can be formed, Tables II-3A, 3B, 3C and 3D include, finally, only 45 measures of efficiency subdivided in a manner that permits the analyst to focus on smaller aggregations as is needed. For instance, there are only eight measures for government, and, among these, only two focused on outputs produced and fiscal governmental inputs to the

TABLE II-2A. PERFORMANCE MEASURE COMPARISON ::1974*

ACTORS & RATIOS \ SYSTEM	SEPTA - CTD			SEPTA - RAD			SEPTA - GCD		
	PRIM	SUPP	TOTAL	PRIM	SUPP	TOTAL	PRIM	SUPP	TOTAL
USER									
Σ all travel costs/pass.-trip	$ 2.58		$ 2.58	$ 3.96		$ 3.96	8.37		$ 8.37
Σ all travel costs/veh.-mi.	$ 10.00		$ 10.00	$ 11.20		$ 11.20	$ 18.44		$18.44
Σ in-system travel costs/pass.-trip	$ 1.06		$ 1.06	$ 1.72		$ 1.72	$ 2.66		$ 2.66
Σ in-system travel costs/veh.-mi.	$ 4.16		$ 4.16	$ 4.83		$ 4.83	$ 5.87		$ 5.87
Σ access costs/pass.-mile	$ 0.55		$ 0.55	$ 0.35		$ 0.35	$ 0.44		$ 0.44
accident costs/pass.-mi.	$ 0.005		$ 0.005	$ 0.003		$ 0.003	$ 0.003		$ 0.003
accident costs/veh.-mi.	$ .05		$ 0.05	$ 0.06		$ 0.06	$ 0.09		$ 0.09
pass.-trips/accident	249,900		249,900	125,900		125,900	191,300		191,300
veh.-mi./accident	63,900		63,900	44,700		44,700	86,900		86,900
Σ all travel costs/pass.-mi.	$ 0.93		$ 0.93	$ 0.61		$ 0.61	$ 0.65		$ 0.65
SOCIETY									
air pollution damage costs/pass.-mi.	0.01		$ 0.01	$ 0.012		$ 0.012	$ 0.0005		$ 0.005
air pollution damage costs/veh.-mi.	0.09		$ 0.09	$ 0.23		$ 0.23	$ 0.01		$ 0.01
GOVERNMENT									
Σ all costs/pass.-trip	$ 0.46	$ 0.01	$ 0.47	$ 0.34	$ 0.03	$ 0.37	$ 1.04	$ 1.04	$ 1.08
Σ all costs/pop. served	$ 28.95	$ 0.76	$ 29.70	$ 1.73	$ 0.16	$ 1.89	$ 8.15	$ 0.33	$ 8.48
Σ all costs/veh.-mi.	$ 1.80	$ 0.05	$ 1.85	$ 0.95	$ 0.09	$ 1.04	$ 2.30	$ 0.09	$ 2.39
labor hrs./pass.-mi.									
OPERATOR									
Σ all costs/pass.-trip	$ 0.54	$ 0.35	$ 0.97	$ 0.84	$ 0.49	$ 1.58			
Σ all costs/rev. pass.-trip	$ 0.61	$ 0.40	$ 1.09	$ 0.96	$ 0.55	$ 1.80			
Σ all costs/veh.-mi.	$ 2.12	$ 1.37	$ 3.79	$ 2.37	$ 1.37	$ 4.45			
pass. trips/no. employees	54,000	113,000	36,700	44,100	127,600	32,800	46,500	28,800	17,800
rev. pass.-trips/no. employ.	48,200	100,200	32,600	38, 0	112,100	28,800	46,500	28,900	17,800
labor hrs./pass.-trip	0.05	0.02	0.06	0.05	.01	0.07			
labor hrs./revenue pass.-trip	0.06	0.02	0.07	0.06	.02	0.08			
veh.-mi./no. employees	13,900	28,900	9,400	15,700	45,300	11,600	21,100	13,100	8,100
labor hrs./veh.-mi.	0.19	0.06	0.25	0.15	.04	.19			
pass.-trips/fleet veh.	132,500		132,500	102,100		102,100	88,100		88,100
rev. pass.-trips/fleet veh.	117,600		117,600	89,700		89,700	88,200		88,200
veh.-mi./fleet veh.	33,900		33,900	36,200		36,200	40,000		40,000
no. stations/sq. mi.									

* The numbers are indicative only; not necessarily accurate for all systems.

TABLE II-2B. PERFORMANCE MEASURE COMPARISON : 1974

ACTORS & RATIOS \ SYSTEM	PATCO			TNJ			DART		
	PRIM	SUPP	TOTAL	PRIM	SUPP	TOTAL	PRIM	SUPP	TOTAL
USER									
Σ all travel costs/pass.-trip	$ 6.87		$ 6,87	$ 7.69		$ 7.69	$ 4.74		$ 4.74
Σ all travel costs/veh.-mi.	$ 17.62		$ 17.62	$ 7.42		$ 7.42	$ 9.18		$ 9.18
Σ in-system travel costs/pass.-trip	$ 1.34		$ 1.34	$ 3.92		$ 3.92	$ 1.30		$ 1.30
Σ in-system travel costs/veh.-mi.	$ 3.43		$ 3.43	$ 3.78		$ 3.78	2.51		$ 2.51
Σ access costs/pass.-mile	$ 0.65		$ 0.65	$ 0.28		$ 0.28	$ 2.10		$ 2.10
accident costs/pass.-mi.	$ 0.004		$ 0.004	$ 0.002		$ 0.002	$ 0.005		$ 0.005
accident costs/veh.-mi.	$ 0.09		$ 0.09	$ 0.03		$ 0.02	$ 0.03		$ 0.03
pass.-trips/accident	111,100		111,000	62,300		62,300	97,400		97,400
veh.-mi./accident	43,300		43,300	64,400		64,400	50,283		50,283
Σ all travel costs/pass.-mi.	$ 0.81		$ 0.81	$ 0.58		$ 0.58	$ 2.91		$ 2.91
SOCIETY									
air pollution damage costs/pass.-mi.	$ 0.004		$ 0.004	$0.007		$ 0.007	$ 0.0		$ 0.0
air pollution damage costs/veh.-mi.	$ 0.09		$ 0.09	$ 0.09		$ 0.09	$ 0.05		$ 0.05
GOVERNMENT									
Σ all costs/pass.-trip									
Σ all costs/pop. served									
Σ all costs/veh.-mi.									
labor hrs./pass.-mi.									
OPERATOR									
Σ all costs/pass.-trip	$ 3.3	$ 0.50	$ 8.74				$ 0.83	$ 0.37	$ 1.20
Σ all costs/rev. pass.-trip	$ 3.37	$ 0.50	$ 8.74				$ 0.83	$ 0.37	$ 1.20
Σ all costs/veh.-mi.	$ 8.64	$ 1.28	$ 22.41				$ 1.61	$ 0.72	$ 2.33
pass. trips/no. employees	241,500	49,200	40,800	18,800	48,800	13,600	38,300	187,300	31,800
rev. pass.-trips/no. employ.	241,500	49,200	40,800	18,800	48,800	12,600	28,300	187,300	31,800
labor hrs./pass.-trip	0.02			0.13	0.05	0.18	0.06		
labor hrs./revenue pass.-trip	0.02			0 15	0.05	0.20	0.06		
veh.-mi./no. employees	94,200	19,200	15,900	19,500	50,600	14,100	19,800	96,700	16,400
labor hrs./veh.-mi.	0.04			0.13	0.05	0.18	0.11		
pass.-trips/fleet veh.	154,300		154,300				56,000		56,000
rev. pass.-trips/fleet veh.	154,300		154,300				56,000		56,000
veh.-mi./fleet veh.	60,200		0,200				28,900		28,900
no. stations/sq. mi.									

TABLE II-3A. COMPOSITE EFFICIENCY MEASURES(OPERATOR)

INPUT TYPES		OUTPUT TYPES: OUTPUT UTILIZED	OUTPUT TYPES: OUTPUT PRODUCED
	FISCAL	a. PT / op.exp.,capital,labor,energy b. RPT / op.exp.,capital,labor,energy c. PH / op.exp.,capital,labor,energy d. POP / op.exp.,capital,labor,energy	a. VM / op.exp.,capital,labor,energy b. VH / total labor costs
	PHYSICAL	a. PT / # stations b. PT / miles of track c. PT / fleet deployed d. PT / # labor e. PT / hrs. labor f. POP / fleet deployed g. POP / # of stations h. PH / hrs. of labor i. PH / # labor	a. VM / fleet deployed b. VM / miles of track c. VM / # of labor d. VM / hrs. labor e. VM / energy used f. AREA / # of stations g. VH / # of labor h. VH / hrs. labor i. EMPL / #labor j. EMPL / hrs.labor

TABLE II-3B. COMPOSITE EFFICIENCY MEASURES(USER)

INPUT TYPES		OUTPUT TYPES: OUTPUT UTILIZED	OUTPUT TYPES: OUTPUT PRODUCED
	FISCAL	a. POP / fare cost, accident, travel time and access cost	a. VM / user fare cost
		b. PT / farecost, accident, travel time, and access cost	b. VM / total accident cost
		c. PT / user fare cost	c. VH / total travel time cost
		d. PM / total access cost	
		e. PH / total fare cost	
		f. PH / total travel time cost	
	PHYSICAL	a. PM / total # of accidents	a. VM / total # of accidents
		b. PT / total # of accidents	b. VH / total user travel time
		c. POP / total # of accidents	
		d. POP / total user travel time	
		e. PH / total user travel time	

TABLE II-3C. COMPOSITE EFFICIENCY MEASURES (GOVERNMENT)

INPUT TYPES		OUTPUT TYPES: OUTPUT UTILIZED	OUTPUT TYPES: OUTPUT PRODUCED
	FISCAL	a. POP / Total government trans.exp. b. PT / Total government trans.exp. c. PT / operating subventions d. PT / taxes lost	a. VM / operating subventions b. VM / Total government trans.exp.
	PHYSICAL	a. PT / Total government labor hrs. b. PM / Total government labor hrs.	

TABLE II-3C

TABLE II-3D. COMPOSITE EFFICIENCY MEASURES (SOCIETY)

INPUT TYPES		OUTPUT TYPES: OUTPUT UTILIZED	OUTPUT TYPES: OUTPUT PRODUCED
	FISCAL	a. POP / Total societal costs b. PT / Total societal costs c. RPT / Total societal costs	a. VM / Total societal costs
	PHYSICAL		

TABLE II-3D

UPTS. By formulating such measures for each UPTS and for each year of operations, the analyst can easily trace the relative governmental contributions to each UPTS.

The set of Tables II-3A to 3D are very helpful for total system assessment by actor or for the summation of all actors and all system operations. However, more detailed efficiency measures are necessary for the analyst who needs to study the system in detail. The previous Tables II-1 and II-2 have already provided the first glimpse of the division of inputs by system component. In fact, Table II-2 includes the first efficiency ratios that focus separately on primary services and support functions for two actors, i.e., the operator and the government. For instance, one can see from Table II-2A that taking into account all the operator's costs applied to primary services, the cost per passenger trip for CTD of SEPTA is 54¢. Taking into account all the operator's costs applied to support functions, the additional cost per passenger trip is 35¢. The sum of all costs is 97¢ per passenger trip in the City Transit Division of SEPTA (all modes). Still, the material revealed by this table is not expressive enough. Additional information, important to the analyst, is available in Table II-4. In this table the relationship of inputs to primary services vs. inputs to support functions of the UPTS are shown. For each specific mode within the three test regions, input analysis was carried out on a system-wide basis for primary vs. primary services, and for primary services vs. support functions, for each year: 1972, 1973, 1974. The input variables of Table II-4 are expressed in terms of dollar costs, employees, labor hours or proxy measurements of other costs, as in the case of user costs or society costs. Table II-4 includes 38 variables applied to all the eleven modes operating within the three test regions. The list of variables is, of course, not all-inclusive (although it includes input variables from the operator, the user and

TABLE II-4. INPUTS TO INPUTS RATIOS: 1974.

OPERATOR / MEASURE	INTERMEDIATE PERFORMANCE MEASURES, 1974 .PRIMARY vs. SUPPORT							
	CTD BUS	CTD TROLL.BUS	CTD TROLL.RL.	CTD RAP. RAIL	CTD AGGREGATE	RAD BUS	R/D TROLL. RL.	RAD AGGREGATE
V/MA(#)	3.95	4.45	3.65	2.63	3.57	19.5	10.8	16.6
V/OCRM(hrs)	0.001	0.002	0.0007	0.0005	0.0009	0.001	0.001	0.004
V/OCRM (#)	2.92	3.91	1.17	0.83	1.70	1.79	1.69	1.77
DCCT /MA (hrs)	12.02	24.88	3.45	4.61	9.17	42.1	33.6	37.8
DCCT /MA(#) (hrs)	6.99	6.86	6.49	5.27	6.45	35	5	30.7
DCCT /OCRM (hrs)/(hrs)	9.46	22.6	1.22	1.58	4.68	3.97	5.39	4.30
DCCT /OCRM (hrs)/ (#)	5.17	6.03	2.08	1.67	3.07	3.21	3.16	3.20
DCCT(#)/MA(hrs	0.004	0.004	0.003	0.003	0.003	0.02	0.01	0.016
DCCT(#)/MA(#)	6.99	6.86	6.49	5.27	6.45	35	5	30.06
DCCT(#)/OCRM's	0.003	0.003	0.001	0.001	0.002	0.002	0.002	0.002
DCCT(#)/OCRM(#	5.17	6.03	2.08	1.63	3.07	3.21	3.16	3.20
PUI/SCI	34.32	63.3	30.5	82.89	42.9	95.7	12.9	33.4
PUI/SOE	18.2	21.7	7.87	22.7	16.5	34.2	22.7	29.8
PUI/SLI	37.7	37.7	21.5	31.5	32.2	87.6	41.2	66.1
PUI/SEI	1542	713	561	713	913	2860	736	1559
A&I/MA(#)	5.16	0.42	0.68	0.83	0.59	**	**	0.09
A&I/OCRM(#)	3.8	4.52	1.95	1.58	2.50	**	**	1.12

TABLE II-4. (Continued)

OPERATOR / MEASURE	INTERMEDIATE PERFORMANCE MEASURES, 1974 .PRIMARY vs. SUPPORT							
	CTD BUS	CTD TROLL. BUS	CTD TROLL. RL.	CTD RAP. RAIL	CTD AGGREGATE	RAD BUS	R/D TROLL. RL.	RAD AGGREGATE
PCI/SCI	7.96	5.54	15.65	17.35	11.1	2.74	7.7	4.33
PCI/SOE	0.97	0.72	0.68	1.44	0.99	0.95	2.05	1.37
PCI/SLI	2.01	1.25	1.87	1.99	1.95	2.44	3.73	3.03
POE/SOE	1.37	1.54	0.77	1.10	1.14	1.21	1.21	1.21
POE/SLI	2.83	2.67	2.13	1.53	2.22	3.10	2.19	2.22
POE/SEI	115.7	50.5	55.6	34.6	63.1	101.1	39.2	63.2
PLI/SOE	1.46	1.56	0.56	0.91	1.07	1.44	0.83	1.21
PLI/SLI	3.02	2.69	1.55	1.26	2.08	3.69	1.51	2.68
PLI/SEI	123	50.9	40.2	28.5	59.2	120.5	27.1	63.3
PEI/SOE	0.06	0.16	0.07	0.17	0.09	0.06	0.16	0.10
PEI/SLI	0.12	0.28	0.20	0.23	0.18	0.16	0.30	0.22
PEI/SEI	5.26	5.34	5.26	5.26	5.25	5.24	5.28	5.28
V/SCI	0.0001	0.0002	0.00009	0.0001	0.0001	0.0002	0.00002	0.00005
V/SOE	0.00005	0.0001	0.00002	0.00003	0.00004	0.00006	0.00003	0.00005
V/SLI	0.0001	0.0001	0.0001	0.00004	0.00007	0.0002	0.0001	0.0001
V/SEI	0.005	0.002	0.002	0.001	0.002	0.005	0.001	0.002
V/MA(hrs)	0.002	0.002	0.002	0.001	0.002	0.01	0.006	0.009

TABLE II-4. (Continued)

OPERATOR / MEASURE	INTERMEDIATE PERFORMANCE MEASURES, 1974 .PRIMARY vs. SUPPORT							
	CTD BUS	CTD TROLL.BUS	CTD TROLL.RL.	CTD RAP. RAIL	CTD AGGREGATE	RAD BUS	R/D TROLL. RL.	RAD AGGREGATE
PSI/SCI	0.23	0.38	0.17	0.30	0.24	0.97	0.15	0.35
PSI/SOE	0.09	0.08	0.06	0.08	0.08	0.29	0.22	0.31
PSI/SLI	0.25	0.23	0.12	0.12	0.18	0.89	0.48	0.70
PSI/SEI	10.4	4.27	3.11	2.61	5.00	29	8.65	16.6

TABLE II-4. (Continued)

OPERATOR / MEASURE	INTERMEDIATE PERFORMANCE MEASURES, 1974 .PRIMARY vs. SUPPORT							
	GCD PENN CENT.	GCD READING	GCD AGGREGATE	SEPTA AGGREGATE	PATCO	TNJ	N.J. AGGREGATE	DART
V/MA(#)	6.27	2.74	4.24	4.56	* *	* *	* *	5.53
V/OCRM(hrs)	* *	* *	* *	0.001	* *	* *	* *	* *
V/OCRM (#)	0.76	0.63	0.71	2.07	* *	* *	0.51	15.6
DCCT /MA (hrs)	* *	* *	* *	9.77	* *	6.48	6.48	* *
DCCT /MA(#) (hrs)	* *	* *	* *	18312	* *	17034	17034	* *
DCCT /OCRM (hrs)/(hrs)	* *	* *	* *	6.60	* *	4.68	4.68	* *
DCCT /OCRM (hrs)/ (#)	* *	* *	* *	7425	* *	10,103	10,103	* *
DCCT(#)/MA(hrs	* *	* *	* *	0.004	* *	0.002	0.002	* *
DCCT(#)/MA(#)	7.21	4.09	5.41	6.94	* *	6.96	6.96	7.47
DCCT(#)/OCRM's	* *	* *	* *	0.002	* *	0.002	0.002	* *
DCCT(#)/OCRM(#	0.88	0.93	0.90	3.15	* *	4.13	4.13	14.0
PUI/SCI	* *	* *	* *	62.1	82.1	* *	82.1	75.8
PUI/SCE	21.4	25.77	23.1	19.03	60.2	16.6	28.9	14.7
PUI/SLI	* *	* *	* *	65.1	* *	49.6	49.6	131
PUI/SEI	825	692	761	885	1039	1082	1053	1009
A&I/MA(#)	2.16	0.69	1.33	0.56	* *	* *	* *	* *
A&I/OCRM(#)	0.26	0.16	0.23	0.83	* *	* *	* *	* *

OPERATOR / MEASURE	INTERMEDIATE PERFORMANCE MEASURES, 1974 PRIMARY vs. SUPPORT							
	GCD PENN CENT.	GCD READING	GCD AGGREGATE	SEPTA AGGREGATE	PATCO	TNJ	N.J. AGGREGATE	DART
PCI/SCI	* *	* *	* *	2.43	14.33	* *	14.33	7.16
PCI/SOE	* *	* *	* *	0.74	10.5	* *	10.5	1.39
PCI/SLI	* *	* *	* *	2.54	* *	* *	—	12.4
POE/SOE	0.71	1.02	0.83	1.05	0.95	1.16	1.10	1.27
POE/SLI	* *	* *	* *	3.61	* *	3.48	4.60	11.4
POE/SEI	38.5	27.4	27.4	49.1	16.5	49.5	40.2	87.3
PLI/SOE	* *	* *	* *	0.63	0.29	0.99	0.80	1.07
PLI/SLI	* *	* *	* *	2.14	* *	2.97	2.97	9.56
PLI/SEI	* *	* *	* *	29.1	5.04	64.98	29.03	73.41
PEI/SOE	0.14	0.20	0.16	0.11	0.31	0.08	0.14	0.08
PEI/SLI	* *	* *	* *	0.39	* *	0.24	0.60	0.70
PEI/SEI	5.26	5.26	5.25	5.25	5.28	5.27	5.25	5.41
V/SCI	* *	* *	* *	0.0001	0.00003	* *	0.00003	0.0003
V/SOE	.00002	0.00001	0.00002	0.00003	0.00002	* *	0.00002	0.00006
V/SLI	* *	* *	* *	0.0001	* *	* *	* *	0.0006
V/SEI	0.0007	0.0005	0.0006	0.002	0.0004	* *	0.0004	0.004
V/MA(hrs)	* *	* *	* *	0.002	* *	* *	* *	* *

TABLE II-4. (Continued)

OPERATOR / MEASURE	GCD PENN CENT.	GCD READING	GCD AGGREGATE	SEPTA AGGREGATE	PATCO	TNJ	N.J. AGGREGATE	DART
	INTERMEDIATE PERFORMANCE MEASURES, 1974 PRIMARY vs. SUPPORT							
PSI/SCI	* *	* *	* *	0.25	0.16	* *	0.16°	0.44
PSI/SOE	0.006	0.007	0.007	0.08	0.12	0.12	0.12	0.09
PSI/SLI	* *	* *	* *	0.27	* *	0.36	0.36°	0.78
PSI/SEI	0.26	0.20	0.23	3.70	2.03	7.91	4.38	5.95

the society), nor all the variables there are of the same degree of pertinence. Nonetheless, it is a very revealing table. For instance, the analyst can use this table to compare the primary to support relationship in the four bus sub-systems in the three regions or the two rail trolley sub-systems, or in order to carry an inter-mode comparison. As Table II-4 indicates, for example, the ratio of the number of employees in the function of directly conducting transportation (DCCT) to the number of employees in repairs and maintenance in the four bus sub-systems for 1974 are:

5.14 for CTD
3.10 for RAD
4.13 for TNJ
and 14.00 for DART

While the ratios for CTD, RAD and TNJ appear to be within the realm of reasonableness, the ratio of DART reveals an abnormality which might be in the their system of classification or in the newness of the system.

Another example can be drawn from the ratio of operating expenses in primary (POE) vs. support functions (SOE). The ratios for 1974 are:

1.37 for CTD
1.21 for RAD
1.16 for TNJ
1.27 for DART

All ratios appear reasonable with the best ratio registered for SEPTA's CTD and the worst for the Southern Division of TNJ. Similar examples can be drawn for many detailed functions. Thus, provided that the data is accurate, and the classifications correct, the analyst may explore the relationships between primary service functions and support functions in all aspects. Furthermore, contrast of ratios formed on the basis of dollar costs vs. other ratios formed with variable expressive of physical inputs, i.e., labor hours, number of employees, etc., can be pursued to reveal discrepancies and disproportional allocations.

4.0 Concluding Comparisons

The previous analysis focuses on the analyst who needs to delve in depth into transit system efficiency and productivity. It seems appropriate at this time to proceed with further structuring the analytical efforts in a manner that permits effective efficiency in the study itself. This is what is suggested with Tables II-5 and II-6 and Figure II-2.

In order that the analyst focus his efforts as soon as possible on the crucial issues of an UPTS Table II-5 is suggested. In this table an association is suggested between a specific ratio of inputs to outputs with a sphere of influence or area of concern. By forming this table, and including actor characterizations, the analyst may be guided directly towards his most pressing needs.

Another table that may prove very useful for the analyst is the trend establishing comparative table of a single input item, presented in all possible forms, as shown for labor in Table II-6. As can be seen from this table, the labor inputs, expressed in labor hours, number of employees and labor cost, for three bus sub-systems and for three test years, are placed in a single table for easy comparison. While the labor input variables are much more complex than suggested by Table II-5 (see Chapter VI), their direct comparisons are always very helpful. In Table II-6, the ratio of labor inputs in primary services are compared with the labor inputs in support functions over a three-year period in three sub-systems.

Finally, the analytical work with each system component and mode may also lead into policy review and change. As the aggregation of analysis proceeds and overall conclusions are reached for entire system components and whole modes of transit, the top management of the system plus its policy-making body may wish to review their general policies with regard to their system organization and resources allocation throughout the system. This is shown schematically in Figure II-2.

TABLE II-5. PERFORMANCE MEASURES AND SPHERE OF INFLUENCE.

Measures	Influence
A. OPERATOR	
1. Pass.Trips/Total Monetary Costs	Productivity as Related to Capital Grants
2. Vehicle Miles/Total Monetary Costs	Productivity as Related to Operating Grants
3. Pass. Trips/Fleet Deployed	Efficiency as Related to Change in Fleet Size
4. Pass. Trips/No. Laborers	Productivity as Related to Change in Transit Employment
5. Pass. Trips/Labor Hours	Efficiency as Related to Operator Labor Expense
6. Vehicle Miles/Fleet Deployed	Efficiency as Related to Change in Vehicle Operation
7. Vehicle Miles/No. Laborers	Productivity as Related to Operator Provision of UPTS Service
8. Vehicle Miles/Labor Hours	Efficiency as Related to Operator Provision of UPTS Service
9. Area Served/No. Stations	Demographic Coverage of UPTS as related to Productive Measure
B. USER	
10. Pass. Trips/Total User Costs	Productivity as Related to User Total Economy
11. Vehicle Miles/Total Accident Cost	Efficiency as Related to UPTS Liability
12. Pass. Trips/No Accidents	Efficiency as Related to UPTS Safety
13. Vehicle Miles/No. Accidents	Efficiency as Related to UPTS Safety
14. Pass. Hours/User Travel Time	Efficiency as Related to Time of Movement

TABLE II-5. (Continued)

Measures	Influence
C. SOCIETY	
15. Pop.Served/Sum of Social Costs	Productivity as Related to UPTS Societal Expense
16. Pass.Trips/Social Costs Minus Air Poll. Damage	Productivity as Related to Social Cost Borne by UPTS
17. Pass.Miles/Air Pollution Damage	Efficiency as Related to Environmental Degradation
18. Vehicle Miles/Pollution Costs	Efficiency as Related to Environmental Degradation
D. GOVERNMENT	
19. Pass.Trips/Total Government Expenditure	Productivity as Related to Government Provision of UPTS Service
20. Vehicle Miles/Total Government Expenditure	Productivity as Related to Government Provision of UPTS Service
21. Pass. Hours/Total Government Labor Hours	Productivity as Related to Government Provision of UPTS Service

TABLE II-6. PRIMARY SERVICES VS. SUPPORT FUNCTIONS INPUT COMPARISON

(Ratios of inputs in primary services over inputs in support functions)

YEAR	SEPTA BUS						TNJ		
	CTD			RAD			Southern Division		
	L H	N O E	L$	L H	N O E	L$	L H	N O E	L$
1974	5.3	3	3	3.6	2.9	3.7	2.7	2.6	3
1973	5.9	3.2	3.3	3.5	2.9	4.2	2.9	3.1	3.1
1972	6.2	3.4	3.5	3.8	3.2	3.9	3	2.7	3

LH = Labor Hours
NOE = Number of Employees
L$ = Labor Cost

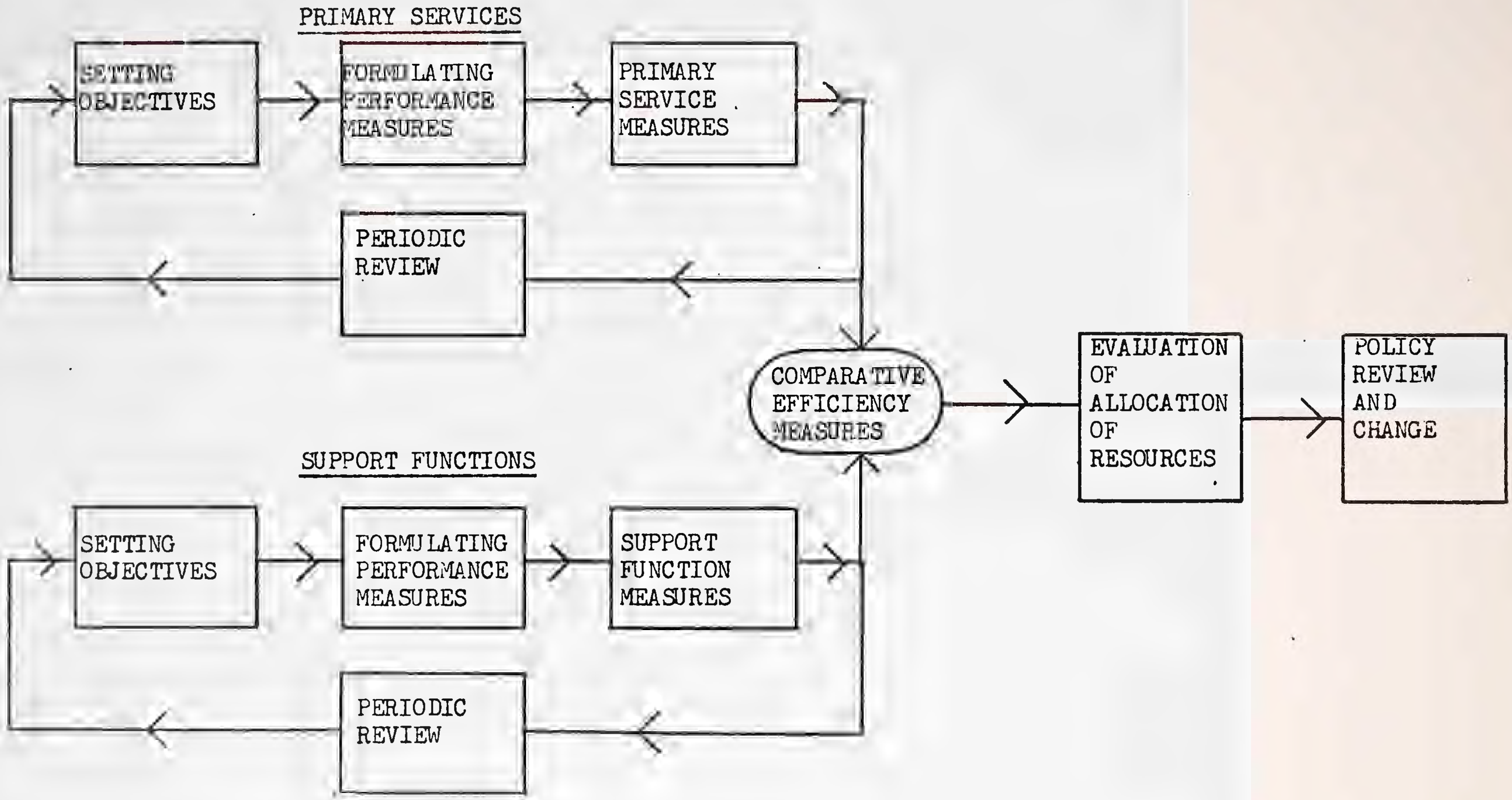


Figure II-2. PRIMARY/SUPPORT RELATIONSHIP VS. POLICY DEVELOPMENT

CHAPTER III

AN OVERVIEW OF UPTS INPUTS

Introduction

With this chapter, the identification, discussion and presentation of the inputs and output accounts of an UPTS is initiated. The intent is to represent, in quantitative and tractable terms, those items that are inputs to the UPTS and which in combination with the outputs of that system, form the basis for determining and assessing the productivity and efficiency of a urban public transportation system.

1.0 System Components

The input accounts, represented in matrix format, are designed to comprehensively incorporate and reflect the many and varied types of inputs to and within the urban transportation system. The UPTS have been classified into the primary services, support functions and the network. System inputs and contributions can then be associated with these three system components. In order to facilitate the understanding of this classification scheme of the input accounts, their relationship with the system components is stated as follows:

Primary: Expenditures which are necessary and sufficient to produce an optimum level of travel service.

Support: Expenditures which are necessary in non-daily operation, and maintenance of the primary service and the network of the system.

Network: Expenditures for major capital fixed assets such as links, nodes, stations, and terminals.

System-wide: Those expenditures which are necessary for all the three system components.

These associations provided the basis for categorizing expenditures within the purview of each of the actors contributing to the UPTS. Further sub-classifications of these functions (and actor categories) would allow for the disaggregation of inputs data into more tractable categories of Capital, Operating Expenditure, Labor and Energy.

2.0 The Actors

As indicated previously, four major actors are considered to be the contributors to the urban public transportation systems. They are the Operator, the User, Society at large, and Government at all levels. Each provides inputs to the system in the form of the two traditional economic commodities, that is, Labor and Capital.

The following discussion focusses on an overall picture of the inputs provided by these four actors, and the implications for analysis that these inputs necessitate. Substantive concerns of each of these types of inputs are addressed in subsequent chapters. The intent here is to provide an overview of the entire spectrum of inputs to an UPTS, and to suggest an overall approach with regard to the specification and inclusion of inputs in the analysis of UPTS.

3.0 Inputs to the UPTS

The first two general and important categories of actor inputs, i.e., labor and capital, are associated with all actors, but particularly so with the Operator and the User.

3.1 Labor

Within the Labor category, two major sub-classes can be identified. First, there is the class of hired labor. Such labor is usually provided by the Operator, with possible addition for labor contributions by the Government. It includes all types of employees who contribute their time, for which they are paid. Their effort can be viewed from several perspectives. It can be studied as purely time spent, or as a dollar equivalent based on the value of that time as indicated by the different wage levels.

Second, there is non-hired labor. This classification includes all the time spent by the users of the transportation system for which there is no direct compensation. Time spent in traveling to and from the system, waiting,and during the actual transportation experience, is a non-compensated input. It is, nevertheless, an important input to the functioning of the system and needs to be considered as such when user inputs are examined.

These types of labor can be measured as number of employees, or passengers man-hours, or as total dollar labor cost. The derivation of these measurements required several stages which are discussed in Chapter VI: "Labor Inputs Accounts (for the Operator-Supplier)" and Chapter X: "User Inputs".

It should be noted that labor, as presently defined, is specifically excluded from the network of the system. This is due to the definitions established at the beginning of this section for primary, support, and network.

3.2 Capital

Capital inputs represent the second general category of inputs and can also be divided into two major types. The first type includes all fixed assets necessary in the system. Land, buildings, permanent construction and all technical works such as power generation and transmission facilities/structures, etc. that are necessary for network development and operation. Rolling stock, equipment, electronic controls, and all signalization equipment are also considered as part of the "capital stock" of the transportation system.

The second type of capital includes the materiel used in the daily operation of the system. Expenditures for fuels and energy falls within this classification of capital along with all non-labor inputs in the system.

Because of the diversity of factors comprising capital inputs, and the need for standard valuation, the most generally utilized unit of measure is dollars. Where applicable capital inputs in discreet forms (i.e., buses, repair units, special facilities, miles of routes, etc.) are also utilized in the matrix of physical inputs.

The standard conventions that have been used to "value" capital inputs must be utilized with caution. For example, in the cases of many inputs, the law may allow any of several methods of depreciation to be used--e.g., straight-line, declining balance, double-declining balance--which seek to ascribe value to a particular capital quantity but in distinctly different ways. Some Operators may understandably choose that method which yields them the maximum profit by distributing the value and consequent expense of capital over an extended period of time relative to their income. Productivity and efficiency analysts should carefully consider which valuation procedure provides the most consistent and realistic estimate of the capital worth (i.e., inputs) of the system.

3.3 Societal Inputs

From the point of view of society all inputs to the transportation system come ultimately from society. For the purpose of an efficiency study, all contributions of inputs not specifically accounted for by the other actors on the system shall be considered to be Societal Inputs. This approach will avoid double accounting which might otherwise occur. In some cases, measuring Societal Inputs through their market prices the analyst may not always succeed to include their actual value to society.

The specific consideration and introduction of Societal contributions to the UPTS represents an expansion of the traditional analytical approach toward UPTS productivity and efficiency analysis. It has been considered here for the following reasons:

(a) Society, as defined, includes not only direct users of the system but also, and particularly, non-users. The objective is to include inputs from and outputs to these non-users of the UPTS.

(b) Society, in relation to the other actors of the UPTS, is important. In both a practical and theoretical sense, society would be concerned with larger issues which involve all points of view, not normally attributable to any particular point of view.

(c) In the case of transportation services, the inclusion of the society's point of view is particularly warranted because of the potential conflict that may exist between the provision of transportation service and the attainment of certain societal objectives such as air quality, land and energy conservation, and accessibility.

(d) Societal inputs are generated by the negative outputs of the system. These are classified as externality costs and are included as inputs, in terms of the direct costs they produce or the costs they necessitate in controlling or alleviating them.

Society contributes and must pay both the externality costs and the opportunity costs associated with a transportation system. All resources including land, labor, and energy can, ostensibly, be utilized for alternative purposes. It is, thus, reasonable and prudent for society to choose that combination of resource utilization that maximizes the net output of those expenditures. Opportunity costs are incurred through this process of selection. Opportunity costs represent the additional costs that arise from foregoing the benefits of resource transfers to the UPTS. Opportunity cost doctrine is simple, yet far-reaching, for it postulates that the true cost of an investment can be measured by the loss of value between the chosen alternative and the best alternative which must be foregone when the action is taken.

The externality cost is based on the negative outputs which the system produces. Externalities are, by definition, the negative outputs of the UPTS, and the costs they produce are, by convention, considered as inputs to the UPTS by Society. They are generated by the operation of the UPTS and sometimes by its very presence. Pollution (air, noise and aesthetic), congestion, differentials in accessibility, the incidence and distribution of crime, and accidents, are typical externalities that arise. These negative outputs are visualized as an input to the system imposed on the societal actor.

Externality costs, attributable to air and noise pollution, congestion on jointly used facilities, differentials in accessibility, crime, need to be similarly defined in terms of their quantity and value. Accident costs associated with the UPTS may, more appropriately, be considered under the user input accounts, even though some accidents clearly involve non-users of the UPTS. This is so in order to avoid double-counting, and to facilitate the analysis. Also, some of the externality costs can be associated with certain system components. Pollution, for example, could only be associated with a primary or support component of the system and not network. Where such quantitative specification is not possible, these items are excluded from further consideration. (See Chapter XI: "Societal Inputs Accounts".)

3.4 Governmental Inputs

Government at all levels, is an actor of considerable import to the transportation system. In the execution of public transportation assistance programs, determined in response to the perceived needs of society, government provides grants, subsidies and loans to operate, improve and construct new transportation systems. These programs also include areas of research and development of new technology, policy formulation and refinement of overall technical planning skills. These contributions represent significant inputs to the UPTS. Furthermore, governments at all levels provide services (i.e., labor) and physical capital in kind to the UPTS, such as police and fire protection, maintenance of jointly used rights-of-way and the use of governmental capital facilities. As discussed in greater detail in Chapter XII: "Governmental Inputs", these contributions are aimed at providing an economic climate for transportation activity beyond that which the market can provide.

Governmental contributions affecting the production of urban public transportation services are of two types, i.e. capital or labor expenditures. Capital inputs can, also, be sub-classified into the following categories:

(1) Monetary Capital. These inputs are usually in the form of purpose-specific direct transfers of monies on the federal, state or local level (purchase of service subsidy, funds for technical studies etc.). They are generally of a non-reimburseable subvention nature and may be given to any public agency, or entity, authorized to operate public transportation.

(2) Physical Capital. These inputs are defined as the transfer of the physical elements of the transport system for the exclusive or shared use of urban public transportation. These inputs constitute an indirect transfer of physical facilities for UPTS use. In Philadelphia, the Broad Street and Market Street subway tunnels and vehicles would represent such an indirect transfer. The City owns and leases
would represent such an indirect transfer. The City owns and leases
to SEPTA the use of this physical capital, yet, for example, the major maintenance and repair costs associated with the tunnels are absorbed by the City. Such arrangements can include the use of additional capital facilities and equipment including rolling stock, stations and trackage and, therefore, can represent considerable capital investment.

Other transportation elements can be, and have been, considered within this input category. Highways, bridges and road and street networks throughout the region would represent another level of governmental input. Associated with these facilities is routine maintenance and the necessary cost associated with the equipment and hardware needed. These expenditures, apportioned to reflect the equitable allocation of costs to public and private transportation activities, represent again a sizable contribution made by government.

(3) Governmental Capital Facilities. Consonant with the expansion of government's role in public transportation, has been an increase, in the need for capital facilities, to house the agencies, services, and functions the government provides.

The expansion in staff and programs at the Federal level as well as the increasing number of state level departments of transportation, both with their associated local and regional offices, represent clear governmental inputs to the urban transportation system in toto, and, as with the allocation of physical capital inputs, should be proportioned to the extent possible.

(4) Governmental Operating Expense. In addition to the monetary and physical capital and facilities contributed in the production of public transportation, governments also engage in functions or have departments for controlling, monitoring or improving services vital to the public welfare. The focus considered here is on those services and activities created directly for the improvement or maintenance of public transportation. On the Federal level, UMTA (Urban Mass Transportation Administration) operates under the auspices of the Department of Transportation and its funding programs. On the local level, the cities maintain traffic engineering departments. Transit Offices are also maintained by most cities. Each of these agencies maintains jurisdictional responsibilities for daily operations and services related to public transportation planning and operations.

The costs incurred in the administration of these activities, as well as those of other agencies associated with public transportation, e.g., air pollution control (Dept. of Health), transit crime and vandalism (Police and local townships), should be included and proportionately allocated to reflect appropriate transit oriented contributions.

3.5 User Inputs

In addition to the inputs contributed by the Operator, Society and Government, the User of the UPTS contributes other very significant inputs to the urban public transportation systems. The users, while consuming the services, also invest their own assets such as money, time, risks, efforts, etc. In return, they expect to receive transportation between origins and destinations at an acceptable level of comfort and convenience.

The identification and specification of these User contributions require the synthesis of two major research efforts. The first involves the determination of appropriate unit costs to be applied to the increments of distance travelled by the User. The second concerns the number of trip or amount of service consumed by the Users of each region. These data sets need then to be synthesized to provide total User costs by mode. The data collected and the results reached are detailed in Chapter X: "User Inputs to the UPTS".

In determining User costs, the traditional economic inputs of capital and labor, associated with the usage of the UPTS, were categorized as follows:

1. Capital Expenditures

   A. Fares

   B. 'Access' Costs
      Access Mode Purchase
      Parking Costs
      Access Mode Operating Costs

   C. Miscellaneous Costs
      Personal Injury
      Property Damage
      Property Loss

2. Labor Expenditures

A. Travel Time
   Access Time
   Wait Time
   In-vehicle Time
   Egress Time

B. Travel Time Value

A third, important input, is also discussed in Chapter X. This input considers the Effort Expenditures of the User as follows:

3. Effort Expenditures

A. Mental (Efforts)
   UPTS operating orientation
   Personal Risks/Security
   Personal Risks/Accidents - Safety

B. Physical (Exertion)
   UPTS station and vehicle design
   Microclimate

The data available on these inputs largely represents aggregate figures derived from national statistics and selected data derived within each of the study regions.

4.0 Summary

In summary, the four major actors of urban public transportation systems contribute capital and labor inputs in many forms. Capital and labor inputs can also be subdivided according to the system component that makes use of each input. This distinction by system elements allows for greater visibility of the extent of interaction within UPTS.

Various levels of understanding can be derived from the input matrixes of the two chapters that follow. The structure and organization of the matrixes allow for both categorical and sub-categorical inclusions of information. The matrix categories included also those types of data which are beyond the particular scope of this study. This is done in order to present as complete a picture of all direct and indirect inputs as possible.

CHAPTER IV

FISCAL INPUTS ACCOUNTS

Introduction

This chapter deals with the fiscal inputs of the urban transportation systems of the three test regions of this project. The fiscal inputs are organized in a comprehensive manner and presented in a matrix form. One such matrix is presented at the end of this chapter with the best possible collection of information from the three test regions. The results of the calculations of the inputs contributed by the four system actors, to the three system components, are presented in this matrix for 1972.

1.0 Matrix Organization and Structure

The fiscal input matrix is organized in a two-dimensional system of entries. Each year requires an individual matrix. **(See Appendix I).**

On the horizontal axis of the matrix the three regions are presented, along with individual classification for each subsystem and each specific mode. On the vertical axis the various entries carry a much more complicated arrangement. On the outset the entire set of data is divided into three distinct groups according to the quality of the quantitative data available. The first group represents data on input variables which are discrete and firm. Such data sets are usually the ones that refer to input variables reported by the operator and the government. The classification also includes data on fares paid by the user. The second group represents data on input variables which are approximate estimates of quantities for which no specific, detailed accounts are available. Such data sets are usually encountered in the use of detailed input information about system components contributed by the operator. Data sets on certain governmental inputs and user inputs are also included in this classification. The third group represents data on input variables which are quantifiable only through proxy values. Such data sets are typically the ones that involve certain types of user inputs as well as societal costs.

According to this initial classification, the input variables of each actor may be found in any of the three data groups, according to the actual nature of the available data. Within each actor, then, the various input variables are classified in association with the system component with which they are associated (i.e. primary services, support functions and the network). At this point the actual nature of each input is examined and grouped into four distinct groups, the following: Operating Expenditure, Capital Inputs, Labor Inputs, and Energy Inputs. In turn, each of the four groups includes specific variables for detailed inputs, plus the total inputs in each group. For instance, for operating expenditures the matrix includes in each case variables referring to:

(a) Total operating inputs for support functions
(b) Managerial and Administrative inputs
(c) Traffic promotion inputs
(d) Repairs and Maintenance inputs
(e) All other operating inputs for support functions

Or

(a) Total operating inputs for primary services
(b) Managerial and Administrative inputs
(c) Transportation functions and Fuel inputs
(d) All other primary functions inputs

Finally, the fiscal input matrix carries along the vertical axis aggregate inputs amounts along several lines. One such line is total system-wide inputs for "all actors" and for all system components. Another such aggregate measure is for each data quality level (discrete, estimated, and proxy) for all actors and for all system components. The last entries in the fiscal input matrix along the vertical axis are for system-wide input variables for each actor, but for all levels of data quality, and all system components.

2.0 Discussion of Results

The fiscal inputs matrix is very revealing indeed in terms of the contributions of the various actors, the nature of their contribution, the magnitude of each contribution, and where exactly within each system each contribution is applicable. The matrix is also revealing of the completeness or paucity of data in each case.

Let us examine the fiscal input matrix for 1972 in some detail. One of the first observations one can make is that the entries are more complete as one moves from each mode to totals for each system, as well as one moves from each system component to the system-wide data on inputs. A second observation is that the number of entries increase as one moves from discrete measures, to estimated measures, to proxy measures, and finally to the summation of all three for system-wide reporting.

In more detailed examination of the 1972 Fiscal Inputs matrix, one may notice that for a particular region (i.e. the Pennsylvania test region where SEPTA operates) the total discrete inputs in terms of operating expenditures is 148.3 million as reported by the operating agency, plus 8.5 million as explicitly expended by government in supplementary functions and network expenditures. Usually this second type of expenditure is not included in the annual UPTS reports of any agency. Subdividing these two sums one may notice that there is considerable difficulty in attributing the funds to each mode included in the system and each system component, and each function within the individual component. For instance, it was possible to specify that of the 148.3 million the user contributed 107.1 million in terms of fare, and the government the remaining 41.2 in terms of operating subventions. Also, the same 148.3 million were separated into 76.0 million on primary service and 72.2 on support functions, leaving only 0.18 million for actual expenditures for the network. The difficulties increase when the analyst attempts to identify expenditures for labor and capital separately and when he tries to pursue this identification further to each function within each system component and each specific mode. As it can be seen, the F. I. Matrix is missing most important entries at this level of data identification.

Moving to the second classification of data, i.e. the estimated inputs to the UPTS, one may observe that a significantly larger number of entries is available. This is so because the analyst may proceed to establish input estimates for each system component, each type of input, and each function from secondary sources; a procedure which includes considerable ambivalence and inaccuracy. For 1972 and for the Pennsylvania region, the F.I. Matrix reports that the sum of the estimated inputs by the operator is 285.4 million accompanied by another estimated user input of 284.1 million. No government or society inputs are identified.

The 285.4 millions of operator estimated inputs are inclusive of the previously mentioned 148.3 million of discrete operator inputs. The 285.4 million of estimated operator inputs include 170.9 million estimated primary services inputs (consisting of operating expenditures and previously unaccounted capital inputs), 93.4 million of support functions inputs (including previously unaccounted capital inputs) and 21.0 million of network capital inputs, previously unaccounted.

The user estimated inputs of 284.1 consists of primarily two items:

i.e. the value of travel time (275.2 million) and the worth of fuel for the access vehicles from and to the UPTS facilities, (8.9 million). Both of these items are discussed in detail in Chapter X, "User Inputs to the UPTS". Travel time in particular is translated into dollar value on the basis of the conventional method of accepting an equivalent (conservative) value of $2.60 per hour, after Lisco (1967).

Moving to the third classification of data, i.e. the proxy calculation of inputs to the UPTS, which include primarily the indirect inputs contributed by the users of the UPTS. Two major items are included here, e.g. the value of the access time to and from the UPTS and the value of the access vehicles. The value of the access time is estimated with a set of numbers that are less specific than the numbers related to the travel time itself. Hence the separation of the two estimates of the value of time. Similarly the value of the access vehicles is rather difficult to determine because of the "sharing" characteristic of the use of these vehicles. The calculation of these two proxy inputs reaches $346.5 million for the access time (at $7.20/hour after (Lisco 1967)) and $166.8 million for the access vehicle (including a shared cost of the access vehicle); a total of $544.2 million contributed by the user of the UPTS. (See Chapter X).

The other proxy measure refers to costs contributed by the society in terms of externality costs of the UPTS. The amount is only $6.3 million indicating the relative minor social costs that urban public transportation systems impose on society. (See Chapter XI.)

The Fiscal Inputs Matrix as presented at the end of this chapter includes also aggregate inputs on system-wide basis. The following numbers extracted from the matrix indicate the summary picture derived for the Pennsylvania region for 1972:

(a)	Total system-wide, all actors inputs	$1.265.million
	Total Primary services, all actors inputs	$ 920.million
	Total Support functions,all actors inputs	$ 126.million
	Total Network functions,all actors inputs	$ 26.million
	Total Other(system-wide)all actors inputs	$ 193.million
(b)	Operator total inputs	$ 285.million
	User total inputs	$ 935.million
	Government toal inputs	$ 27.million
	Society total inputs	$ 6.million
	Mixed actor inputs	$ 12.million
	Total System Inputs	$1.265.million

Similarly, tracing of the inputs of the other two test regions reveal commensurate augmentation of total system inputs by component and contributing actor. Notice should, of course, be made here of the fact that all capital inputs which are contributed by government, one way or another, are being included in the "operators" classification. In fact, however, government inputs are as follows:

Capital Contributions:	285-148=	$ 137.0 million
Operating Subsidies:	148-107=	$ 41.0 million
Government Expenses:	=	$ 8.5 million
Total Government Inputs		$ 186.5 million

3.0 Summary and Conclusion of Fiscal Inputs

The matrix presentation of the fiscal inputs for any single year presents a comprehensive and revealing picture of what is contributed during a year for the operation of an urban public transportation system. Within this picture the usually reported operating budget of the operating agency represents a small proportion of the total system inputs. A still smaller proportion is represented by the direct fares paid by the users of the system. Interestingly enough, the users do contribute the lion share of the total system inputs, i.e. 935 out of 1265 million, only a small proportion of which represent direct fares contributed the system (i.e. 107 out of 935 million, the remaining $828 million being contributing cost in terms of travel time, access time, and access vehicle cost). Another interesting and revealing finding is that in terms of out-of-pocket public costs the UPTS in the Pennsylvania Region in 1972 absorbed the following inputs:

$ 107	million	User Fares
$186.5	million	Government Expenditures
$293.5	million	

This sum of direct expenditures corresponds to about $1.06 per passenger trip completed at that year (274 million trips).

The discussion in this chapter of the results presented in the Fiscal Inputs matrix, focused only on the summary column of one region. However, similar observations can easily be made for the other two regions and for the other years included in this test (1973 and 1974). The detailing of the data into each operator and each mode is of course relevant for only such a complex region as the Pennsylvania region. The numbers in each column is usually mutually exclusive except in the cases where a discrete number is missing and reference is made to the estimated category (E/C) in which case the estimated number is inclusive of the corresponding discrete but unavailable number. In cases where no number was available or could be estimated the matrix indicates a shaded blank. Similarly in cases where any number would be inapplicable for a particular item.

URBAN PUBLIC TRANSPORTATION SYSTEM FISCAL INPUT MATRIX 1972

IN CURRENT U.S. DOLLARS

TABLE NUMBER:

ACTOR / SYSTEM / INPUT	PENNSYLVANIA REGION: SEPTA Bus	SEPTA Trolley Bus	SEPTA Trolley Rail	SEPTA Rapid Transit	C.T.D. TOTAL	SEPTA Bus	SEPTA Trolley Rail	R.A.D. TOTAL	SEPTA Penn Central	SEPTA Reading Co.	G.C.D. TOTAL	REGION TOTAL	NEW JERSEY REGION: PATCO Rapid Transit	T.N.J. Bus	REGION TOTAL	DELAWARE REGION: DAPT Bus
DISCRETE – Operator, primary, op. exp.	28,492,508	2,170,932	9,443,997	12,756,998	83,863,235	E/C	E/C	5,236,207	9,414,000	8,011,100	17,425,100	76,124,442	3,230,313	E/C	E/C	2,44,500
DISCRETE – Operator, support, op. exp.	29,962,369	1,415,291	10,268,082	17,413,179	45,944,891	E/C	E/C	4,339,549	13,824,600	8,137,200	21,958,300	72,249,230	3,109,335	E/C	E/C	[illegible]
DISCRETE – Operator, network, capital										180,200	180,200	180,200	E/C		E/C	
DISCRETE – Operator, system-wide	49,654,877	3,585,823	12,991,679	26,175,137	92,308,116	E/C	E/C	10,075,856	22,735,600	16,149,300	38,883,900	148,267,872	5,419,648	E/C	E/C	2,49,454
	1,143,117	196,644	1,021,419	1,832,436	4,193,616	150,599	261,124	411,723	1,788,300	1,574,626	3,362,926	7,968,265	721,891	E/C	E/C	E/C
DISCRETE – Government				5,370,750	24,231,750			2,697,000			208,000	27,136,750		750,000	750,000	2,844,725
Government, primary					16,530,000			2,597,000				19,127,000		750,000	750,000	2,844,725
Government, support					2,331,000			100,000			208,000	3,142,400				2,844,725
Government, network capital				5,370,750	5,370,750							5,370,570				
DISCRETE – User, primary	42,775,420	3,135,736	13,161,609	20,840,704	79,913,468	4,040,000	1,906,148	5,946,149	12,571,000	8,686,000	21,257,000	107,116,616	5,831,563	9,966,635	5,777,128	1,433,[illegible]
ESTIMATE – Operator	92,652,761	6,868,892	44,025,759	76,697,168	220,244,579	11,670,402	14,586,956	26,257,758	22,735,600	16,149,300	38,883,900	285,386,237	100,053,567	13,691,123	113,743,690	4,524,[illegible]
Operator, primary	53,756,889	4,985,247	22,395,674	53,169,497	139,102,403	7,886,089	6,582,085	14,468,174	9,414,000	8,011,100	17,425,100	170,995,677	38,264,854	3,673,826	42,038,630	3,439,436
Operator, primary capital	29,164,377	2,714,775	13,452,097	40,402,939	85,739,163	4,108,223	5,123,644	9,231,867				94,971,035	36,056,541		11,219,130	1,590,977
Operator, energy	960,218	165,181	851,992	1,539,246	3,522,637	126,603	219,344	345,947	1,502,172	1,322,686	2,824,858	6,693,343	606,338	211,336	817,724	D/C
Operator, support	32,911,282	1,916,116	14,173,862	16,060,035	65,061,295	3,710,543	3,153,440	6,863,983	13,321,600	8,137,200	21,458,800	93,384,078	5,612,615	4,016,297	9,648,932	1,[illegible]
Operator, network	1,584,594	67,429	6,956,222	7,412,636	16,080,881	74,170	4,851,431	4,925,601				21,006,482	56,056,078		56,056,078	
Operator, system-wide	43,092,934	3,233,069	24,034,079	50,521,431	120,936,373	5,272,495	10,909,407	16,181,902	D/C	D/C	D/C	137,118,275	94,632,919	13,690,123	94,633,919	2,082,572
ESTIMATE – User, primary	105,110,000	7,880,000	31,910,000	46,110,000	191,010,000	23,870,000	5,800,000	29,670,000	34,610,000	28,830,000	63,440,000	284,120,000	10,420,000	24,302,000	34,722,000	4,672,451
	104,070,000	7,800,000	31,590,000	44,150,000	187,610,000	23,070,000	5,400,000	28,470,000	32,010,000	27,150,000	59,160,000	275,240,000	8,840,000	24,230,000	33,110,000	4,[illegible]
	1,040,000	80,000	320,000	1,960,000	3,400,000	800,000	400,000	1,200,000	2,600,000	1,680,000	4,280,000	8,880,000	1,580,000	72,000	1,612,000	
PROXY – User	184,350,800	14,310,600	52,374,000	104,210,000	360,247,400	25,769,000	12,128,000	37,896,000	86,398,000	59,626,000	146,024,000	544,167,400	52,630,000	63,522,000	116,152,000	15,[illegible]
User, primary capital	35,370,800	2,747,600	10,630,000	33,010,000	81,798,400	10,890,000	4,390,000	15,280,000	41,360,000	28,390,000	69,760,000	166,838,400	25,060,000	40,452,000	65,512,000	[illegible]
User, primary op. exp.	3,420,000	258,000	1,136,000	3,270,000	8,014,000	908,000	463,000	1,461,000	12,438,000	8,866,000	21,304,000	30,839,000	7,320,000	670,000	8,490,000	[illegible]
	2,190,000	168,000	688,000	2,200,000	5,256,000	748,000	348,000	1,096,000	12,320,000	8,460,000	20,780,000	27,132,000	7,460,000	450,000	7,910,000	[illegible]
	1,020,000	70,000	360,000	770,000	2,220,000	60,000	25,000	85,000	64,000	26,000	90,000	2,195,000	20,000	90,000	110,000	[illegible]
	220,000	20,000	88,000	480,000	808,000	100,000	90,000	270,000	54,000	380,000	434,000	1,512,000	340,000	130,000	870,000	35,547
User, primary labor	145,560,000	11,305,000	45,570,000	67,930,000	270,365,000	14,390,000	6,775,000	21,165,000	32,600,000	22,370,000	54,970,000	346,500,000	19,750,000	23,400,000	43,150,000	[illegible]
PROXY – Society, primary	2,660,000	180,000	631,000	1,037,000	4,508,000	1,197,000	338,000	1,535,000	109,000	77,000	186,000	6,229,000	798,000	824,000	1,622,600	[illegible]
AGGREGATE FISCAL INPUTS – System-wide	427,542,981	32,373,338	147,104,866	254,265,612	861,294,197	70,330,515	42,763,975	113,094,490	169,745,000	121,684,800	291,429,700	1,269,818,387	167,737,[illegible]	113,053,551	275,[illegible]	[illegible]
Discrete	62,775,420	3,135,736	13,161,609	26,211,454	104,145,219	4,040,000	1,906,148	5,946,148	12,571,000	8,866,200	21,645,200	131,736,566	5,831,563	10,716,635	16,548,198	4,[illegible]
Estimate	197,762,761	14,748,892	75,935,758	122,607,168	411,254,579	35,825,515	28,391,827	63,717,342	70,667,000	53,115,900	123,782,900	602,754,821	[illegible]	37,992,[illegible]	[illegible]	[illegible]
Proxy	187,010,800	14,490,600	58,007,000	105,247,000	364,755,400	26,965,000	12,466,000	39,431,000	86,507,000	59,703,000	146,210,000	550,[illegible]	53,428,000	[illegible]	117,774,000	15,[illegible]
Categorical totals – Operator	92,652,761	6,868,892	44,025,758	76,697,168	220,244,579	11,670,802	14,586,954	26,257,768	22,735,600	16,148,300	38,883,900	285,386,237	100,053,567	13,691,123	113,743,690	[illegible]
Categorical totals – User	289,460,800	22,190,600	89,286,000	171,160,704	631,170,768	53,678,000	19,834,148	73,512,148	130,579,000	97,144,000	234,281,000	949,404,016	[illegible]	[illegible]	[illegible]	[illegible]
Categorical totals – Society	2,660,000	180,000	631,000	1,037,000	4,508,000	1,197,000	338,000	1,535,000	109,000	77,000	186,000	6,229,000	798,000	824,000	1,622,600	[illegible]

E/C: Not Available; D/C: Not Applicable; Incomplete Total

[illegible]

CHAPTER V

THE PHYSICAL INPUTS MATRIX

Introduction

Physical units are useful in understanding the relationship of the various inputs and outputs of an UPTS. For the operator of urban public transportation services, physical inputs play a highly visible role. The operator combines the various physical inputs in an optimum mix to produce the outputs of the system. Symbolically, the operator is operating under similar laws as a chemist who combines elements in a pre-specified formula to produce a compound. The process is visualized below.

A (Seat-miles) = B (Rolling Stock) + C (Labor-hours) +
D (Management-hours) + E (Maintenance Facilities +
F (Way Facilities) + (Repairs and Maintenance hours)

Of course, the operator must also evaluate expected revenues and input limitations when considering major decisions,but clearly the importance of physical measures of inputs is crucial to decision-making.

Physical measures also play an important role removing unit price distortions. The variety of accounting and valuation techniques also present certain distortions of inputs. The use of physical counts of various inputs, however, removes such distortions. Still, physical counts tend to introduce another type of distortion. For example, measures based on simple vehicle inputs cannot reveal differences among vehicles. A 33-seat bus differs from a 53-seat bus both in price and service, for example. Such differences are only visible if disaggregated data for each bus type is available. In addition, physical measures do not account for the portion of price difference is attributed to quality differentials. More specifically, while both the Market Street Subway cars of SEPTA (rail-rapid system) and the cars of the Lindenwold Line are used to produce seat-miles, significant differences in quality of the two services are not apparent from inventory information alone. Such differences can be expressed better in the price differences of the two vehicles, once historical and inflationary differences are extracted.

Finally, the physical inputs matrix can provide for a uniform measure over time intervals. Such uniformity of measure is not produced by manipulation of data through price indices or other ad hoc methods, but rather is explicit within the measure. It becomes very useful in understanding the flow and mixture of inputs over time frames and in more clearly identifying the effects of various input combinations.

The physical inputs matrix is particularly useful for representing labor inputs. This is so because the variability of wage rates, the addition of fringe benefits, and the regional differences tend frequently to conceal as much as they reveal of the real labor inputs in the production of any given set of outputs.

1.0 Types of Physical Inputs

The physical input matrix is not based on a common denominator, or unit of measurement, but it utilizes a variety of types of measures for each actor as well as for each system component. The following high description highlights the variety of measures utilized for each major type of inputs.

1.1 Capital Inputs

The units of measurement of capital inputs include the rolling stock, fixed facilities and equipment, of all systems components. The primary services system utilizes measures of the rolling stock. The support functions system component is dominated by floor area measures and by measures related to the support functions provided within the system. For instance, the floor area available for maintenance activities and the number of repair bays are felt to be critical factors in establishing system capabilities. For the network system component, the units of measurement focus on the extent of the system in terms of trackage, route miles or number of routes. Finally, a partial measure of system availability is introduced by counting the number of stations or stops. While a more detailed incorporation of capital categories is possible and indeed was initially used in this project, it is believed that the above measures "capture" the essence of the capital inputs of an UPTS.

1.2 Labor Inputs

Headcount data and labor hours provide a satisfactory measure of labor inputs for most analytical needs of an UPTS. Additional measures, such as overtime and weekend working hours, would have been very helpful in most cases, too, but such measures are usually not made available by the various operators. Labor inputs are divided for the purposes of this study into five discernible service functions, the following:

(1) Labor providing the direct transportation service;

(2) Labor incidental to directly providing service;

(3) Labor in management and administration functions;

(4) Labor performing major repair; and

(5) Labor performing routine maintenance.

Government also provides sizable labor inputs to UPTS in various types of service functions. The use of local police for patrol, safety and enforcement related to public transit is a valuable input which has been considered. The administration of grants, subsidies and contracts for UPTS is a second major labor input of government at various levels. Finally, the labor of local traffic engineering directly assists UPTS in planning routes and optimizing the services provided by the operator.

The sum total of these government inputs of labor represents a significant and necessary element of supplying public transportation services. While such labor data is difficult to obtain,the inclusion of such data should find a place in Productivity, Efficiency, and Quality studies to represent this significant input.

1.3 Energy Inputs

Measures in kilowatt hours are the only measures of energy included in the Physical Matrix. This type of inputs represents the energy utilized to directly conduct the transportation system.

2.0 Data Classification

A variety of sources and forms of data have been utilized to develop the Physical Matrix. To represent the reliability and variability of the data, a system of categories was developed to present the differences of data quality. Differences in quality stem, generally, from either inherent aspects of the measure or the lack of available # data directly measuring the measure indicated.

2.1 Direct Data

Direct data is characterized as being clear and requiring no manipulation, i.e., data readily available for use. Such items as the number of vehicles in a fleet and the number of employees by work task category clearly reside in this category. Elements of this subset are characterized, moreover by high reliability and accuracy as well as being free of a priori assumptions which "soften" the quality of the data. The dominance of the direct data in the Physical Matrix is not surprising, since physical measures are denoting specificity. In the matrix this data is included in the discrete data group.

2.2 Indirect Data

Several inputs to UPTS are not characterized by discrete measures of direct data and are thus formed using two at least data sources. For instance, by dividing or multiplying two data items the analyst produces an estimated measure. Thus the estimated input data represent a less distinct and discrete data basis. For example, two general methods are available to compute regional average trip time. One may sample a population and use the mean value as representative of average travel time. This procedure is more costly and time consuming than an alternative method, such as the method utilized by the system operators who usually derive their estimations on the basis of the actual vehicle users in their system. This is done utilizing average vehicle speed over all routes, average vehicle trip length, and average vehicle occupancy.

2.3 Proxy Measures

While none of the categories selected for inclusion in the Physical Input Matrix are classified as proxy, a brief discussion of this data category is in order. Through the use of data from external sources such as national averages, regional averages, or system averages, several measures of UPTS may be developed without the use of individual operator data. A brief examination of the categories of the proxy measures indicated in the Fiscal Matrix (see previous chapter) shows the difficulty inherent in obtaining other data for these input variables.

2.4 Conceptual Measures

Certain inputs to UPTS may defy quantification, even with the use of any proxy variable because they are, still, conceptually unfettered or a methodology for measurement remains undeveloped. For example, it has frequently stated that travel produces fatigue for the traveler. However, it is unclear, for instance, how such fatigue can be measured, what kind of fatigue it is meant, and how much does each trip contributes.

Many issues of importance need to be addressed in quantifying such input measures. While detailed discussion of these issues is beyond the scope of this work, the problem components can be identified as follows:

(1) Definition of the concept

(2) Identification of the factors constituting the concept

(3) Specification of the factor relationships

(4) Determination of the magnitude of the factors

(5) Development of the methodology for measuring the concept

(6) Verification of the methodology for concept consistency

3.0 Discussion of Results

The 1972 matrix of Physical Inputs at the end of this chapter (and the 1973 and 1974 Physical Input Matrice, included set Appendix I of this Volume), reveal a number of findings of particular interest.

The significance of the physical data is that the information herein may reveal for the analyst important data. Such information may relate to all three major groups of inputs to the system, i.e. capital, labor, and energy.

Although the 1972 Physical Input Matrix does not include much of the desired data, it can still provide important insights. For instance, one may observe the total number of vehicle units actually utilized by each mode, the number of route, the route miles, the number and size of the station and all other actual, physical dimensions of each system. Instead of their dollar cost the analyst has in his availability the actual system parts and parcels. Any output accomplishments of the system will have to finally be referred back to the various and specific system components which contributed in producing the system's output. If the analyst be able to also have in his disposal the variations of the system's units during the various operational stages of the system (peak hour; off-peak hour; base period, weekends; past, present and future variations, etc.) he then can carry a much more detailed, accurate, and revealing analysis of the system's performance. For example, one may notice in the 1972 Physical Inputs Matrix that the bus system of the City Transit Division (CTD) of SEPTA have 1485 buses available of which only 1112 were utilized during the peak hours, while during a typical day up to 1349 buses were used by the system. This information is very instructive in many ways. For instance, the ratio $^{1112}/_{1485} = 0.75$ is far too low for immediate comfort for any system since it suggests that about one quarter of the buses were not needed (or used) even during the hours of peak demand. The explanation in this case can be found in the ratio $\frac{1349}{1485} = 0.9$ that about 90% of all buses of the system were used sometime during a typical day in 1972. The explanation goes further to indicate that more than 15% of buses in use during a typical day in 1972 were in need for replacement (breakdowns, accidents, etc.). Obviously, improvements in any system would have to be sought in such areas of unsatisfactory state of affairs.

Another set of pertinent observations can the analyst make with regard the labor inputs to the system. For instance, observing the summary column of SEPTA (Pennsylvania Region) the analyst may compare the actual physical unit of labor devoted to each system component in terms of either headcounts or working hours. Comparing inputs of labor units to support functions vs. primary services,the analyst may notice that while the distribution of operating costs between the two system components was in 1972 almost 1 to 1. (see Fiscal Input Matrix 72 and 76 millions are entered for the two system components). the labor units ratio is only 0.40 (1974 are 4700). Pursuing this comparison one step further, one may notice that in terms of workhours the ratio is only 0.28; another important drop indicating the extreme concentration of overtime in the provision of service, rather than in support functions.

Further within the support functions, a number of important observations can be made. With regard to Repairs and Maintenance one may notice that this function absorbs 71% of the workers of support functions, but utilizes 74% of the workhours; indicating again that, within support functions, the overtime work is primarily placed within the Repairs & Maintenance functions. Comparing Repairs & Maintenance functions with primary services, one may notice that while it absorbs 29% as much workers as the primary services $\frac{(1432)}{(4700)}$ it utilizes only 20% as much actual workhours than the primary services. Again the relative excessive concentration of overtime in the provision of primary services is revealed.

Detailed accounts of the physical inputs of an UPTS are indeed instrumental for crucial managerial and planning decisions for the system in any region. Unfortunately the present project was able to collect only a fraction of the important data for each region and subsystem. For this reason no detailed and specific comparisons of each system and mode within the three test regions can be made. However, the project's objective that focussed on the need to reveal and organize the important data appropriately for intensive efficiency studies is well served with formulation of the Physical Inputs Matrix and the few entries, exemplary entries that are included herein.

URBAN PUBLIC TRANSPORTATION SYSTEM

PHYSICAL INPUT MATRIX 1972

TABLE NUMBER:

ACTOR	SYSTEM	INPUT	DESCRIPTION	UNITS	PA SEPTA Bus	PA Trolley Bus	PA Trolley Rail	PA Rapid Transit	PA C.T.D. TOTAL	PA SEPTA Bus	PA Trolley Rail	PA R.A.D. TOTAL	PA SEPTA Penn Central	PA Reading Co	PA G.C.D. TOTAL	PA REGION TOTAL	NJ PATCO Rapid Transit	NJ T.N.J. Bus	NJ REGION TOTAL	DE DART Bus
DISCRETE: OPERATOR	PRIMARY		Operator Input Totals: Operator Primary Input Totals:																	
		CAPITAL PDOPSV	NUMBER OF VEHICLES IN FLEET/D	#	1485	131	394	490	2470	210	54	264	324	178	502	3236	75	415	490	74
		PDOPPV	VEHICLES USED DURING PEAK HRS/D	#	1112	93	264	264	1733							1733				64
		PDOPOV	No. OF OPERATIONAL VEHICLES/D	#																
		PDOPDV	No. OF VEHICLES DEPLOYED DAILY/D	#	1349	131	563	489	2832											
		LABOR	Operator Labor Input Totals:																	
		PDOPLT	LABOR HOURS EXPENDED IN DCCT TOTAL/D	HRS	7,783,601	512,540	1,509,752	1,372,023	11,177,916	740,620	292,274	1,032,894				12,210,810	171,663	1,210,126	1,210,126	243,556
		PDOPLD	LABOR HOURS IN DCCT	HRS	7,101,904	454,441	1,271,816	977,070	9,810,281	588,232	234,525	822,757				10,632,989		999,106	1,170,769	
		PDOPLR	LABOR HOURS RELATED TO DCCT	HRS	676,697	58,099	237,936	394,953	1,367,685	152,388	57,749	210,137				1,577,822		201,020	201,020	
		PDOPET	EMPLOYEES UTILIZED IN DCCT TOTAL/D	#	2460	199	698	993	4350	350	100	350				4700		666	666	
		PDOPED	EMPLOYEES IN DCCT	#	2029	167	565	780	3491	267	69	336				3827		550	550	
		PDOPER	EMPLOYEES RELATED TO DCCT	#	371	32	133	223	769	85	31	114				873		116	116	
		ENERGY	Operator Energy Input Total:																	
		PDOPPE	KWH OF POWER CONSUMED/D	KWH	395.3×10^6	16.4×10^6	96.4×10^6	172.86×10^6	670.96×10^6	50.94×10^6	24.6×10^6	75.54×10^6	70.4×10^6	85.0×10^6	155.4×10^6	901.9×10^6	36.5×10^6	$.844 \times 10^8$	120.9×10^6	19.9×10^6
	SUPPORT		Operator Support Input Totals:																	
		CAPITAL	Operator Capital Input Totals:																	
		PDOSAT	BUILDING FLOOR AREA TOTAL/D	SQFT																
		PDOSAO	FLOOR AREA OF GENERAL OFFICES	SQFT																
		PDOSAM	FLOOR AREA OF MAINTENANCE FAC	SQFT																
		PDOSVB	NUMBER OF REPAIR BAYS/D	#																
		PDOSVG	AVERAGE NUMBER OF VEHICLES IN GARAGE/D	#																
		PDOSVP	NUMBER OF PARKING SPACES/D	#				1300	1300			1300	6551	3589	14,140	11,440	8832		8832	
		LABOR	Operator Labor Input Totals:																	
		PDOSLT	SUPPORT LABOR HOURS TOTAL/D	HRS	1,265,790	95,014	705,207	1,192,365	3,202,783	191,798	63,440	255,238				3,558,021				
		PDOSLA	MANAG & ADMIN LABOR HOURS TOTAL	HRS	521,483	39,104	158,333	266,349	929,676	18,825	7,530	26,355				956,031		134,236	134,236	
		PDOSLM	MAJOR REPAIR LABOR HOURS TOTAL	HRS	492,227	15,725	407,098	628,998	1,534,042	113,568	41,932	155,500				1,691,542		173,106	173,106	
		PDOSLR	ROUTINE MAINT LABOR HOURS TOTAL	HRS	262,080	40,185	139,776	297,024	739,065	59,405	13,978	73,383				812,448		94,032	94,032	
		PDOSET	SUPPORT EMPLOYEES TOTAL/D	#	710	52	396	671	1829	109	36	145				1974		245	243	
		PDOSEA	MANAG & ADMIN EMPLOYEES TOTAL	#	274	20	83	141	518	10	4	14				532		85	85	
		PDOSEM	MAJOR REPAIR EMPLOYEES TOTAL	#	276	9	233	360	878	65	24	89				967		104	104	
		PDOSER	ROUTINE MAINTENANCE EMPLOYEES TOTAL	#	150	23	80	170	423	34	8	42				465		56	56	2
	NETWORK		Operator Network Input Totals:																	
		CAPITAL	Operator Capital Input Totals:																	
		PDONMT	MILES OF TRACK TOTAL/D	MILES			171	58	229		45.2	45.2	269.6	340	609.6	883.8	33		33	
		PDONMY	MILES OF YARD TRACK TOTAL	MILES				4	4								4		4	
		PDONMS	MILES OF TUNNEL/SUBWAY TRACK TOTAL	MILES			6	37	43								5		5	
		PDONME	MILES OF ELEVATED TRACK TOTAL	MILES				17	17						8	25	2		2	
		PDONRM	ROUTE MILES (Two-Way)	MILES	1679	41	167	46	1983		45.2	45.2	269.6	340	609.6	2587.8	29	1899	1928	
		PDONNS	NUMBER OF STATION STOPS/D	#													12		12	
		PDONFA	FLOOR AREA OF STATIONS/D	SQFT									252,375	20,500	277,875	277,875				
	SYSTEM-WIDE		Operator System-wide Input Totals:																	
		CAPITAL	Operator Capital Input Total:																	
		PDOWFA	S/W FLOOR AREA TOTAL/D	SQFT									257,375	20.500	277,875	277,875				
		LABOR	Operator Labor Input Totals:																	
		PDOWHT	S/W LABOR HOURS TOTAL/D	HRS	9,049,381	603,554	2,314,959	2,564,388	14,880,699	952,419	355,714	1,298,332				15,669,021		1,344,242	1,344,262	
		PDOWET	S/W EMPLOYEES TOTAL/D	#	3180	251	1094	1654	1065	449	136	485				4960		911	911	
DISCRETE: USER	PRIMARY		User Input Totals: User Primary Input Totals:																	
			AVERAGE FARE PAID/D	$	.35	.35	.35	.35	.35	.35	.35	.35				.35	.51	.68	.53	
			[illegible]	#	1691	117	435	971	2464	107	34	141				2145	47		42	
ESTIMATE: OPERATOR	PRIMARY		Operator Input Totals: TRANSIT [illegible] POLLUTION/E	LBS	1,138,492				1,138,492	172,759		172,759		48,016	48,016	1,359,267				64,900
			ENERGY CONSUMED [illegible] TRACTION/E	KWH	223.6×10^6	13.8×10^6	80.9×10^6	145.2×10^6	564.34×10^6	42.8×10^6	20.7×10^6	63.5×10^6	59.1×10^6	71.4×10^6	130.5×10^6	758.34×10^6	30.7×10^6	70.9×10^6	101.6×10^6	16.72×10^6
	SUPPORT		OPERATOR SUPPORT ENERGY INPUT TOTAL/E	KWH	66.6×10^6	2.63×10^6	15.43×10^6	27.65×10^6	107.47×10^6	8.15×10^6	3.93×10^6	12.09×10^6	11.3×10^6	13.6×10^6	24.9×10^6	144.46×10^6	5.8×10^6	12.5×10^6	18.3×10^6	3.2×10^6
			OPERATION STATIONS	KWH	53.9×10^6	2.3×10^6	13.5×10^6	24.2×10^6	94.04×10^6	7.13×10^6	3.44×10^6	10.58×10^6	9.9×10^6	11.9×10^6	21.8×10^6	126.42×10^6	5.1×10^6	11.1×10^6	16.9×10^6	2.8×10^6
			[illegible]	KWH	7.7×10^6	$.33 \times 10^6$	1.93×10^6	3.45×10^6	13.43×10^6	1.02×10^6	$.49 \times 10^6$	1.51×10^6	1.4×10^6	1.7×10^6	3.1×10^6	18.04×10^6	$.7 \times 10^6$	1.7×10^6	2.4×10^6	0.4×10^6
ESTIMATE: USER	PRIMARY		User Input Totals: [illegible]	MIN	10.2	14.2	14.2	15.2	12.3	34.6	16.1	29.9	21	25.1	22.6	16.1	13.6	41	16.4	12
ESTIMATE: GOVERNMENT	SUPPORT		Government Input Totals: Government Support Input Totals:																	
		LABOR	GOVERNMENT LABOR HOURS TOTAL/E	HRS																
			POLICING & SAFETY LABOR HOURS	HRS																
			LOCAL TRAFFIC [illegible] HOURS	HRS																
CONC.: USER	PRIMARY		User Input Totals: User Primary Input Totals:																	
			PATRONS [illegible] TRANSIT/E																	
			[illegible]																	

KEY: Not Available
Not Applicable
Incomplete Total

CHAPTER VI

LABOR INPUTS ACCOUNTS

Introduction

In this chapter, the measures of labor inputs are being discussed. The term, "labor inputs" used here refers to three measurement units: number of employees, man-hours and total dollar labor cost. The derivation of these measurements passes through several stages of preparatory work. The first stage requires the disaggregation of total labor headcount data provided by each operator in order to divide labor inputs according to the division of the system into components and functions, i.e., direct transportation operation, other primary operations, administrative and managerial operation, repair and maintenance, and lastly transportation promotion and marketing. The second stage involves the derivation of man-hour data. This is calculated by multiplying a work unit factor with the total headcount data (the work unit factors represent the average workhours per employee in each component and function of the system. The last stage requires the disaggregation of labor expenses for each labor category. This disaggregation is made either according to the distribution of the total number of workers or by employing a fixed distribution factor derived from a particular year where detailed available information is available.

The procedures listed above involve continuous cross-checking and data consistency checks. The following sections present a general overview of the data sources, level of detail in data classification and of the comprehensiveness in the data availability. In addition, this chapter discusses some of the general problems encountered and the need for several general data modifications that arise in processing the pertinent data.

This chapter can also be read in combination with Appendices C and G, in which additional details and specific discussion items central to the understanding of labor inputs are also presented.

1.0 Definition of the Labor Input Categories

By definition, those workers who are allocated to the provision of the daily transportation services belong to Primary Services Component of the system. This group may include drivers, yardmen, some field supervisors, and some primary maintenance labor, etc. In contrast, workers who are engaged in major maintenance or repair, and supervision of system-wide activities, are included in the support functions component of the system. This group also includes workers in major maintenance of facilities, rolling stock, as well as all the managerial personnel of the system.

The network component includes workers who are engaged in major construction of new networks and stations. Since, however, most of the network construction workers were hired only during construction of the network, they are not included in any operational report and thus are not included in the present analysis. Therefore, in processing the operator's labor input variables, we are only concerned with primary and support function labor.

In an UPTS, there are three distinct labor groups: (1) labor which is directly and immediately related to the provision of transportation services; (2) labor devoted to maintenance and repair activities (of both rolling stock and fixed facilities); and (3) A broad classification of managerial and administrative personnel that is responsible for a variety of functions within the system.

By definition, the first category belongs to primary function; with regard to the second category, however, some problem arises as to whether part of the maintenance labor should belong to the primary function (i.e., fare box maintenance, air condition repairing, etc.) and the other part (i.e., major maintenance of structure) should belong to support functions, per se. Therefore, it was necessary to separate the maintenance labor into routine maintenance labor (primary services) and major maintenance labor (support functions). The third category is placed under support function since they are clearly supportive the provision of transportation services. In order to examine more closely the relationship between the labor productivity in the "promotion of transportation" operations, an attempt is made to extract another labor category, i.e. workers responsible for providing telephone information, and receiving and processing complaints and requests from the public.

Thus, the following five labor classifications are included: (1) labor in direct transportation operation; (2) labor in other primary operations (including primary maintenance labor); (3) labor in administrative and managerial support activities; (4) labor in major repair and maintenance support activities; and (5) labor in transportation promotion. Each group includes the following:

(1) Labor in Direct Transportation Operation. In terms of headcounts, this category includes all the employees who are directly engaged in the provision of daily transportation service, i.e., transportation operators (drivers and trainmen), tower men, yard men,etc.

(2) Labor in Other Primary Operations. This category includes all employees who are not directly related to the provision of daily transportation service but are necessary in providing better services. This group includes depot and other direct supervision of transportation operation; route controllers and checkers; power plant operations; minor repair and maintenance for rolling stock only, i.e., fare box

repair, heat/air conditioner maintenance and/or other minor electrical equipment inspection and maintenance.

(3) Labor in Administrative and Managerial Support Activities. This category includes all the management and administrative personnel, and all supervisory staff who are not directly engaged in the provision of daily transportation performance. Also, employees, whose activities relate to transportation training programs are included in this category.

(4) Labor in Major Repair and Maintenance Support Activities. These activities include major maintenance work for rolling stock and physical assets and thus include the following operations: (a) major overhaul; (b) major maintenance of rolling stock; (c) maintenance of way; (d) maintenance of track and structures; and (e) maintenance of buildings. In addition to these maintenance activities, this category also includes those employees engaged in servicing activities.

(5) Labor in Transportation Promotion and Marketing Support Activities. Employees in this category are responsible for providing telephone information, receiving public complaints and requests, maintaining contacts with news media, and the provision of other passenger services.

2.0 Distribution and Shift of Manpower

From the above derivation process, it can be concluded that most of the inter- or intra-functional distribution were made according to the distribution of headcounts. Herefore, in this section, headcounts are taken as an index to show the inter- or intra-functional manpower distribution and shift of each operator.

2.1 Distribution of Manpower

(a) Comparison of Inter-modal Distribution of Labor.

Table VI-4 shows SEPTA CTD total headcounts distribution. Table VI-4 shows the percent of primary and support workers for each mode. From these figures, it can be noted that the percentages of primary service workers on bus and trolley bus lines are higher than those of trolley rail and rapid transit lines. A plausible reason for this difference might be that trolley rail and rapid transit modes require more maintenance labor for the track maintenance and structure maintenance activities. This is especially true in rapid transit systems where more than 40% of the workers belong to the support function. (The major difference is the higher percentage of repair and maintenance labor.)

Examining Table VI-5 for the case of SEPTA RAD, the relatively low percentage of administrative workers that can be observed is due to the aggregation of SEPTA's personnel structure. The Administrative and Finance Departments in SEPTA, as shown in most operating statements, is under the CTD classification.

In general, all bus systems tend to have more labor involved in the primary services whereas rail systems required more labor in support function.

(b) Comparison of Inter-Systems Distribution of Labor.

Table VI-5 shows the labor distribution among the various transit modes in the three test regions and the four basic functional divisions. The interesting observations that can be made from this table are several. First, concerning the four bus systems in the three regions the percent of headcounts in the primary services varies from a low of 57.5% for SEPTA-RAD to a high of 66% for DART. With regard to managerial and administrative personnel a

TABLE VI-4. PERCENT OF PRIMARY AND SUPPORT WORKERS BY MODE 1974.

OPERATOR	MODE	% of workers in PRIMARY FUNCTION	% of workers in all SUPPORT FUNCTIONS
SEPTA-CTD	Bus	75.0%	25.0%
	Trolley Bus	76.2%	23.8%
	Trolley Rail	61.2%	38.8%
	Rapid Transit	55.8%	44.2%
SEPTA-RAD	Bus	74.8%	25.2%
	Trolley Rail	72.0%	28.0%
SEPTA	Total	74.3%	25.7%
DART	Bus	83.0%	17.0%
TNJ	Bus	72.0%	28.0%

TABLE VI-5. INTRA-FUNCTIONAL LABOR DISTRIBUTION OF EACH MODE

OPERATOR	MODE	TRANSPORT OPERATION	OTHER PRIMARY OPERATIONS	MANAGEMENT and ADMINISTRATION	REPAIRS and MAINTENANCE	OTHER
SEPTA-CTD	Bus	62.6%	12.3%	9.9%	14.6%	0.6%
	Trolley Bus	62.8%	13.4%	10.3%	12.8%	0.7%
	Trolley Rail	48.5%	12.6%	8.7%	29.6%	0.6%
	Rapid Transit	41.0%	14.9%	9.9%	33.6%	0.6%
CTD	TOTAL	54.4%	13.1%	9.7%	22.2%	0.6%
SEPTA-RAD	Bus	57.5%	17.3%	1.9%*	23.3%	
	Trolley Rail	51.8%	20.8%	4.3%*	23.1%	
RAD	TOTAL	56.1%	18.1%	2.5%	23.3%	
DART	Bus	66.0%	16.9%	9.8%	6.0%	1.3%
TNJ	Bus	60.3%	11.8%	9.4%	17.6%	0.9%

NOTE: These data were derived from 1974 Headcount Data.

distinct similarity can be seen in the three regions with the only exception of SEPTA-RAD for which the managerial personnel is provided by SEPTA-CTD. With regard to repairs and maintenance personnel the distribution varies dramatically from a low of 6% for DART to a very high of 23.3% for SEPTA-RAD. Second, concerning the two light rail (trolley rail) systems in the Pennsylvania region the distribution of personnel appears similar except that, again, the total personnel devoted to primary services in SEPTA-CTD is only 48.5% of the total. This is so because of, perhaps, the inclusions of all RAD managerial personnel in the CTD statistics. Still one may notice that repairs and maintenance personnel for CTD is considerably higher than the corresponding personnel for RAD. Finally, concerning the rapid transit system in the region the data available states that for strictly primary services only 41% of the total personnel is allocated. Another 14.9% is devoted to maintenance functions.

On the basis of this data, Table VI-5 clearly suggests that differences in labor distribution are more due to the modal distribution than to the scale of operations. Although significant differences in the labor distribution within systems are also present, the difference associated with the modes seem to be more distinct than the differences associated with the scale of operations.

2.2 Shift of Labor Distribution Over Time

From Figures VI-1 through VI-5, several general observations can be made. For example, for SEPTA CTD and DART a perceptible upward movement on labor inputs is discernable, even within the short period of only three years (1972-1974). For TNJ, on the other hand, a small contraction of manpower is shown. With regard to the distribution of manpower among functions, a relative stability can be observed, with the possible exception of the bus system of SEPTA-CTD where a relative proportional increase of support functions labor can be observed.

Unfortunately no detailed data on labor distribution from PATCO could be obtained.

3.0 Overview of Data

At this point a number of observations need to be made concerning the labor data of the three test regions, and by extension concerning the availability, readiness, and quality of data on labor inputs for UPTS in 1976. First, each of these operators operate at a different scale (geographic coverage as well as different levels of financial resources) and thus the consequent information provided by these operators are at different levels of detail and comprehensiveness. Second, the breakdown by mode is generally not distinct or clear-cut. Therefore, modification of the data to represent modal distributions were necessary. Third, in the year 1974-1975, SEPTA changed its accounting system, thus the classifications given for 1974 data are totally different from that of 1973, 1972, and 1971. This necessitated a revised and extremely careful processing procedure for data disaggregation. Fourth, Penn Central and Reading are now in bankruptcy proceedings and were operated under the jurisdiction of the Federal District Court on a day-to-day basis.[1/] The takeover was scheduled for July 1975, but it is still not completed. Most of the Rail Division staff of 1974 has remained to help preserve and improve railroad service performance and facilities maintenance during the takeover period. After the acquisition, SEPTA plans to re-evaluate the staff positions. Therefore, the SEPTA General Contract Division, Rail,

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1/ SEPTA, Resources Utilization Plan, 1974 and 1975. (See "Commuter Rail Operation" section.)

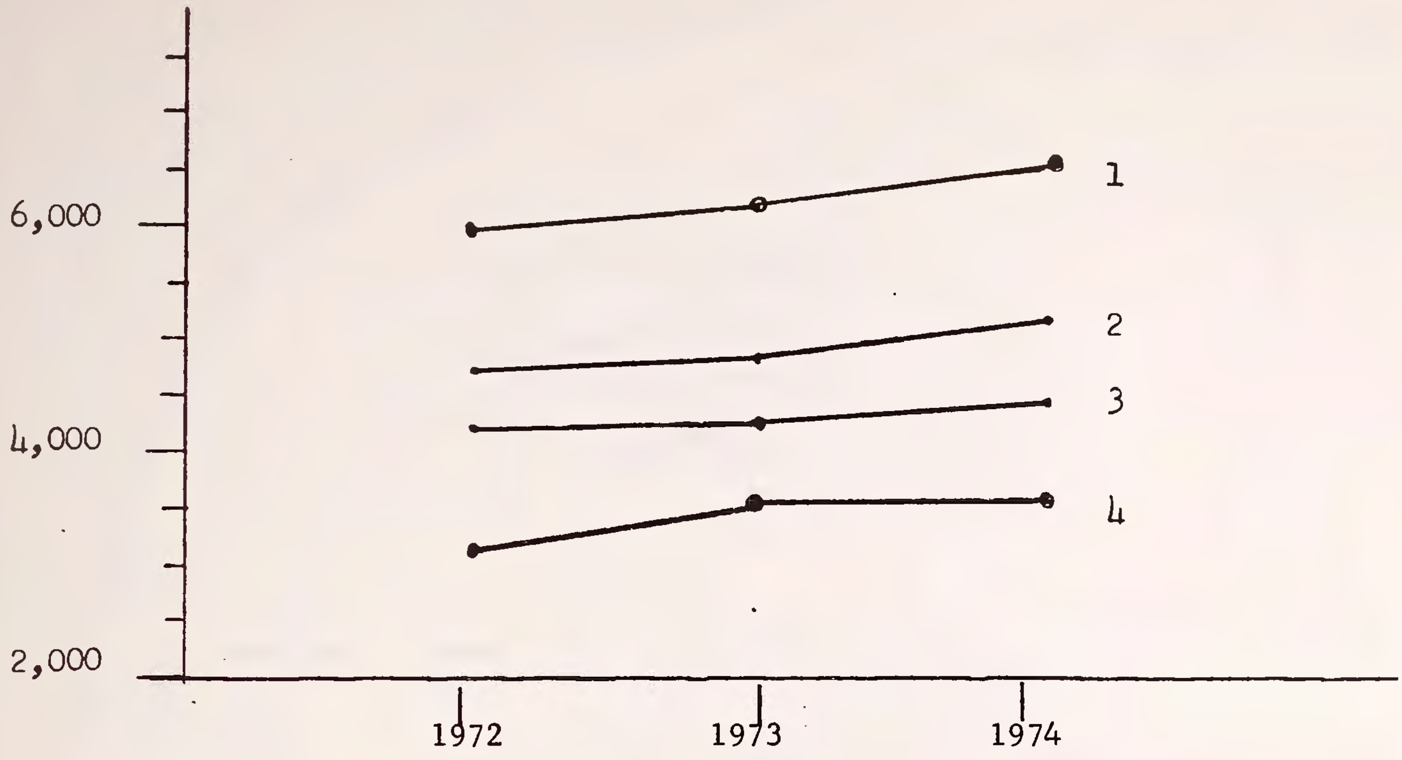

Figure VI-1. SEPTA C.T.D. TOTAL HEADCOUNT DISTRIBUTION

Figure VI-2. SEPTA C.T.D. BUS HEADCOUNTS DISTRIBUTION

Curves: (1) Total Operator Employees (Sum of Primary and Support)

(2) Sum of Management and Administration and Primary Employees

(3) Total of Primary Employees

(4) Employees in the Direct Conduct of Transportation

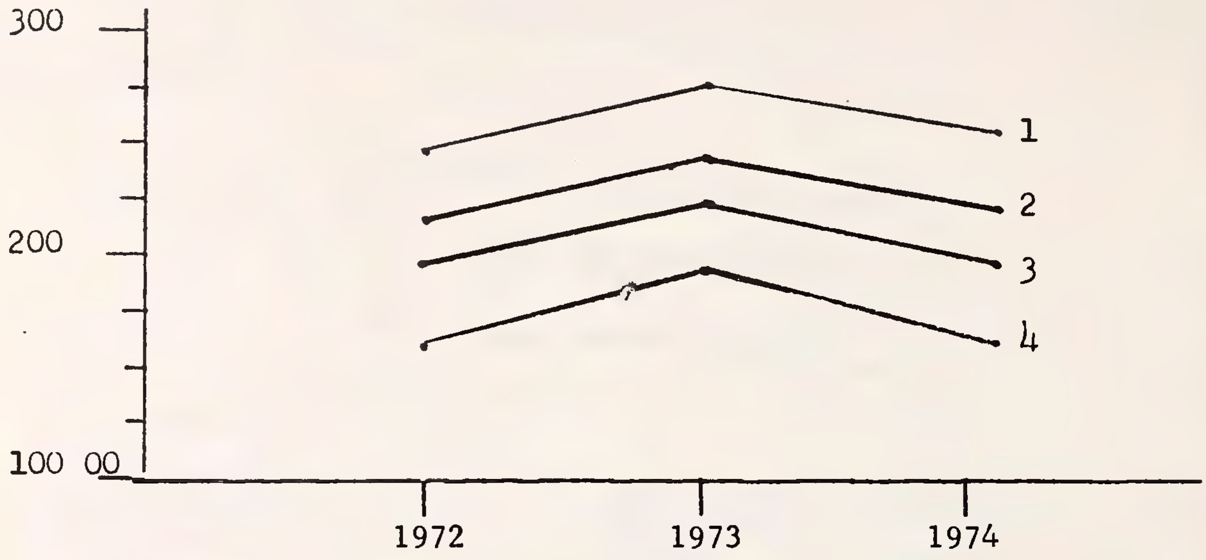

Figure VI-3. SEPTA C.T.D. TRACKLESS TROLLEY HEADCOUNTS DISTRIBUTION

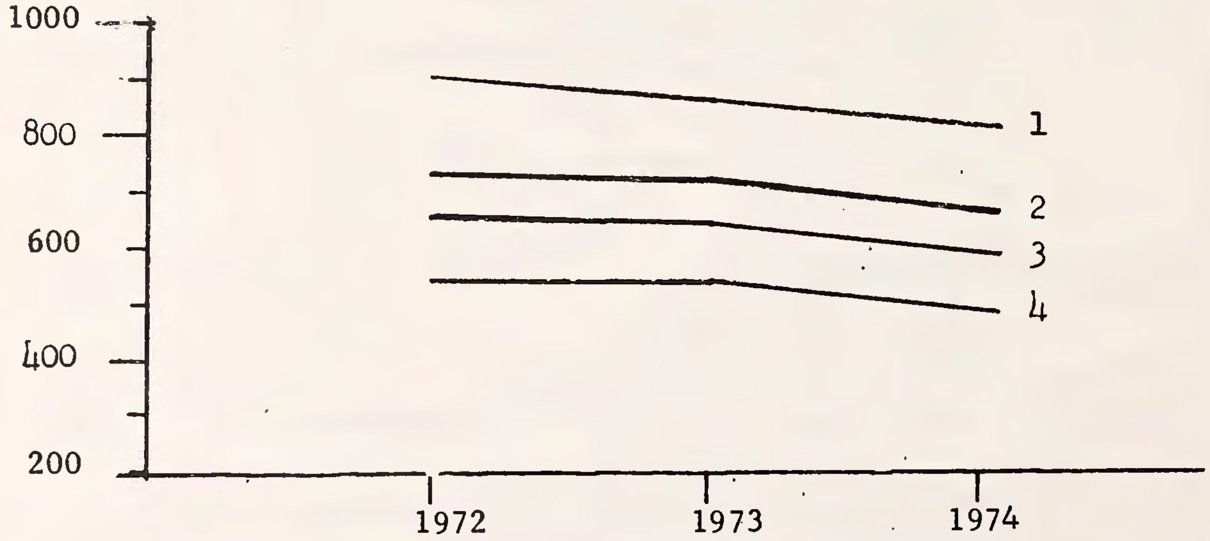

Figure VI-4. TNJ SOUTHERN DIVISION HEADCOUNTS DISTRIBUTION

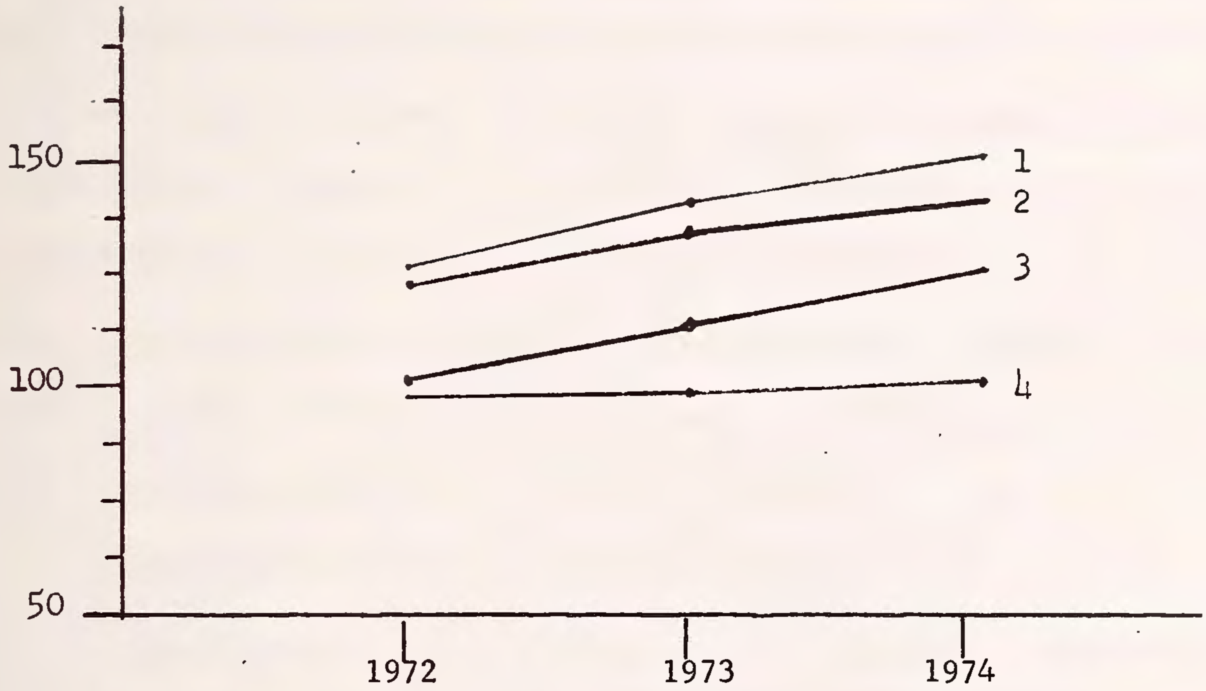

Figure VI-5. D.A.R.T. BUS HEADCOUNTS DISTRIBUTION cannot be considered as normally operating organization.

Concerning CTD of SEPTA, detailed descriptions about the tasks performed by each labor group were available and thus it was not difficult to distribute the headcount data into the 5 major labor input categories. However, for SEPTA RAD, TNJ and DART, there was no such detailed information available. Thus a high level of potential error in disaggregating total headcount for these groups is possible. This is especially true in distributing maintenance labor between primary and support functions.

The breakdown of data among modes represents another important problem for multi-mode regional systems such as SEPTA. Headcount data is not generally given in a modal breakdown format. For example, supervisor and administrative labor in SEPTA's Administration Department serves the entire system and, therefore, distinctions between CTD and RAD, as well as by mode, become almost impossible.[2/] Also, Man-hour figures are not usually available. Only from the accounts of "employee lost time", and overtime data can these figures be derived. These data are actually, however, labor paid-hours, rather than actual work hours. Thus, one still does not have available actual work hours by mode and by function.

The disaggregation of labor costs also encounter problems. For efficiency studies, labor costs should be calculated on the basis of total actual work hours and the individual's pay scale rather than on the general-

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2/ For the sake of completing the breakdown of data in all cases, the research team of this project utilized the only available alternative, i.e. disaggregating the headcount data according to the total number of passengers or total vehicle miles of each specific mode. A similar assumption was applied for the modal breakdown of transportation promotion labor. However, it should be realized that the produced results would probably yield very little revealing information, since the modal distribution of input data were made according to the distribution of the out-put data.

ized distribution of total employee salaries. However, individual pay scale data is not generally available, nor is actual employee work hour data available.[3/]

In general, the consistency (i.e., reliability) of data sources, needed to provide an accurate region-wide basis for productivity measurements represents a major problem. As discussed in Appendix G, each operator maintains its own accounting classifications. In order to compare systems, it is necessary that the level of detail in respect to the tasks performed be consistent among operators. For example, more detailed information about maintenance activities is necessary in order to provide a more accurate minor/major maintenance breakdown.[4/] Other particular data concerns focus on the man-hour inputs such as employee lost time, overtime, actual work hours vs. paid hours, etc. All such data are instrumentally important and need to be provided directly from all the operators, in order to derive accurate and comparable productivity measures.

The second major concern is the possible errors arising in the data synthesis process. This concern focuses on the need to incorporate the "qualitative" aspects of labor inputs such as age structure, sex composition, working experience mixture, education, etc. In most studies, as well as in this one, due to the limitations of time and data availability, this information is not included.

3/ For the sake of completing the tables of this section, both of these data sets were derived using aggregate labor costs and total head count data, utilizing a method that is based on disaggregating total labor cost data according to the distribution of total headcount within each operator. Thus, some degree of inaccuracy may exist in cases where there are different accounting systems for headcounts and labor cost.

4/ Detailed minor/major maintenance disaggregation tables for SEPTA CTD 1974 were included in Appendix G as a reference.

Another major concern arising from the synthesis of labor inputs in this study stems from the lack of detailed data on overtime work hours. Since there were no comprehensive overall overtime work hours data for PATCO, DART and SEPTA (CTD and RAD), the overtime distribution was assumed to be uniform over the modes and the operators. In the case where no employee overtime was mentioned, it was assumed that all employees worked only on regular schedules.

4.0 Technology Changes

One issue that is usually left out of the quantative analysis is the changes of technology. In most short-term analysis, the external factors are considered as unchanged over the years studied, but in the real world, technology does have some influence on the system even within a few years time. This influence may be in two different ways:

(1) Changes which increase output but do not affect the marginal rate of substitution between labor, capital, or other systems inputs. This can be easily measured from input/output analysis.

(2) Increasing capital/labor ratio. For example, technological change could reflect a labor saving substitution, or it might imply the upgrading of labor skills. Both types of technological changes only marginally were taken into account in the present study because of lack of data available from all operating systems in the three test regions.

Another issue in labor cost adjustment concerns the regional variations in wage rates. In comparing transportation labor costs across several regions, differentiation in quality of labor inputs will produce differentiation in wage rates which may, then, influence the outcome of productivity measurements.

This can be especially crucial when dealing with the already well developed regions versus a developing region. However, in the current study, the three test regions are rather similar to each other. Thus, such regional variations were not taken into account in the current study.

The composition of labor distribution for each operator varied little across the years, but a significant difference appears when distributions are compared among regions. One conclusion that can be drawn is that when the system is operating at a smaller scale, a larger proportion of labor will be involved in primary transportation operation (drivers). As the operation scale of the system becomes larger, it tends to diffuse into more differentiated levels of intermediate functions. Thus, the percentage of administrative and managerial staff will tend to be increased to facilitate larger system needs. Therefore, in cross-regional comparisons, we must recognize that the differences in each labor input variable imply not only the differences of productivity but also the differences of operational scale.

5.0 Conclusions

Most of the analytical information included in this discussion of labor inputs to the UPTS in the three test regions came from SEPTA's City Transit Division. Clearly this division of SEPTA is the best prepared one to search for productivity and efficiency optimization solutions. The relationship between primary services and support functions only in this division can be traced into sufficient detail and be revealed. This project, for instance, could have progressed very little without the data and the assistance provided from this division. Furthermore, many of the assumptions that were necessary in pursuing the exploration of the other systems within the three test regions were based on the data provided by the CTD.

In terms of the evaluation of data availability it seems also clear that the 1974 data was the most complete and usable. The initial intention was to carry out an analysis of the five year period 1970-74. However, it turned out that there were hardly any complete data sets available for 1970 and 1971. As the years approached 1975 the data availability on labor distributions and specifications improved markedly. Following this trend, and taking into account the new data requirements of Section 5 of the 1974 U.S. Mass Transportation Act, plus the UMTA's decision to move ahead toward the implementation of the FARE system it seems clear that labor data for 1975, 1976, and thereafter would be much more complete, available and suitable for the triple analysis of productivity, efficiency and quality of service. Within such a context, the relationship between primary services and support functions would easily be illuminated and scrutinized.

CHAPTER VII

CAPITAL INPUTS TO THE UPTS

Introduction

This chapter discusses the capital inputs to the UPTS. The discussion is divided into four parts. First, an extensive classification and description of the various capital inputs is carried. Then a brief discussion of the special evaluation difficulties is presented. Third, a brief discussion of the various capital accounting methods is included. The chapter concludes with a brief presentation of the approach followed in this project in taking into account the capital inputs of the various UPTS within the three test regions.

The present effort departs from previous investigations, because it attempts to distinquish capital inputs by type and by component of the system where each input item is applied.

Further, the data on capital inputs is also subdivided according to the nature and the reliability of the data sets themselves.

Two basic approaches, the fiscal one (i e., using dollar values) and the physical one (i.e., using discrete units of facilities) are available for analyzing capital inputs. Within these generic groups any specific type of capital assets can be identified. Two such types are the fixed capital assets and the liquid capital assets. Fixed capital items provide the inventory of fixed assets such as land, buildings and networks. Liquid capital includes the resources consumed in the operation and maintenance of the system. The data items are grouped according to the intrinsic quality of each data input. Only values for fixed capital inputs are discussed. The values of liquid capital are included in the category of operating expenses in order to separate that type of capital from fixed assets. Such a distinction is both useful and informative. Liquid and fixed capital vary not only conceptually but also in the nature of their use in the UPTS. Further, disaggregation of capital in this manner better facilitates the separate analysis of capital and labor contributions to the productivity of an UPTS.

The capital inputs discussed below are clearly represented in the Matrix of Fiscal Inputs. Capital items are identified according to the system components (Primary Services, Support Functions, and the Network) in which they are applied and according to the actor that contribute them.

1.0 Multiple Classification of Capital Inputs

The analysis of the capital inputs of UPTS requires that each type of capital inputs be examined carefully and properly be included in the system's capital accounts. Three systems of classifications appear rather obvious. One according to the actor who contributes each specific input, a second one according to the functional role of each input; and a third one according to the fiscal aspects of the specific input.

1.1 Actor Classification of Capital Inputs

(A) Operator Capital Inputs

This type of capital inputs should be distinguished according to the extent which each input item is discrete, estimated or proxy.

Discrete Capital Inputs. Discrete capital inputs can be defined as those inputs whose source and value are readily identifiable. Operators, for example, employ discrete inputs such as rolling stock, car shops and garages and miles of subways to provide transportation services.

Estimated Capital Inputs. The category of derived capital inputs is most closely related to the calculation of replacement costs of inputs. In a very real sense, the use of replacement factors involves capital valuation indirectly. That is, knowing replacement cost of a particular equipment with given service characteristics, the analyst may proceed to estimate the capital inputs to the UPTS, based on the optimum service characteristics displayed by the equipment. Clearly, the most likely categories for indirect measurement are rolling stock, way equipment and buildings.

Proxy Capital Inputs of Actors. The use of proxy data is most directly linked to the capital category of land valuation. For all transportation suppliers (but especially fixed guideway systems), land occupied by buildings and by the network are critical inputs. The characteristics of these two categories of land, however, vary significantly. This variation suggests the use of different valuation procedures.

(B) Government Capital Inputs

One element which clearly distinguishes transportation services from other industries, is the involvement of the public sector. Significant capital inputs are made by the government into nearly all aspects of providing transportation services. In the area of capital for urban public transportation systems these inputs are more clearly defined than in the other system's components.

Discrete Public Capital Inputs. Publicly owned land, rolling stock and structures are the prominent categories of public capital inputs. In many cities, close co-operation between the governmental unit and the transit operator have resulted in joint ownership of various capital items. For example, SEPTA and the City of Philadelphia are the owners of rolling stock, of miles of subway tunnels, and of elevated lines.

Estimated Public Capital Inputs. For the UPTS, derived public capital inputs include items such as land which have been supplied to transportation operators indirectly ranging in scale from scale from Federal Land Grants to acquiring lands under eminent domain.

(C) User Capital Inputs

The capital inputs that the user contributes to the UPTS are limited and restricted into one type of user: i.e., the suburban commuter. This type of user usually needs an approach vehicle in order to move to and from the public transportation facility. This approach vehicle represents then a singular capital investment by the user. Its total cost, or a proportion of its costs, depending on the pattern of its use, should be considered as a capital input to the operations of the UPTS itself.

1.2 Capital Inputs by System Components

Capital inputs are provided by various UPTS actors and are used in serving the various system components. Each operator contributes the majority of capital inputs to the UPTS but government contributions are becoming increasingly more substantial. In general, capital items can be segregated by the service they provide through the system components.

Primary Capital Inputs. Included in the primary inputs category are resources both necessary and sufficient to produce optimum transportation service. The major categories of primary inputs suggested are shown in Table VII-1. While such items as passenger equipment are clearly primary inputs, the criteria for inclusion of categories such as interlockers is related to the provision of an optimum service. Such controlling mechanisms allow safer operation as well as contributing to faster travel times. Clearly, the electrical distribution systems of operators provide the energy necessary to operate the service and are included in the list of primary service capital inputs.

The above categorization holds for modes generally classified as rail rapid transit. For the three test regions, the high speed lines of SEPTA, the commuter rail lines of Penn Central and Reading, and the Lindenwold Line were considered using this suggested categorization. Table VII-1 lists the various types of capital inputs of the primary services associated with each specific mode of travel within an UPTS.

Support Capital Inputs. Defined to include use of resources for all support functions of a UPTS, such as major maintenance and repair of the primary and network components, management and administration, training and personnel services, etc. the capital inputs for support functions are dominated by buildings and structures. Table VII-1 shows the distribution of these support inputs by each individual mode of an UPTS.

The data available for the operators within the three test regions, with the notable exception of SEPTA, can be disaggregated by mode with little difficulty. Most of the SEPTA data for City Transit Division (CTD) is, unfortunately, aggregate for two or more of the four modes of travel grouped in this Division.

Network Capital Inputs. The category of network capital inputs includes major expenditures for fixed assets. Primarily, the assets considered in the network group are related to fixed guideways in such systems and to the general way structures which perform transportation services in the three test regions under consideration. Table VII-1 indicates the types of capital inputs that each mode may require for its network.

1.3 Functional Capital Inputs

Previous productivity studies have examined capital inputs to transportation systems at an aggregate level of input. Such a level of analysis, however, avoids direct confrontation with the problems the analyst

TABLE VII-1. CAPITAL INPUTS BY SYSTEM COMPONENT

System Component	Capital Input Categories	Rapid Rail + RR + Subway	Trolley Rail	Trolley Bus	Motor Bus
Primary Services	Passenger Equipment:Rolling Stock	X	X	X	X
	Passenger Equipment:Pass.Shelters	X	X	X	X
	Service Equipment(i.e. Fare Collection)	X	X	X	X
	Signals to Interlockers	X	X		
	Communication Systems	X	X	X	X
	Underground Conduity	X	X		
	Electrical System	X	X		
	Information System	X	X	X	X
	Safety System	X	X	X	X
Support Functions	Repair Shops	X	X	X	X
	Garages	X	X	X	X
	Burn Houses	X	X	X	X
	Administration Building	X	X	X	X
	Miscellaneous Service Buildings	X	X	X	X
	Maintenance Depots	X	X	X	X
	Shop Equipment	X	X	X	
	Roadway Equipment		X	X	X
	Land in Support Functions	X	X	X	
Network	Rights-of-way	X	X		
	Roadway	X	X	X	
	Tunnels	X	X		
	Bridges	X	X	X	X
	Viaducts	X	X	X	
	Elevated Structures	X	X	X	
	Stations	X	X		
	Parking Lots	X	X	X	X
	Terminals	X			

soon encounters when he undertakes to carry out disaggregated analysis.

The distribution of capital investment should also be made along functional lines. Four general categories were developed for use in the analysis of capital stock.

(1) Way Capital. The way capital can be best defined as capital investment directly associated with or physically located on the path of the mode. Items included in this category are, for example, land used for right-of-way, tunnels and subways, and the fixed guideway components. (Rails, ties, fastenings, etc.)

(2) Buildings and Structures Capital. The category of buildings and structures poses few, if any, conceptual difficulties. Obvious examples of this category are general office buildings and maintenance facilities.

(3) Equipment Capital. Previously discussed as either permanent or short-duration operating equipment, it conceptually includes those items which are necessary for the proper utilization of other capital stock. For example, the lighting fixtures and associated relays, switches and transformers are all necessary for the proper use of the passenger vehicles.

(4) Transportation Capital. Transportation capital is utilized to facilitate the provision of public transportation. Such investments as parking lots, bus shelters, operator owned billboards or other promotional or informational investments are examples of such capital.

1.4 Fiscal Accounts of Capital Inputs

Capital items are characterized by their heterogeneous nature. Because of this, the use of monetary values has been frequent in incorporating capital inputs. However, the use of monetary values should not be made without first examining where the data to be used is coming from, especially since there is a variety of methods that can be used to assign monetary values to capital. The capital equipment supplied as inputs by the operator must also be separated into "short-duration" and "permanent" equipment. The life expectancy of these two types of capital differ markedly, resulting in different impacts on productivity. Short duration equipment is usually found in the primary services and support function components of the system. Permanent equipment is usually found as part of the network component of the system. To categorize equipment, the susceptibility of the equipment to technological innovation should also be taken into account. That is, equipment readily improved, (i.e., fare collection equipment), is entered as short duration, operating equipment. **(See Also Appendix B).**

Incorporating the dollar value of new capital includes some additional difficulties. The dollar value of new capital is readily available from governmental sources as well as from the annual balance sheets of transit operators. The dollar value of new capital investment is usually then mixed with accounts of previous capital investments using "book value" of these investments. The aggregation of new capital dollar values with depreciated values of capital stock results in a hybrid of dollar values which can often become misleading.

The dollar value of capital utilized should also be examined for the impact that time plays on the value of capital. The transit industry, possibly to a greater extent than other industries has been faced in the recent past with rapidly rising costs of capital investment. Industry publications and the Federal Bureau of Labor Statistics provide indices of both an aggregated price index and of specific commodity indices. The vulnerability of transit capital to rapidly escalating costs suggests the use of commodity indices for such purposes especially if data is available concerning inventory, original cost, and age distribution of the capital stock. **(See Also Appendix B)**

2.0 Special Valuation Difficulties

Several capital items require special attention to highlight the idiosyncracies of the items and the elusive nature of their value.

(1) Land. The land occupied by buildings used by transportation suppliers is perhaps the less difficult category to value. Clearly, the low level of sales of land of such proportions precludes the use of a market approach to valuation. Additionally, developers are not usually drawn to such sites for a wide variety of reasons related to the site, market conditions, or financial constraints. The alternative use of a site can be used to determine the value of land in such situations.[1/] For example, SEPTA land occupied by the 2nd and Wyoming complex is adjacent to residential properties. Lacking qualities normally attributed to commercial and industrial uses, it would be reasonable to assume the alternative use of the tract would be residential. It is a rather simple matter to transform the value of the alternative use using generalized land values for the surrounding areas.

The land occupied by rights-of-way pose a different and more difficult matter to resolve. Varying in width from 50 to 400 feet, rail rights-of-way for roadbed sections are at a minimum 37 feet. In a similar fashion, line lengths vary from 3.9 miles to 33.3 miles on the Penn Central Manyunk and the Reading Trenton lines. Finally, the right-of-way passes through the entire spectrum of land values from central business district to agricultural.

1/ A major failure of this approach is the exclusion of a factor related to the higher value of assembled land versus subdivided land in urban areas. While this exclusion leads to an underestimation of value, the rare sale of such assembled tracts in urban areas precludes any but arbitrary values being assigned to the assembly factor.

(2) Buildings. The specialized nature of transit related buildings and the non-existent file of current sales virtually eliminates the use of market valuation techniques. Additionally, advances in the art of construction and the use of new materials suggest that transit facilities erected today would bear small resemblance to facilities erected as recently as 10 years hence. The analyst is therefore left with less than optimum alternatives. Book values as one alternative include distortions already discussed. Unit costs for replacement of the structure, however, avoid manifest preferences for structural form and composition. Ultimately, the analyst should tailor the valuation to perceived preferences of the operator as well as local policies.

(3) Rolling Stock. Intensely affected by rising costs, rolling stock is particularly difficult to assess. In their discussion of capital inputs in Transportation Productivity, Scheppach and Woehlicke propose a workable approach. The suggestion is to develop blocks of homogeneous capital inputs, based on their functions and service characteristics within the UPTS. Assuming that the efficiency of the block declines at an increasing rate as a function of time, efficiency indicators based on historical data then are applied to deflate the inputs of the entire block. This framework suggested Scheppach and Woehlicke is most useful in structuring depreciation schedules to reflect the rate of depreciation.

(4) Way Structures. (tunnels, bridges, viaducts, elevated frames, stations, etc.) This represents a special functional class of capital assets, all of which is usually included under the classification of the system's network. The problems included in this class of capital assets are based on both functional obsolescence of a facility as well as on its structural deterioration. Finally, major policy decisions concerning urban development

at large may increase or decrease the significance and/or value of a way structure.

3.0 Accounting Methods of Capital Assets

It is generally acknowledged that the capital assets of the urban public transportation system decline in value through use. (land holdings in the urban public transportation system is a notable exception.) To account for this consumption of resources, depreciation of the original value over an estimated useful life for the asset is used. There are three general methods in the field as follows:

(1) Straight Line Depreciation: As the name implies, straight line depreciation reduces the accounting value of assets uniformly throughout the useful life of the asset. Specifically, the account is annually reduced by an amount 1/N, where N equals the projected useful life. The uniformity of this procedure is most appreciated for predictability and stability.

(2) Sum of Years Digits Method: Essentially, this method allows slower recapture than the declining balance approach. The annual depreciation is calculated through the use of a fraction whose numerator is the remaining years of useful life and whose denominator is the projected useful life normalized over all the years of the projects projected life. This method implies that an asset depreciates by declining amounts as the years of useful life are consumed.

(3) Non-Accounting Methods: The main non-accounting approach in capital valuation is the use of replacement cost of the capital item. Two alternative methods are generally identifiable within this general approach. (a) Market Replacement Cost Method. The market replacement philosophy

requires valuing assets using replacement costs of presently available items. For example, this method requires that the "Eighty footers" used by area commuter lines be "replaced" by "Silverliners" even though the service characteristics of the items are not related one to one. This philosophy implies a uniform level of service for all lines serviced by the Penn Central and Reading, although, in reality, the "Silverliners" operate only on particular lines. (b) Historical Replacement Method. The historical approach requires estimation of the current replacement cost to reproduce an identical item. While price indices may be used to develop the required values, considerations of technological innovation and "optimum" service for each period enter in determining the meaningfulness and/or acceptability of even considering the costs of reproducing an identical and already obsolete facility.

As an indication of the problems included in choosing one of the available accounting methods one may point to the fact that frequently the courts are called upon to determine the social value of the capital assets of a transportation system. The judicial branch of government has often been likened to a "social barometer." In the field of transportation, the courts have often served as social determinants of the social value of a given facility.

An early decision of the I.C.C., Excess Income of St. Louis & O'Fallon, 124 I.C.C. 3., involved recovering income in excess of contemporary rates of return. "What the Commission approved was a synthetic valuation, consisting of present land values, of reproduction costs at 1917 unit prices for old structures installed prior to June 30, 1914, and of both the estimated and recorded actual investments of the new structures installed thereafter."2/

2/ Wu, Shao-Tseng, Railroad Valuation and Fair Return, University of Pennsylvania Press, Philadelphia, 1930, p. 19.

The final determination of this matter by the U.S. Supreme Court held, in fact, that the cost of reproduction must be given equitable consideration in valuation attempts.

Of course, cost of reproduction can be calculated by two ways. In the economic sense, cost of reproduction is most clearly associated with a substitute item, providing, presumably, service reflecting technological innovations. The courts have, on the other hand, repeatedly associated reproduction cost with the provision of an identical item.

While in 1930, the Supreme Court in United Railways v. West,(280 U.S. 234) held that the annual depreciation charge should be based on the "present value" instead of on the original cost of the depreciable property,[3/] (together with an unstable depreciation rising and falling in harmony with prices), a 1944 decision, Federal Power Commission v. Hope Natural Gas Co., (320 U.S. 591),reversed this position.[4/]

The ambivalence of the judiciary can be viewed as a reflection of societal uncertainty in dealing with the issue of capital depreciation. Capital costs need to be developed for an optimum urban, public transportation system (UPTS). A system can be characterized, as optimum on the basis of either of two determinations. In the first sense, optimum can be based on the physical usefulness of a capital item. Second, an optimum facility can be characterized as such on the basis of the functional role it plays; for instance a capital item may be evaluated on both physical obsolescence and on time obsolescence.

3/ Locklin, Philip D., Economics of Transportation, 1972, Homewood, Illinois. p. 343.

4/ Ibid, p. 355.

As explained earlier, market replacement may determine values of present equipment through the use of state-of-the-art substitutes. At first it would seem that the first adjustment to capital cost valuation would be the inclusion of the difference in cost between the simple replacement of the old equipment and the depreciated cost of substitute, modern day equipment. **(See Also Appendix B).**

To create a more realistic approximation, the capital cost produced above should be adjusted and factored into constituent components by introducing control variables. For example, one may use price indices, inflation indices and quality improvement coefficients as control variables. The quality improvement coefficients can then be factored into components of speed, comfort, energy use, etc. The various components may then be valued through the use of proxies or indirect standards to generate costs per unit.

While complex and potentially arbitrary, the above procedure is a tool useful in determining the capital costs of sub-optimum facilities and equipment at a given year. Alternatively a procedure has been suggested for use in the FARE proposal which does not possess the complexity of the above procedure but does provide the uniformity of information necessary to compare systems in different urban areas.[5/]

Adjusting historical cost through the use of price indices assigned to the capital category, adjusted costs are then utilized to determine book value, accumulated depreciation and annual depreciation. The formula

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5/ Project FARE Task IV Report, UMTA, Nov. 1973, Vol. II. "Reporting System Instructions," p. 9.3-2.

as reported is:[6/]

$$C(Adj.) = C\ (Hist.)\ \frac{X\ PI_N}{PI_A}$$

where, $C(Adj.)$ = price-level adjusted cost

$C(Hist.)$ = historical cost represented by acquisition year

PI_N = price index for current year

PI_A = price index for acquisition year

4.0 Valuation Methods Used In The Test Regions

Primarily as a function of data availability, the capital values which appear on the Fiscal Matrix represent the various accounting methods in each region. The search for a uniform presentation of capital value for the three regions was not successful. The use of book values were

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6/ Within the suggested improvements included in the FARE reporting system, improvements in reporting of capital items are especially significant. Specifically, three reporting forms recommended for use in FARE are most significant.

(1) Form 110. Part A of Form 110, "Property Subsidiary Schedule," provides for reporting by mode additions to and retirements of Transit Operating Property. Various vehicle types are listed with appropriate columns to enter the value of additions and retirements of revenue vehicles. Part B of Form 110 provides for an accounting of the physical units added and retired; again by vehicle categories. In combination, the forms provide a detailed examination of revenue vehicles flow.

(2) Form 111. Form 11, "Revenue,Vehicles," provides extensive inventory information for the flow of revenue vehicles, including such information as year of acquisition, number of vehicles and acquisition cost. Form 111 allows the analyst to trace a vehicle from acquisition to retirement.

(3) Form 112. "Fixed Assets" includes of the categories of service vehicles, of building and of structures, support equipment, office equipment furniture as well as all land holdings. Form 112 presents the monetary value of the assets.

adopted purely on the basis of prevalence and availability. Indeed, the paucity of capital data for several operators cannot be explained easily. Good management of resources suggests visibility of present and past assets. The lack of such information clearly points to the use of less than optimum management practices.

Pennsylvania Region: SEPTA

City Transit Division (CTD). Complete data for CTD is available for additions and retirements to the capital stock. The values represented are book values and represent the state-of-the art for CTD capital stocks. To facilitate distribution of inputs, three procedures were utilized to tailor the data to the criteria established for support inputs.

(a) The categories of rails and rail fastenings, miscellaneous way expenses, special work items, distribution bonds, tunnels and subways and signals and interlockers were distributed on the basis of the percentage of track miles of each mode.

(b) The categories of shops, carhouses and garages and miscellaneous buildings and structures were distributed using the model percentage distribution for bus, trolley bus and trolley rail modes.

(c) The categories of general office buildings, service equipment, passenger equipment, shop equipment, furniture, automotive equipment and land holdings were distributed using the passenger mile percentage contribution of the four City Transit Division modes. As stated earlier, for all other operators the more general distribution of accounts shown on Table VII-1 was utilized.

Red Arrow Division (RAD). Data available for RAD is disaggregated by modes and is presented for all years under consideration. Book values were once again the most readily available data for all capital inputs.

General Contract Division (GCD). The only available information for the capital stock of the commuter rail lines, Penn Central and Reading, is the appraisal performed by the United States Railway Association (USRA). The R-1 form filed by Reading with the Interstate Commerce Commission was reviewed. Unfortunately not all property dedicated to commuter rail service is highlighted in this form and several major assumptions were necessary to produce useful information.

New Jersey Region: PATCO

Values of capital presented for PATCO were developed using straight-line depreciation of reported capital values. Direct comparisons of performance measures based on capital inputs between PATCO and other modes must consider the differences associated with the valuation technique employed to avoid incorrect conclusions.

New Jersey Region: Transport of New Jersey (TNJ)

Capital values for TNJ are presented on a system-wide basis. Thus major assumptions are required to disaggregate this data. For this reason the value of capital assets of the southern division of TNJ is available for only one year and it represents simply the book value of these assets.

Delaware Region: DART

Book value of assets is also presented for DART for the years under consideration. This data required conversion from fiscal to calendar year presentation to provide uniformity with values presented for other operators.

CHAPTER VIII

ENERGY INPUTS TO THE UPTS

Introduction

The energy involved in providing mass transportation service is a comprehensive as well as an evasive quantity to compute. It is comprehensive in that finding the total energy consumption by a mode of transit involves more than a cursory assessment of tractive effort expended. The estimation of energy used for transit service is an evasive task in that there are both tangible and intangible factors which are combined in determining the energy "needs" of an operator who provides transit service for the other three actors--the user, society, and government.

The organization of this chapter is based on the contribution made by each actor with regard to energy. For each actor, the primary, support, and network categories (as previously defined) will be scrutinized, in turn, to explicate the input data and input analyses, the output data and output analyses, and the derived measures of transit system performance. Nonetheless, there are sufficient insights presented at this juncture to elicit further comment and potential expansion of some areas toward developing energy elements in greater breadth and depth.

The operator will be assessed in three areas along the energy dimension. First, for the primary functions, the annual amount of energy consumed in providing vehicular traction and the cost of that amount will be computed for each mode over the period 1970-74. Then using the passenger miles and the vehicle miles traveled by each mode, sets of load (occupancy per vehicle) curves by mode and for all modes are developed. Cost figures also are relatively compared over all modes for the period studied. Second, maintenance and repair of all transit elements are examined as partly primary, partly support functions. Third, construction and manufacture energies are discussed under the network category.

1.0 Primary Functions

1.1 Concepts and Measures

The annual energy amount and energy cost associated with vehicular traction were computed for each mode. The general method used was to calculate the annual transit energy amount for 1970-74. This includes the energy used for vehicle traction, energy used for vehicle, station, and facility operation. Using a relationship developed in assessing the Lindenwold High Speed Line by Boyce and others,[1/] the average tractive power exerted in vehicle locomotion was established at 84% of the total energy use. Similarly station operation accounts for an average of 14% of the total energy and maintenance functions for another average of 2% of the total energy needs of an UPTS. Of course, the relative percentage of energy used for traction does differ from mode to mode. Yet, for the purposes of the current analysis these average proportional distributions are satisfactory.

The outputs included in this analysis are annual revenue passenger-miles and vehicle-miles for the years 1970 through 1974.

1/D.E. Boyce et al., Impact of Rapid Transit on Fuel Consumption and Cost for the Journey to Work: An Analysis of the Philadelphia-Lindenwold High Speed Line, Regional Science Dept., University of Pennsylvania, 1975.

The objectives in carefully and thoroughly analyzing energy use patterns are threefold:

(1) to determine the changes in energy consumption intramodally over the time period;

(2) to determine the changes in energy consumption among the test regions over the time period; and

(3) to assess ways of conserving modal energy.

In persuing these objectives, the performance measures are transformed within an energy framework by using energy precepts in a public transport context. Since efficiency measurements express how well a component of the transit system is functioning, the measures of energy efficiency (generally a ratio of output to input variables) as applied to primary services in order to indicate the extent to which energy conservation is being achieved.[2/]

The total annual passenger-miles divided by the total annual vehicle-miles for a mode is one way of computing the average number of passengers per vehicle for that mode.[3/] This method was used to compute load factors for all modes for the years under investigation in this project, too. Relative percentages of maximum loading capacity were also calculated for each mode by accepting that on the average one-third of the fully-loaded bus, trolley rail car, and trolley coach car are standees, two-thirds of a fully-loaded rapid transit car or High Speed Line car are standees, and 0% of a fully-loaded commuter train are standees.[4/] (See Table VIII-1.) It was further

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2/A.R. Tomazinis, Productivity, Efficiency, and Quality in Urban Transportation Systems, Lexington Books, D.C. Heath & Co., Lexington, Mass., 1975, CH. 5.

3/Ibid.

4/1974 National Transportation Study Data, Penn. Portion, Phila.-Trenton Urbanized Area, Report No. NTS-X-1, Revision B, Delaware Valley Regional Planning Commission, May 1973.

assumed that the maximum vehicle capacity figures remained invariant with respect to the time period of the project.

1.2 Vehicle Efficiency

Energy efficiency is expressive of the distance traveled by a transit vehicle per unit of fuel consumed. This quantity is a measure of how well fuel is converted into usable vehicle traction. Units are in terms of vehicle-miles per BTU. Another measure of energy efficiency is defined by the distance traveled by people (using a transit vehicle) per unit of fuel consumed. This quantity is a measure of how well a public transport mode performs its primary function--the movement of people. Units are in terms of passenger-miles per BTU. (Figures VIII-1 to VIII-4.)

The extent to which the transport services provided are considered desirable and thereby usable from the consumer's viewpoint define quality. From the operator's vantage point, measures of quality are reflected in how well he can supply the user with the type of service that the latter wishes. There are many pertinent quality measures[5] in each UPTS but for the purposes of the present project one such item would be enough. Frequency of service has been chosen and scrutinized later on in this chapter from the energy savings accrued from harmonic variation of modal stopping patterns.

1.3 Loading and Cost Curves

Loading curves give the variation of vehicle energy efficiency as loading ratios increases for a particular transit mode in a particular year. The method employed to derive the loading curves is to first compute the original loading factors for the mode. Next, this original loading factors are changed in order to find (for the vehicle efficiency measure) what the

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5/Tomazinis, p. 20.

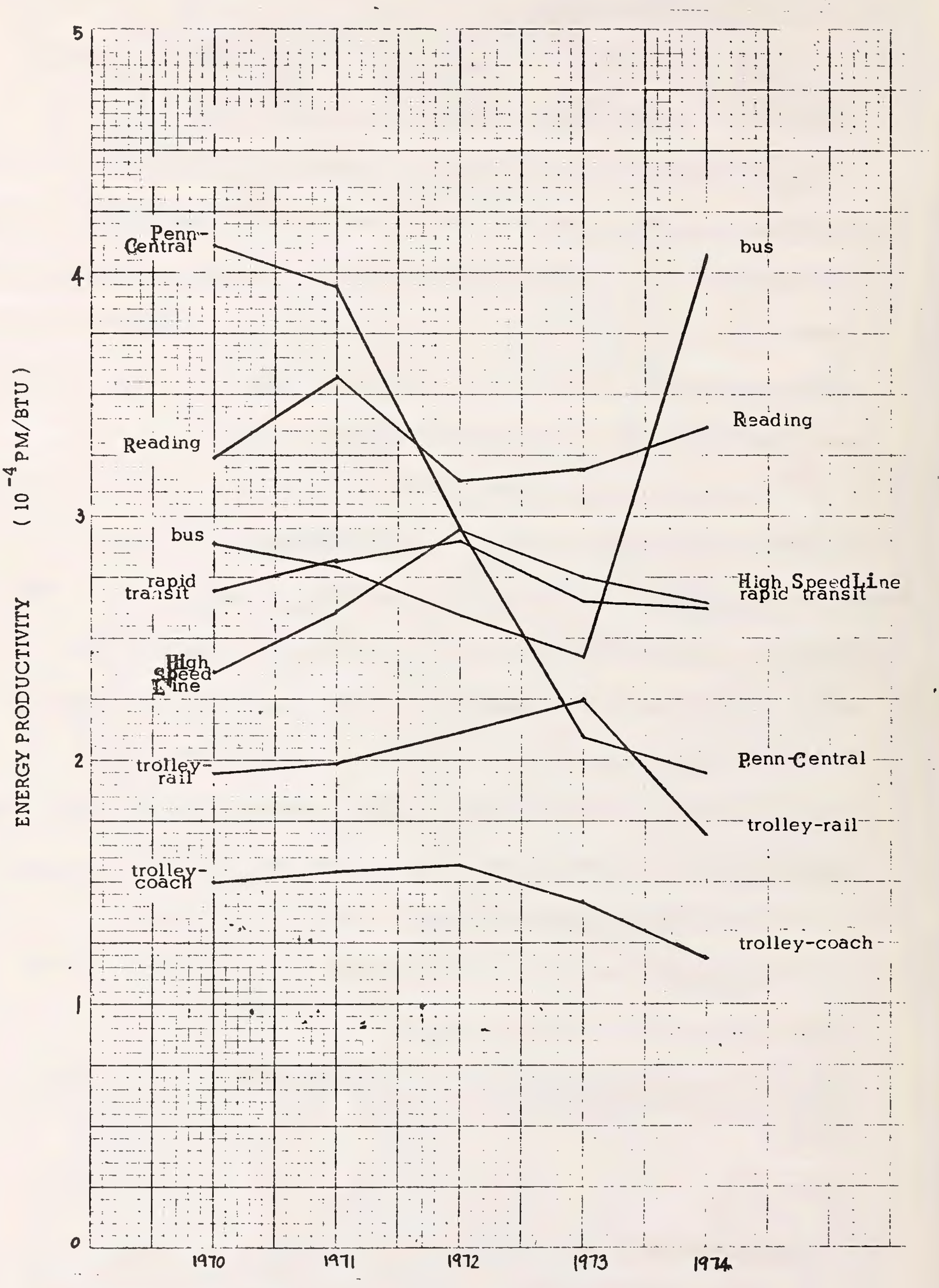

FIGURE VIII-I. ENERGY PRODUCTIVITY BY MODE
(PASSENGER MILES PER BTU)

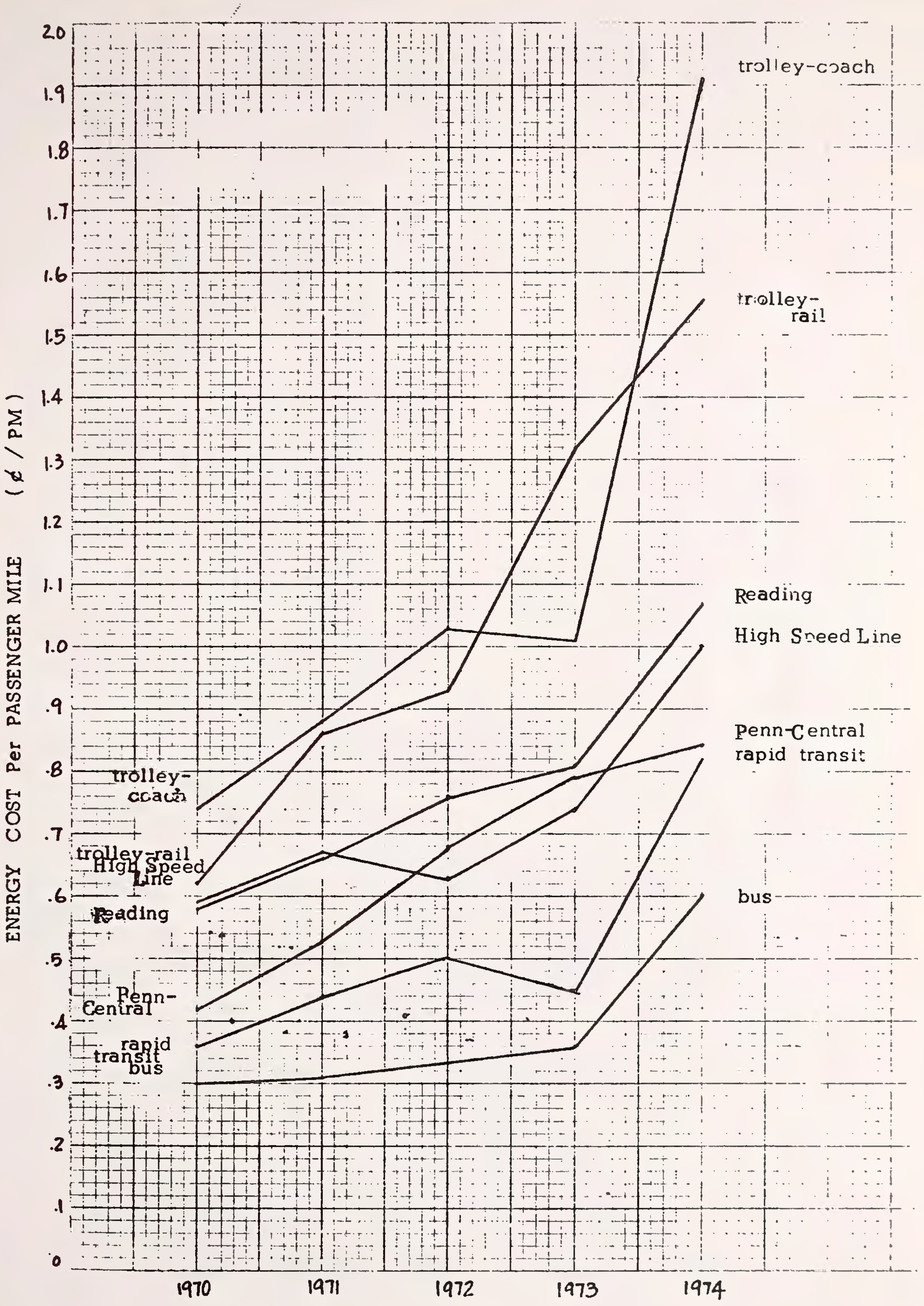

FIGURE VIII-2. ENERGY COST PER PASSENGER MILE

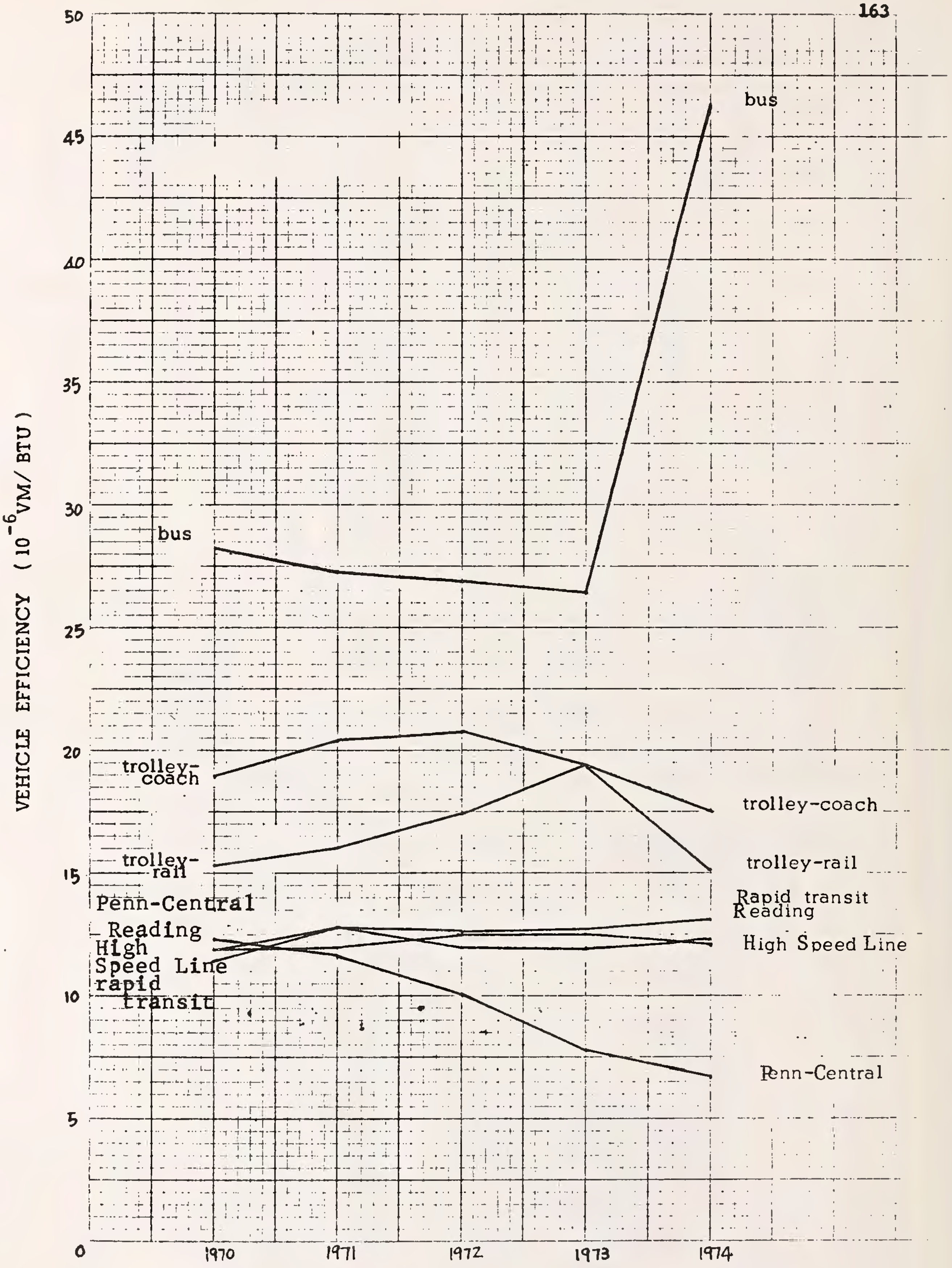

FIGURE VIII-3. ENERGY EFFICIENCY PER VEHICLE MILE - VEHICLE MILE

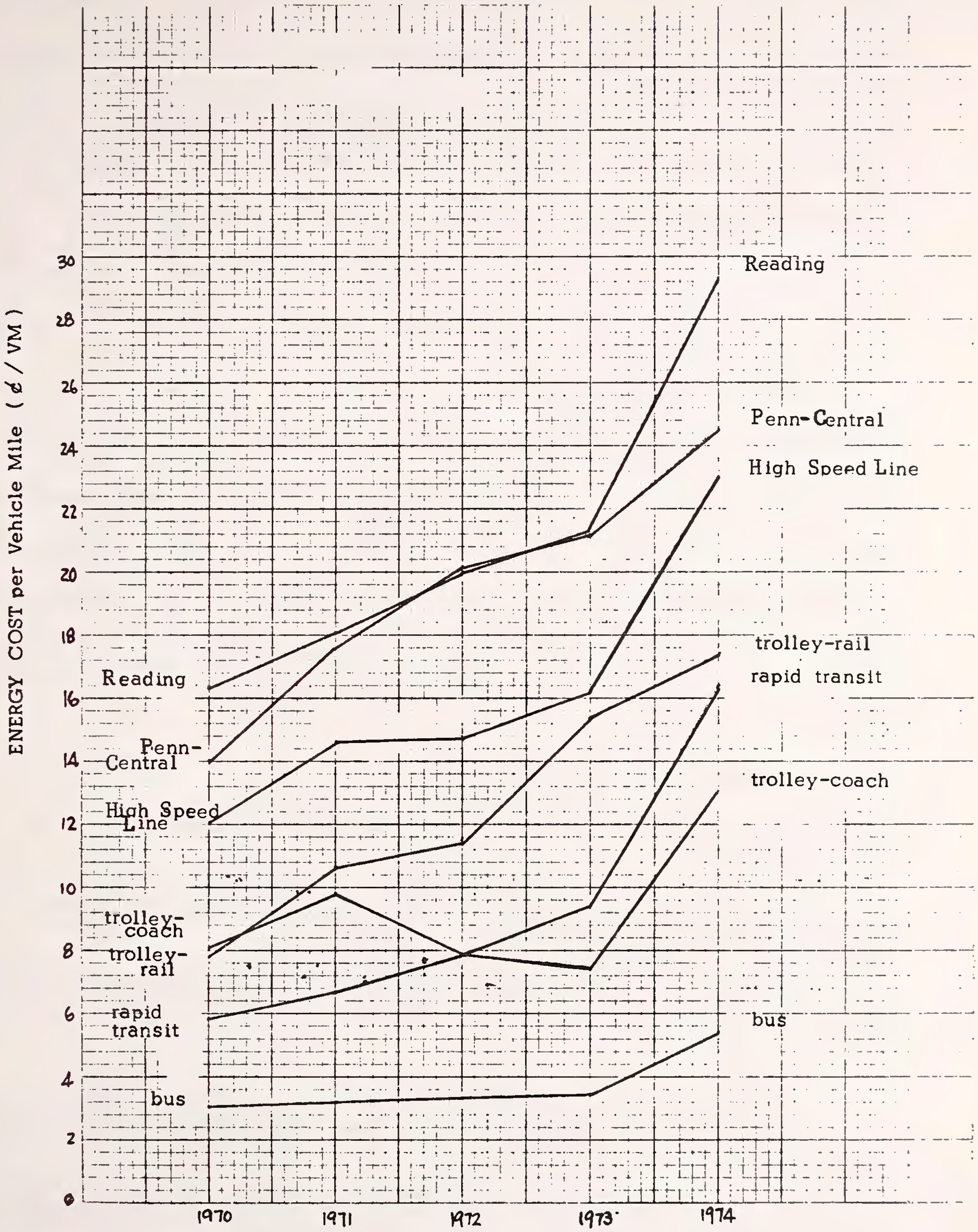

FIGURE VIII-4. ENERGY COST PER VEHICLE MILE vehicle miles traveled would be. The vehicle-miles are, in turn, divided by the energy consumption for that year in order to find the vehicle efficiency values of each loading factor. The loading curve computed is thus repeated for all years of the mode and over all modes. Changing the loading factors reveals also what the passenger-miles would be while keeping vehicle miles constant at its given value. Similarly cost curves can also be drawn to present how the energy cost per vehicle-mile (at the original value of vehicle efficiency) varies from 1970 to 1974 amongst the modes. The energy cost per passenger-miles from 1970 to 1974 varies amongst the modes can also be graphically shown. (See Also Appendix E).

Data from SEPTA, Reading, Penn Central, and PATCO provided the passenger-mile and vehicle-mile data for all modes except the High Speed Line over all years.[6,7,8] Data from SEPTA also provided energy amount and cost information for all non-commuter rail modes.[9] For these latter modes, data was used from the Reading and Penn Central companies separately.[10,11] Finally, the data on the High Speed Line came from work previously done by Boyce.[12]

6/Information from Chris Skierski, Senior Accountant, SEPTA, Nov. 19 and Dec. 5, 1975.

7/Information from William Boone, Assistant Manager, Operational Planning, SEPTA, Nov. 24, 1975.

8/Information from Jim Melvin, Manager, Accounting-Rail Division, SEPTA, Nov. 20, 1975.

9/Tomazinis, ch. 5.

10/Information from Ed Deery, Manager, Passenger Service, Reading Co., Nov. 11, 1975.

11/Information from E.F. Strain, Manager, Suburban Accounting, Penn Central Transportation Company, Nov. 16, 1975.

12/Boyce, Impact of Rapid Transit

TABLE VIII-1. LOADING CAPACITIES

MODE	AVERAGE SEATS PER VEHICLE	AVERAGE NUMBER OF STANDEES	TOTALLY LOADED VEHICLE
Bus	50	25	75
Trolley Rail	50	25	75
Trolley Coach	50	25	75
Rapid Transit	60	120	180
Penn Central RR	80	0	80
Reading RR	90	0	90
High Speed Line	75	150	225

study was conducted which also integrated energy considerations into the analysis.[15] In this study it was found that as bus stops are reduced or signal timing made progressive, fuel consumption can be reduced and vehicle speed be increased. In the analysis that follows a similar task is undertaken. Herein, each mode will be analyzed with regard to the differences per unit of fuel consumed, associated with differences in frequency of service.

For all on-street modes (bus, trolley rail and trolley coach) the rou route data was taken from the Delaware Valley Regional Planning Commission.[16] The strategies and related variables (particularly the variation of the frequency) of the bus energy study,[17] are extrapolated to include Trolley Rail and Trolley Coach. For all fixed rail modes (Rapid Transit, commuter rail, and the High Speed Line), the frequency variations during off-peak and peak periods are of different magnitude.

Figure VIII-5 gives the number of stops per common distance (assuming an original value of 8, then 6 and then 4 stops per mile) for each on-street mode, and the subsequent change in energy consumption, and therefore, vehicle efficiency associated with the frequency variation. The relative percent changes in fuel consumption are taken from the intra-city bus energy study and assumed to be the same for diesel and electric vehicles.[18] The change in number of stops occurs under a non-progressive traffic signal control system. The base energy consumption and vehicle efficiency informa-

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15/A. Muzyka et al., "Bus Operations and Energy Conservation," Traffic Engineering, Vol. 45, Nov. 1975, pp. 18-22.

16/1974 National Transportation Study Data.

17/Muzyka, pp. 18-22.

18/Ibid.

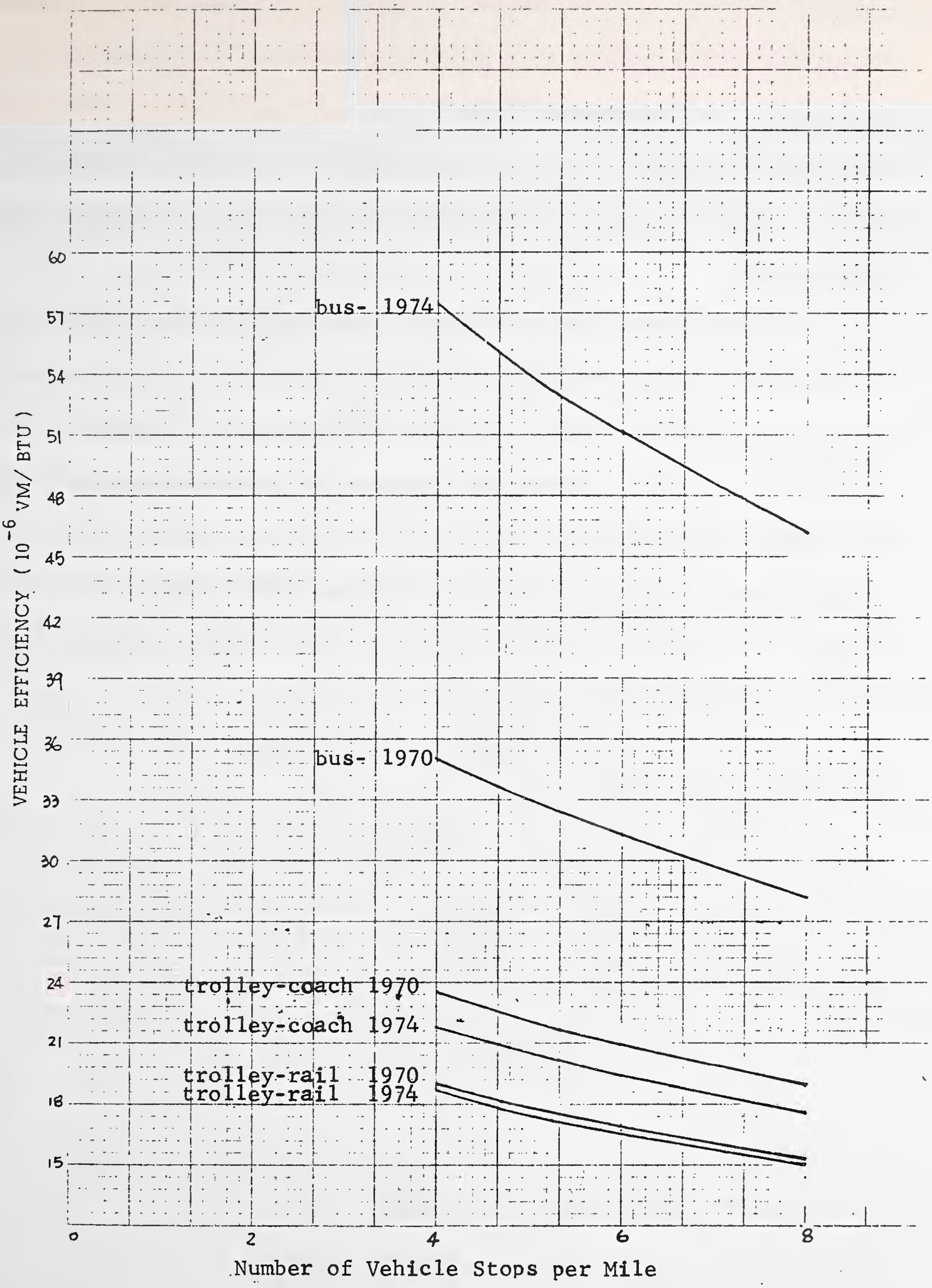

FIGURE VIII-5. ENERGY EFFICIENCY vs. QUALITY OF SERVICE tion are taken from the section A-3 above for this example. The energy consumption figures are obtained by multiplying the base figures by the percentage change in the bus fuel consumption achieved by reducing the number of stops.[19/] The new set of figures generated are used to compute vehicle efficiency for each number of stops (holding the original vehicle-miles constant). This procedure is identically executed for bus, trolley rail, and trolley coach.

The graphs show that as the number of vehicle stops is reduced, the modal energy consumption is decreased, and the corresponding vehicle efficiency is increased. The intra-modal and inter-modal variations of vehicle efficiency are similar to the load curves. Of course before any action along these lines the analyst should incorporate passenger needs into the decision-making process. In order to conserve fuel, the passenger must be retained and sustained if the system is to successfully operate under any energy-modification plan.

2.0 Support Functions

In this discussion, all maintenance functions are lumped together for ease of clarification. Using the Boyce percentage of 2% (for consistency in modal analysis) of the total energy demand being allocated to maintenance purposes,[20/] a chart of maintenance energy used in each year for every mode can be composed from the information in Section 1.3 of this chapter. (See

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19/*Ibid*.

20/Boyce, *Impact of Rapid Transit* .

Table VIII-2.) However, to properly decompose this energy by work task, implement and facility for each mode in a transit system is not feasible under the current accounting system for the two operators discussed herein.[21/] As an example, under the present procedure for cost assessment, SEPTA does extract the cost of lighting and heating all maintenance facilities, by mode; yet, this cost is aggregated. The proposed FARE System is a step towards this needed disaggregation and standardization of the expense reporting procedure for transit agencies.[22/] As examples of how this system could help define elements of maintenance energy, consider the following: some categories for a mode which are included in the FARE System, yet not found with present SEPTA accounting practices, are:

(a) a category for heat, light, and power purchased from an outside utility company for purposes other than propelling revenue vehicles;

(b) a category for gasoline, diesel fuel, lubricating oil, etc. used to operate service vehicles; and

(c) the costs of the various types of energy and total consumption that are given in an Energy Consumption Schedule.

The above three illustrations are for non-commuter rail modes. For the passenger train, a different FARE System is proposed that disaggregates energy consumption into energy consumed by maintenance of switching facilities, way, cars, and transmission facilities.

21/Conversations with William Boone, Assistant Manager, Operational Planning and Chris Skierski, Senior Accountant, SEPTA, Dec. 2 & 3, 1975.

22/Project FARE Task IV Report, Task IV Report for July 1973-Nov. 1973 Period and Project Summary, Vols. I - V, Dept. of Transportation-Urban Mass Transportation Administration, Nov. 1973.

TABLE VIII-2. MODAL MAINTENANCE ENERGIES

MODE	UNITS	1970	1971	1972	1973	1974
BUS (Hypothetical)	10^{10} BTU 10^{3} Dollars 10^{-6}¢/ BTU	3.63 31.52 2.07	3.51 30.53 2.07	3.54 30.79 2.07	3.65 32.19 2.09	2.16 52.93 5.81
TROLLEY RAIL	10^{10} BTU 10^{3} Dollars 10^{-6}¢/ BTU	1.53 18.36 2.66	1.30 22.13 4.04	1.29 25.6 4.71	1.16 34.59 7.09	1.47 38.86 6.26
TROLLEY COACH	10^{10} BTU 10^{3} Dollars 10^{-6}¢/ BTU	.29 3.20 2.64	.24 3.31 3.24	.24 3.93 3.85	.26 3.74 3.42	.29 6.62 5.45
RAPID TRANSIT	10^{10} BTU 10^{3} Dollars 10^{-6}¢/ BTU	2.99 28.73 2.28	2.52 31.22 2.95	2.50 36.63 3.47	2.68 31.85 2.83	2.85 61.34 5.12
PCRR	10^{10} BTU 10^{3} Dollars 10^{-6}¢/ BTU	1.30 22.33 4.09	1.35 28.3 4.97	1.75 35.35 4.80	2.35 38.66 3.92	2.56 41.74 3.88
RR	10^{10} BTU 10^{3} Dollars 10^{-6}¢/ BTU	1.37 25.59 4.45	1.23 29.2 5.66	1.31 31.48 5.69	1.28 32.80 6.09	1.27 45.71 8.57
HIGH SPEED LINE	10^{10} BTU 10^{3} Dollars 10^{-6}¢/ BTU	.77 10.63 3.33	.75 13.13 4.04	.78 14.47 4.28	.77 15.72 4.76	.85 23.71 6.66

Thus, the set of input energy data for support functions should include figures for vehicle, station facility, and way maintenance. Also, information as to the relative energy efficiencies of certain maintenance equipment would be needed. Equipment which consumes less energy in its manufacture and operation should be noted. Such information should be noted for both rolling stock and maintenance equipment.

Concerning data on outputs from support functions the information needed would consist of support functions achieved with a given amount of energy. Such data would focus on such items as the utilization of electromechanical and insulatory modification processes to the heating and cooling systems, primarily, of both the mobile and stationary objects within the transit system.

One set of efficiency indicators could be derived from total system operations. Examples include the fraction of energy cost for units of support functions as part of total support function cost, as well as the fraction of energy used for support functions as part of total support function energy. (In this analysis, it is explicitly assumed that maintenance energy <u>and</u> its cost account for 2% of total energy and total energy cost, using the work of Boyce.[23/] In future research, one could relax this constraint to investigate what effect varying maintenance energy both intra- and intermodally would have on energy use patterns.)

Another set of efficiency indicators would be more specifically geared to repair and maintenance only and include total vehicle miles operated per unit of energy used in maintenance or vehicle miles generated per unit cost of energy spent to maintain vehicles and facilities. Also, the

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23/Boyce, Impact of Rapid Transit .

average amount of energy needed to do maintenance on a vehicle, the energy used in vehicle storage, and the energy used in maintaining and repairing user-oriented parking facilities could be requested.

3.0 Network Variables

Unlike primary services or support functions, network variables pose different requirements with regard to energy. The major goal of an energy analysis of UPTS networks is to find the energy requirements in constructing the transit network and the associated facilities. Such items as network, electrification, track work, stations, terminals, tunnels, parking areas, and overhead structures are included.[24,25] The objective needed to achieve the above goal is an input/output analysis. Network components are fixed assets within the framework of an UPTS consequently they play little role, if any, in the efficiency of the day-to-day transit system operation. Thus, developing measures of efficiency, to assess transit operation performance, from the network perspective, is not necessary.

24/Delaware Valley Regional Planning Commission, Capital Cost for Transit Projects, June 1973.

25/R.A. Herendeen and C.W. Bullard, Energy Costs of Goods and Services, 1963 and 1967, Center for Advanced Computation, University of Illinois, CAC Document No. 140. Nov. 1974.

CHAPTER IX

IDENTIFICATION AND MEASUREMENT OF OUTPUTS FROM UPTS

Introduction

The proper identification and accurate measurement of the outputs of an Urban Public Transportation System is a difficult task and is a challenge for the planner.

The principal source of difficulty in the measurement of such outputs lies in the fact that, from its very inception, an Urban Public Transportation System (UPTS) starts generating continuous direct outputs, which, in turn, produce many and complex indirect repercussions throughout an urban region.

This chapter is an attempt to highlight the conceptual output definition and measurement and also to offer a more complete explanation of the mechanics of output production from an UPTS. It also presents a summary of two output measured in the three test regions.

The following section of the Chapter sets certain criteria for the definition of these outputs. It then discusses the mechanics of output production and clarifies the reasons for the problems of measurement of outputs from an UPTS.

Section 2.0 deals with the output variables that are included in this project. Section 3.0 deals then with a system of classification of output variables and finally, Section 4.0 discusses some of the problems of aggregation of output variables. **The chapter concludes with the Outputs Matrix for 1972, (for the years 1973 and 1974 see Appendix I).**

1.0 Definitions of Outputs and Problems of Measurement

1.1 Definition of Output

The outputs of an Urban Public Transportation System (UPTS) may generally be understood as the consequences produced by the UPTS through the process of its translation of inputs into services. The important point to understand in this statement is that outputs cannot be produced unless the process of input translation takes place, or, simply, until services are produced.

From this standpoint, "passengers" per se are input elements and can even be viewed as society's input to primary services,[1/] whereas, person-trips completed are clearly outputs produced by the system.[2/] The passenger-mile is an output since this reflects the translation of the passenger input into a certain length (miles) of service. In other words, an output can be said to have been produced only when service has actually been provided. Similarly, the rolling stock (vehicle) is an input made by the operator to the primary services and the vehicle-mile is an output of one of its translated forms. The vehicle-hour may be viewed as the "service time," an output translated form of the rolling stock (vehicle) input, and so on.

1/ A detailed explanation of this view is presented later on under the discussion of specific outputs.

2/ For the purpose of this project, to simplify the matter, each passenger is assumed as implying only one completed person-trip.

The statement on "outputs" would however be more comprehensive and accurate if two more qualifications were included in it.

The first qualification is that only the positive consequences can be viewed as outputs. The logic is very clear in this case because the negative consequences entail additional expenses. These are simply extra operating or capital inputs which the system must pay to eliminate or negotiate the harm it does to individuals or to society (as pollution, noise, etc.) in its area of operation. Thus, accidents, injuries, damages, pollution, and so on are some of the negative consequences produced by the urban public transportation system and which on the basis of the argument presented above, can best be understood as "effective inputs."

The second qualification to the statement on outputs is that outputs should be considered as being producible from only those portions of services which are intended and, therefore, effective according to system design. Thus, the vehicle-mile presented in annual reports of various agencies may be partly misleading if operating agencies do not isolate the portion of vehicle-miles which is necessary in movements of vehicles to and from their overnight stations. In other words, the net output must be associated with only services available to the public.

Thus, a more accurate definition of outputs should take into account three essential caveats:

(1) Outputs can exist only when the system translates inputs into actual services.

(2) The positive and not the negative consequences of the UPTS account for outputs from the system.

(3) The effective part, only, of the vehicle-mile produced by the UPTS should be considered.

Therefore, the final definition of the outputs of an UPTS may be stated as follows:

> The outputs of an UPTS may be defined as the positive consequences produced by the UPTS through the process of translation of System inputs into effective services.

1.2 The Mechanics of Output Production

Output Production in UPTS is a complex process and may be best understood as a continuous process of supply of outputs in response to a demand for such outputs at a given period of time and at a given location. The process may be said to begin with the inception of the system and may continue as long as the system is functioning. Thus, there are three distinct aspects to Output Production in UPTS:

(a) Output production potential of the system;

(b) Potential demand for outputs; and

(c) Production of outputs by the system.

The total potential of the system to produce outputs depends on such factors as the quality of inputs, quantity of inputs, distribution of inputs, the availability of resources in the region (whether it be in the form of capital, labor or energy) and so on. Outputs supplied immediately by the system are in reality, the direct consequences of the process of input conversion (or simply, service provision) by the system. These are the "direct" outputs. Examples are vehicle-miles, passenger-miles, vehicle-hours and so on. However, the UPTS unlike many other systems, is an open system and its performance is often strongly influenced by the environment within which it operates. Thus the total system potential can be divided into the "direct" system potential due to intrinsic system characteristics, and into potential due to environmental association with which a given system is bound. (See Figure IX-1). Certain environmental associations are economic vitality of the region and the locational distribution of its markets.

Thus, the total system's potential to produce outputs essentially depends on two factors:

(i) Intrinsic characteristics of the UPTS; and

(ii) Significance of the environmental associations of the system.

The production of outputs by the UPTS may be defined as the process of matching demand for and supply of outputs in the area of influence of the System during a given period of time.

The pattern of the production of outputs is a critical factor affecting directly the utilization of these outputs. If a proper control on the production process is not maintained, undesirable and wasted outputs, both systemic and accidental (particularly the former), may be produced. The regulation of the production of outputs should be associated with the correct interpretation of the potential demand for the outputs. Problems, however, arise when the demand is latent. For instance, in the case of sections of the society that are transportation disadvantaged, actual

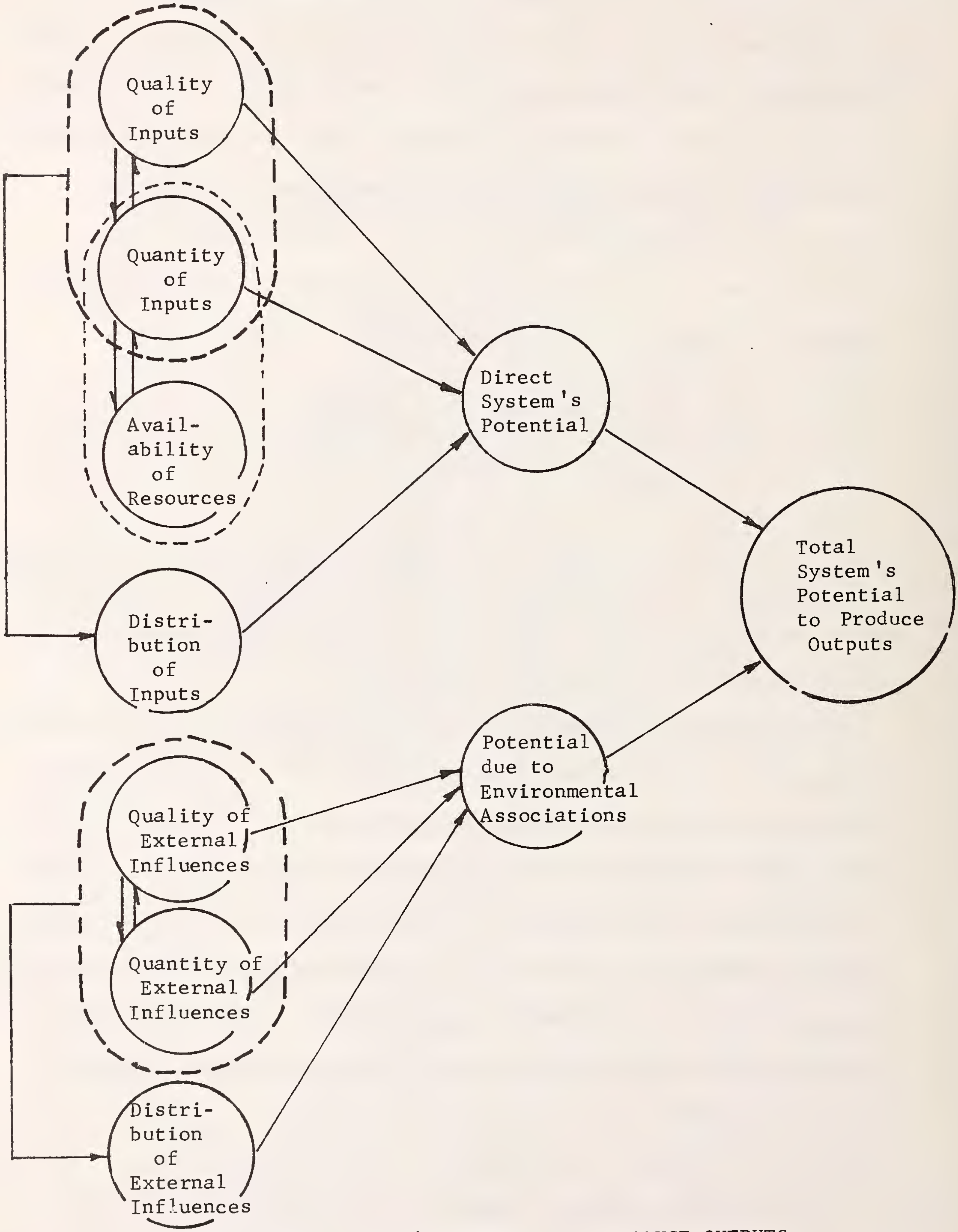

Figure IX-1. SYSTEM'S POTENTIAL TO PRODUCE OUTPUTS need and desire for travel is seldom expressed, and thus frequently insufficient amount of transportation service is provided. The reverse can also be observed in other sections of an urban region where over-production of outputs may result.

The pattern and level of production of outputs of the UPTS must necessarily be based on the purpose for which the system exists i.e. is it there to provide optional services, or as a social services delivery system to provide essential services for all residents of an urban region?[3/]

Another aspect of the mechanics of output production is that most of the outputs of the system are produced by the primary services of the system. The network also produces some limited outputs primarily of indirect nature. No outputs that are meaningful outside the system are produced by the support functions of an UPTS. With regard to the receivers of outputs it should be noted that the direct user of the system is the receiver of the most direct outputs of the system. The operator "receives" also several outputs from the system's primary services and these outputs are also those outputs that the operator puts in the market. The society is usually the receiver of most indirect outputs and the government receives whatever else indirectly is being produced by the network and the primary services of the system.

1.3 Reasons for the Problems of Measurement

Problems of output measurement arise because many outputs of the UPTS are dynamic in nature and because other outputs are the consequence of a continuous process of production. For instance, "areal organization of space," an output discussed later on, is a phenomenon which is really a

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3/For a clear enunciation and a detailed treatment, see the following texts: (a) Tomazinis, A.R., Urban Transportation Systems Viewed as Social Services Delivery Systems, Transportation Studies Center, University of Pennsylvania, 1974, and (b) Williams, E.N., ed., Delivery Systems for Model Cities: New Concepts in Serving the Urban Community, Center for Policy Study and Center for Urban Studies, University of Chicago, 1969.

"dynamic process" rather than a "static happening." "Accessibility to employment," another output discussed later on, is continuously affected by changes in job distribution in any region, and again the result of a dynamic process. The very nature of a transportation system symbolizes dynamism, and expresses a continuous process of change in the urban environment.

This dynamic nature of the Urban Public Transportation System's outputs and the external impacts of the environment on the UPTS are the principal causes of the difficulty experienced in output measurement.

2.0 Output Variables

The following twenty-four output variables appear very pertinent for urban public transportation systems. Their detailed definition and brief description is helpful in understanding their significance in an efficiency analysis of UPTS.

2.1 Vehicle-Hours Output

"Vehicle-Hours" may be defined mathematically as follows:

$$\text{Total Vehicle-Hours} = \sum_{i=1}^{n} (V_i x h_i)$$

where, V_1, V_2, ... V_i are the number of vehicles providing h_1, h_2,.....h_i hours of service.

The "vehicle-hour" is a direct output of the Urban Public Transportation System. It may be viewed as an output produced by the system through the process of using the rolling stock (vehicle) during a certain period (vehicle-hours) of actual service provision.

2.2 Vehicle-Miles Output

The "vehicle-miles" may be defined mathematically as follows:

$$\text{Total Vehicle-Miles} = \sum_{i=1}^{n} (V_i \times_i m)$$

where, V_1, V_2, ... V_i .. V_n are the number of vehicles providing m_1, m_2 .... m_i .. m_n miles of service.

The "vehicle-mile" is another direct output of the Urban Public Transportation System. It may be understood as an output produced by the System through the use of the rolling stock (vehicle) for a certain length of distance (vehicle-miles) in actual service provision.

The vehicle-mile, measures should not include for instance, vehicle travel from and to overnight depots.

2.3 Total Passenger Trips Completed

This output variable is very obvious. It is a direct output of the system and of direct interest to the operator and the user of the system. It includes all passenger trips regardless of fares paid.

2.4 Revenue Passenger Trips Completed

This output variable is exactly like the one before but includes only passenger trips for which fare has been paid in some manner.

2.5 Passenger-Miles Output

The "passenger-mile" output variable may be defined mathematically as follows:

$$\text{Total Passenger-Miles} = \sum_{i=1}^{n} (P_i \times m_i)$$

where, P_1, P_2 ... P_i, .. P_n are the number of passengers utilizing m_1, m_2 ... m_i .. m_n miles of service.

The "passenger-mile" is a direct output of the UPTS. The "passenger-mile" output is probably the single most important direct output produced by the UPTS and truly symbolizes the purpose of the system as a means of conveyance for the public.

One of the most significant uses of the "passenger-mile" as an expression of the extent to which services have been utilized is in its relation to the "vehicle-mile" which expresses the quantity of services offered by the UPTS.

2.6 Seat-Miles Output

The seat-miles output variable is more than the vehicle-mile, representative of the production (supply) of outputs of a system and may be defined as the distance-translation of the rolling stock (seat) input for the provision of services by the UPTS.

Mathematically, it may be stated as

$$\text{Total Seat-Miles} = \sum_{i=1}^{n} (s_i \times V_i \times m_i)$$

where, V_1, V_2, ... V_i, .. V_n are the number of vehicles providing m_1, m_2, ... m_i, .. m_n miles of service and S_i = average number of seats in Vehicles V_i

The seat-miles variable, per se, is a direct output of the system.

2.7 Operating Vehicle Seat Hours

This output variable presents the amount of service available to the public during the working hours of a vehicle, a line, or a whole system. Seat hours also reflect the amount of "uncompromised" service available in a vehicle. It is,of course, an extension of the vehicle hours output variable presented in 2.1 above, and it adds a dimension related to the size of the vehicles themselves.

2.8 Satisfaction from Travel Experience

This output may be defined in terms of a ratio between supply of service to the demand for service, (i.e., the user's service need). This is then more properly a measure of the quality of the output than of the quantity of output.

The measure of quality of outputs concern primarily the user of the system. However the measures for the quality of service are quite nebulous and arbitrary and usually discussed and described with the help of proxy measures.

2.9 Information Not Related to Travel Experience

This output is conceptionally self-explanatory. However its measurment is again quite difficult. One way of doing so, using again proxy measurments is to use the number of advertisements in a vehicle which as an indicator reflects only to a certain degree, the information obtainable by the user. For the purposes of quantification we may specify that a single piecy of advertisement can give only one piece of information.

2.10 Safety Gained from Travelling with Mode

This output may be defined as: the extent to which the transit system has a better record of accident or incident occurrence than other parts of the city (region).

For example,

if: the accident record in houses is: 12 accidents/100,000 user hrs.

and the transit system accident record is: 5 accidents/100,000 user hrs.

System Safety Output gain is: then, (12 - 5) = 7/100,000 user hrs.

2.11 Mobility Provided

Mobility of a given population in a given region may be defined as its potential for movement, provided by the UPTS between various activity centers in the region.

There are three aspects to mobility of any given population in a given region. The first aspect is the population's expressed demand for mobility which depends on the socio-economic characteristics of the population in the influenced area. The second aspect is the supply situation existing in the UPTS. The third aspect is the latent travel demand within a region.[4]

Thus, the mobility provided by the Urban Public Transportation System might be measured in terms of a proxy variable as a ratio between the supply and demand in a region. Another measure might be the total ability of the system to move about residents of the region. In this case the mobility provided by the system would be equal to the seat-miles that the system offers at a given period of time.

2.12 Accessibility Provided

Accessibility proveded by a system within a region may be defined in terms of the ease of movement provided between activity centers, and can be expressed, indirectly, as the relationship between travel time and opportunities available within intervals of travel time.

Accessibility to population and accessibility to employment centers are two distinct outputs of an Urban Public Transportation System and are produced as consequences in two completely different demand situations. Whereas "accessibility to population" depends on population size and a

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4/See, for instance, Hoel, L.A., et. al., "Latent Demand for Urban Transportation," T.R. Research Report, Carnegie-Mellon University, Pittsburgh, 1968.

demand characteristic which is generally stable, the "accessibility to employment" depends on numerous unstable demand-influencing factors. The economic health of a region, and the spatial distribution of employment influence the significance and the measurement of this output variable.

Thus accessibility to employment centers may be conceived as a relatively indeterminate output and should be treated differently. A suitable, but proxy, indicator for accessibility is possible in terms of the percentage of population and employment within a specific traveling distance.

2.13 Areal Organization of Space

The output variable "areal organization of space" in any region may be defined as the consequence of the system on the relationship between spaces and activity centers in that region.

Areal organization of space is perhaps one of the most critical outputs of the Urban Public Transportation System. In its simplest interpretation, it may be viewed as a consequence of such other outputs as accessibility and mobility.

However, what makes "areal organization of space" particularly difficult to measure is its dynamic nature, and incremental scale. Also its relationship with the land market is fluid and difficult to pin down because of its dependence on factors such as the economic, social, political, locational and technological situations and the interrelationship existing between them and the total urban system.

2.14 Image of System

The output variable "image of a system" may be defined as the perceived value of the UPTS and can be said to exist in the minds of users and non-users, who are influenced by the service quality components of the system.

Factors indirectly influencing the "image "variable are all the direct outputs of the system and other indirect outputs like accessibility (of both population and employment), mobility of the population and employment the areal organization of space, system's usefulness during natural calamities, and man-made catastrophes, the extent of population, area and employment served and so on.

Undoubtedly, since the "image" is a dynamic concept, the output becomes generally indeterminate. However, indicators like "letters of commendation/complaint" books or articles written in important news media go a long way in unravelling this putput.

2.15 <u>Non-Transportation Use of Transportation Facilities</u>

This output may be defined as the extent to which the UPTS facilities produce utility for other urban purposes. This may happen in cases where the UPTS facilities are used for educational purposes, or for other commercial purposes. No specific measurement unit appears available for this kind of system output.

2.16 <u>Taxes Contributed</u>

This output is self-explanatory and refers to any taxes contributed by the UPTS towards the needs of the government (federal, state and local).

2.17 <u>Defense Potential</u>

This output may be defined in terms of the system's manpower and equipment potential to assist in the protection and movement of people and goods during war hostilities and other man-made as well as natural catastrophes.

The critical factors which influence the contribution of an UPTS to defense potential are the areal organization of space, the system's built-in flexibility to respond to various natural and man-made catastrophes, and so on. Such factors themselves are dependent on accessibility and mobility which the system can offer to the population. Another important factor determining the defense contributions of the system is the extent to which the system's transportation facilities have utility for non-transportation purposes (in this case, defense).

Many factors make this output indeterminate, plus such exogenous influences as the general economic welfare and the existing political situation which sets constraints on the production of this important output.

A very broad indicator may be suggested in this case in terms of "value of existing areal organization of space per dollar of governmental expenditure on defense purposes at a given price level."

2.18 Usefulness During Natural Calamities

This output has been defined as "the extent to which the system is responsive during a given natural calamity."

This output is an indirect output produced by the UPTS depending predominantly on the society's need for protection against various natural calamities. Floods (a common occurrence in various parts of the country), earthquakes, heavy snowing, torrential rains, cyclones, etc. create a need for building into the system, a kind of quality which can withstand such shocks, protect the system's potential users and thereby respond to various trying situations.

The system's built-in responsiveness to various calamities is generally indeterminate since the nature, magnitude and location of those calamities cannot be determined.

However, a stochastic estimate can be made based on the frequency of occurrence of specific natural calamities of various magnitudes which are common to different regions and thereby "system's responsiveness design cost" determined. It can be evaluated, for instance, as is done in the construction of dams, using probability theory to account for calamities of various types and magnitudes.

2.19 Promotion of Governmental Social Objectives

This output may be defined as the "degree to which the UPTS is instrumental in the promotion of government's social objectives."

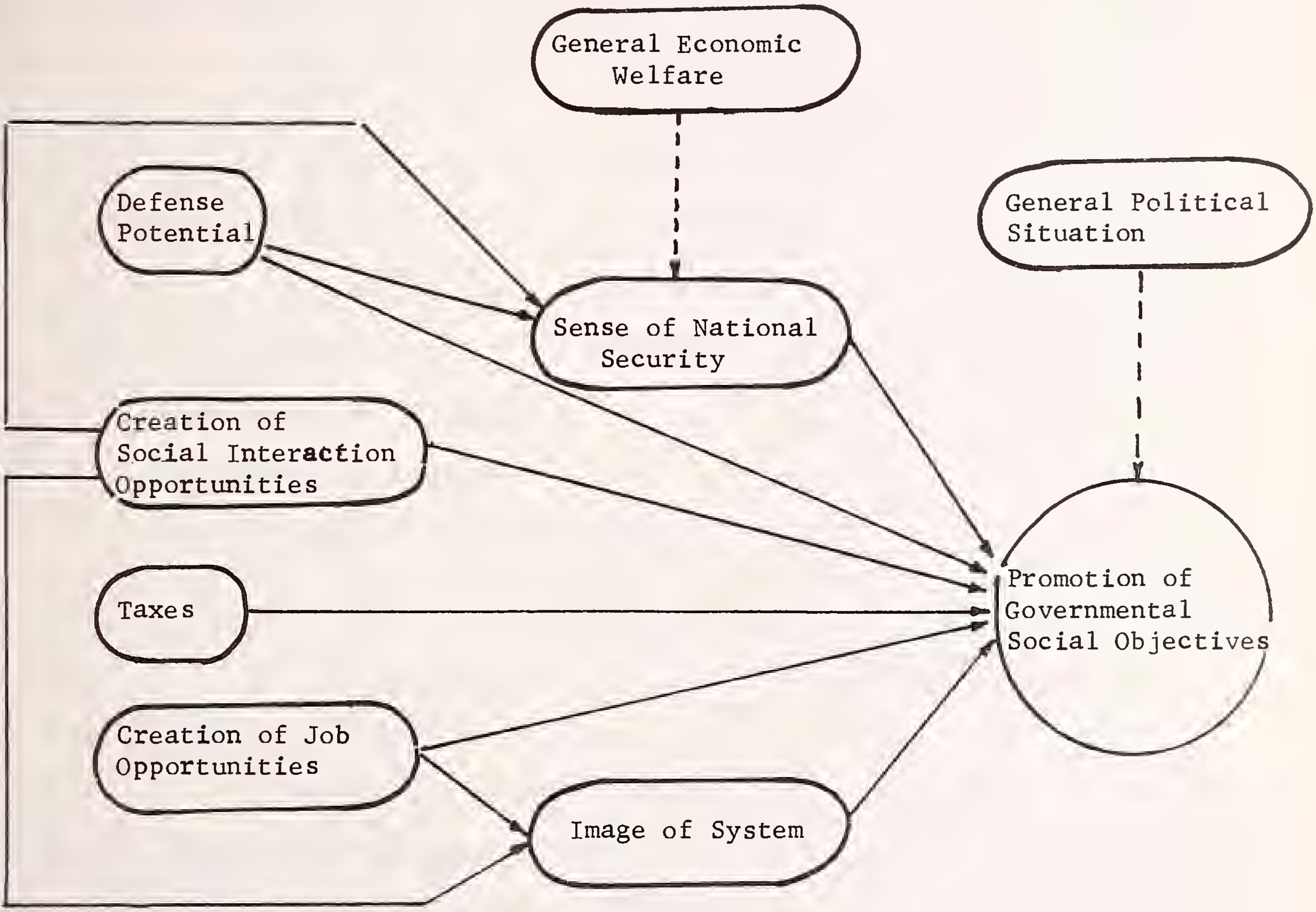
"Promotion of governmental social objectives" may be viewed as a particularly important output that can be expected from the UPTS. This output cannot be said to exist in totality at any particular point of time but may be understood as starting as a process and gradually dissipating until it has served its purpose.

It is, therefore, a dynamic output produced indirectly by the UPTS and may be viewed as being dependent on such factors as creation of job opportunities, social integration, creation of social interaction opportunities, defense potential, image of system and sense of national security. Figure IX-2 presents a sequence of such dynamic relationships concluding with the promotion of governmental social objectives.

The problem of measurement may be attributed to various indeterminate external factors influencing it, such as economic welfare and the general political situation. The latter is the most immediate external influence and is chiefly responsible for making this output indeterminate.

2.20 Area Served

The "area served" may be viewed as an indirect output being produced as a result of the production of vehicle-miles output in a given region. The "area served" in effect is the actual influence area of the Urban Public Transportation System.



NOTE: Broken lines indicate environmental associations.

Figure IX-2. PROMOTION OF GOVERNMENTAL SOCIAL OBJECTIVES OUTPUT

It should be considered as an output simply because it is the effect of actual transit operation rather than a cause. Besides, this output (area served) can be produced only after certain input translation into outputs (vehicle-miles) by the UPTS has taken place. The "area served" figure generally reported by the operating agencies is based more on convenience in terms of size of the region in which the UPTS operates, whereas the effective area served should take into account the actual proximity of transit lines to the users. For this reason, unserviced sections of a region should be excluded from regional totals.

2.21 Population Served

The "population served" output may be considered as an indirect output produced by the UPTS as a consequence of production of the "passenger-mile" output. The population served may therefore be attributable to only that portion of the population who become direct or indirect users of the system at one time or another and who may be considered as "served" by the UPTS.

The "population served" figure stated generally by agencies is partly misleading because it frequently represents all the population that live within the region in which the UPTS functions.

2.22 Employment Served

Employment served is an output indirectly produced by the UPTS based on the existing employment and the areal organization of space. It is further affected by the generation of additional employment by the UPTS. There are basically two types of employment which are served by the system as a consequence of the system's translation of inputs into services:

(a) Existing employment and

(b) Generated employment.

Since it is difficult to isolate the generated employment, this limitation has been accepted for the project and the figures presented by operating agencies have been considered with this limitation in view.

2.23 Creation of Job Opportunities

This is an indirect output which is even more difficult to measure than the previous one. This output also affects the extent to which the government's social objectives are achieved, the system's image, national prestige and so on. (See Figure IX-3.)

"Creation of job opportunities" may again be viewed as an indeterminate output dependent on the indeterminate external influence--the general economic situation, i.e., conduciveness of the economy towards the creation of new employment opportunities in the area of influence of the UPTS.

2.24 Economic Growth

The economic growth as an exclusive output from the UPTS may be observed as directly being produced by the increase in land values, and/or employment, due to the UPTS.

This output itself depends on several factors:

(a) The increase in land values due to the UPTS;

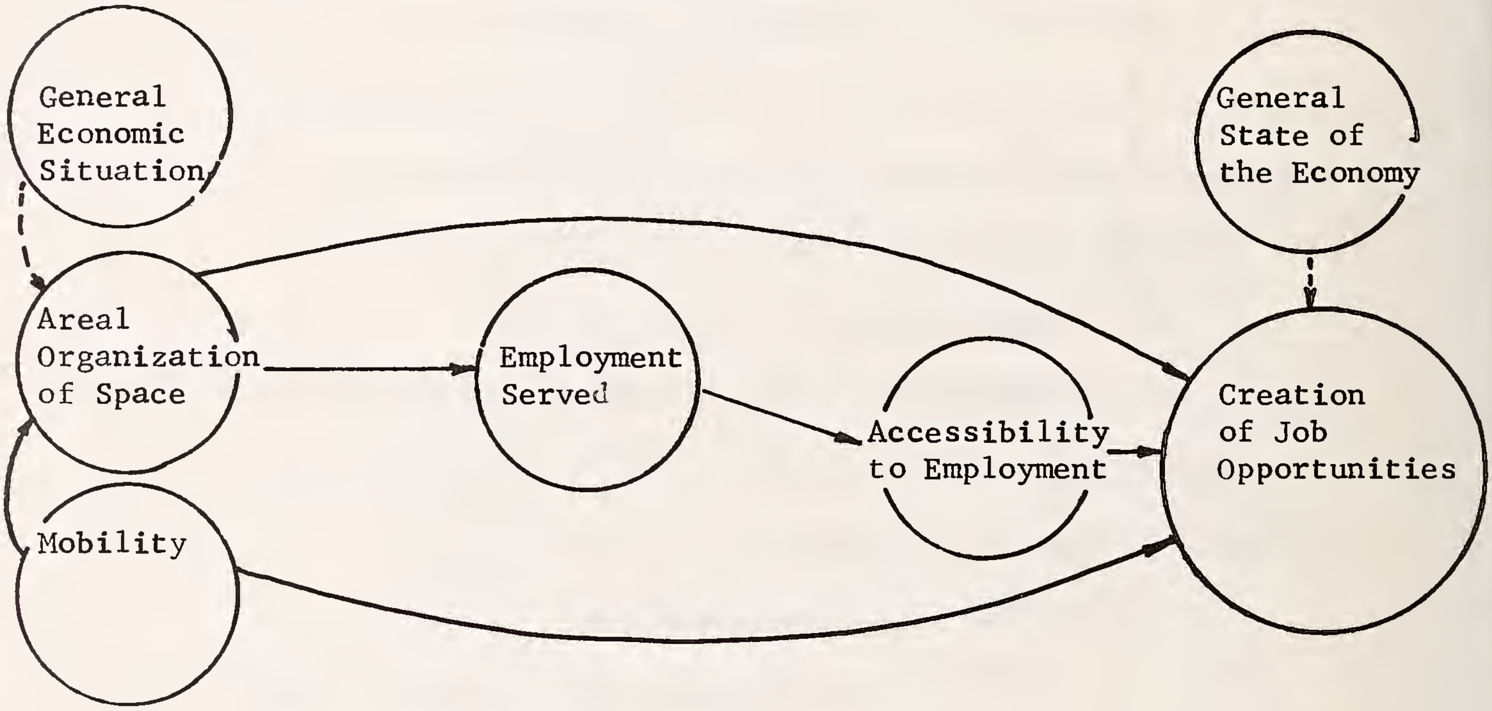
(b) The state of the region's economy; and

(c) The region's resource potential.

Since all influences affecting it are indeterminate, it becomes extremely difficult to measure this output. No indicators have therefore been suggested.

3.0 Output Variables Classification

Based on the extent to which an output variable represents a measure directly derived from the system's operations, one can easily divide the



NOTE: Broken lines indicate environmental associations.

Figure IX-3. CREATION OF JOB OPPORTUNITIES OUTPUT twenty-four output variables presented in Section 2.0 into four major groups or classes:

(1) Direct output variables,

(2) Estimated output variables,

(3) Proxy output variables, and

(4) Conceptually definable outputs.

Another classification that needs to be introduced in reviewing output variables is with regard to the actual sources of output generation within each UPTS. In fact there are three sources of output generation within each system, i.e., the <u>primary services</u>, the <u>support functions</u>, and the <u>network component</u> of the system.

Finally there is a <u>third</u> classification system in accurately perceiving the complex set of output variables from an UPTS. This classification system is based on the <u>receiver</u> of each output. There are in fact frequently recognized in this report, four actual receivers, the <u>operators</u>, the <u>users</u>, the <u>society at large</u>, and the <u>government</u> at all levels.

The organization of the output variables along this triple classification system is shown in the Output Matrix, presented at the end of this chapter for 1972 and in Appendix I for 1973 and 1974.

A note would need to be made at this point concerning three essential problems usually found in output analysis. First, one should note, that most transportation system outputs are perishable commodities which if not consumed at the moment and point of their production are lost forever. Second, one can easily note that the list of output variables include great variability as to unit of measurement (real or proxy, or conceptual only). For this reason there is considerable doubt whether all the system outputs can ever become additive. In many cases one may even see variations of measurement of the same item. This observation brings the concern to the third problem, i.e., the great risks that are apparent in the list of output variables for double counting in any effort to aggregate output variables to any "total measure".

3.1 Rationale for Conceptual Reclassification of UPTS Outputs

Returning now to the first classification of output variables it seems intuitively important to carry it out in order that a better understanding of the identification and the measurements of the outputs be achieved. The four new conceptual categories are presented below with their rationale along with the specific outputs involved in each category.

Direct Outputs. This category includes all those direct and measurable UPTS outputs which were immediately produced by the system through the process of its translation of system inputs into effective services.

The following seven completely tangible output variables are considered in this category:

(a) Vehicle-Miles

(b) Seat-Miles

(c) Passenger-Miles

(d) Vehicle-Hours

(e) Seat-Hours

(f) Total Person-Trips Completed

(g) Revenue Person-Trips Completed

Vehicle-miles, seat-miles, vehicle-hours, and seat-hours are expressive of what has been produced and made available to the user. Passenger-miles, person-trips completed, and revenue person-trips completed are expressive of what has been consumed.

Estimated Outputs. This category includes those derived indirect outputs for which a satisfactory and direct proxy measure or indicator is possible.

Thus, essentially, between categories 1.1 and 1.2 all those outputs, which are easily identifiable and satisfactorily measureable, are included thereby dividing the entire set into, basically, the tangible and intangible outputs, the latter being comprised of the remaining two categories. The UPTS Outputs, which may fall under the direct proxy category, are:

(a) Population Served

(b) Employment Served

(c) Mobility of Population

(d) Area Served

(e) Area Accessibility to Population

(f) Taxes Contributed by the System

The first five output variables are of direct concern to society at large. Taxes contributed, if any, are of primary concern to the government.

Proxy Outputs. This classification is expressive of those indirect outputs of the UPTS which could be, though, in reality, they are very difficult to measure without a unifying proxy variable.

The proxy indicators suggested for this category of outputs are almost always approximate in character. The Outputs included in this category are:

(a) Satisfaction from Travel Experience

(b) Information not Related to Travel Experience

(c) Safety Gained from Traveling with Mode

(d) Non-transportation Use of Transportation Facilities

(e) Creation of Job Opportunities

(f) Usefulness during Natural/Man-Made Catastrophes

(g) Promotion of Governmental Social Objectives

Conceptually Defined Only Output Variables. This last category is suggested for inclusion in the UPTS Output Matrix because such outputs are not only indirect and indeterminate in nature but are also extremely hard to measure in any satisfactory manner, and frequently are even difficult to conceptualize with clarity.

This group of output variable is frequently desireable to be included in order to reduce conceptual ambiguities of the other output variables, and in order to, on occasion, avoid excluding from consideration UPTS contributions of major significance for a particular locality and time period. They are:

(a) Areal Organization of Space

(b) Defense Potential

(c) Inducement for Economic Growth

(d) National Image or Prestige

3.2 Rationale for Classifying Outputs by the Receiving Actor

One of the principal benefits from the classification of outputs in terms of the various UPTS actors is the contribution that is added to a comprehensive framework for evaluation of UPTS. To this end, such an approach also allows evaluation of the role of various UPTS participants who act as investors as well as receivers of outputs from the UPTS.

It would be unsatisfactory, for instance, to consider an UPTS only from the operator's perspective since the operator-producer does not control or invest all the required inputs nor is concerned with all outputs from the system. Besides, the perishability of the commodity (services) produced and the fact that only a proportion of the services produced is actually consumed introduces grave doubts as to whether productivity studies from the perspective of the operator alone can serve the purpose.

The various outputs attributed to particular actors in the Output matrix reflect the areas of concern of each participant and their specific interests in helping the UPTS towards the achievement of its objectives.

For instance, the operator who is involved with the construction, operation, maintenance, and overall management of the UPTS is the major receiver of the "Direct Outputs," e.g., primary services such as vehicle-miles, seat-miles and so on, because this is what he puts up "for sale" in the market and his survivability is assured only as long as he can make these services available to the user.

The user, on the other hand, is primarily interested in the completion of his trip and is not the least bit interested in the extent of services offered by the operator as long as *his* need is being met. Thus, the user's chief concern is with the direct output, "Person-Trips Completed." The user's secondary interest is in such non-quantifiable, indirect outputs as satisfaction from travel experience and information and safety gained from travelling. The user's concerns, in general, may be viewed as complementary to that of the operator in the sense that he (the direct user) is the *raison d'etre* of the system, and so, the operator-supplier strives for the complete satisfaction of the user-consumer.

Classification of outputs by actors further helps us understand that the operator and the user are generally the direct receivers of outputs from the UPTS while the society and the government are largely the indirect beneficiaries. The role of the government can be simplified as being an instrument of the society to achieve collective goals. The government invests while the society-at-large collects. Thus, the government derives such indirect and generally, intangible outputs as promotion of governmental social objectives, defense potential, system's usefulness during catastrophes and national image--all of which have a direct influence on society's collective welfare.

The society's interest, on the other hand, to the extent to which the UPTS produces desirable outcomes, reduces production of undesirable outcomes and restricts the need for additional societal inputs to the system. Thus, such indirect, conceptual and sometimes indeterminate outputs as mobility, accessibility, creation of various opportunities and areal organization of space simply reflect the role of the UPTS as producer of an intermediate good, from the society's perspective, towards the achievement of general social welfare.

4.0 Problems of Aggregation of Output Measures

Problems in aggregating the measures of various UPTS Outputs arise because of many reasons, all of which may be attributed to the nature of the UPTS Outputs. In essence, the problems may be associated with:

(a) the mechanism of production of the UPTS Outputs,

(b) the nature of the UPTS Outputs,

(c) the nature of the measures of the UPTS Outputs, and

(d) the limitations of the available actual methods of aggregation.

The purpose of this section, is therefore, to throw some light on these problems, explore possible ways of negotiating them and finally derive conclusions on the suitable course of action for the project.

4.1 Aggregation Problems Associated with the Mechanism of UPTS Output Production

As observed earlier, the UPTS Outputs are both the translations of system inputs into tangible services as well as the consequences of interaction of these outputs not only within themselves but also with the environment in which they exist. As the consequential production of outputs takes place with combinations of first-round of outputs giving rise to second round of outputs, the new putputs become increasingly difficult to isolate and chances of double-counting arise.

Under such circumstances, when there are possibilities of double-counting (for example, "the accessibility" output generated in 1975, which includes contributions from earlier years) a gross aggregation of all output measures will result in a very high degree of inaccuracy being built into the assessment of UPTS Outputs. Such problems become increasingly dominant as the specificity of outputs decreases. The figures on the following page may be considered as conceptual indicators of the possible range of such problems.

4.2 Aggregation Problems Associated with the Nature of the UPTS Output

The problems associated with the nature of the UPTS Outputs may be examined from basically the following two perspectives:

(a) the nature of the outputs, and

(b) the relationship between outputs and "actors".

An explanation of these situations that produce aggregation problems would run as follows:

The Nature of the Outputs. The main purpose of the Urban Public Transportation System is to provide the public with essential and continuous services which constitute the primary output of concepts. Derived or second-round outputs of the system are also outputs that can best be understood as the consequence of a continuous process of production. For instance, "areal organization of space" is a phenomenon which is really a dynamic process rat-ther than a static happening. "Accessibility to population" is another UPTS output continuously affected by changes in job and housing distribution in any region, and is again the result of a dynamic process.

Thus, any gross aggregation of the UPTS Outputs measures will include an increasing degree of inaccuracy, because of intangible and indeterminate elements that include an increasing degree of error.

Differences of Utility to Different Actors. Another problem that is included in any "lump-sum approach" in aggregating outputs may result from ascribing uniform utility of an output to a particular actor. Different actors usually derive varying utilities from the same UPTS Outputs. Furthermore, another problem of aggregation arises from the fact that the same output can, on occasion, have variable utility for the same actor, under different set of circumstances. A very illustrative example is presented by the following excerpt:

> "In a commuting situation, for example, let us consider a man who works in the central business district from 9 a.m. to 5 p.m. and resides in the suburbs 15 miles away. By leaving his home at 8:30 a.m., he can walk to a train station, catch the 8:35 (cost$.50), arrive downtown at 8:55, and walk to his office. For 50 cents (money), 10 minutes of walking (effort), and 30 minutes of total travel time (time for walking, waiting, and riding), he accomplishes one trip which enables him to earn his income. If the train should arrive four hours late, his inputs (specifically time and stress) would increase substantially. On the other side, he would still be completing one trip (of the same length), but since his working day was cut in half, the opportunity to earn money will most probably be only a fraction of his previous potential. Obviously, the utility of the second is far lower than the utility of his typical trip. Unfortunately, there is hardly anything in the field that can assist the planner-analyst in an actual quantification of these variations, in a manner that will permit him to utilize the resultant measures in an efficiency and productivity study."[5]

4.3 Problems Associated with the Nature of the Measures of the UPTS Outputs

Problems of aggregation associated with the nature of the measures of

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5/A.R. Tomazinis, Productivity, Efficienty and Quality in Urban Transportation Systems, Lexington Books, D.C. Heath & Co., Lexington, Mass., 1975. p. 170.

the UPTS Outputs are of major importance because there seems to be little that can be done to effectively overcome them. For example, one cannot add apples and oranges to obtain a satisfactory and representative aggregate total, except if he shifts into another unit of measurement and a more generic classification system. In UPTS it is questionable whether vehicle mile, can or should be added to vehicle hours, or to passenger hours or to seat miles. Each variable is a discreet quantity total. Considering also the fact that each output variable frequently measures the same quantity, or a variation thereof, in a different manner the analyst can understand the equation that is required.

4.4 Possible Methods of Aggregation

In spite of all the above concerns, there appear to be three possible general approaches which can be thought of as usuable, with various degrees of reservation, in aggregating different UPTS Outputs:

(a) the microeconomics (utility) approach,

(b) the systems approach, and

(c) the "dollar-value of output" approach.

The Microeconomics (Utility) Approach

This approach is based on the assignment of a utility to each measure from all the points of view which then can be added in a cardinal manner. The assignment of utilities is, of course, not a simple matter, and would require extensive empirical work.

The Systems Approach

This approach involves ranking and weighting all the outputs in terms of their priorities from the planner-analyst's overall systems perspective.

The ranking would then be added to reach a total proxy ranking of each system's output. This is a subjective approach and the quality of the results would heavily depend on the understanding and judgment of the individual(s) who assign the ranking to each output measure.

The "Dollar-Value of Output" Approach

This approach is relatively the simplest one to apply in the sense that it only requires dollar "proxy" values for limited number of specific outputs. The dollar outputs can then be compared rather easily with the dollar values of the inputs that were made to the system.

TABLE NUMBER:

URBAN PUBLIC TRANSPORTATION SYSTEM

OUTPUT MATRIX : 1972

Direct outputs and estimated outputs

Regions / System components	Direct – Operator: Vehicle-miles	Seat-miles ($\times 10^3$)	Passenger-miles	Vehicle-hours	Seat-hours ($\times 10^3$)	Passenger-hours	Direct – User: Total person-trips completed	Rev. passenger-trips completed	Estimated – User	Estimated – Society: Population served	Employment served	Mobility provision	Area served	Area accessibility to population	Estimated – Government: Taxes contributed
Primary services									–						
Support functions															
Network		–													
System-wide															
Pennsylvania Region (SEPTA) – City Transit Division (CTD): subway	13,363,186	815,143	365,114,920	748,399	45,262	–	58,892,000	56,607,594	–	–	–	–	–	–	–
CTD: trolley rail	7,923,353	396,150	82,032,617	990,419	49,500	–	38,148,000	37,973,436	–	–	–	–	–	–	–
CTD: bus	34,667,830	1,733,400	288,691,330	5,777,971	288,900	–	123,803,000	121,298,879	–	–	–	–	–	–	–
CTD: trolley bus	2,103,217	96,738	16,018,499	350,536	16,146	–	9,462,000	9,422,641	–	–	–	–	–	–	–
Total CTD	58,057,585	3,041,431	691,847,366	7,861,325	399,808	N.A.	226,303,000	225,302,554	–	N.A.	N.A.	N.A.	N.A.	N.A.	2,772,000
Red Arrow Div. (RAD): trolley rail	1,525,371	76,250	33,201,214	–	–	–	5,724,000	5,646,465	–	–	–	–	–	–	–
RAD: bus	5,260,618	263,050	96,893,574	–	–	–	12,210,000	11,991,779	–	–	–	–	–	–	–
Total RAD	6,785,989	339,300	130,094,788	N.A.	N.A.	N.A.	17,934,244	17,638,244	–	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
General/Contract Operations (GCD): penn central	7,349,900	641,190	212,305,720	–	–	–	18,109,000	18,108,813	–	–	–	–	–	–	–
GCD: reading	6,579,660	547,800	179,017,200	–	–	–	12,404,000	12,429,798	–	–	–	–	–	–	–
Total GCD	13,929,560	1,188,990	391,322,920	N.A.	N.A.	N.A.	30,538,317 (estimate)	30,538,611	–	N.A.	N.A.	N.A.	N.A.	N.A.	
Total Pennsylvania Region (SEPTA)	78,813,134	4,569,721	1,213,265,074	N.A.	N.A.	N.A.	274,777,561	273,479,409	–	3,850,000 (projected)	1,525,500 (projected)	1186.8 (derived)	2,185 sq. miles	N.A.	N.A.
New Jersey Region: patco (rapid transit)	4,120,000	309,000	96,500,000	137,205	–	–	10,973,000	10,941,576	–	–	–	–	–	–	18,020
tnj (feeder bus)	10,043,000 [illegible]	490,098	–	–	–	–	1,226,710 [illegible]	–	–	–	–	–	–	–	–
Total New Jersey Region	14,163,000	799,098	N.A.	N.A.	N.A.	N.A.	12,199,710	N.A.	–	1,996,000	N.A.	400.8 (derived)	N.A.	N.A.	N.A.
Wilmington Region: dart (bus)	1,972,671	98,650	7,983,987	115,293	–	–	4,989,992	5,042,252	–	385,856	–	–		90% by bus	58,061
Total Wilmington Region	1,972,671	98,650	7,923,987	115,293	N.A.	N.A.	4,989,992	5,042,252	–	385,856	N.A.	256.2 (derived)	N.A.	90% by bus	58,061

Proxy (indirect) outputs and totally unspecifiable outputs

Regions / System components	Proxy – User: Conservation from travel expense	Information not related to travel	Safety gained from travelling with mode	Proxy – Society: Creation of an integrated community	Accessibility to employment	Decrease of [illegible]	Creation of job opport.	Proxy – Government: [illegible]	Promotion of govt. objectives	Unspecifiable – Society: Sense of organization of space	Unspecifiable – Government: Defense potential	Inducement for economic growth	National image or prestige
Pennsylvania Region (SEPTA) – CTD: subway	–	–	–	–	–	–	–	–	–	–	–	–	–
CTD: trolley rail	–	–	–	–	–	–	–	–	–	–	–	–	–
CTD: bus	–	–	–	–	–	–	–	–	–	–	–	–	–
CTD: trolley bus	–	–	–	–	–	–	–	–	–	–	–	–	–
Total CTD	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	18,575,000 [illegible]	N.A.	N.A.	N.A.	N.A.
RAD: trolley rail	–	–	–	–	–	–	–	–	–	–	–	–	–
RAD: bus	–	–	–	–	–	–	–	–	–	–	–	–	–
Total RAD	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	1,875,000 [illegible]	N.A.	N.A.	N.A.	N.A.
GCD: penn central	–	–	–	–	–	–	–	–	–	–	–	–	–
GCD: reading	–	–	–	–	–	–	–	–	–	–	–	–	–
Total GCD	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Total Pennsylvania Region (SEPTA)	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
New Jersey Region: patco (rapid transit)	–	–	–	–	–	–	–	–	–	–	–	–	–
tnj (feeder bus)	–	–	–	–	–	–	–	–	–	–	–	–	–
Total New Jersey Region	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Wilmington Region: dart (bus)	–	–	–	–	–	–	–	–	–	–	–	–	–
Total Wilmington Region	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.

COMMENTS

GENERAL GUIDELINES

(1) Any number stated as 4 325,000 C indicates the source as well as a footnote to it, where the numeral 4 refers to "footnote 4" and the letter C refers to "source C."
(2) All operating statistics are presented on the basis of the calendar year and not the fiscal year.
(3) Data given by source "F" for Wilmington consider only the City and not the total SMSA.
(4) Data given by source "B" were derived data. See internal paper on "Energy Inputs," Dec. 5, 1973.
(5) The following total average vehicular capacity (seats/vehicle) figures were used for determining "seat-miles" and "seat-hours." (a) SEPTA -- subway, 41; trolley rail, 50; bus, 50; trolley bus, 46; Penn Central, 87; and Reading, 83. (b) PATCO -- 75. (c) TNJ -- 48.8. (d) DART -- 50 (taken same as for SEPTA bus). (see source "E1.")

FOOTNOTES

(1,2) The definition of "person-trips completed" includes the assumption that each "passenger" indicates a single completed person-trip. Transfer passengers are excluded here.
(3) For SEPTA, this data refers to non-agricultural employment.
(4) The indicator for mobility has been suggested as "seat-miles per capita," based on SMSA population.
(5) Accessibility to bus or rail has been defined as the percentage of SMSA population (or employment) within ¼ mile band of bus stops, for bus, or within ½ mile band of rail stops, for rail mode, in any given region.
(6) This refers to "payroll taxes" only. Other forms of contributions would be state gasoline and diesel tax, amortization of bond discount, property taxes, licenses, sales tax on purchase of material, etc. These have not been included since comprehensive data was not available.
(7) Two indicators have been suggested here: (a) Seat-hours per passenger-hour and (b) square feet per passenger divided by 8 square feet.
(8) The indicator suggested for this output is "the number of commercial or non-commercial advertisements in each vehicle in each system."
(9) "Safety gained from travelling" has been defined as "the extent to which the transit system has a better record of accident or incident occurrence than other parts of the city (or region)." For instance, if we have transit system record of 5/100,000 user-hours and a housing record of 12/100,000 user hours, then the system safety output equals (12 - 5) = 7/100,000 user-hours.
(10-18) A satisfactory measure of such conceptual, indeterminate and unspecifiable outputs could not be reached. For further elaboration, see output position paper in Dec. 1 - Dec. 31, 1973 Progress Report.
(19) This data was derived using the average trip length for DART as 1.6 miles. (Source: Delaware Dept. of Highways & Transportation, National Transportation Study, Narrative Report, August 1974.)
(20) Data received from Mr. Madison Edgerton (TNJ) on Nov. 10, 1975 in a telephone conversation with Mr. Gordon Bets.
(21) Only includes Nov. and Dec. 1972 (the first two full months of feeder service).
(22) Assumed approximately same as for 1974.

CHAPTER X

USER INPUTS TO THE UPTS

Introduction

The direct users of UPTS while consuming the services of these systems, they invest important assets of their own such as money, time, risks, efforts, etc. In return they expect to receive transportation at an acceptable level of comfort and convenience. This section is concerned with these inputs of the direct user of an UPTS.

This chapter presents the results of estimations of user costs for the three test regions as well as some of the data and methodological issues encountered, as well as the definitions and assumptions used in the derivation of the user cost estimates.

1.0 Determination of User Cost Items

In properly assessing user costs, two parts of such costs needs to be included. One part of user costs is associated with travel to or from the UPTS mode. The other part is associated with the use of the service of the UPTS mode. The first user cost includes all items related to travel that are external to the main UPTS mode or its stations. The second part of user costs includes all the items related to travel that are internal to the main UPTS mode.

Thus, two separate financial structures (Access and Transit) are used to assess the full costs in each user. The purpose of this section is to present the full cost equation of each part of the cost as well as to show the derivation of each particular component.

1.1 Access User Costs

The user access costs, for any mode, can be stated with the equation:

$$AC = AT + VC + PC + CR + AAC + SC \quad (1.0)$$

where, AC = total access cost (in dollars per passenger mile for each completed access round trip)

AT = access time cost

VC = vehicle cost

PC = parking and/or tolls cost

CR = crime cost

AAC = accident cost

SC = social costs (including delay and pollution costs)

Each of the terms on the right hand side of the equation are discussed below:

<u>Access Time Cost</u>. This is represented as: $AT = (aT_1 + bT_2) / pm$ (1.1)

where, AT = total access time cost (in dollars per passenger mile per access round trip)

T_1 = time from origin to UPTS boarding station (hours)

a = value of access time to user (dollars per hour)

T_2 = time from UPTS exit station to destination(hours)

b = value of egress time to user (dollars per hour)

Also,

$$aT_1 = a_1T_{1s} + a_2T_{10} \quad (1.11)$$

where, T_{1s} = travel time between origin and UPTS station

T_{10} = return travel time

a_1 = value of user travel time in getting to station

a_2 = value of user time in <u>returning</u> to trip origin

Also,

$$bT_2 = b_1 T_{2s} + b_2 T_{2d} \tag{1.12}$$

where, T_{2s} = travel time between UPTS exit station and destination

T_{2d} = return travel time

b_1 = value of user travel time in getting from exit station to destination

b_2 = value of user travel time in returning from destination to exit station

Also,

$$pm = \sum_i vm_i \ (p / v)_i \tag{1.13}$$

where, pm = passenger miles traveled fro the access round trip

vm_i = vehicle miles logged at access stage i of trip

$(p / v)_i$ = passengers per vehicle at access stage i of trip

i = trip stage (generally, one of four states: origin-boarding station, exit station-destination, destination-exit station, or boarding station-origin).

Data on user access and egress times as well as value of user time can be obtained from regional attitude surveys.

Vehicle Cost. Basically, this figure is the composite vehicle cost factored for only access and egress usage. So that the equation used is:

$$VC = \sum_k VC,$$

where, VC_k = vehicle cost for each mode over the access round trip (dollars per passenger mile)

$$VC_k = \left[(OC_k + NOC)_k \sum_i VM_{ki}\right] / pm_k \tag{1.2}$$

where, OC_k = operating costs for vehicle k (dollars per vehicle mile)

NOC_k = non-operating costs for vehicle k (dollars per vehicle mile)

pm_k = passenger miles traveled per access round trip, as in (1.0)

Also,

$$pm_k = \sum_i VM_{ki} \ (p / v)_{ki} \tag{1.21}$$

where, VM_{ki} = vehicle miles traveled at access stage i by mode k

$(p / v)_{ki}$ = passengers per vehicle over access stage i in mode k and:

$$OC_k = (f + m + t)_k \qquad (1.22)$$

where f = fuel cost for mode k

m = maintenance cost for mode k

t = tires, accessories & miscellaneous cost for mode k

$$NOC_k = (d + i)_k \qquad (1.23)$$

where d = depreciation for mode k

i = insurance cost for mode k

Data for vehicle costs can be obtained from a wide variety of sources.[1,2,3/] Average access and egress distance can be found in the National Transportation Study,[4/] as well as in specific surveys for early systems.

Parking and Toll Costs. This figure is obtained in a straight forward manner.

$$PC = \sum_k PC_k$$

where PC_k = parking and/or toll costs for mode k, or

$$PC_k = \sum_i (p_i + l_i)_k \,/\, pm_k \qquad (1.3)$$

where P_i = parking costs at access stage i for mode k

l_i = toll costs at access trip stage i for mode k

pm_k = passenger miles traveled by mode k per access round trip

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1/"Costs of Operating an Automobile," U.S. Department of Transportation, April, 1972.

2/S. Wildhorn et al. "How to Save Gasoline: Public Policy Alternatives for the Automobile," Rand Corp., Santa Monica, Calif., Oct., 1974.

3/T.E. Keeler et al. The Full Costs of Urban Transport, Part III, "Automotive Costs and Final Intermodal Cost Comparisons," Institute of Urban & Regional Development, Univ. of Calif. Berkeley, Monography #21, July, 1975.

4/Federal Highway Administration. National Transportation Study, Report #8 "Home-to-Work Trips and Travel," U.S. Department of Transportation, August, 1973.

Data for parking costs can be collected through field studies.[5]

Crime Costs. Although difficult to report, crime costs per transit access/egress round trip can be viewed as:

$$CR = \sum_k CR_k$$

where CR_k = crime cost per mode k (dollars per passenger mile)

$$CR_k = \left[(VA_k + PA_k + PO_k) \sum_i VM_{ki} \right] / pm_k \qquad (1.4)$$

where VA_k = vandalism to mode k (dollars per vehicle mile)

PA_k = personal assault in connection with mode k (dollars per vehicle mile)

PO_k = personal offense in connection with mode k

pm_k = access passenger miles traveled by mode k

VM_{ki} = vehicle miles traveled by mode k at access trip stage i

Vandalism includes theft or impairment of the mode. Personal assaults include robbery, sex offenses and homicide. Personal offenses include vagrancy, disorderly conduct and narcotics offenses. Attaching numbers to these types of crime costs can be achieved by using recorded data and expanding the set to include the universe of incidents. Vandalism is covered in many cases by vehicle insurance; personal assault generally requires medical treatment in which statistics could be compiled as to the location, cost, and transport situation related to the crime. Finally, personal offenses include fines to the UPTS user for illegalities. Studies have recently been conducted that try to assess how true crime costs might be quantified in a UPTS system.[6,7,8] Yet, much work remains to be done in

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5/See for instance, Highway Research Board, Parking Principles, Special Report #125, 1971.

6/E.J. Thrasher and J.B. Schnell. "Scope of Crime and Vandalism on Urban Transit Systems," Transportation Research Record #487, 1974, pp. 34-36.

7/Robert Shellow. "Central Issues in Transit Security," in Proceedings - 15th Annual Meeting, Transportation Research Forum, 1974, pp. 235-239.

8/Ronald C. Johnson. "Mass Transit Security in Chicago," in Proceedings - 15th Annual Meeting, Transportation Research Forum, 1974, pp. 225-234.

properly tabulating and translating information to fit the crime cost equation given above.

Accident Costs. As with all of the other categories above, some information is also available about this category. Yet, the problem still remains to quantify what the accident costs are.

Using an accident analysis method,[9/] presented in a fairly recent paper, the following equation is derived:

$$AAC = \sum_k AAC_k$$

where AAC_k = accident cost per mode k (dollars per passenger mile)

$$AAC_k = \left[(FA_k + I_k + PD_k) \sum_i VM_{ki} \right] / pm_k \qquad (1.5)$$

where FA_k = fatal accidents of mode k (dollars per vehicle mile)

I_k = personal injuries sustained while using mode k (dollars/vehicle mile)

PD_k = property damage incurred by mode k (dollars per vehicle mile)

pm_k = passenger miles of access traveled by mode k

VM_{ki} = vehicle miles traveled by mode k at access trip stage i

Again, much work is needed in properly collecting and manipulating the data needed above to produce an accurate picture of accident costs. The proper achievement of usable cost data about these accident types[10,11/] is essential to any further accident analysis.

The equations (1),(1.1),(1.2),(1.3),(1.4) and (1.5) serve to illustrate the component parts which are required to fully assess user-inputed access costs. The equations are necessarily similar and linear for ease of conveyance of the cost factors. A sensitivity analysis of these equations over

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9/G. Hartman. "Societal Costs of Motor Vehicle Accidents, National Highway Transportation Study, April, 1972.

10/P. Abramson. "An Accident Evaluation Analysis, Transportation Research Record #486, 1974.

11/"City Transit Division Fact Book," SEPTA, 1974.

various trip types and socio-economic levels both geared to a regional perspective would be very desirable of course, but beyond the scope of this project. A few studies have already been conducted of access mode usage.[12,13/] Yet, no study to date has attempted to produce an explicit method of access user cost accounting.

This is in essence the nature of the equations (1.) to (1.5).

1.2 Transit User Cost

The structure of analysis applicable to this part of user costs, closely parallels the above equation set. The assumptions of linearity, common units and fully-distributed costs by completed round trips are the same here as under Section 1.1. The basic user access data obstacles, including regional emphasis, data gathering procedure, quantification of factors and use in forming performance measures, are similar for the transit user cost accounting as well. The total transit user cost equation parallels the total access user cost equation with the following basic exceptions: (1) vehicle cost is replaced by total fare cost (including transfers and special rates for elderly, handicapped, etc.); (2) there is no parking or toll cost; (3) the vandalism category of the crime cost is not applicable here (the operator absorbs the vandalism costs); (4) in this case, because the user cannot be both a passenger and an operator of a vehicle (as in the case with the access modes), the property damage factor under accident

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12/S.L. Dickerson and E. Goodson. "A Low-Cost/High Performance Resolution of the Urban Transportation Problems of Congestion, Energy and Pollution, Intersociety Conference on Transportation, Atlanta, July, 1975.

13/P. Fisher and P. Vitan. The Full Costs of Urban Transport, Part I, "Economic Efficiency in Bus Operations: Preliminary Intermodal Cost Comparisons and Policy Implications," Institute of Urban and Regional Development, Univ. of Calif., Berkeley, Monograph #19, Dec. 1974.

cost is not relevant; (5) passenger miles and vehicles are for transit miles accumulated; and (6) the access time cost is replaced by transit time cost.

Thus, the main equation for transit user cost is:

$$TUC = FC + TT + CR + TAC \qquad (2.0)$$

where TUC = transit user cost

FC = fare cost to user

TT = transit time

CR = cost to user

TAC = transit accident cost to user

For fare cost we have:

$$FC = \Sigma_k FC_k$$

where FC_k = fare cost on mode k (dollars per passenger mile)

$$FC_k = \left[FA_k \Sigma_i VM_{ki}\right] / pm_k \qquad (2.1)$$

where FA_k = fare cost on mode k (dollars per vehicle mile)

VM_{ki} = vehicle miles traveled at trip stage i by mode k

pm_k = passenger miles traveled per round trip as in 1. access cost accounting (for transit user costs VM=pm)

For transit time cost we have:

$$TT = (CT_3 + dT_4) / pm \qquad (2.2)$$

where TT = total transit time user cost (dollars per passenger mile per completed trip)

T_3 = waiting time for UPTS mode (hours)

C = value of waiting time to user (dollars per hour)

<u>or</u> $$CT_3 = C_1T_{3d} + C_2T_{30} \qquad (2.21)$$

where T_{3d} = station waiting time for to destination trip

T_{30} = station waiting time for to origin trip

C_1 = value of user time in waiting for to destination trip

C_2 = value of user time in waiting for to origin trip

Likewise,

T_4 = transit travel time (hours)

d = value of transit travel time to user (dollars per hour)

or $$dT_4 = d_1 T_{4d} + d_2 T_{40} \qquad (2.22)$$

where T_{4d} = transit travel time to destination trip

T_{40} = transit travel time for to origin trip

d_1 = value of user time in traveling to destination

d_2 = value of user time in traveling to origin

again: $$pm = \sum_i VM_i \, (p/v)_i \qquad (2.23)$$

pm = passenger miles traveled per transit round trip

where VM_i = vehicle miles logged at in-vehicle stage i of trip

$(p/v)_i$ = passengers per vehicle at in-vehicle stage i of trip

i = transit trip stage (generally, one of two: origin station to destination stop or destination station to origin stop)

Crime user cost is expressed with an equation similar to equation (1.4) but without VA_k(vandalism cost to mode k).

Transit user accident cost is expressed with an equation similar to equation (1.5) but without property damage component.

One observation concerning transit cost data is that the availability and format of this type of information is better and more plentiful than with the access user cost data. However, the requirements for data completeness and usability are still quite large.

2.0 Data and Methodological Issues

The task of measuring user costs encounters similar data and methodological problems to those associated with the other cost measuring aspects of this research project. That is, problems of variable definition and data aggregation, scale, specificity, conformity and consistency. Serious methodological questions are, of course, imbedded in all these aspects.

2.1 Specific Data Issues

Six particular observations can be made with regard to the data issues that user cost measurement encounters:

(a) Most data sets required to derive travel unit costs for access and transit are generally available on a national basis. Such data, however, may frequently be found devoid of cost differentials between systems and study regions. Localized data, as it exists, may also be aggregated over all the modes in use in a system.

(b) Specific local data on operating and maintenance costs of 'access' vehicles as well as value of time by category (access, wait, transit, transfer and egress time) is either not directly available or is derived for use within or for particular analytical frameworks.

(c) Data consistency remains a key issue. Often such data sets are either represented inconsistently or are not derived in a uniform manner (i.e., considers different variables/factors in formulating identical measures). Thus the analyst may frequently find studies with similar analysis, and similar data, yet, very dissimilar results. Whether such differences result from computational inaccuracies or methodological inequalities - it is uncertain.

(d) Trip purpose and time of trip (i.e., peak and off-peak) correlate to the value of time. Analysis that considers total user costs must therefore not only consider the work trip, and "other" trips (home-based and non home-based), but also the time of day each trip was made. Unfortunately data sets are considerably more prevalent for an analysis of the work-trip market than for other trip purposes and/or time of day variations.

(e) For this project the estimation of user costs, regardless of purpose and/or trip characteristics are based upon actual and not perceived costs incurred. The differential can be considerable. Studies have observed the mode choice behavior of individuals to be very sensitive to perceived costs (e.g. out-of-pocket costs) relative to the total costs of the trip. If this criterion of perceived cost is followed, then in the evaluation of productivity, and efficiency, the full monetary and resource inputs by the user would not be included. However, the notion that actual cost varies considerably from perceived costs requires that the variation between them be documented and fully explained.

(f) In the Philadelphia and New Jersey Study regions, considerable differences exist between the correlations of mode, areas of origin and the values of time, crime, risk and effort. In order to meaningfully evaluate the attributes of the UPTS, relative to the quantity and quality of user inputs, these differences by mode and areas of origin must be identified and considered.

2.2 Specific Definitional Issues

The determination of user cost items makes use of several variables which include considerable ambivalence and there need particular definitional constraints. The following definitions are therefore supplementary descriptive explanations to the items already incorporated in section (1.0).

(1) User Time Cost. These costs are borne by the user of the UPTS system. They include the travel time from the place where the trip begins to the spot where the UPTS vehicle is boarded (access time costs), the time spent transferring from one vehicle or route to another (transfer time costs), time from the place of the last stop

to the destination point of the journey (egress time costs).

The literature on time valuation and transportation is voluminous. Haney[14/] lists 47 studies, up to 1961 in the transportation literature which used a value of time. About 15 of these studies derived a value of time using a methodology based on consumer behavior. Boyd and Walton[15/] summarize several estimates of travel time value for contemporary intercity travel. Research into the value travelers place on travel time has occupied many transportation specialists, because savings in travel time usually is one of the largest benefits of an investment in new or improved highways or other transportation facilities.

To have empirical validity, a numerical dollar value of travel time must be based on observations of travelers' behavior. Travelers often have choices between alternatives offering different combinations of time and money costs. Transit versus private automobile, toll versus free roads, and train versus airplane are examples of such choices. Statistical techniques (including probit, logit, and discriminant analysis) have been used to explain modal choice of individual travelers, on the basis of time cost differences (among other factors) between alternative modes. Time valuation is inferred from the relative weights found for time differences, which establishes a rate of exchange between dollars and hours. Explanations of these statistical techniques and their application to modal choice and travel

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14/Haney, Dan G., The Value of Time for Passenger Cars: A Theoretical Analysis and Description of Preliminary Experiments, Menlo Park, California: Stanford Research Institute, May 1967.

15/Boyd, J. Hayden and Gary M. Walton, "The Social Savings of Nineteenth Century Rail Passenger Services," Explorations in Economic History, Spring-Summer, 1972.

time valuation can readily be found in Warner[16/] Lisco[17/] and Quarmby[18/] among others.

Recent research into the valuation of urban commuters' travel time has shed light on two issues relevant to this study: (a) the relation of travel time value to the traveler's wage rate or average hourly earnings, and (b) the relation between the value of in-vehicle travel time and the value of walking and waiting time. There is limited information on the value travelers place on "comfort" or on the relation of the value of travel time to total time of the journey. Nevertheless, there is some evidence that comfort and total time are important influences on travel time valuation.

There is substantial evidence that the perceived value of transit (in-vehicle) time is less than the traveler's wage rate. An early study by Beesley[19/] using a limited comparison of money and time differences, found that the average the perceived value of time to be is about one-third of the average hourly wage for his sample. A large-scale study by Quarmby[20/] replicated Beesley's result when only money

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16/Warner, Stanley L., Stochastic Choice of Mode in Urban Travel: A Study in Binary Choice, Evanston, Illinois: Northwestern University Press, 1962.

17/Lisco, Thomas E., The Value of Commuters' Travel Time: A Study in Urban Transportation, PhD. Dissertation, University of Chicago, June 1967.

18/Quarmby, D.A., "Choice of Travel Mode for the Journey to Work: Some Findings," Journal of Transport Economics and Policy, September 1967.

19/Beesley, M.E., "The Value of Time Spent in Traveling: Some New Evidence," Economica, Vol. 32, 1965.

20/Quarmby, D.A. op. cit.

and time differences were considered. Consideration of other variables such as walking and waiting time and whether the car was used for work, resulted in an average in-vehicle travel time perceived value of 20 to 25 percent of average wage rate. Stratified estimates showed this proportion to be roughly constant across income. Lave[21/] incorporated a factor of proportionality between time value and hourly wage directly into his estimating relationship. Using this methodology, he found in-vehicle time valuation equal to 42 percent of hourly wage. Thomas and Thompson[22/] found that in-vehicle time value increases $.40 per hour for every $1.00 per hour of hourly wage.

There is also some evidence that out-of-vehicle time is valued at a higher rate by the user than in-vehicle time. Lisco[23/] found walking time values on the order of $7.20 per hour, based on the decline of parking lot charges with distance from the Chicago Loop. This compares with his estimate of about $2.60 for in-vehicle time, implying walking time valuation 2.8 times the in-vehicle time. Quarmby[24/] concludes that "walking and waiting time are worth between two and three times in-vehicle time." These findings are also consistent with

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21/Lave, Charles A., "A Behavioral Approach to Modal Split Forecasting," Transportation Research, Vol. 3, pp. 463-480, December 1969.

22/Thomas, Thomas C. and Gordon I. Thompson, "The Value of Time for Commuting Motorists as a Function of their Income Level and Amount of Time Saved," Highway Research Record, No. 314, 1970. Also, "Discussion," by Thomas E. Lisco.

23/Lisco, Thomas E., op cit.

24/Quarmby, D.A. op. cit.

other work by Goldberg[25/] as quoted by Quarmby[26/].

Travelers are apparently willing to pay a premium for the comfort of private auto over transit, even when money and time costs are equal (also taking into account the differences in weights placed on in-vehicle time, walking time, and waiting time). There is, as yet, only limited empirical evidence of the relationship of this premium to transit or auto attributes. By conjecture only the crowding characteristic of conventional peak-hour transit may explain much of this premium, since the differential attributable to walking and waiting time has already been explicitly accounted for. Other limited evidence suggests that passengers value other attributes as well; i.e., privacy, safety, etc. that are peculiar to each travel mode.

It may be that average travel time valuation is not independent of total time spent on the trip, as assumed. Evidence on this point as it applies to urban travel is unclear. A study by Institute for Defense Analyses[27/] found that transatlantic air passengers valued time at a higher proportion of their incomes than domestic passengers. This was determined on the basis of passenger willingness to pay jet surcharges. Thomas and Thompson[28,29/] found nonlinearities in the value of travel time but they considered time value as a function of the

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25/Goldberg, L., "A Comparison of Transportation Plans for a Linear City," Paper presented to the International Conference on Operations Research and the Social Sciences, organized by the Operations Research Society, Cambridge, England, 1964.

26/Quarmby, D.A. op. cit.

27/Asher, Norman J., et al, Demand Analysis for Air Travel by Supersonic Transport, Institute for Defense Analyses, December 1966.

28/Thomas, Thomas C. and Gordon I. Thompson, op. cit. 1970.

29/Thomas, Thomas C. and Gordon I. Thompson, "Value of Time Saved by Trip Purpose," Highway Research Record, No. 369, 1971.

difference in time between the two alternatives, rather than as a function of the total time.

Most of the studies indicate that transit (in-vehicle) time is given a value of approximately 40 percent of the traveler's wage rate. Further, the studies discussed indicated that walking and waiting time are valued at approximately two and one-half times in-vehicle time. Hence, the perceived value of walking and waiting time would be approximately equal to the travelers wage rate.

(2) Access Vehicle Operating and Maintenance Costs. These costs are defined as those user expenses associated with the usage of the UPTS, as follows:

(a) Fares - out-of-pocket expenditures

(b) Access costs - (only those capital expenditures used directly for access to and egress from the UPTS). They are:

- Access vehicle purchase costs
- Repairs and Maintenance
- Replacement tires
- Accessories
- Gasoline
- Oil
- Insurance
- Garaging, parking
- Tolls
- Taxes

(c) Miscellaneous costs

- Personal injury:
  - non-reimbursed health care
  - loss of salary
- Property damage:
  - non-reimbursed property value
  - non-reimbursed claim expenditures
- Property loss:
  - non-reimbursed property value
  - non-reimbursed claim expenditures

(3) Accident Costs. The direct costs involved with travel accidents are defined as the overall costs to the user caused by accidents. Total costs include loss of property due to damage, medical costs, legal and court fees, values for loss of work time, loss of vehicle use, loss of future earnings, pain and suffering.

(4) Crime Costs. The costs of crime to the user/consumer may be viewed analogously to that of accident costs. They are defined as loss of property due to theft or damage, medical costs, legal and court fees, values for loss of work time, loss of future earnings, pain and suffering. Appendix F contains an extensive inventory and discussion of crimes within the UPTS in the Philadelphia region.

(5) Risk Costs. Risk is defined as that potential for loss associated with the uncertainty of the psychological and physical environments that the user will encounter on his trip. These uncertainties would be associated with what kind of route will one traverse, the people one will contact, how long will it take, whether transfers will be necessary, and if so, how will this be accomplished and where will one end up?

Risk can be further defined in association with a particular choice situation as comprising four categories:

(a) risk of time loss (time lost);

(b) risk of hazard loss (crime ratios);

(c) risk of ego loss (ratio of captive/choice ridership); and

(d) risk of money loss (fare and time differentials between modes.

The measurement of the above suggests the need for further research. However, if each risk category is viewed as the differential between modes on a system-wide basis, then valuation is possible. This hypothesis will be tested in subsequent tasks of this project.

(6) Effort Costs. The effort required in traveling is another type of input contributed by every user of public transportation systems. These inputs are mental as well as physical and both are, unfortunately, only marginally measurable. In spite of the difficulty in measuring effort, it seems that there is evidence to suggest that the level of effort required from the user can affect his choice of travel modes as much as the time and out-of-pocket cost requirements. There are two distinguishable types of effort associated with the use of UPTS; the following:

Mental Effort. The primary mental effort required of a user is a heavily "front-end loaded" investment for public modes. These users must gain an understanding of the network, the schedule and the fare structure of each mode. The required continuing mental effort drops to a relatively low level once the user becomes familiar with these characteristics.

Physical Effort. The task of establishing unit costs for physical effort is very important. Units of measurement for effort inputs can be based on several conceptual formulations. One such measurement may relate pounds of weight and energy consumed to horizontal and vertical movement required in order to use the various modes of transportation.

A study may use an average expenditure of energy utilized in using each mode of travel. Recognition may also be given to the fact that some people need or enjoy some physical exercise while others cannot tolerate or sustain any extra effort.

Another means of measuring physical effort in travel is the ratios of standees to seated travellers in any mode. This is a more direct but "proxy" method of measuring physical effort,and because of its directness and availability of data, it is frequently suggested for use in actual comparative measurements.

3.0 User Costs in the Three Test Regions

Following the relationships presented in section (1.0) and the definitions and constraints elaborated in sections (1.0) and (2.0), an effort was made to estimate the user costs in the three test regions. The step-by-step calculations are shown in a schematic way in Appendix H of this volume, utilizing the PATCO as an example and choosing only one year. The results of these estimations are shown in Table X-1 for PATCO High Speed Line and for the years 1971, 1972, 1973 and 1974. Table X-2 presents the results for all the three major operators in the three test regions (SEPTA, TNJ, PATCO). Data for DART has been inserted directly to the Fiscal Input Matrices because of its simplicity.

Reviewing Tables I and II, the analyst may notice that two more columns are inserted with Access Vehicle energy cost and energy amount consumed. Because of the current interest in energy consumption it was thought desirable to produce these accounts, although energy cost *per se* is included in the operating cost of the access vehicle.

Tables I and II also reveal that from the total user cost the proxy costs of access time accounts of about 40% of the total cost, more than twice as much as transit time cost. Also,the costs of fares accounts for about 15% of the total "proxy" cost inputed by the user while he travels with UPTS. The sum of time costs (access and transit) account for as high a percent as 80% of total costs. Taking into account "out of pocket" costs (i.e., Parking costs and Fares) one may notice that these costs account for about again 15% of the total "proxy" user costs. Obviously the best of parking is relatively small as is the costs for accidents, taken in an aggregate form.

TABLE X-1. OPERATOR - PATCO HIGH SPEED LINE

Year	Access Time Cost (10^6 \$)	Access Vehicle Operating Cost (10^6 \$)	Parking Cost (10^6 \$)	Access Vehicle Energy Cost (10^6 \$)	Access Vehicle Energy Consumption (10^{10} BTU)	Access Vehicle Accident Costs (10^6 \$)	Transit Time Cost (10^6 \$)	Fare Revenues (10^6 \$)	Transit Accident Cost (10^6 \$)	Total for Year (10^6 \$)
1	2	3	4	5	6	7	8	9	10	11
1971	16.94	5.36	.84	1.30	48.88	.28	7.59	4.54	.02	35.57
1972	19.75	6.48	.98	1.58	56.98	.34	8.84	5.83	.02	42.24
1973	18.28	6.44	.92	1.56	52.74	.34	8.19	5.54	.02	39.73
1974	19.40	8.44	.98	2.22	55.96	.38	8.69	6.16	.02	44.07

TABLE X-2. OPERATOR TOTALS (SEPTA-TNJ-PATCO)

Year	Access Time Cost (10^6 \$)	Access Vehicle Operating Cost (10^6 \$)	Parking Cost (10^6 \$)	Access Vehicle Energy Cost (10^6 \$)	Access Vehicle Energy Consumption (10^{10} BTU)	Access Vehicle Accident Costs (10^6 \$)	Transit Time Cost (10^6 \$)	Fare Revenues (10^6 \$)	Transit Accident Cost (10^6 \$)	Total for Year (10^9 \$)
1	2	3	4	5	6	7	8	9	10	11
1971	706.93	25.27	10.32	5.97	258.06	1.25	328.77	116.99	2.14	1.192
1972	680.18	25.61	9.44	6.12	242.15	1.31	308.35	111.06	3.04	1.139
1973	659.89	26.25	9.14	6.38	182.3	1.36	303.41	113.69	2.46	1.116
1974	661.93	35.52	9.40	8.87	222.71	1.53	306.31	124.76	2.54	1.142

CHAPTER XI

SOCIETAL INPUTS ACCOUNTS

Introduction

In the broadest sense, society is the generator of all inputs and the recipient of all outputs of the Urban Public Transportation System (UPTS). Society is, also, the source of the expressed desire for increased public transportation facilities. The identification of society as an actor often presents a confusing situation due to the non-mutually exclusive nature of society's constituents, i.e., the operator, the user, and the government.

In examining society's inputs within the rigorous framework of the Fiscal and Physical Input Matrices, careful analysis and consistent accounting is required in order to avoid double counting of inputs from operators, government and users.

1.0 Types of Societal Inputs

The concept of an input to the UPTS, from any of the actors, suggests a sacrifice or contribution of either money, physical facilities, or labor. Most of the more tangible input items are more properly detailed under user, operator and government. What remains are the intangible contributions which only society as a whole entity provides. These are primarily the costs produced from the adverse impacts of the UPTS, and, secondarily, the costs representing the opportunities sacrificed. For the present study, these are referred to as opportunity and externality costs. Figure XI-1 (see page 185) provides a schematic layout of these two types of societal inputs.

1.1 Opportunity Costs

The argument for inclusion of opportunity cost focuses on the scope of its definition regarding the UPTS. The concept of opportunity cost, stated simply, is:

> "If 'X' amount of dollars, manpower, resources and effort is invested in one alternative, what is the sacrifice incurred by not investing 'X' in some other alternative? This sacrifice, if any, is then the opportunity cost of the 'X' amount of investment."

This cost is intuitively as important as the actual costs which society incurs for the UPTS. However, some difficult conceptual issues are remaining unresolved with regard to the opportunity cost of UPTS. If, for instance, society expresses a desire for improved public transportation and the government funds the appropriate programs to serve this desire, should an opportunity cost be added for not "investing" those funds in, say, housing programs? Or should the opportunity cost to society be derived from not investing these funds in a highway program? Or, more generally, is there an opportunity cost at all given for any government funding programs? To introduce specific opportunity cost for UPTS funding raises major issues which are beyond the scope and intent of this study. Therefore, the notion of opportunity cost has been dropped from consideration as an input to the UPTS.

1.2 Externality Costs

Throughout this study, externality costs have been defined as the negative outputs or infringement upon society from construction and operation of the UPTS. Typical items that are externality cost inputs include the adverse environmental impacts due to air and noise pollution; the increased incidence of crime on transit facilities; the aggravating congestion levels due to mixed traffic on common use facilities; and the acquisition of rights of way or impairment of its aesthetic qualities. Transportation planners strive continually to minimize the effects of these impacts when evaluating different alternatives. Nonetheless, the costs that these inputs produce on the society as a whole must be considered.

2.0 Input Discussion

The societal externality costs presented above, are further categorized according to the system's component that necessitate these costs, i.e. into primary, support, network and system wide inputs. Following another system of classification based on the immediacy of the occurrence, the same externality costs can be classified as follows:

(1) Primary Externality Cost. Impacts resulting directly from constructing and providing the transportation service (roadways, railways, tunnels, bridges, stations, terminals, parking facilities, vehicles, etc.)

(2) Secondary Externality Cost. Impacts resulting indirectly from the provision of the services or the support functions, including maintenance areas and equipment for transit vehicles, automobiles and truck service facilities, roadway and railway maintenance shops and equipment.

(3) Tertiary Externality Cost. Impacts resulting from those portions of industries, directly or indirectly related to UPTS service (vehicle manufacturers, oil refineries, power generation, steel and concrete manufacture, etc.)

3.0 Individual Externality Elements

Societal externality system inputs are extremely difficult to quantify and frequently as difficult to satisfactorily define. Amounts of some types

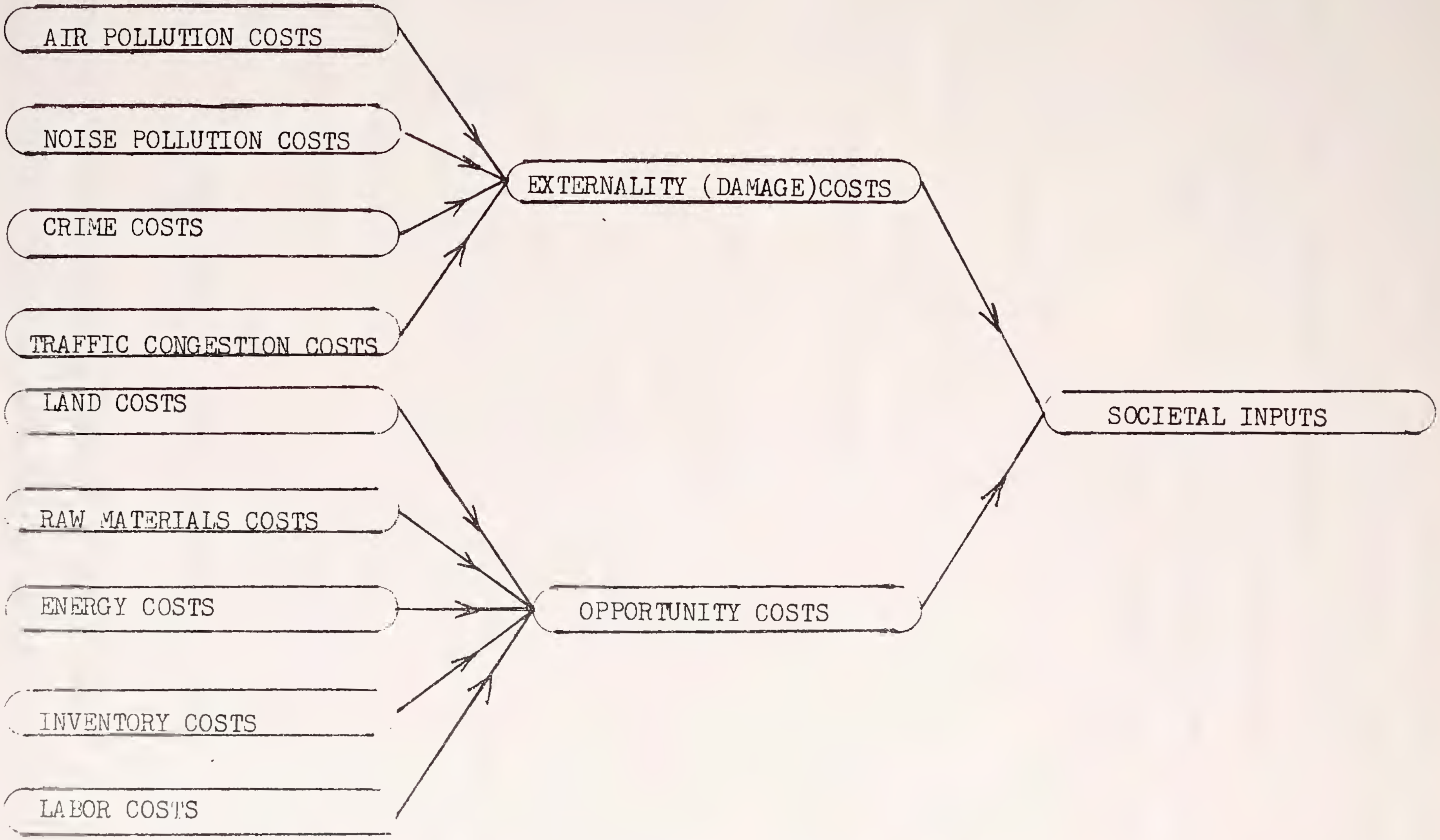

Figure XI-1. SOCIETAL INPUTS

of costs, such as the costs that air pollution produces, mean nothing to society unless it affects the quality of life. Nevertheless the analyst must come to grips with the situation -- measure what can be measured and interpret the consequences to society. What follows is a discussion of each previously presented externality input item and comments on each input.

3.1 Air Pollution Cost Inputs

The operation of the UPTS results in emissions of air pollutants which incur costs. The costs of controlling or mitigating air pollution are expenditures planned, paid and accounted for by the government as an operating expense. The residual cost incurred to members of society at large are the externality costs of air pollution which are considered here as additional societal cost inputs to the UPTS.

Externality costs are caused by the emissions which are uncontrolled or unavoidable. These costs are numerous and diverse, ranging from the laundering of soiled clothes to losses in property values and losses of human life. Some of the more direct, or tangible, damage costs can be quantified using the results of several national studies. (See Table XI-1). However, many impact costs of air pollution are more indirect, less tangible, and therefore less quantifiable. These are costs that are including the costs of long-term cumulative effects of low levels of pollution, and the costs of synergistic effects where two pollutants may combine in the atmosphere to produce, under certain circumstances, an even more harmful, third pollutant.

The quantification of impact costs represent at best an estimated proxy number. An approach suitable for obtaining such impact costs from UPTS is as follows:

TABLE XI-1. SOCIETAL COSTS[1/] (Pollution)

ITEM	COST (1968) (10^6 dollars)
Repainting steel structures	100
Commercial laundering, cleaning & dyeing fabrics	800
Washing cars	240
Damages to agricultural crops & livestock	500
Damages to air travel	40-80

OTHER QUANTIFIABLE ITEMS	COST NOT ESTIMATED
Replacing & protecting precision instruments	CNE
Maintenance of cleanliness in production of food, beverages, and other consumables	CNE
Maintenance of homes & furnishings	CNE
Decrease in property values	CNE
Fuels wasted in incomplete combustion	CNE
Medical costs: chronic diseases (asthma, emphysema, bronchitis) & lung cancer	CNE

1/Source: Council on Environmental Quality, 1st Annual Report, 1970.

(1) Establish vehicle-mile relationships for annual operating statistics, for each travel mode and variations of operating conditions,

(2) Use the best available and most recent data found for air pollution production and damage costs to society (i.e., as documented by the Environmental Protection Agency). Estimates can be per vehicle mile, or for the summation of the transportation operations of each mode.

Data on pollution production and resulting damages are usually available on a national basis (See Tables XI-2 and XI-3), or on a regional basis, associated with each major sector of the economy: industrial, commercial, residential, power generation and transportation and for the five major pollutants: carbon monoxide (CO); hydrocarbons (HC); nitrogen oxides (NO_x); sulfur oxides (SO_x); and particulates (P's). By relating these data to the operations of UPTS in the three test regions for each test year, an indication of the costs borne by society from air pollution from the UPTS can be computed.

The data in Table XI-4 was treated in a number of steps to develop local statistics characteristic of the three test regions.[1/] Further disaggregating calculations based on SEPTA and DVRPC travel statistics yielded the disaggregate results as presented in the 1974, 1973, and 1972 Fiscal and Physical Input Matrices.[2/]

A major assumption in generating these dollar values is that all modes retained the air pollution control levels of 1972. Actually, this is a valid assumption for all electrified modes, as the Philadelphia Electric

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1/City of Philadelphia, Dept. of Public Health, Air Management Services, "Emission Inventory and Air Quality Data Report to the Air Pollution Control Board", Oct. 1974 (revised).

2/DVRPC, AADV Primary and Second Road System, 1970.

TABLE XI-2. ESTIMATED NATIONAL AIR POLLUTION COSTS FOR 1968

TYPE OF COST	ANNUAL COST ($x10^9$ dollars)
DAMAGE COSTS	
Materials damage	\$4.8 1/
Damage to crops	.1 2/
Cleaning of soiled materials	(3)
Damage to human health	6.1 4/
Damage to animal health	(3)
Reduced property values	5.2 5/
Other	(3)
AVOIDANCE COSTS	(3)
TOTAL	\$16.2

1/ Includes damages to approximately 50 materials thought most susceptible to air pollution deterioration.

2/ Includes direct visible damages affecting the yield, quality, or marketability of field crops and forests

3/ Not estimated

4/ Includes estimated expenditures on treatment and prevention of illnesses caused by air pollution (in excess of the primary air standards) plus income lost because of morbidity and early mortality.

SOURCE: The Cost of Air Pollution Damages; A Status Report, EPA, 1973.

TABLE XI-3. ESTIMATED NATIONAL AIR POLLUTION DAMAGE COSTS WITH NO POLLUTION CONTROL, 1968 and 1977.

DAMAGE CLASS	1968 1/	1977 2/
HEALTH	$6.1	$9.3
RESIDENTIAL PROPERTY	5.2	8.0
MATERIALS and VEGATATION	4.9	7.6
	$16.2	$24.9

1/ In 1968 dollars

2/ In 1970 dollars

SOURCE: The Cost of Air Pollution Damages; A Status Report, EPA, 1973.

TABLE XI-4. AIR POLLUTION COSTS AS A SOCIETAL INPUT

NOTE: These proxy figures were derived for Pa.-N.J.-Del. test regions in 1974.

EXTERNALITY (DAMAGE	COST IN DOLLARS
SEPTA 1. HEALTH	$2,430,104
2. VEGATATION AND MATERIALS	$1,970,354
3. RESIDENTIAL DAMAGE	$2,101,711
4. OTHER PROPERTY DAMAGES	$ 768,848
TOTAL PENNSYLVANIA REGION	$7,336,730
TOTAL NEW JERSEY REGION	$1,388,549
TOTAL DELAWARE REGION	$ 131,263

SOURCES:

1. SEPTA Rail Statistical Data 1974.
2. RAD Operating Statement, SEPTA, 1974.
3. Economic Evaluation of Transit Plans for KCMR, MRI 1975.

Company has not yet installed air pollution controls. However, this is not true for SEPTA's buses which has been increasing their fleet with tail exhaust stacks and other air pollution control equipment between 1972 and 1974.[3/] Consequently, the cost estimates for 1973 and 1974 might be slightly overestimated for the bus fleet of SEPTA.

For those public transportation modes representing stationary sources of air pollution, i.e., the electrified trolley rail and bus, subways and commuter rails, another approach was taken. City of Philadelphia emissions data indicate that power generation accounted for 6.8% by weight, of total 1974 Philadelphia emissions. To determine the portion released to public transportation, the electricity purchases made by SEPTA in 1974 for its electrified modes was divided by PECO's total revenues for 1975.[4/] These statistics were used to allocate costs among SEPTA's various divisions and modes (using vehicle miles traveled figures from the Output Matrix).

Finally, to further allocate total damage costs to damage type for the Pennsylvania test region, health, materials and vegetation, and property damages, proportional to the 1974 national totals, were estimated. These data were entered into the Inputs Matrix for 1974.

3.2 Noise Pollution

In the daily operation of the UPTS, noise is continuously emitted from the rolling stock, such as buses, rail rapid transit cars and the commuter trains. The decibel levels they achieve frequently border on the maximum threshold level of pain to the human ear. The suffering from such excessive noise is spread between users and non-users and thus represent a

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3/Control mechanisms on the buses are, however, operator cost inputs to control negative system outputs.

4/PECO, "Financial Supplement to the 1974 Annual Report," 1974.

type of societal cost. These costs, are important societal costs to be considered, but unfortunately very elusive of all quantification efforts.

The government inputs section describes the additional costs of controlling noise pollution through engineering remedies currently employed. Generally, the degree of investment is directly proportional to the noise level generated by the UPTS. The Federal Noise Standards, shown in Table XI-5, indicate the threshold limits that society is willing to accept for various modes of transportation. In order to meet these standards, there is frequently a need to undertake additional expenses in the construction and/or operation of various UPTS modes. Such expenditures are usually applied by the operator-supplier of the system and are invested on the following:

(1) improved bus mufflers,

(2) cushioned railroad and rail rapid transit ties,

(3) silencers on subway ventilation shafts,

(4) acoustical tile designs of subway platforms and stations,

(5) welded rail for rail transit, and

(6) bailing arrangements both structural and natural.

It is the difference between these standards and the actual noise levels in a community that produces the additional societal costs of noise. Table XI-6 indicates clearly how great the differences between standards and actual levels can be. When transportation facilities produce such extensive noise levels, especially during moments of work or relaxation, the societal costs can be quite important. Unfortunately, even in these cases, the analyst can do very little in quantifying societal noise costs unless there is evidence of some kind of permanent physical harm. Even then the translation of some hearing loss into equivalent dollar loss represents a difficult analytical step.

TABLE XI-5. FEDERAL NOISE STANDARDS

Source	Maximum Level	Distance from roadway 25 feet	100 feet
Urban Land Use - Commerical	75 dBA		
Urban Land Use - Residential	70 dBA		
Urban Land Use - Park	65 dBA		
Automobile			
20 mph		56 dBA	50 dBA
40 mph		64	58
60 mph		70	64
Truck (any speed)		82	76
Diesal Bus		86	80
Transbus		76	70
Metro Car (40 mph)		83	77

SOURCE: Federal Registrar

TABLE XI -6. PUBLIC TRANSPORTATION NOISE - PHILADELPHIA [1/]

Source Type and Location	Below Ground	Above Ground
Subway-Elevated Train		
inside cars	82-95 dBA	78-90 dBA
on boarding platform	92-98	83-93
at cashier's booth	90-93	82-88
Trolley Car (Subway-Surface)		
inside cars	74-87 dBA	65-75
on boarding platform	84-100	80-85
at cashier's booth	83-84	none

1/J. H. Botsford, in Proceedings, of Transportation Noises, A Symposium on Acceptability Criteria, edited by J. D. Chalapnik, University of Washington Press, 1970.

3.3 Transit Crime

Throughout the United States, crime levels have been steadily increasing in all areas. This is also the situation in most UPTS facilities. Just to what extent a portion of transit crime statistics can be attributed to, transit services or facilities, is somewhat doubtful. However, the fact remains that crime does occur on UPTS facilities. Do such facilities induce or facilitate criminal activity? If the answer to this question is positive and an intrinsic relationship between crime and UPTS is presumed then, of course, additional societal costs inputs to the UPTS due to the occurrence of crime must be added in all cases. **(See Also Appendix F).**

Estimating a dollar equivalent or societal cost of damages related to transit crime would need to include hospital costs, disability payments, loss of income, other family losses as well as, insurance premiums. No such effort was possible with the confines of the present project.

3.4 Other Societal Input Items

Of the initial list of societal externality inputs, the preceding inputs were found to be the most worthwhile for further consideration. The remaining inputs of traffic congestion, land value losses, and aesthetic consequences were found to be highly desirable as cost inputs, but extremely difficult to pursue both conceptually and quantitatively. On this basis, these items were excluded from further consideration.

CHAPTER XII

GOVERNMENTAL INPUTS

Introduction

Traditionally, studies examining the cost of urban public transportation systems (UPTS) have focused on contributions by the system's user, and/ or the system's operator. Rarely has the government's point of view been considered. With increased government involvement, and multiple direct and indirect contributions, on all levels, pertaining to public transportation operations, construction, and planning, the government's side of the entire system requires greater attention.

In providing public transportation inputs, the government's role is one of responding to the needs of society by:

(1) Defining the public priorities and appropriate policy action.

(2) Collecting the taxes for funding policy implementation programs.

(3) Allocating the tax resources to the most critical priorities and programs for implementation.

In the execution of the implementation programs, government has been providing land, facilities, grants, and loans to improve our nation's public transportation systems. These programs have also included areas of research and development for new technology, policy formulation and refinement, as well as improvements of overall technical planning skills. Thus, contributions from government at all levels represent significant inputs to the total UPTS.

In previous chapters, the various actors participating in the UPTS have been discussed in extensive detail. The government's contributions are in addition to those from the user, operator and society. The total UPTS inputs are the sum of operator, user, society and governmental contributions. Each actor's contribution is the aggregate of his respective individual component inputs. For government these component inputs are divided initially into two major categories, capital and labor, which are further subdivided into specific capital and labor components. A description of these major categories and the rationale supporting their development is subsequently discussed.

In this chapter the government inputs to the UPTS of the three test regions are described and quantified to the extent possible. Conceptual and practical problems related to developing the data base are also being presented. The results of the estimations are presented in the Fiscal and Physical Input Matrices discussed in chapters IV and V.

1.0 Types of Governmental Inputs

Governmental inputs affecting the production of urban public transportation services are of two types, either capital or labor contributions. Capital items may be further subdivided into a number of categories:

(1) Monetary Capital

(2) Physical Capital

(3) Governmental Capital Facilities

(4) Governmental Operating Expenses

On the other hand, labor inputs are evident within a broad spectrum of government services associated directly or indirectly with the support or administration of public transportation services. Typical examples include the salaries and related costs for planning, administration, tax collection and security enforcement by different agencies from all levels of government, i.e., Regional Planning Agencies, City Planning and Transportation Agencies, the local UMTA regional office, etc.

Figure XII-1 displays the range of government input items which have been considered within the scope of this study.

1.1 Capital Inputs

A distinction must be drawn among the differing connotations affixed to capital inputs. For this study, capital inputs refer to both monetary and physical transfers of resources for UPTS use. Monetary Capital inputs to the UPTS are usually in the form of direct transfers of monies on the federal level, purchase of service subsidy on the local level, and funds for technical studies on the regional level. Physical Capital can be defined as the transfer of physical elements of the transport system for the explicit or shared use of urban public transportation. Items within this category include in these regions the Broad Street and Market Street Subway/Elevated tunnels, the Benjamin Franklin Bridge which supports the Lindenwold Line, and numerous parking facilities throughout the region used as transit "park-'n-ride" facilities. The single most important element within this classification is the existing highway network. The use of these facilities by public transportation is most certainly a sizable governmental contribution to the provision of public transportation services.

Monetary Capital. The UPTS are usually the recipients of various governmental monetary inputs characterized by specific purposes. These inputs are of a non-reimbursable grant or subvention variety, originating from all levels of government. On the federal level, monetary capital inputs may be given to any public agency permitted to operate or improve public transportation. Thus, Urban Mass Transportation Administration (UMTA) funding for Section 3 capital facility construction and right-of-way acquisition, may be given to local townships, counties, cities or state governments.[1/] This money may be used for each of the three major service components

1/Section 3,5,9 funds are appropriated for public transportation under the Urban Mass Transportation Act of 1964, as amended.

TOTAL GOVERNMENT INPUTS			CONTRIBUTION BY LEVEL OF GOVERNMENT			
			LOCAL	STATE	FEDERAL	REGIONAL
CAPITAL	MONETARY CAPITAL	FACILITIES SECTION(3)	X	X	X	
		OPERATING SUBSIDY SECTION(5)	X	X	X	
		STUDIES&PLANNING SECTION (9)	X	X	X	X
	PHYSICAL CAPITAL	TUNNELS, HIGHWAYS,	X	X	X	
		BRIDGES; OTHERS	X	X	X	
	GOVERNMENT CAPITAL FACILITIES	ADMINISTRATION BUILDINGS	X	X		X
		TRANSPORTATION FACILITIES	X	X		X
	GOVERNMENT OPERATING EXPENSES	TRAFFIC DEPARTMENTS	X	X	X	
		TRANSIT OFFICES	X	X	X	X
		MAINTENANCE	X	X		
		SAFETY, POLLUTION, NOISE-AIR	X	X	X	
LABOR	ADMINISTRATION		X	X	X	X
	PLANNING		X	X	X	X
	FINANCING		X	X	X	
	MAINTENANCE		X	X		
	LAW ENFORCEMENT		X	X		
	LEGISLATIVE		X	X	X	

Figure XII-1. GOVERNMENT INPUT ITEMS

of the UPTS; network construction and rehabilitation, primary services (rolling stock), and support (maintenance) facilities. These funds are currently provided on an 80% federal share and 20% local share basis. Prior to 1972, the split was 2/3 federal and 1/3 local.

Another source of monetary input falls within the provisions of Section 5 of the same Act. Section 5 funds may be used for either purchase and construction of facilities or for operating subsidy. The choice is up to the individual grant recipient as to the usage. These funds are provided on a 50% federal share and 50% local share basis.

A third source of funds is the Section 9, technical study grants of the same Act. For the most part, these grants are made to regional planning agencies or state Departments of Transportation for transit planning analyses, transit operating studies or for special projects.[2/] In each region of the area, these are usually given to the Metropolitan Planning Organization for distribution to the specific operating agencies.

A final source of UMTA funding is with the grants available for research, development and demonstration projects under Section 6 provisions. Although these funds are ostensibly inputs to each specific UPTS, the realization of their direct impact upon specific productivity levels of individual UPTS is somewhat doubtful. For this reason, this funding source is not included in the analysis.

Physical Capital. The Physical Capital items, as previously mentioned, constitute the indirect transfer of physical facilities for UPTS use. The Broad Street and Market Street Subway tunnels in Philadelphia, provide an excellent illustration of an indirect transfer. Under a nominal

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2/Additional money is available under Section 12, for elderly and handicapped studies.

lease agreement of $1.00 per year, SEPTA may operate transit services within these rights of way. Other arrangements include the use of various capital facilities and equipment including rolling stock, stations and trackwork and represent sizable capital investments of the government devoted to the UPTS of the region. Moreover, the maintenance and repair costs associated with these facilities are paid for by the City of Philadelphia budget.[3/] Again, the amortized cost of these facilities in addition to maintenance and upkeep expenditures are important inputs contributed by government to the UPTS.

Other transportation elements that are also governmental physical capital inputs include the highways, bridges, and road and street networks throughout the region. As in the case of the subway tunnels owned by the city, the proportional costs of these highway facilities should be credited as the governmental physical capital contribution to the region's UPTS. Thus, right of way, relocation, construction, and bond interest costs for such facilities are input credits to the UPTS.

Associated with the fixed highway facility are the auxilliary or support functions such as traffic control, snow removal and routine maintenance. Each of these functions requires equipment and hardware; i.e. trucks, compressors, service vehicles and tools for maintenance; traffic control devices to insure free flowing traffic movement; and specialized public transportation equipment, e.g. bus pre-emption equipment, exclusive bus lane channeling controls, grade-crossing safety devices, etc.

For all of the items just mentioned, certain difficulties arise when use of facilities is shared by more than one mode, i.e. auto, truck and

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3/These input costs are included in the Governmental Operating Expense classification; and are mentioned here for emphasis.

transit. To determine an equitable allocation of the costs attributed to each mode's individual use, a formula needs to be developed similar to the "user" cost placed on the trucking industry. Thus, all shared use of road and highway construction, right of way, maintenance (equipment) and related physical costs would be totaled; amortized and discounted by appropriate interest and life cycle assumptions and allocated to each mode on the basis of its proportionate use.

The growth of the governmental role in urban transportation has also produced, in many cases, an additional need for capital investment, i.e., the capital investment required in order to house the agencies, services, and functions the government provides. Many cities (and counties) have buildings, parts of buildings, garages, and other facilities totally devoted to servicing, in one way or another, the public transportation system of their region. Even many states have urban transportation administrations. On the federal level the increased importance and activities of the Urban Mass Transportation Administration and that of the Urban Planning Division of the Highway Administration are well known. These last mentioned facilities on the state and federal levels constitute clear governmental inputs to the urban transportation system in toto and, therefore, require parceling out to the various urban regions. Although the tendency has been to avoid the inclusion of these elements, it is important to point out the relative significance of including this type of governmental input.

1.2 Governmental Operating Expenses.

Governmental entities, at all levels, have functions or departments for controlling, monitoring or improving services vital to the public's welfare. Many of these services are created directly for the improvement or maintenance of public transportation. For example, on the federal level, the Urban Mass Transportation Administration falls under the auspices of DOT policies and funding programs. On the local level, the City of Philadelphia, for instance, maintains a traffic engineering department plus a transit office within the Department of Public Property. Each of these agencies maintains daily operations and services related to public transportation planning and operations. Each incurs administrative and overhead costs, all for the purpose of enhanced urban mobility (see Table XII-1). The proportionate transit based contribution of these agencies' operating budgets has for the most part been ignored as worthwhile input to the UPTS. Moreover, other agencies and departments also contribute to the benefit of the UPTS. These include, for example, the Department of Public Health in the City of Philadelphia, which maintains an air pollution control program; the police department of the City of Philadelphia and all local townships, which control transit crime and vandalism; and the judicial system of each jurisdiction, that hears cases of transit vandalism, crime and transit accident cases.

Other entries as shown in Figure XII-2 are discussed subsequently and indicate other governmental control services such as noise and air pollution control and safety. Again, the costs allowable in this category are only those related to operating expenses directly or indirectly paid for by government.

Noise Pollution Control. Relatively recently, governments have been instituting programs to combat intolerable noise conditions within our cities. The state of the art in transit technology, has progressed to the point where some North American systems have taken positive action to reduce noise pollution due to the UPTS. Toronto, for example,

TABLE XII-1. DIRECT AND INDIRECT GOVERNMENTAL INPUTS[1/]

CITY OF PHILADELPHIA
OPERATING FUNDS
STATEMENT OF APPROPRIATION ACTIVITY BY PROGRAM
FOR THE FISCAL YEAR ENDED JUNE 30, 1974

Program / Sub-Program / Element	Adjusted Fiscal 1974 Appropriations	Encumbrances	Expenditures	Total Obligations	Unencumbered Balance of Appropriations
Transportation Program					
Mass Transit					
Public Transportation Services	$ 14,159,055.84	$ 207,018.00	$ 13,949,437.04	$ 14,156,455.04	$ 2,600.80
Streets and Highways					
Construction and Maintenance	$ 14,506,614.83	$ 3,442,548.79	$ 10,695,836.46	$ 14,138,385.25	$ 368,229.58
Surveying and Engineering Design	2,616,658.23	7,127.41	2,598,547.80	2,605,675.21	10,983.02
Street Lighting	6,198,040.00	849,912.01	5,341,444.55	6,191,356.56	6,683.44
General Support	754,965.00	65.27	753,122.20	753,187.47	1,777.53
Emergency Snow Removal	173,277.00	25,000.00	116,640.69	141,640.69	31,636.31
	$ 24,249,555.06	$ 4,324,653.48	$ 19,505,591.70	$ 23,830,245.18	$ 419,309.88
Traffic Control and Enforcement					
Traffic Regulation and Enforcement	$ 11,843,900.00	$ 35,185.98	$ 11,727,860.13	$ 11,763,046.11	$ 80,853.89
Traffic Court Operations	2,528,928.00	27,087.06	2,423,616.57	2,450,703.63	78,224.37
Accident Records Report Reproduction	11,369.00	694.20	9,171.40	9,865.60	1,503.40
Traffic Engineering	2,403,894.00	116,297.67	2,275,645.95	2,391,943.62	11,950.38
Traffic Safety	69,394.00	-	55,300.66	55,300.66	14,093.34
Parking Meter Collections	243,902.00	8,530.52	231,000.20	239,530.72	4,371.28
Parking Enforcement Officers	963,064.00	92,649.91	827,301.52	919,951.43	43,112.57
Parking Meter Maintenance	369,078.00	15,165.17	209,071.13	224,236.30	144,841.70
Pedestrian Safety - Streets	2,896.51	-	2,896.51	2,896.51	-
Pedestrian Safety - Police	12,970.00	-	-	-	12,970.00
Highway Safety Traffic Engineering	52,089.19	-	52,089.19	52,089.19	-
Traffic Operations Program	129,249.98	-	110,342.86	110,342.86	18,907.12
Traffic and Highway Engineering Training Project	25,385.00	-	-	-	25,385.00
Emergency Towing	30,047.00	-	14,177.88	14,177.88	15,869.12
Provision of Retirement Benefits	191,876.00	-	127,092.83	127,092.83	64,783.17
Fatal Accident Reduction Enforcement Program	4,000.00	-	4,000.00	4,000.00	-
Employees' Welfare Plan	50,460.00	-	36,900.00	36,900.00	13,560.00
Social Security Payments	60,616.00	-	60,616.00	60,616.00	-
Public Transit Crime Reduction Program - Discretionary Grant	1,000,859.00	66,836.37	381,193.00	448,029.37	552,829.63
Pedestrian Safety Program - Streets	72,181.49	-	15,899.11	15,899.11	56,282.38
Traffic Control Device Inventory Program	182,111.81	-	114,765.75	114,765.75	67,346.06
Reproduction of Accident Reports Program	843.00	-	843.00	843.00	-
	$ 20,249,113.98	$ 362,446.38	$ 18,679,783.69	$ 19,042,230.57	$ 1,206,883.41

1/Source: City of Philadelphia. Director of Finance. Annual Report, 1974.

has rubber-tire vehicles, BARTD has special floating slabs supporting the trackwork, and the new DOT sponsored Transbus is equipped with special mufflers. Aside from these capital intensive features, some city governments have experimented with controlling UPTS noise levels by more cost-effective techniques, such as spraying acoustical treatments (fluffy absorbant materials) on the interior subway walls. For the most part, these control costs have been financed with federal and local participating governments under Section 3, of the UMTA program and extend to major noise control projects including the following:[4/]

(a) Welded rail on new rail transit systems;

(b) Acoustic tiles throughout the subway interior;

(c) Silencers on ventilation shafts;

(d) Floating slabs on trackwork; and

(e) Physically baffling designs or innovative landscape architecture.

For these agencies, all expenses related to every day transit related operations, is an indirect transfer of capital inputs. Maintenance costs of supervisory vehicles, special equipment for conducting public transportation analyses, including traffic counters and travel questionnaires, and rudimentary office supplies are operating costs absorbed by the government but not usually credited as an input to the UPTS.

Air Pollution Control. The operation of the UPTS results in emissions of air pollutants, largely attributable to bus operations. Many government agencies have initiated programs designed to mitigate or control the adverse environmental impact of these pollutants.

4/This type of governmental input cost would, of course, be more appropriately entered under the capital input category of "Monetary Capital".

In the City of Philadelphia, for example, an air resource management program within the Air Quality Division has been operational since 1969. For 1974, the budget for this program amounted to approximately $1 million.[5/] The major functions of the division are to maintain a real-time air quality surveillance system and to accumulate a data bank of air quality measurements. In relation to the UPTS, these efforts can provide pollutant estimates resulting from the various forms of public transportation to determine their degree of compliance with national air quality standards.

Transit Crime Control. The area of transit crime also results in governmental expenditures to the UPTS. The maintenance of an aggressive crime reduction program generates costs for watch dog and transit police facilities, alarm boxes, and closed circuit monitoring of station facilities. The attendant administrative costs of providing these security forces, and the costs of bringing criminals and vandals involved in transit crimes to court are oftentimes overlooked. Table XII-2 details some of the vandalism statistics for the Philadelphia area commuter railroads. The central costs of keeping crime as low as possible is an important element in providing an attractive level of transit service. Consequently, these expenditures are as valuable to the UPTS as costs of more frequent service or of new rolling stock. The reason being that if the UPTS is not safe, the potential or present user will not use it, regardless of how comfortable, convenient or attractive it is in comparison with a safer alternative.

During 1975, the Philadelphia Police Department maintained a 228 officer and 56 dog transit police force for CTD of SEPTA. Based on a conservative average of $15,000 per officer, this amounts to almost

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5/1974 Budget; City of Philadelphia. Office of Finance Director, 1974.

TABLE XII-2. VANDALISM -- COMMUTER AREA RAILROADS: SEPTA[1/]

Vandalism Type	Number of Incidents by Year			
	1971	1972	1973	1974
Stoning involving Passengers	1370	994	977	893
Windows Broken in Passenger Cars	1388	858	665	422
Personal Injury to Passengers while on Train	258	104	116	72
Personal Injury to Passengers in Station	174	141	202	174
Track Obstructions	511	563	784	760
Switch & Signal Damage	375	628	744	541

1/Source: DVRPC, Planning and Developing Transit in the Delaware Valley, July 1975.

$3.5 million in direct salaries alone. Moreover, in 1974 the City of Philadelphia initiated a crime reduction program of $381,000. As it can be seen, then, the control of crime is requiring an increasing amount of government expenditures.

Traffic Control. The major portion of any governmental budget dedicated to traffic control is highway based. The costs of insuring that the highway networks are operating at a reasonable level of service include planning studies, traffic count programs, signalization equipment and the overall administrative and overhead expenses for normal operations. Transit benefits directly and substantially from these expenditures for improved highway operations. In a corridor where traffic congestion is to be relieved by highway improvements, overall travel speeds will improve. Consequently, the buses operating in mixed traffic will be capable of achieving higher speeds, which ultimately improve their level of service and operating costs. These costs of traffic control are also inputs to the UPTS and should be apportioned by a calculation similar to the allocation rationale of Physical Capital inputs.

Maintenance Expense of UPTS Facilities. An oftentime overlooked expense borne by local governments is due to the part-time maintenance and upkeep of local UPTS facilities. These facilities can range from bus stop benches to major "park and ride" facilities. Maintenance includes repainting, mowing of grass, paving of entrance ways to local streets and possible installation costs for any UPTS facility which improves the comfort and convenience for each jurisdiction's transit user.

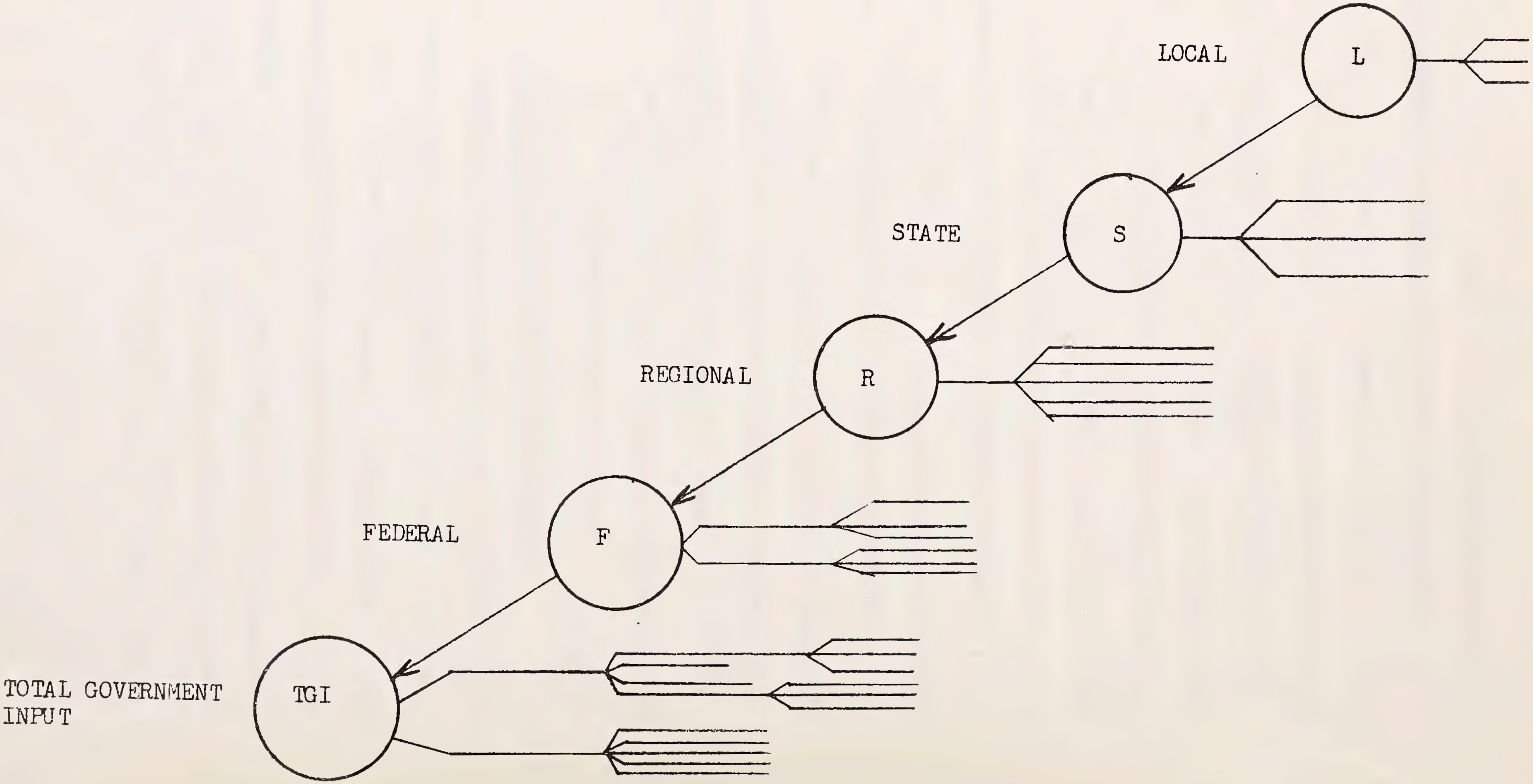


Figure XII-2. HIERARCHY OF GOVERNMENTAL INPUTS

1.3 Labor Inputs

Labor inputs to the UPTS occur at various levels of government which support or provide control in public transportation planning and operations. The major categories, as shown in Figure XII-1, include: administration, planning, financing, maintenance, law enforcement, and legislative or regulatory functions. These functions, and the labor inputs they necessitate, may be strictly local or they may be state or federal ones, at which time they may cover in their jurisdiction more than one urban region (i.e., the Federal Environmental Protection Regional offices). It may be noted that these same functions have been previously described in detail under capital inputs or operating expenses. Labor inputs may thus be logically viewed as labor based contributions, labor costs and working hours, which are necessary to implement the capital inputs, and to carry out operations.

Clearly, from the discussion in Section 1.1, "Capital Inputs," numerous problems arise in disaggregation when a modal separation of common use facilities is necessary. In labor inputs, these identical situations are present. At all levels of government, the appropriate governmental inputs would have to be apportioned by the mode and proper function before they could be used in a study on efficiency.

1.4 Summary of Governmental Input Sources

The detailed outline of the individual input items which government may contribute to the UPTS was shown in Figure XII-1. A clarification of the concept of government participation from all levels can be schematically seen in Figure XII-2. As can be seen, the UPTS is the recipient of the total inputs from all levels of government, local, state, regional, and federal.

2.0 Governmental Inputs By System Component

As discussed within prior sections of this study, the UPTS include three major components: the network, the primary transportation services, and the auxiliary or support functions. Each of these system components receives both capital and labor contributions from the government, in the form of either direct or indirect transfers.

A significant portion of analysis requires the identification and association of the nature and magnitude of governmental capital (monetary, physical or transfer of use) investment in each component (i.e., network, primary, and support services) and the resulting impact on system outputs derived from the expenditure. Thus, UMTA Section 3 monies, as an example, dedicated to system-wide capital improvements must be segregated by amounts spent on network facilities, primary services and support functions. Moreover, these disaggregations must be further divided among the various modes comprising the system.

This methodology has been followed in this study for government inputs from all levels. Consequently, the coordinated funding packages among federal, state, regional and local agencies, necessitated individual scrutiny to determine if funds were earmarked for a particular system facility or service. The results are included in the estimates reported in the Fiscal and Physical Input Matrices for each region.

3.0 Considerations of Government Input Measurement

Conceptually, the task of accounting for government inputs is quite simple. However, completing this task represents a difficult effort in terms of data collection, refinement and assignment to the appropriate governmental contributor. The sources of governmental input data are many and include city, county, state and federal budget publications, capital budgeting programs, resources utilization plans and individual transit property operating statements.

As described in the initial sections of this report, the present study has been innovative in terms of attempting to evaluate total system inputs of resources and outputs of transit services. Unfortunately, most of the data sources and agencies are not currently geared to accounting procedures and data inventories required by such a study. This situation dictated the development of assumptions and ground rules for an equitable identification and distribution of monetary and resource transfers. Some sample problems and necessary assumptions are given subsequently. The resultant data is presented, of course, in the Fiscal and Physical Input matrices as well as in the Output matrix for each year and region.

3.1 Determination of Magnitude and Value of Indirect Transfers

A major problem arises in determining the quantity and dollar value of the indirect monetary and resource transfers. For transportation facilities providing multiple mode use (e.g. the highway network), an allocation formula must equitably apportion total costs (capital, operating, and maintenance) in relation to the individual mode usage. In order to allocate the indirect monetary or resource transfers, simple proportions were developed based on total vehicle-miles traveled by all modes and the vehicle-miles traveled by the public transportation modes.

3.2 Allocation of Direct and Indirect Transfers to Appropriate Government Level

In collecting data for operating subventions, as an example, the total amount of funds entered on a SEPTA operating statement must be disaggregated to indicate the participating local jurisdiction's contribution, and the sub-modes (i.e., trolley, bus or rapid transit) share of the contribution.

4.0 Data Collection

The data inventory and research required for specifying the governmental inputs represents a formidable undertaking. Although in principle, the notion of government inputs is clearly straightforward, the collection of meaningful statistics in some instances is virtually impossible. These difficulties are largely due to the varied accounting procedures among government agencies at all levels.

It is unfortunate that government agencies in addition to the individual transit properties do not follow a uniform procedure for assembling and presenting the detailed data important to this study. This difficulty alone represented the single most important chance of data collection error or inaccuracy. During the conduct of the study the following data checks and balances were encouraged:

(a) Data Collection Procedures. The widespread nature of the study area, which included three states, four operators and numerous local governments and planning agencies, required the judicious assignment of staff personnel for interviews and statistical searches. Telephone and letter requests were the most commonly used methods of making contacts with the various government agencies. The degree of cooperation and expediency in responding to data requests varied considerably. However, a general trend appeared that indicated that the larger the governmental agencies, the greater the difficulty in retrieving the requested data.

(b) Typical Data Collection Problems. As previously mentioned, the single most important data problem involved reconciling each agency's "in-house" accounting system against each other. The manner in which budget entries of postponed debt, depreciation, listing of receivables (i.e., ordered but not delivered capital grant items) and conversion of fiscal year to calendar year statistics were handled variously throughout the hierarchy of governmental levels.

(c) Data Reliability and Verification. All data underwent a certain amount of processing and refinement. Checks were completed for accuracy and consistency in dollar magnitudes by a cross-checking with related services. Trends were verified as to reasonableness by contacting the individual governments. On the aggregated scale all federal capital grants and operating subsidies were checked to determine if the approximate split required by the local governments were on the order of 80 - 10 - 10 percent (Section 3, federal, state, local), and 50 - 50 percent (Section 5, federal, local).

5.0 Government Input Results

Upon reviewing preliminary data, it became evident that the retrieved data was of varying degrees of reliability. This is not to say that the data was incorrectly interpreted or reported, but rather that estimated or derived data had to be developed to meet the needs of the study. The results were the establishment, again of three class of input data the following:

(Group 1) Hard Data. For government inputs, a hard data item was one which was taken from a published direct source or from direct contact with the appropriate agency. For instance, in determining the individual operating subsidies that the various governmental units make to SEPTA operations, direct contact with the budget departments of these agencies were the basis of each entry.

(Group 2) Estimated Data. This class of data was based on estimations from indirect sources. For instance, given a statistic such as the number of transit officers employed, and applying an average salary, an annual expenditure was developed.

Due to the nature of government inputs, no data fell into the category of proxy data on inputs, and consequently did not have to be further elaborated. The actual data collected for each region and system operator is shown in the Fiscal and Physical Input Matrices.

CHAPTER XIII

CONTRIBUTIONS AND CONCLUSIONS OF THIS PROJECT

This chapter of the project on efficiency studies of urban public transportation systems concludes with a brief list and description of the contributions and findings that the research effort reported herewith, is believed, has produced.

1.0 Contributions

Three types of contributions one may cite are coming out from the research effort of this project, the following:

1.1 The Matrix Format of Inputs and Outputs of UPTS:

In Chapters IV, V and VI a detailed description is provided of the three essential elements of this project, i.e., in Chapter IV the matrix that presents the UPTS inputs in a fiscal (dollar based) form; in Chapter V the matrix that presents the UPTS inputs in physical (distinct units) form; and in Chapter VI the matrix that presents the outputs of the UPTS in physical, distinct unit form. This presentation of inputs and outputs of UPTS came out of continuous efforts to present the inputs and outputs of UPTS in a comprehensive and illuminating form that would permit a more accurate and detailed understanding of what is taking place in such systems. As can be seen, three essential characteristics are included in these matrices. First, they include in a cumulative manner all the inputs contributed by each of the four interacting actors, i.e., the systems operators, the direct users, the society at large and the government at all levels. Second, they include a specification of where exactly within an UPTS the inputs are applied, i.e., the primary service component, the support functions component, or the network. Third, they include a differentiation of the information according to the firmness and directness of the data related to each input or output variable. Thus, the variables in each matrix are divided into direct data input and output variables, estimated data input and output variables, and finally variables with proxy data that can be established on the basis of some acceptable or plausible convention.

Such a comprehensive and lucid presentation of input and output data is absolutely necessary for any comprehensive analysis of the efficiency and productivity of UPTS. While the matrices as presented in this report may still be improved in detail and clarity, the essential contribution they make toward such studies should not be underestimated.

1.2 The Uses of Efficiency Measurements:

The second important contribution that this report offers is in the kind of applications it suggests of the efficiency (and productivity) measures that can be derived for each UPTS.

Essentially there are three types of meaningful relationships between inputs and outputs that can be derived. While the derivation of such ratios *per se* represent no innovation in the field, by any means, the richness and the variety of such ratios are, of course, new dimensions of this analytical tool. The three types of meaningful ratios (or relationships) are the following:

(a) System outputs over system inputs: expressive of unit costs for each output in terms of the input used.

(b) Component inputs over component inputs: expressive of the comparative support that is provided for each system component.

(c) Component <u>outputs</u> over component <u>outputs</u>: expressive of relative production capabilities of each system component or system function.

These three essential types of ratios (or relationships) can, then, be seen being helpful in the five following points of concern:

(i) <u>Mode Comparisons</u>. Any and all the three types of the ratios above are usable in at least three situations, i.e., when a comparison is desired of a mode of travel over a number of years (trend analysis); when a comparison is desired of the efficiency of a mode over several regions (interregional system analysis); and when a comparison is desired of the efficiency between modes of travel (intermodal analysis).

(ii) <u>Regional Comparisons</u>. Again the three types of ratios can be very useful in three other types of situations, the following: when a comparison is desired among UPTS operating in regions of distinctly different types; when a comparison is desired among UPTS serving regions of distinctly different scale; when a comparison is desired among UPTS in different regions governed under distinctly different managerial styles or approaches.

(iii) <u>Actorial Comparisons</u>. The three types of ratios can also be proven very helpful in the cases where comparisons are desired between inputs and outputs as related to each actor that interacts with the UPTS. Such comparisons involve usually several systems, and any or all four actors of UPTS. Commensurability between inputs and outputs for each actor can thus easily be traced and compared.

(iv) <u>Comparisons Between Types of Inputs</u>: Ratios of the input-to-input type can frequently be proven very helpful (as well as ratios of outputs over inputs) when a comparison is desired of the effectiveness of each type of input (labor types, capital types, or labor vs. capital) in achieving pre-determined system objectives.

(v) Comparisons of Component Effectiveness. All three types of ratios between inputs and outputs can frequently be proven instrumental in situations where comparisons are desired of the effectiveness with which inputs applied to the various system components (primary services, support functions, networks) can produce system outputs. In many respects a central part of the present project focused on this exact type of comparison.

1.3 A Vertical System of Efficiency Measurements:

The third type of contribution that one may cite is the vertical, and sometimes cumulative, system of efficiency indicators that is being introduced and discussed in Chapters I and II. This system of measurements is of particular significance because of its flexibility in meeting different levels of responsibility in managerial and planning concerns. Clearly the efficiency and productivity of UPTS needs and must be examined at several levels of decision making, from the simple function of the superintendent of a single function to the level of the division chief, the level of the executive manager and even that of the chief policy maker of a metropolitan region. The contribution that this project introduces is a cumulative system of indicators with ever-enlarged data basis and a sequential elimination procedure of partial indicators. Should a planning or a managerial problem emerge in a UPTS with such a system of performance indicators, the analyst would always be able to identify and trace the relationships that reveal the roots of the problem.

2.0 Conclusions

The research effort reported in this project can be concluded with eight major findings-conclusions as listed below. As this project was primarily exploratory and methodological in nature, no specific finding is reported with regard to the specific systems operating within the three test regions. The eight findings reported here are thus procedural and substantive rather than system specific.

(1) The operator inputs to UPTS are among the easiest to account for. Although they are quite substantial, they usually include only part of the inputs required for the normal operations of the system. The inputs by the operator can also be traced relatively easily to the point of their application within the system, i.e., the primary services, the support functions, the network, or other more specific functions within the system.

(2) The government at all three levels, contributes substantial indirect inputs for the installment and operation of UPTS. The amounts vary but are extensive and in some ways can even be half as much, or more, as the actual operating costs of the system itself. These governmental inputs are above and beyond any direct subventions usually necessary for the operations of the UPTS. They include many types of governmental expenditures that are devoted to urban public transportation under one auspices or another. Such expenditures include governmental inputs for capital expansions, or for facilities used or owned by one governmental level or another but devoted to the operation of UPTS. They also include other direct operating expenditures for governmental functions that are devoted to the need of public transportation. Because of this diversity of expenditures of this type, and because of the indirect sources of these

governmental inputs to UPTS, they are usually overlooked and they are not taken into account when inputs inventory is undertaken. Based on the significance of these type of inputs, however, it seems imperative to suggest that they must be included in any future analysis of UPTS cost inputs, regardless of the difficulties in data identification and collection.

(3) The contributions of the direct users of UPTS are indeed extensive and multiple, far beyond the often-cited, out-of-pocket fare payed by the user to the operator of the system. These contributions, or inputs, include the extra travel time required, the risks for accidents and incidents, and of becoming the victim of a crime, the inconvenience and discomfort experienced, the muscular effort needed to exert in going to and from the facilities of UPTS, or the effort needed in getting in and out of the vehicles and, sometimes, while traveling through the system. Also such inputs include the investment needed for supplementary modes of travel for getting to and from the facilities of UPTS.

Obviously, user inputs are many and quite important from the point of view of the user. According to conventional translations of such inputs into proxy dollars, the total user costs can be seen as being 5 to 10 times as much as the typical fare paid in most urban public transit systems. This finding is very disturbing indeed, and, if generally true, can explain much of the relative demand inelasticity found to fare variations within urban areas. Also the findings of the present studies suggest that additional studies must be undertaken for a comprehensive and accurate accounting of user inputs for UPTS. Such studies must also include the means of translating the diverse user inputs into uniform and additive accounts. The findings of the present study indicate that the challenging task of incorporating the user inputs into efficiency and productivity studies is also one of the most important tasks in the field, indeed.

(4) The societal inputs to UPTS are found to be much smaller in magnitude, and even in significance than the inputs of the other three actors. These inputs are primarily externality costs and, it seems, they are getting to be either stable or even slightly smaller, as the air pollution and noise pollution effects of buses are placed under control. The estimates of the present study indicate that society contributes inputs to urban public transit through the additional costs that these systems necessitate because of the negative outputs that these systems produce in their everyday operations. The second type of probable societal costs are the opportunity costs which some authors have suggested. In the present project, such costs have been considered as inappropriate and excluded from the estimates.

(5) The labor inputs to the UPTS have been found to be extremely important within the accounts of the operator of the system. With the elimination of capital recovery costs from most UPTS operator accounts, labor costs winded up representing 70 to 80% of the reported annual operating costs of UPTS. The analysis of labor inputs for an efficiency and productivity study have proven to be both very complicated to complete and very important to include. The complications stem from the variety of such inputs. Labor inputs can be counted in terms of labor costs in dollars paid, in terms of individuals employed, and in terms of the amount of working hours invested in the production process. Each measurement has its own problems. Labor costs involve the analysis of direct and fringe benefits costs. It also involves skill's composition and wage rates in each system. Headcounts face the problem of full-time and part-time employees, and the lack of specificity about the extent of employment during the year for each employee. Working hours is on one hand, the most sensitive measure of

labor inputs, but, on the other hand, face the problem of counting separately overtime, or weekend working time.

In addition to these complications, labor inputs need to be allocated carefully to each system component and each system function. In fact, this detailed allocation of labor inputs need to be matched with similar specifications of output measurements. The complication in this effort is, of course, that outputs have frequently different divisibility characteristics than labor inputs. For instance, supervisory or managerial labor can be allocated to specific products only in a proportional manner, or be retained as managerial labor per se, without any specific product association.

Labor input analysis for UPTS has been found much more important than the emphasis it has received until now. Efficiency improvements in the operations of UPTS rest almost exclusively on the efficiency with which labor is utilized in these systems. Such utilization involves very detailed allocation of labor into specific functions, as well as specific relationships between detailed functions within the system. Unfortunately, until now, only gross labor counts have been maintained by most systems and only gross, and generalized efficiency measurements for the entire system have been carried out.

(6) Capital inputs present another problem. Current input accounts, and typical efficiency studies for UPTS have tended to exclude capital inputs from their concern. For a number of years, such inputs came from distinct governmental actions in the form of special grants to UPTS or to other governmental units. Since these grants did not include, as a rule, provisions for repayment, no capital recovery factor had to be determined.

It is rather meaningless, and at times very misleading, to exclude capital inputs from efficiency and productivity analysis. Capital inputs contributed by the operator (or the government) take many forms. Fixed assets, rolling stock, land and even materiel, are included in this classification. All types of capital inputs need, then, to be annualized for their proper incorporation. In this respect two major questions arise: i.e., the matter of life expectancy of each capital asset and the matter of potential interest on the capital invested. Capital investment, current and past, need to be associated with a specific life period during which the investment is useful. There is great uncertainty as to what is the useful life of most transit facilities. In many cases a determination is made on the basis of the prevailing circumstances and the political climate.

The problem of choosing a capital depreciation method enters also, along with the problem of whether or not to include any interest rate for the invested capital. The determination of the annual capital inputs to an UPTS requires the satisfactory resolution of all these questions before it can be effected. The present study reveals some of these problems and call for more intensive studies.

(7) Energy inputs to the UPTS have also emerged as an important component of the problem. Efficiency analysis of such systems would need to incorporate concerns of energy efficiency with regard to both certain modal characteristics as well as certain operational characteristics of each system. This study has only just touched this part of the problem. Further studies would need to delve in depth into such aspects of UPTS as vehicle selection, route selection, route characteristics, speeds, as well as several support functions characteristics.

(8) The outputs of the urban public transit systems have also been found to be very elusive and difficult to both define and measure. Beyond the few output variables which have traditionally been taken to

represent system outputs (i.e., vehicle miles, passenger miles, seat miles, and vehicle hours) the problem of incorporating secondary or indirect outputs of UPTS into efficiency and productivity studies represents still a major challenge. In this project only direct outputs, was possible to be utilized for efficiency and productivity measures. Output variables utilizing estimated data and/or proxy data were avoided because of the uncertainty that they introduce. Hopefully such data will soon be accepted broadly enough to permit its use for comparisons and analytical studies.

3.0 Further Considerations

At the conclusion of this list of findings, it seems important to stress two important observations. First, this project was not able to complete the counting of all the inputs and all outputs of the UPTS in the three test regions. Time limitations, budget limitations and lack of authorizations to extract promptly all pertinent data from the various operators within the three regions prevented the research team from completing the comprehensive, and exhaustive study of inputs and outputs that originally was expected. Hopefully the Planning Agencies and the various Operating Authorities within the three test regions will undertake such a task in the near future.

Second, this project has not been able to complete the detailing of all the inputs by function and system component. In this respect, the efficiency indicators presented in Chapter II are not yet accurate and complete enough for comparative conclusions. Again, the local Planning Agencies and the Operating Authorities within the region would, hopefully, undertake such a task in the near future.

In both cases the fact of the incomplete or not detailed data basis did not prevent the project from reaching its primary objective, which was methodological and conceptual rather than a case study of three regions.

Finally, another important point should be made concerning the difference between the emphasis of this study and the emphasis of the typical planning studies. Planning Agencies usually focus their studies on additional physical facilities and their manifestations, i.e., a typical construction cost and a typical type of service offered. Unfortunately, Planning Agencies seldom focus on operational costs and problems. Either they ignore such problems or implicitly accept that the best possible accomplishments have already been reached by the prevailing practices in the field, and that the remaining dominant need is for additions and extractions of facilities and services. In contrast to their emphasis, the present study focused on actual operations of UPTS. Such an emphasis includes both the task of incorporating all inputs to the system as well as the task of determining a system-wide optimality in the allocation of these inputs within the system and within the pattern of the offered services. In regions where current operations of UPTS are draining the financial capabilities of the local institutions, there are few expectations that such systems will be expanded and/or improved substantially. For instance, it is rather difficult to expect strong support for a major expansion and improvement for a system like SEPTA when the analyst discovers that its current annual operations require from the various governments, more than $100 million in direct subventions and more than $150 million in indirect subventions for a level of operations that does not exceed 100 rides per person per year. This level of governmental support exceeds 70¢ per ride, or twice as much as the direct user contributes. If the analyst adds to these accounts, the inputs required from each user, beyond the payment of the fares, in terms of extra time inputs, and risk of accidents, incidents of crime, plus in terms of supplementary investments needed to move to and from the UPTS facilities, he may soon realize the great magnitude of the costs involved and the drain in resources its current annual operations necessitate.

The realization of this situation suggests that there is a major need in the field of urban transportation for planning studies that extensively and intensively focus on the subject matter of this study, i.e., the productivity, efficiency and quality of the operations of UPTS. It seems rather appropriate to state here, at the conclusion of the present study, that it is high time for modern urban transportation planning to place major emphasis on the operating productivity, efficiency, and quality of the urban public transportation systems that are profusely being planned in the various metropolitan regions of the country.

APPENDICES

APPENDIX A: DEFINITIONAL DETERMINATION OF SYSTEM COMPONENTS

B: OPERATOR INPUTS: CAPITAL ASSETS TABLES

C: ENERGY USAGE BY UPTS VEHICLES

D: DATA ON FARE STRUCTURES

E: LOAD CURVES AND ENERGY CONSUMPTION

F: CRIME, RISKS, AND ACCIDENTS IN THE PHILADELPHIA REGION

G: LABOR INPUTS DETAILING AND SUPPLEMENTARY TABLES

H: NUMERICAL APPLICATION OF USER COST ESTIMATES

I: INPUT AND OUTPUT MATRICES

APPENDIX A

DEFINITIONAL DETERMINATIONS OF SYSTEM COMPONENTS

The UPTS is functionally divided into three major system components. The definition of each of these components has been formed as follows:

(a) The Primary Services Component. Included in the primary services component are those activities, expenditures and resources necessary and sufficient to produce optimum travel service. The critical aspect of this definition is the production of optimum travel service. While it is generally held that the simple ability of a vehicle to negotiate a guideway (fixed modes only) is enough, increasing evidence mounts that aspects of level of service (L.O.S.) are important ingredients to the very definition of travel service. For instance, it is not enough that a bus simply arrives at a stop, it is important to add that the bus arrives on time, is clean, comfortable and reliable. Using this definition and concept of optimum primary service, the following capital inputs are included in the primary services system component.

It is readily understandable that revenue vehicles which deliver the transit service should be included in the primary component. Additionally, those revenue vehicles held in reserve as replacement units for vehicles manifestly delivering the service should be included. It also follows that the wreckers, service cars and other "first-aid" type services should be considered as primary becuase of their direct role in providing optimum service in the event of breakdowns. Finally, funds used to purchase revenue equipment must be considered as part of the primary component. Carbarns and other parking or vehicle overnight storage structures in which activities such as cleaning, minor repair and other primary services might also be performed. Station services and the activities adjoining stations should be included. As a clarification, only those areas of the station used in providing transit service should be included in this input.

The inclusion of signals and interlockers as a primary service capital input is logically derived from the concept of L.O.S. consideration. These devices are undeniably essential to providing fixed guideway transit service. The importance of safety to travellers is evident in the literature of transit service. The use of signals in such fixed systems is a firm and unbending engineering principle. The engines or locomotive units of transit service must also be considered as primary components.

Typically, urban transit systems on fixed ways are operated using third-rail or overhead catenary distribution systems. It is apparent that the provision (generation), transmission and distribution of electrical service is a necessary factor in delivering transit service. Transit operators must also input land in various uses into the provision of transit service. Clearly, the land occupied by the structures that are parts of the primary services are vital to the provision of such services and is, thus, part of the requirement in the provision of primary services.

(b) Support Functions Component. Includes the activities, expenditures and resources consumed in the non-daily operation and maintenance of the primary and network facilities. The support component is largely explained by maintenance and shop facilities and equipment. A crucial element of the support component is the non-daily aspect of the support function. The primary component which has been indicated to include daily cleaning, maintenance and repair, highlights this distinction.

The physical structures of garages and shops wherein major maintenance and repairs are performed are included in this classification. As with structures of the primary component, the land upon which these structures are situated is also considered an element in the support component. Additionally, the equipment necessary to perform major maintenance and repair activities is enveloped by the support component. Work cars are also included in the support function. Clearly, the distinction between daily and non-daily holds for this factor as for others. Towing vehicles, sand/salt cars perform primary functions while supply cars, rail grinders perform support functions.

Another category included in the support component are miscellaneous way structures. Typically section houses, storage facilities along the way, parking lots and garages, and similar structures are included. Finally, all management, administration, central computer services, personnel, finances, training and acquisitions departments, and the associated facilities, land and equipment are clearly parts of the support functions of an UPTS.

(c) The Network System Component. The network system component includes major capital fixed assets such as links, nodes, stations and terminals. The network is viewed as a clearly identifiable group of elements. These elements often are the obvious manifestation of the existence of a transit system.

For all transit systems, the terminals and stations are most clearly related to the network. It is at these points that the user of the system enters or exits a transit system. These loci draw the user and are seen as the most direct manifestation of transit usage. The links which exist to connect the various stations also serve a network function. While for bus systems the link is the highway along a specified route on a map, for fixed guideway systems, the link is paramount and more obvious. Namely, the link, in fact, guides the way and includes ground level facilities, funnels, bridges, or elevated structures or various combinations thereof.

APPENDIX B

OPERATOR INPUTS: CAPITAL ASSETS

Contained in this appendix are the following items of information:

1.) Graphic presentation of Depreciation and "Gapping" due to Increased Replacement Costs -- Figure B-1.

2.) Selected Wholesale Price Indices -- Table B-1.

3.) Data on Operator Capital: Inputs Unit Cost -- Table B-2.

4.) Depreciation Schedule - PATCO -- Table B-3.

Figure B-1

GRAPHIC PRESENTATION OF

DEPRECIATION AND "GAPPING"

DUE TO INCREASED REPLACEMENT COSTS

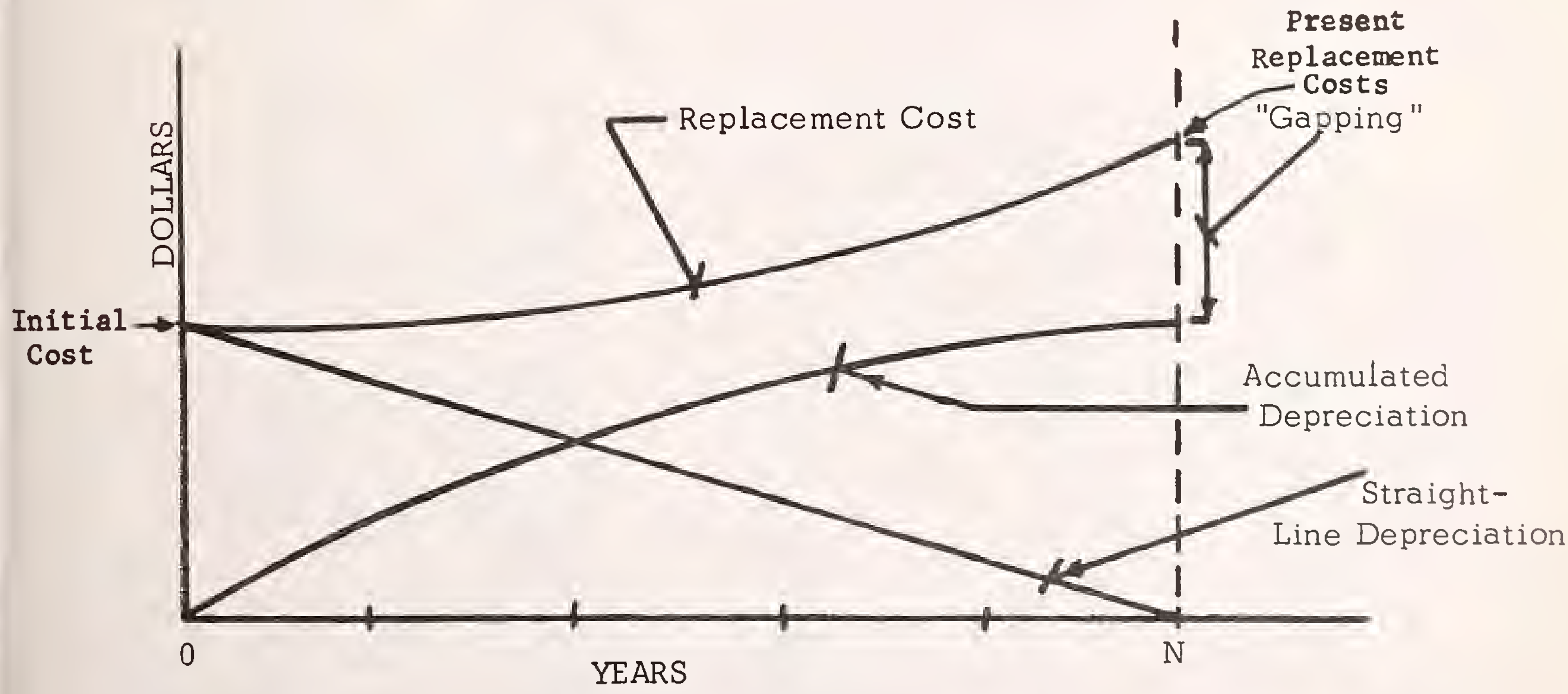


TABLE B-1.

SELECTED WHOLESALE PRICE INDICES

(A) WHOLESALE PRICE INDEX RAILROAD ROLLING STOCK

YEAR	INDEX	YEAR	INDEX
1961	100.2	1968	106.8
1962	100.5	1969	112.4
1963	100.5	1970	119.2
1964	100.5	1971	121.1
1965	100.9	1972	128.77
1966	101.2	1973	134.7
1967	103.6	1974	163.8

(B) WHOLESALE PRICE INDEX MOTOR BUSES (1967=100)

1949	727	1962	96.6
1950	73.3	1963	96.7
1951	75.7	1964	96.8
1952	76.7	1965	96.8
1953	78.3	1966	97.7
1954	78.6	1967	100.0
1955	79.3	1968	103.6
1956	83.6	1969	106.9
1957	90.2	1970	111.2
1958	93.7	1971	115.0
1959	96.0	1972	117.3
1960	95.8	1973	120.0
1961	96.6	1974	129.6

(C) CONSUMER PRICE INDEX, ALL ITEMS (1967=100)

YEAR	INDEX	YEAR	INDEX
1949	71.4	1962	90.6
1950	72.1	1963	91.7
1951	77.8	1964	92.9
1952	79.5	1965	94.5
1953	80.1	1966	97.3
1954	80.5	1967	100.0
1955	80.2	1968	104.2
1956	81.4	1969	109.8
1957	84.3	1970	116.3
1958	86.6	1971	121.3
1959	87.3	1972	125.3
1960	88.7	1973	133.1
1961	89.6	1974	147.7

SOURCE; Evaluation of Rail Rapid Transit and Express Bus Service in the Urban Commuter Market, Institute for Defense Analysis, U.S. Department of Transportation, 1973.

TABLE B-2.

DATA ON OPERATOR CAPITAL INPUTS UNIT COST

Listed below are the various units costs and price indices used to generate values presented in the charts attached to the main report.

Item	Unit	1973 Unit Cost
Parking Space	(1) Space	$ 600
51 Seat Bus	(1) Bus (W A/C)	40,000
46 Seat Bus	Bus (W A/C)	37,291
45 Seat Bus	Bus (W A/C)	36,700
39 Seat Bus	Bus (W A/C)	36,508
33 Seat Bus	Bus (W A/C)	29,000
Third Rail	78,550 Linear Feet	1,147,494
Catenery	1 Mile, 1 Track	69,190
	1 Mile, 2 Track	113,000
Concrete Subway	Linear Foot	1,495
Mainline Track	Linear Foot	35
Yard Track	Linear Foot	30
Elevated Track	Linear Foot	61
Commuter Rail Car	(1) "Silverliner"	255,000
Market-Frankford Cars	(1) Multiple-Unit Car	178,000
Patco Cars	(1) Multiple-Unit Car	256,000
	(1) Single-Unit Car	191,000
Trolley Rail Coach (RAD)	(1) Single-Unit Car	168,300
Broad St. Subway Cars	(1) Single-Unit Car	214,000
Subway Surface Cars	(1) Single-Unit Car	262,500
Tunneling	Linear Foot	1,495

SOURCE: Capital Costs For Transit Projects
DVRPC, June 1973.

TABLE B-3.

DEPRECIATION SCHEDULE
DELAWARE RIVER PORT AUTHORITY - SOUTHERN NEW JERSEY RAPID TRANSIT SYSTEM
SCHEDULE OF INVESTMENTS IN FACILITIES AT COST AS OF DECEMBER 31, 1971 AND
DEPRECIATION ON THESE FACILITIES FOR THE YEARS 1970 AND 1971

I.C.C. Account No.	Account Description	Estimated Life (Years)	Assets Balance 12/31/71	1971	1970
501	Engineering	100	$ 6,736,911	$ 66,160	$ 65,240
502	Right of way	--	11,219,130	---	---
503	Other land	--	3,953,542	---	---
504	Grading	100	10,657,942	105,621	106,184
505	Ballast	53	398,989	7,541	7,356
506	Ties	32	777,380	24,332	24,106
507	Rails	37	2,260,964	61,046	60,660
508	Special work-track	35	714,091	20,423	15,464
510	Track and roadway labor	35	2,427,281	69,420	67,258
511	Paving	16	295,471	18,467	18,420
513	Tunnels and subways	100	5,454,954	51,723	48,873
515	Bridges, trestles and culverts	75	6,115,437	80,925	80,254
516	Crossings, fences and signs	20	1,562,496	77,950	77,664
517	Signals and interlocks	34	2,938,840	86,118	82,121
518	Communication systems	32	1,256,351	39,324	38,305
521	Distribution	40	5,421,660	135,490	131,518
523	Shops, carhouses and garages	46	2,007,572	43,606	43,139
524	Stations and miscellaneous buildings	50	10,342,778	205,994	196,865
524-1	Stations and miscellaneous buildings-escalators	25	43,993	1,760	880
530	Passenger cars	25	8,342,628	334,517	331,089
533	Electric equipment of cars	15	5,492,072	366,530	365,839
536	Shop equipment	25	525,603	20,210	19,142
536-1	Miscellaneous equipment	10	58,536	4,284	1,402
537	Furniture	15	502,571	32,105	33,479
539	Power plants	40	754,888	16,159	18,695
544	Transmission equipment	30	6,397,085	217,193	212,744
551	Construction and equipment work in progress	--	236,584	---	---
			$96,895,749*	$2,086,898	$2,046,697

*Cost of the facilities was allocated to the above accounts in accordance with the code of Federal Regulations for electric railways -- Part 1202.

APPENDIX C

ENERGY USAGE BY UPTS VEHICLES (1971 - SEPTA)

A. Motor Bus (for CTD and RAD Divisions Combined)

(1) (a) Motor fuel expenditure (CTD) -- $1,113,021

(b) Motor fuel expenditure (RAD) -- $ 138,481

(c) Total motor fuel expenditure -- $1,251,502

(2) (a) Unit cost of motor fuel (CTD and RAD) -- $.1199/gallon diesel fuel

(b) Motor fuel consumed (CTD) -- 9,282,911 gallons of diesel fuel

(c) Morot fuel consumed (RAD) -- 1,154,971 gallons of diesel fuel

(d) Total Motor fuel consumed -- 10,437,882 gallons

(3) Total energy consumed -- 1.44043×10^{12} BTU (from (2d) and conversation factor)

(4) Total vehicle operation energy --(1971) 1.22436×10^{12} BTU (85% of (3))

(5) Total Vehicle operation energy cost--(1971) $1,063,777 (85% of (1c))

B. Trolley Rail (CTD only)

(1) (a) Electric power expenditure -- $ 951,099

(b) Total Vehicle Operation Energy Cost -- $808,434 (85% of (1a))

(2) (a) Unit cost of electric power -- $0.013203/kwh

(b) Total electric energy consumed -- 72,036,582 kwh

(c) Total energy consumed--0.7708×10^{12} BTU (from (2b) and conversation factors)

(3) Total vehicle operation energy--0.6552×10^{12} BTU (85% of(2c))

C. Rapid Transit

(1) (a) Electric power expenditure -- $561,261

(b) Total vehicle operating energy cost -- $1,326,072 (85% of (1a))

(2) (a) Unit cost of electric power -- $0.013203/kwh

(b) Total electric energy consumed -- 118,250,470 kwh

(c) Total energy consumed--1.2653 X 10^{12} (from (2b) and conversion factor)

(3) Total vehicle operation energy--1.0755 X 10^{12} BTU (85% of (2c))

D. Commuter Railroad -- Reading

(1) (a) Electric power demand -- $ 606,100

(b) Electric energy-- 666,400

(c) Diesel fuel -- 65,500

(d) Total energy expenditure $1,338,000

(2) (a) Unit cost for electric power demand -- $2.99/kwh

(b) Electric power demand consumed -- 202,709 kwh (from (1a) and (2a))

(c) Unit cost for electric energy -- $0.0137/kwh

(d) Electric energy consumed -- 48,642,335 kwh (from (1b) and (2b))

(e) Total electric energy consumed -- 48,845,034 kwh (sum of (2b) and(2d))

(f) Total BTU equivalent of(e)-- 0.52264 X 10^{12} BTU

(3) (a) Unit cost for diesel fuel -- $.1262/gallon

(b) Total diesel fuel consumed -- $19,017 gallons (from(1c) and (3a))

(c) Total BTU equivalent of(b)-- 0.0716 X 10^{12} BTU

(4) Total energy consumed -- 0.5942 X 10^{12} BTU (sum of (1c) and (3a))

(5) (a) Total vehicle operation energy -- 0.5051 X 10^{12} BTU (85% of (4))

(b) Total vehicle operation energy cost -- $1,137,300 (85% of (1d))

APPENDIX D

II. DATA ON FARE STRUCTURES

All of the public modes in the study area have a fare structure for their users which determines a portion of their monetary input. The following inventory of existing fares is arranged in order to treat each operation separately, i.e.,

(a) Pennsylvania Region:

(i) CTD and RAD Fare Structures: Summer 1975

Fare Type	Fare
Base Fare	35¢
Senior citizens (off peak hours)	Free
Senior citizens (peak hours)	10¢
RAD increments per zone	10¢
Transfers	05¢
Increment for trip beyond City limits	20¢
School children	10¢
Handicapped persons (off peak hours)	Free
Handicapped persons (peak hours)	25¢

(ii) Penn Central and Reading Fare Structures:

Within the city limits of Philadelphia:

.60	one way (peak hours)
.50	one way (off peak hours)

All fares for trips between the Philadelphia CBD and stations beyond the city limits, including Wissinoming, Tacony, Holmesburg Junction and Torresdale on the PC Trenton branch, are mileage based and are quoted in special tables; they vary from 55¢ to $1.45.

A joint fare arrangement between SEPTA and Penn Central & Reading Railroad provides reduced fare transfer privileges at 36 stations with portions of 32 intersecting SEPTA bus routes. Reduced fares are available for travel between non-terminal stations on this sytem. A penalty of 10¢

is incurred when fare is paid on the train by a user boarding at a station with an open ticket office.

The fare structure of SEPTA is generally a "flat fare" arrangement in contrast to the commuter railroad fares which are related to the various lengths of trips in miles.

b). FARE STRUCTURE OF THE NEW JERSEY REGION

The fare structure within the New Jersey Region of this study is shown in the following Table D-1.

TABLE D-1.

Distance	PATCO Fares	T.N.J. Fares
Zone A	$.35 (Philadelphia to Camden)	$.40 (Basic Fare)
Zone B	$.50 (Philadelphia to Ferry Ave.)	$.50
Zone C	$.60 (Philadelphia to Haddonfield)	$.55
Zone D	$.75 (Philadelphia to Lindenwold)	$.60

NOTE: (1) Transfers between T.N.J. routes = $.10

(2) School fares = 2/3 adult fare (T.N.J.)

(3) Each succeeding zone = $.05 additional (T.N.J.)

(4) Between stations in New Jersey $.45 (PATCO)

c). WILMINGTON/DART REGION

DART has a base cash fare of $.35 with free transfer privileges. The fare structure is presented in Table D-2 below.

TABLE D-2.

CURRENT DART FARE STRUCTURE

SINGLE-ZONE FARES

Adult Cash Fare	35¢
Tokens	Five for $1.50 (30¢ average fare)
Book of 36-Ride Tickets	$9.00 (25¢ average fare)
Book of 10-Ride, 2-Zone Tickets	$4.00 (40¢ average fare)
Transfer	Free
10-Ride Student Tickets - School Hours only	$1.50 (15¢ average fare)
10-Ride Student Ticket - Valid Anytime	$2.00 (20¢ average fare)
Book of 20-Ride Senior Citizen Tickets - 9:30 A.M. to 3:30 P.M. only	$3.00 (show Medicare card at time of purchase 15¢ average fare)

TWO-ZONE FARE
(ANY ONE OF THE FOLLOWING)

60¢ Cash
1 Token plus 25¢

2	36-Ride Tickets
1	2-Zone Ticket
1	DART Transfer plus 25¢ Cash
1	DART Transfer plus 1 36-Ride Ticket
2	Student Tickets
2	Senior Citizens Tickets
1	DART Transfer plus 1 Student Ticket

THREE-ZONE FARE
(ANY ONE OF THE FOLLOWING)

70¢ Cash
2 Tokens plus 5¢

2	36-Ride Tickets plus 10¢
1	2-Zone Ticket plus 15¢
1	DART Transfer plus 35¢
1	DART Transfer plus 1 Token plus 5¢
1	DART Transfer plus 1 36-Ride Ticket plus 10¢
1	DART Transfer plus 2 Senior Citizen Tickets
1	DART Transfer plus 2 Student Tickets
3	Senior Citizen Tickets
3	Student Tickets

APPENDIX E

LOAD CURVES AND ENERGY CONSUMPTION

Chart E-1 contains information on the vehicle mileage (at a given passenger mileage) resulting for different load factor levels. Energy consumption per vehicle mile and energy costs per gallon are given. Vehicle energy efficiencies at the actual load factor and for a range of load factors are then calculated. Energy cost on a vehicle mile basis is found and is called energy efficiency. The foregoing analysis is done for five modes.

Chart E-2 contains information on the passenger mileage (at a given vehicle mileage) resulting for different load factor levels. Energy consumption per vehicle and energy costs per gallon are again given. Energy productivities at the actual load factor and for a range of load factors are then calculated. Energy cost per passenger mile is found and is called energy productivity. The foregoing analysis is done for five modes.

Graphs E-3 and E-4 (derived from Charts E-1 and E-2) illustrate relative energy factors versus load factors percentages for modes under study.

Graphs E-5 and E-6 (derived from Charts E-1 and E-2) represent relative energy costs versus energy measures over all modes.

CHART E-1: VEHICLE EFFICIENCY ANALYSIS: 1971

	ANNUAL PASSENGER MILES (PM) (000)	ANNUAL VEHICLE MILES (VM) (000)	ANNUAL LOAD FACTOR (P/V)	VM @ 20% LOAD FACTOR (VM) (000)	VM @ 40% LOAD FACTOR (VM) (000)	VM @ 60% LOAD FACTOR (VM) (000)	VM @ 80% LOAD FACTOR (VM/BTU) (000)	VM @ 100% LOAD FACTOR (VM) (000)	ANNUAL ENERGY CONSUMPTION (BTU) x10[12]	COST OF ANNUAL ENERGY CONSUMPTION ($)/(¢/BTU) (000)	VE @ 20% LOAD FACTOR (VM/BTU) *	VE @ 40% LOAD FACTOR (VM/BTU) *	VE @ 60% LOAD FACTOR (VM/BTU) *	VE @ 80% LOAD FACTOR (VM/BTU) *	VE @ 100% LOAD FACTOR (VM/BTU) *	VE @ ORIGINAL LOAD FACTOR (VM/BTU)	ENERGY COST PER VEHICLE MILE (¢/VM)
SEPTA																	
BUS	696,358	41,509	16.8	46,423	23,211	15,474	11,605	9,284	1.2244	1,063	37.9	18.96	12.64	9.48	7.58	33.9	2.56
CTD&RAD			(22.4%)							(.87)							
100% L.F.=75 pass./V																	
TROLLEY RAIL	153,800	7,866	19.5	10,253	5,126	3,417	2,563	2,050	0.6552	808	5.65	7.82	5.22	3.91	3.13	12.0	10.28
CTD			(26.0%)							(1.23)							
100% L.F.=75 pass./V																	
RAPID TRANSIT																	
CTD	590,600	15,631	37.8	11,405	8,202	5,468	4,101	3,281	1.0755	1,327	15.3	7.63	5.08	3.81	3.05	14.6	8.42
100% L.F.=180 pass./V			(21.0%)							(1.23)							
RAILROAD	172,200	5,848	29.4	9,566	4,783	3,188	2,391	1,913	0.5051	1,137	18.9	9.47	6.31	1.74	3.79	11.6	19.44
GCD			(32.6%)							2.25							
100% L.F.=90 pass./V																	
PATCO																	
HIGH SPEED RAIL	82,800	3,780	21.9	1,840	920	613	465	368	0.3167	551	5.8	2.90	1.94	1.47	1.16	11.9	14.63
100% L.F.=223 pass./V			(9.7%)							(1.7)							

$* = x10^{-6}$

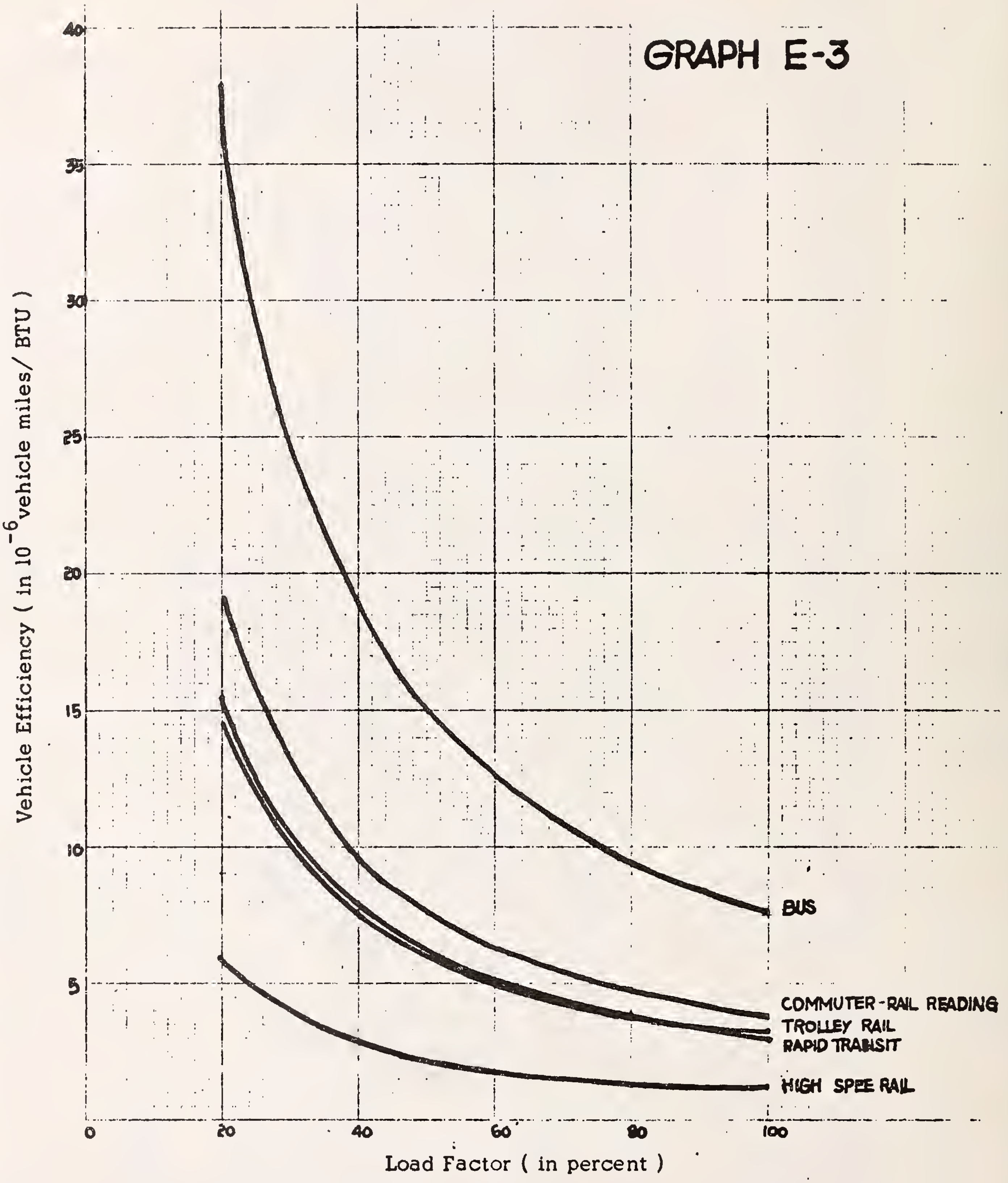
L.F. LOAD FACTOR

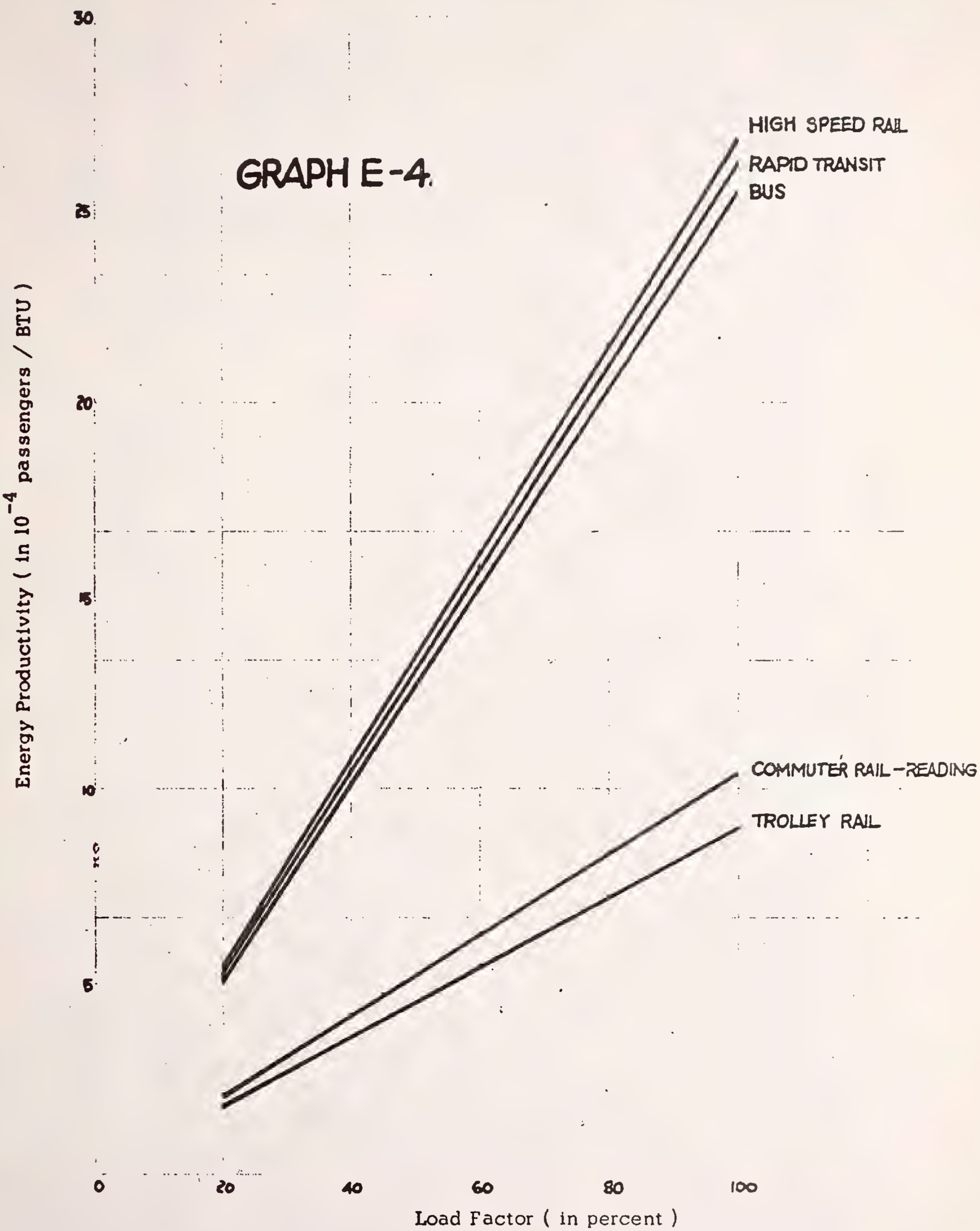
V.M. VEHICLE MILES

V.E. VEHICLE EFFICIENCY

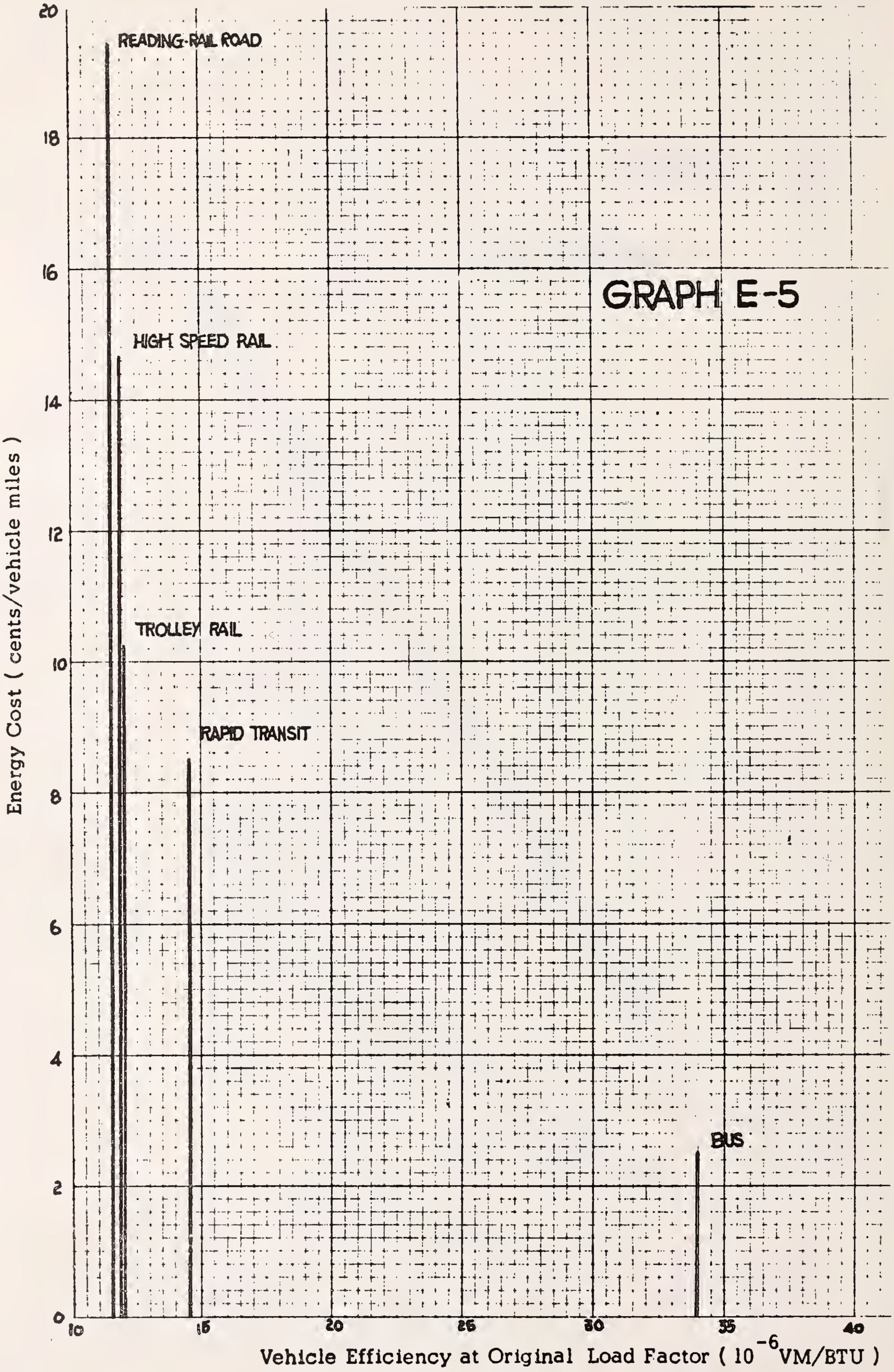
CHART E-2: ENERGY PRODUCTIVITY ANALYSIS: 1971

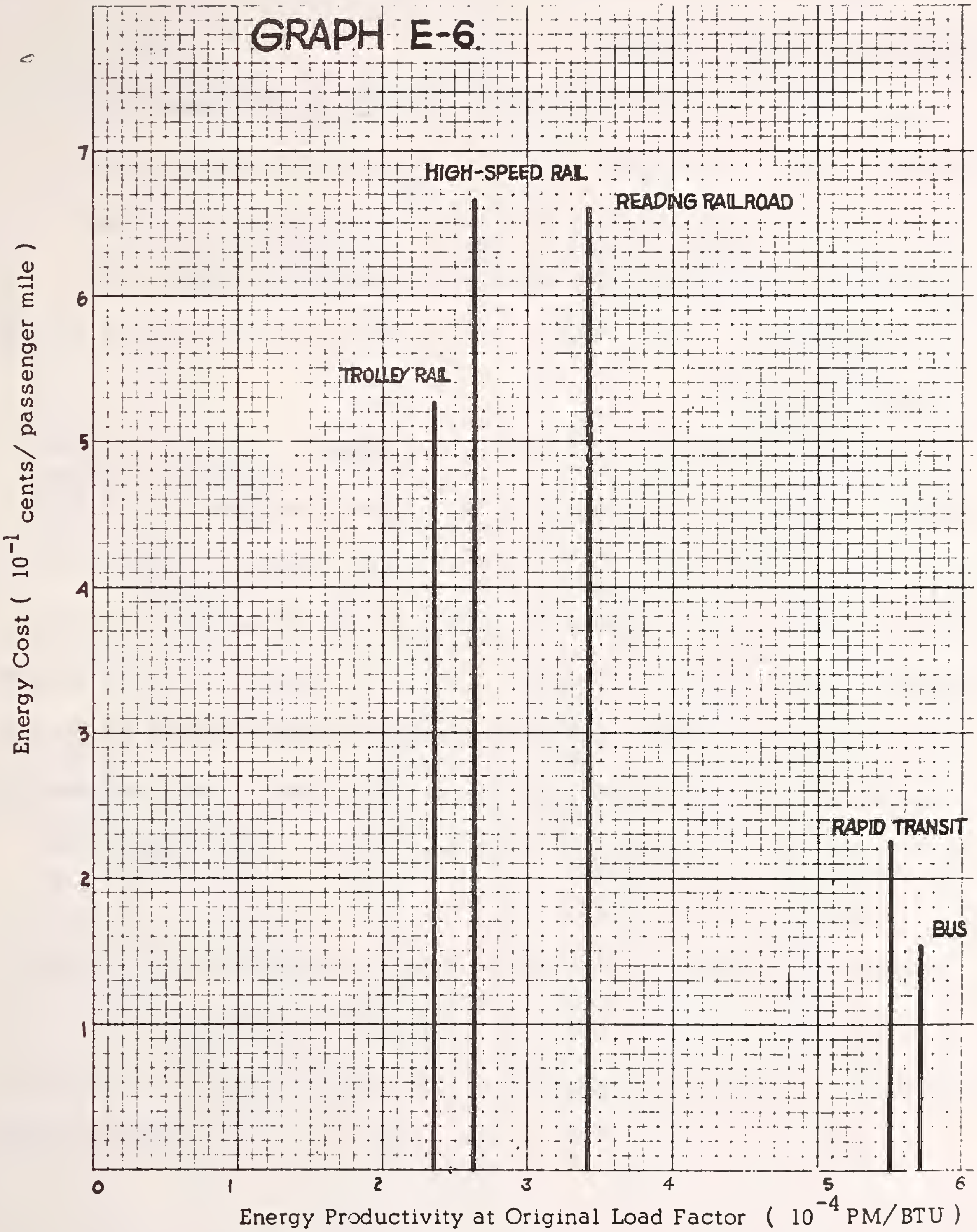
	ANNUAL PASSENGER MILES (PM) (x10³)	ANNUAL VEHICLE MILES (VM) (x10³)	ANNUAL LOAD FACTOR (P/V)	PM @ 20% L.F. (PM) (x10³)	PM @ 40% L.F. (PM) (x10³)	PM @ 60% L.F. (PM) (x10³)	PM @ 80% L.F. (PM) (x10³)	PM @ 100% L.F. (PM) (x10³)	ANNUAL ENERGY CONSUMPTION (BTU x10¹²)	COST OF ANNUAL ENERGY CONSUMPTION ($x10³)/(¢/BTU)	EP @ 20% L.F. (PM/BTU) (x10⁻⁴)	EP @ 40% L.F. (PM/BTU) (x10⁻⁴)	EP @ 60% L.F. (PM/BTU) (x10⁻⁴)	EP @ 80% L.F. (PM/BTU) (x10⁻⁴)	EP @ 100% L.F. (PM/BTU) (x10⁻⁴)	EP @ ORIGINAL L.F. (PM/BTU) (x10⁻⁴)	ENERGY COST PER PASS. MILE (¢/PM)
SEPTA																	
BUS	696,358	41,509	16.9	622,636	1,245	1,867	2,490	3,113	1.2244	1,063	5.0[illegible]	10.17	15.26	20.34	25.43	5.69	0.153
[illegible]			(22.[illegible])							(0.87)							
100% L.F.=75pass./V																	
TROLLEY RAIL	153,800	7,886	19.5	118,004	236	354	472	590	0.6552	808	1.8	3.6	5.4	7.2	9.0	2.35	0.526
CTD			(26.0%)							(1.23)							
100% L.F.=75pass/V																	
RAPID TRANSIT	590,600	15,631	37.8	562,747	1,125	1,688	2,250	2,813	1.0755	1,327	5.23	10.46	15.70	20.93	26.16	5.49	0.225
CTD			(21.0%)							(1.23)							
100% L.F.=180pass./V																	
RAILROAD	172,200	5,848	29.4	105,280	210	315	421	526	0.505	1,137	2.0[illegible]	4.17	6.25	8.34	10.42	3.41	0.66
[illegible]			(32.6[illegible])							(2.25)							
[illegible] L.F.=9[illegible]pass./V																	
PATCO																	
HIGH SPEED RAIL	82,800	3,780	21.9	170,100	340	510	680	850	0.3167	551	5.37	10.74	16.11	21.48	26.85	2.61	0.666
100% L.F.=225pass./V			(9.7%)							(1.7)							


GRAPH E-3
Vehicle Efficiency (in 10^{-6} vehicle miles/ BTU)
40
35
30
25
20
15
10
5
0
20
40
60
80
100
Load Factor (in percent)
BUS
COMMUTER-RAIL READING
TROLLEY RAIL
RAPID TRANSIT
HIGH SPEE RAIL



GRAPH E-4.
HIGH SPEED RAIL
RAPID TRANSIT
BUS
COMMUTER RAIL-READING
TROLLEY RAIL
Energy Productivity (in 10^{-4} passengers / BTU)
Load Factor (in percent)
30
20
10
5
0
20
40
60
80
100


GRAPH E-5
READING RAIL ROAD
HIGH SPEED RAIL
TROLLEY RAIL
RAPID TRANSIT
BUS
Energy Cost (cents/vehicle miles)
Vehicle Efficiency at Original Load Factor (10^{-6} VM/BTU)
20
18
16
14
12
10
8
6
4
2
0
10
15
20
25
30
35
40


GRAPH E-6.
HIGH-SPEED RAIL
READING RAILROAD
TROLLEY RAIL
RAPID TRANSIT
BUS
Energy Cost (10^{-1} cents/ passenger mile)
Energy Productivity at Original Load Factor (10^{-4} PM/BTU)
0
1
2
3
4
5
6
7

APPENDIX F

CRIME, RISKS, AND ACCIDENTS IN THE PHILADELPHIA REGION

(a) Some Crime Statistics

The traveler's desire for safety and security influence his travel decisions. For instance, a large number of people will ride subways only during peak rush hours with the idea that the crowded conditions made it a safer environment. A number of riders fear travelling on subways after 6 p.m., and, even around 3 p.m. when schools let out for the day.*

Travel by bus versus by subway is frequently influenced by the feeling that buses were safer. When users were questioned as to their awareness of police protection on UPTS, it was found that people are not generally aware of the presence of police except around City Hall and primarily during the day. Upon being questioned about the user's knowledge of crime on the UPTS, several people admitted to being armed with the full intent of using their weapons if threatened. Most riders agree the main problem is related to the platform area. Many stations are dark, dingy and unsupervised.

The total crimes reported in the subway-elevated system of SEPTA for 1971 totaled nearly 800 (See Table F-1). There were well over 200 reports of the more serious offenses, including 15 rapes, 166 robberies,

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*This finding is verifiable through many literary sources, but pertinent information was also provided by the Mayor's Criminal Justice Improvement Team, Philadelphia, based on data gathered from the policy and security management consultants during an evaluation study of SEPTA's 1973 application for funds from the U.S. Dept. of Justice, Law Enforcement Assistance Administration.

19 aggravated assaults, 14 burglaries and 20 cases of larceny over $50. In the class of less serious crime, there occurred 88 cases of larceny under $50, 68 assaults, 235 counts of vandalism, 24 weapons offenses, 34 sex offenses, 4 narcotics offenses, 1 charge of gambling, 68 reports of disorderly conduct, 4 vagrancy and 62 miscellaneous crimes.

TABLE F-1.

TOTAL CRIMES IN SUBWAY-ELEVATED SYSTEM FOR 1971 AND 1972 WITH PERCENTAGE CHANGE

Part I	1971	1972	% Change
Homicide	0	1	+100
Rape	15	5	-66.6
Robbery	166	177	+6.6
Aggravated Assault	19	21	+10.5
Burglary	14	9	-35.7
Larceny (Over $50)	20	26	+30.0
TOTAL	234	239	+2.1%
Part II			
Larceny (Under $50)	88	82	-6.8
Assault	68	54	-20.5
Vandalism	235	124	-47.2
Weapons Offenses	24	31	+29.1
Sex Offenses	34	42	+23.5
Narcotics Offenses	4	13	+225.0
Gambling	1	1	0.0
Disorderly Conduct	68	28	-58.8
Vagrancy	4	6	+50.0
All Others	62	50	+19.3
TOTAL	558	431	-22.7%
TOTAL OFFENSES	791	670	-15.3%

Table F-2 presents similar statistics derived from crime incidents reported on the surface vehicles of SEPTA for the same year.

TABLE F-2.

TOTAL CRIME ON SURFACE VEHICLES FOR 1971 AND 1972 WITH PERCENTAGE CHANGE

Part I	1971	1972	% Change
Homicide	2	1	-50.0
Robbery	3	14	+366.7
Aggravated Assault	27	20	-25.9
Burglary	1	-	-100.0
Larceny (Over $50)	9	10	+11.1
TOTAL	42	45	+7.1%

Part II	1971	1972	% Change
Larceny (Under $50)	26	31	+19.2
Other Assaults	27	18	-33.3
Vandalism	63	46	-27.0
Weapons Offenses	2	2	0.0
Sex Offenses	3	2	-33.3
Narcotic Offenses	2	1	-50.0
Disorderly Conduct	16	7	-56.3
Other	7	10	+42.9
TOTAL	146	117	-19.9%
TOTAL OFFENSES	188	162	-13.8%

Of course, there were also many other types of incidents that were not reported to the Police, but which were still dangerous or at least bothersome to the 222,621,034 Philadelphia area transit riders in 1971. These included minor thefts and assaults; loud, boisterous behavior; horseplaying, youths running and frightening riders; holding doors and delaying vehicles; and shaking down persons riding alone.

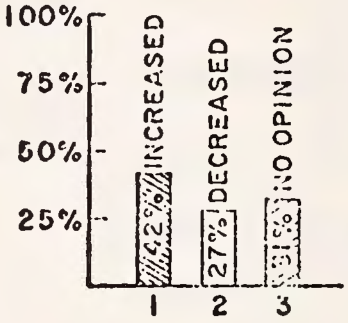
Finally, the results of a survey conducted in Philadelphia in 1971 can be noted. A total of 5771 individuals were asked about safety on the SEPTA system. Up to 2997 people living within 6 blocks of the subway were telephoned, while another 297 were approached while riding on the train. Another 303 individuals were questioned while waiting on the platform. The remaining 2177 were stopped on the street as they approached the transit stop. Of this group, fully 46% flatly stated that they felt unsafe while being a passenger.

The graphs on the next page in Table F-3 indicate the responses received to some of the central questions of the 1971 survey:

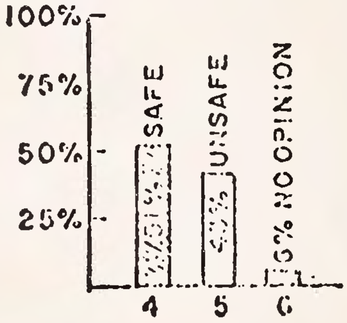
TABLE F-3.

TOTAL RESPONSES
(N=5771)

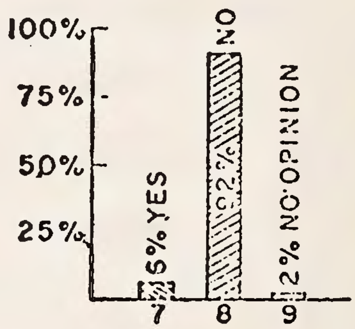
A. In the past year do you feel crime in the subways or on buses has increased or decreased?



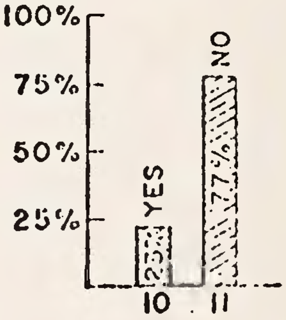
B. How do you feel when you ride the subway or bus?



C. In the past year, has anyone mugged, robbed or threatened you while you were riding the subway or bus?



D. In the past year, do you know anyone who was mugged, robbed, beaten, or threatened while they were riding the subway or bus?



(b) <u>UPTS Risks</u>

The Table F-4 below illustrates the vandalism activity that users of the commuter railroads were exposed to from January 1971 through December 1974.

TABLE F-4.

VANDALISM ACTIVITY ON PHILADELPHIA COMMUTER AREA RAILROADS
COMPARISON OF INCIDENTS DURING YEARS 1971 THROUGH 1974

	Number of Stonings Incidents Passenger				Number of Windows Broken - Passengers				Personal Injury With Claim Potential Due to Vandalism				Passenger Station Vandalism				Number Cases Track Obstructions				Switch & Signal Damage			
	'71	'72	'73	'74	'71	'72	'73	'74	'71	'72	'73	'74	'71	'72	'73	'74	'71	'72	'73	'74	'71	'72	'73	'74
January	47	57	34	59	50	54	32	18	13	12	3	3	24	9	22	16	32	38	46	50	18	23	38	31
February	109	48	46	61	84	40	32	27	12	7	3	2	13	6	16	22	51	38	45	35	31	43	31	29
March	157	130	85	134	149	119	56	53	36	7	9	8	14	12	23	18	60	55	67	117	34	46	50	84
April	178	132	119	110	178	125	93	64	37	12	14	13	22	9	23	21	53	83	81	105	36	68	94	45
May	183	167	183	101	197	130	117	59	27	17	16	16	15	19	17	17	56	78	131	84	33	96	209	85
June	141	101	83	101	179	93	53	52	33	9	12	12	12	10	22	15	33	58	69	58	39	82	59	59
July	69	63	64	78	59	46	41	34	19	8	6	4	12	12	16	7	36	33	49	71	38	39	49	40
August	80	61	82	73	96	48	24	27	19	5	8	5	13	6	9	8	36	39	66	57	17	31	59	41
September	78	70	60	47	86	47	34	26	20	9	7	4	9	13	16	13	25	29	59	51	13	31	49	33
October	140	80	118	61	133	64	104	32	17	10	30	1	12	19	15	16	43	51	73	64	41	54	39	38
November	91	43	56	30	79	45	43	10	12	6	5	3	13	11	10	7	50	34	72	33	36	62	36	28
December	97	42	48	38	98	47	36	20	13	2	3	1	15	15	13	14	36	27	26	35	39	53	31	24
TOTAL	1,370	994	977	893	1,388	858	665	422	258	104	116	72	174	141	202	174	511	563	784	760	375	628	744	541
% Change '74-'73				(8.6)				(36.5)				(37.9)				(13.9)				(3.1)				(27.
% Change '74-'72				(10.2)				(50.8)				(30.8)				23.4				34.9				(13.
% Change '74-'71				(34.8)				(69.6)				(72.1)				0.0				48.7				44.

SOURCE: DVRPC, 1975
Planning & Developing Transit
In Delaware County

Users of a transit system have to encounter the risk of an accident or incident over which they have little ability to avoid or control if vandalism took place while the facility is in use. In addition to these acts of vandalism, the risk of other incidents must seriously be taken into account. For instance in 1971, the SEPTA system recorded approximately 38 complaints per 1,000,000 riders. Of these nearly 65% were dissatisfaction with employees with the balance due to service difficulties or the behavior of other system users.

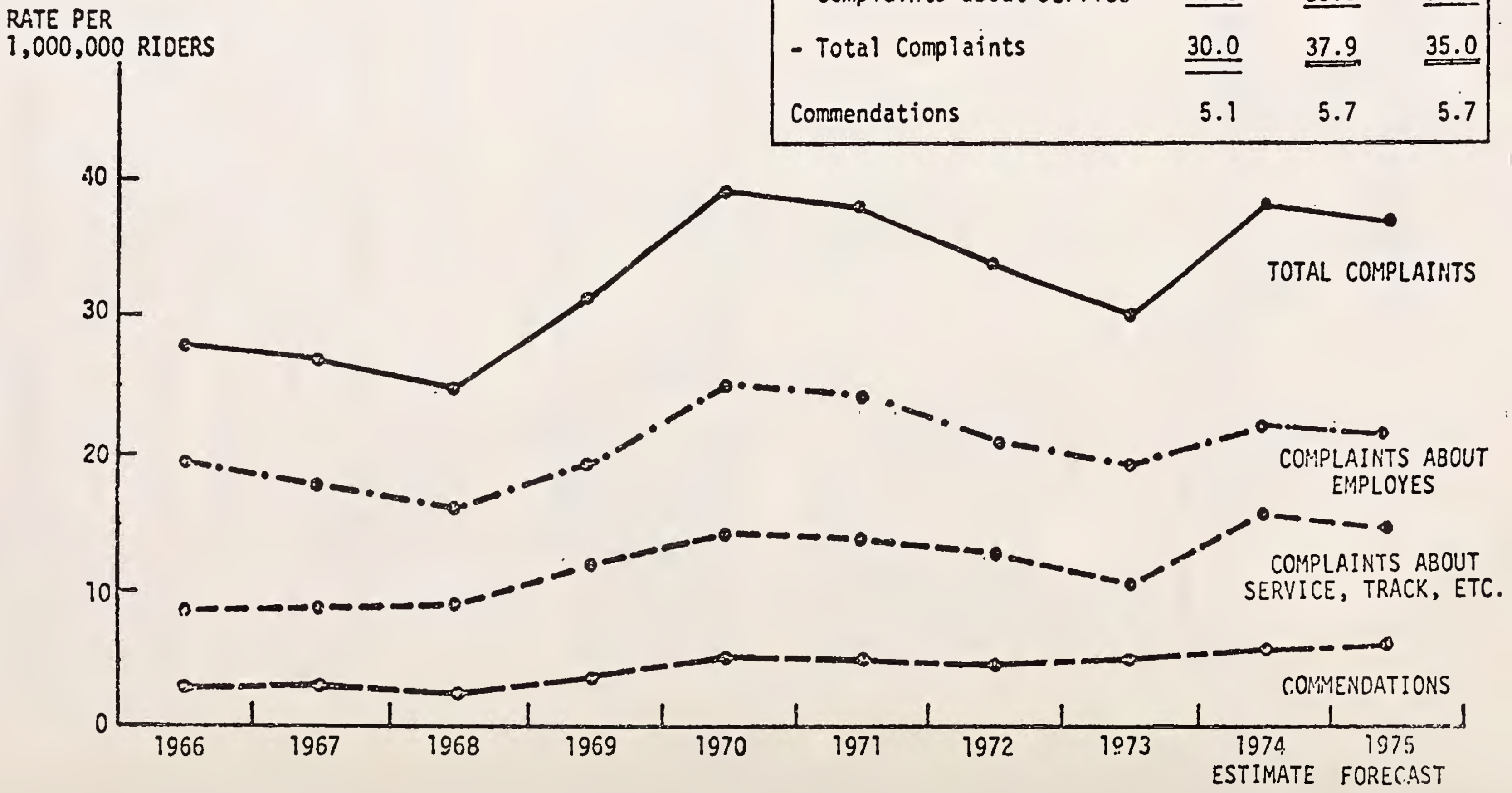
The chart below (Figure F-5) plots the complaints and commendations received by SEPTA from their riders.

TABLE F-5.

TRANSIT SYSTEM – OUTPUT MEASURE

PUBLIC COMPLAINTS AND COMMENDATIONS PER MILLION RIDERS

	1973	1974	1975
RATE PER 1,000,000 RIDERS			
- Complaints about Employees	19.5	22.3	21.0
- Complaints about Service	10.5	15.6	14.0
- Total Complaints	30.0	37.9	35.0
Commendations	5.1	5.7	5.7

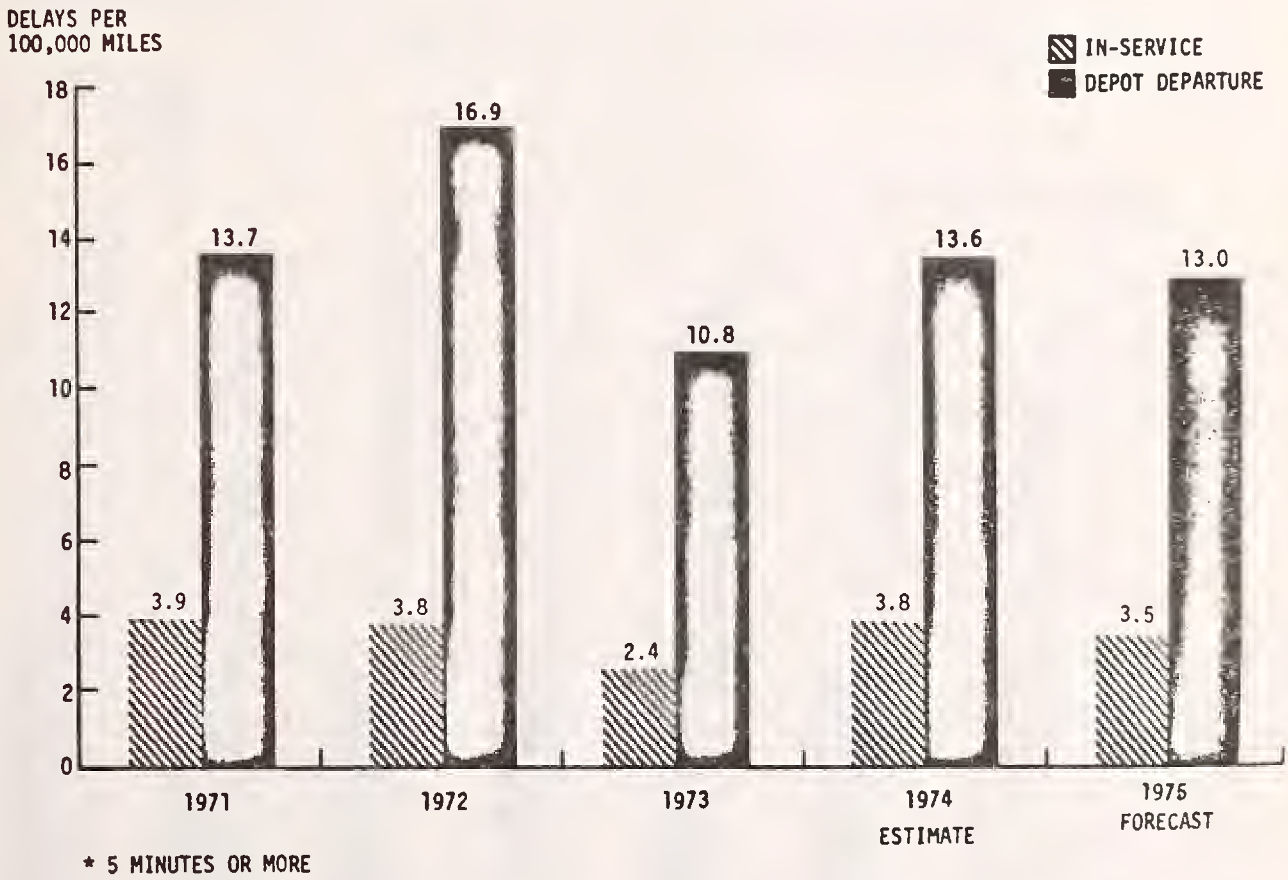


SOURCE: SEPTA, '1975 RESOURCES UTILIZATION PLAN.'

Lost time and/or service delay data indicate the success of SEPTA in adhering to their established schedule. These risks are displayed in the chart below (see Figure F-1). All manpower related delays of more than 5 minutes have been plotted to show annual service delays per 100,000 miles.

Figure F-1.

CITY TRANSIT DIVISION
TRANSPORTATION RESPONSIBILITY SERVICE DELAYS
DELAYS* PER 100,00 MILES

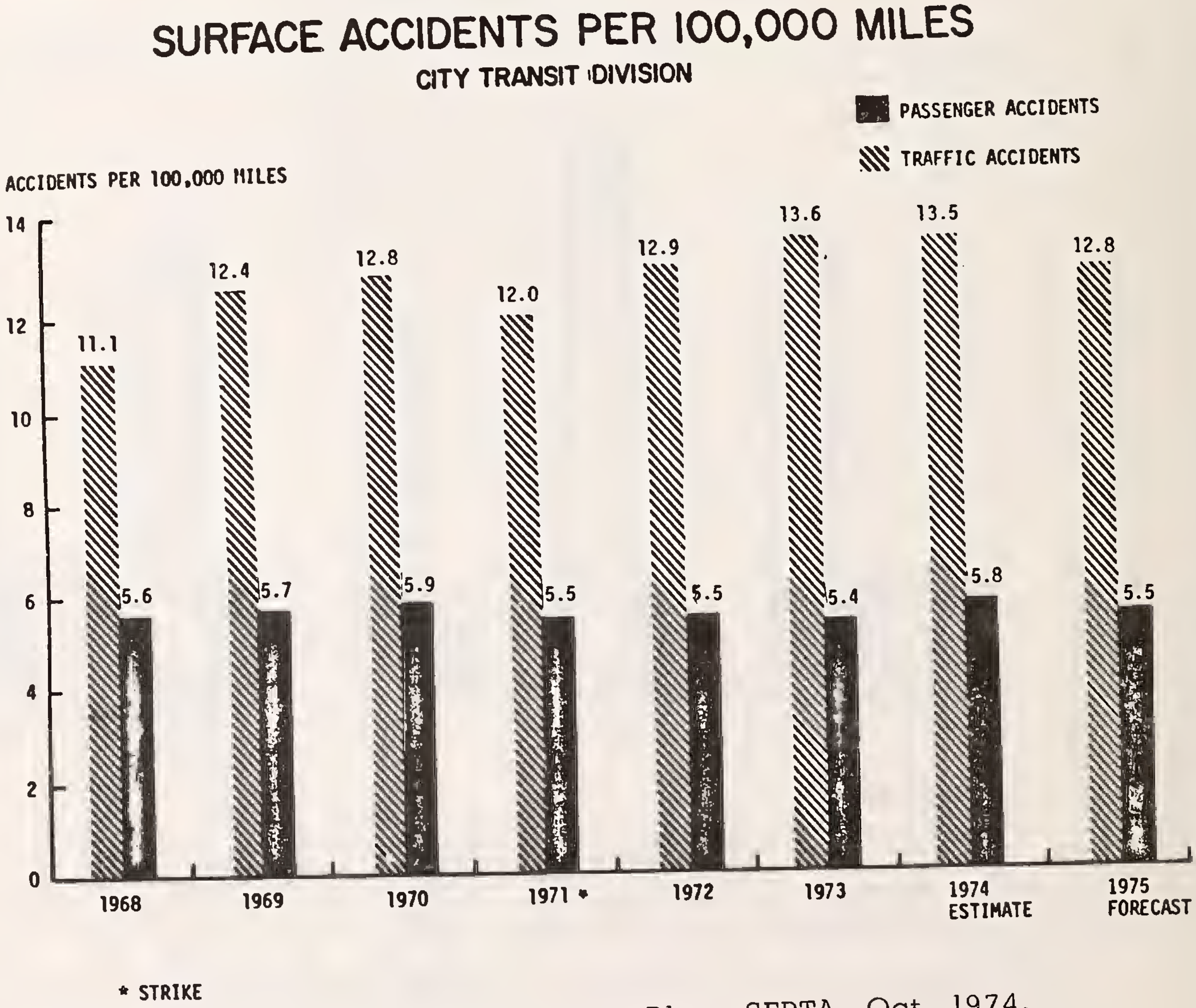


SOURCE: 1975 Resources Utilization Plan, SEPTA, Oct. 1974

(c) UPTS Accidents

The accident rate as portrayed in the chart (see Figure F-2) below indicates one of the user's risk inputs as stated as a measure of how well the service is delivered. SEPTA has displayed only the surface accident rate because they state that subway-elevated accidents usually involve passengers that fall on stairways and platforms as opposed to accidents due to employee action.

Figure F-2.



SOURCE: 1975 Resources Utilization Plan, SEPTA, Oct. 1974.

APPENDIX G

LABOR INPUTS DETAILING AND SUPPLEMENTARY TABLES

1.0 The Derivation Process

This section describes the process of deriving the labor input measures and the assumptions that have been made to facilitate the disaggregation of the total labor input data. As each operator maintains its own accounting system and labor classification, it would be more appropriate if each operator is treated individually. In general however, the derivation process involves three stages:

(1) Disaggregation of the total headcount data;

(2) Derivation of the man-hours.

(3) Distribution of the total dollar labor cost data.

Since employee fringe benefits and pensions, in most cases, are not included in the employee payroll accounts, the fringe benefits and pensions were distributed either according to the direct dollar labor cost (average salary per employee) or to the headcount distribution.[1]

1.1 SEPTA - CTD

(a) Total Headcount. For the year 1974, SEPTA's CTD has the most detailed information both on headcounts and the work breakdowns. In those situations where there is no sufficient information (e.g., 1971-1974),

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1/Part of the fringe benefit costs are related to salary (i.e., pension to retired employee, pension funding, FICA, fringe benefit billed, etc.) and others are related only to the headcount rather than the salary (i.e., Blue Cross & Blue Shield, group life insurance, sick leave, uniform & tool allowance, workman's compensation, etc. Thus, in distributing fringe benefit expenses, items were handled separately with respect to headcounts and average salaries.

input measures were derived by applying those relationships already derived for 1974 under the assumption that all employee distribution factors would be constant throughout the previous years concerned. The derivation process is described as follows:

(1) Direct Transportation Operation. This category includes all those employees directly instrumental in the provision of services--drivers, trainmen, yardmen, and towermen etc. The 1974 data were taken from "SEPTA Resources Utilization Plan 1975", and for the years 1971-1973, data were taken from "SEPTA - CTD Departmental Payroll Reports". Because this data source provided consistent information both in headcounts and labor cost from 1972 to 1974, the error which might have occurred later in ~~the~~ deriving of labor cost was eliminated. Since there are no distinctions made in the data for yardmen for the years 1971-1973, the data were disaggregated according to the distribution factors derived from the 1974 data.

(2) Labor in Other Primary Operations. This category includes direct transportation supervision P/T check, power plant employees and those engaged in minor maintenance activities. Modal breakdown of the transportation supervision and P/T check were made according to the headcount distribution in the "Direct Transportation Operation" category that have been derived previously. The task description of all maintenance activities supplied by "SEPTA Work Unit Report" were very explicit for inter-functional as well as inter-modal breakdown. As shown from the data, 336 employees out of 840 maintenance workers in the Rolling Stock and Shop Department were involved in minor maintenance activities, i.e., 40% of the workers in the Rolling Stock and Shop Department were involved in primary function and the other 60% in support function. This distribution ratio was held constant

for all previous inter-functional years since detailed data were not available for those years. In addition, the modal distribution factors for power plant operators in 1974 was similarly derived and held constant for the previous years.

(3) Labor in Administration and Managerial Activities. This category includes employees in the administrative and finance departments and the supervision staff in the transportation department (depot and field supervision). Engineers and people who work on schedule planning were also considered within this category. Since no detailed information was available, the inter-modal breakdown was made according to the passenger distribution among each mode.

(4) Labor in Repair and Maintenance Activities. The remaining maintenance labor in Rolling Stock and Shop (excluding those in the primary function) represents 505 out of the total 840 employees,or 60% of this category. In addition, the residual employees in the facility department (excluding those who operate power plants and engineers) were also included in this category. The two sets of intermodal distribution factors for Rolling Stock and Shop and Facility Departments respectively were derived from 1974 "SEPTA Work Unit Report" and were held constant throughout the previous year.

(5) Labor in Transportation Promotion and Marketing Activities. Total headcount data for this category were available for each year and modal breakdowns were made according to the total passenger distribution of each mode

(b) Man-hour Data. In order to derive man-hour data, employee lost time and overtime data had to be determined. With this information, the work time multiplier per employee was then derived, after some further data adjustments. Considering the data availability and convenience of calculation, each worktime multiplier was simply converted into man-hours per year per employee and then multiplied by the total headcount data.

The employee lost time data from "SEPTA Work Unit Report 1974" were given partially on the department level and partially according to each task performed. These data was averaged by using the number of employees in each task and a proper level of aggregate data was derived. Then, by using the following equation, the man-hour inputs for each labor input category was derived.[1/]

(365 days - employee days lost - weekends - holidays) x 8 hours = man-hours/years or $8 \cdot \left[365-(x+y+z)\right]$ = Actual Man-hours/year/employee

Based on the above calculation, the following equation is applied for the final derivation of man-hour data:

$$\frac{\text{man-hours}}{\text{employee/year}} \times \text{number of employees} = \text{total man-hours/year.}$$

There are some arguments about the results derived from this process. They arise primarily from the homogeneity of skill in labor inputs. Labor, age and sex, structure, differential in working experience, and overtime conversion factor; all these affect the qualitative as well as quantitative aspect of modification of man-hour input. However, all these items do not enter, yet, the determination of man-hours estimated for each function.

(c) Labor Cost. Most of the labor cost data were available in aggregate form only. The only detailed labor cost information is the SEPTA

1/Employee "lost days" includes authorized leave.

1974 payroll printout, but this only accounts for one month (Dec. 1974). Thus a set of functional as well as inter-modal breakdowns are first derived by using this source of data. Then this distribution of costs is used to derive labor cost from other data sources that give more comprehensive breakdowns for each year.

Distribution of fringe benefits were made in two ways: (a) those related to annual salaries were distributed according to total labor cost of each labor category, and (b) those relating to headcounts such as medical care expenses were distributed according to headcounts.

One exception, however, is that the labor cost data from "SEPTA Payroll Statement 1975" shows that the distribution of labor costs for Rolling Stock and Shop among primary and support function is about 360/588, in spite of the indication that the employment ratio is about 0.4 to 0.6. Thus, the distribution of labor expenses among primary and support function for Rolling Stock and Stock and Shops department are assumed to be made according to the ratio 0.4 : 0.6. This distribution is held for the years 1973, 1972, and 1971.

1.2 SEPTA - RAD

(a) Total Headcount. The 1974 and 1973 data were taken from "SEPTA Resource Utilization Plan", 1974 and 1975. The 1972 were taken from "SEPTA RAD Department Payroll Report" and "SEPTA RAD Operating Expenses Report".

(1) Direct Transportation Operation. In 1974, 50 employees out of 390 were transportation supervision staff. Therefore, the breakdown of transportation labor in direct transportation operation and other primary operations was made according to this ratio for the years 1972 and 1973. Also, the inter-modal breakdown was made accord-

ing to the ratio derived from 1974 data.

(2) Labor in Other Primary Operations. This included the transportation supervision staff, P/T checkers and minor maintenance labor. Since no detailed information is available to subdivide the maintenance labors into primary and support function, the interfunctional distribution ratio that had been derived from City Transit Division (CTD) was used from the "1974 SEPTA Work Unit Report." However, it should be noted that both Rolling Stock and Shop Departments and the Facility Department in City Transit Division were related to the major or minor maintenance activities. Thus, in calculating the inter-functional distribution ratio, the aggregated headcounts data was used. Based on the 1974 data, the interfunctional distribution ratio should be 0.3 : 0.7, i.e., 30% labor in primary functions and 70% in support functions.2/ This ratio was held constant for all the previous years. Since no detailed information was given for inter-modal breakdown, the assumption is made that the total headcounts are to be distributed according to the percentage of passengers that each mode carried.

(3) Labor in Managerial and Administrative Activities. This category includes administrative employees only and the modal breakdown was made according to the number of drivers of each mode.

(4) Labor in Repair and Maintenance Activities. Data for the above categories were given in the "SEPTA RAD Departmental Payroll Report", for 1972, 1973, 1974. Inter-functional and inter-modal breakdowns were made according to the same assumptions as mentioned in (2) above.

2/There were 2058 employees related to maintenance activities (1278 in the Rolling Stock and Shop Department and 780 in Facility Department) out of which 601 employees were in primary function (505 in minor maintenance and 96 in power plant operation). Thus, altogether, there were 30% (601/2058) of the total maintenance employees in primary function and 70% in support functions.

(5) Labor in Transportation Promotion and Marketing Activities. No labor data was specifically designated and, therefore, available for this category. According to "SEPTA Operating Expenses Report" these data were combined with that of the City Transit Division (CTD).

(b) Man-hour Data. So far as the limitations of data availability are concerned, employee lost time or overtime data for RAD cannot be established. Therefore, it is recommended that the work time multiplier for each labor input variable of CTD be utilized here in order to provide a more feasible approximation.

(c) Labor Costs Data. Labor expense data were taken from the "SEPTA RAD Departmental Payroll Reports" for 1974 and 1973 with the cost distribution among employee groups made according to the headcount distribution. Then, the possible labor cost data was extracted from the 1974 operating expenses report, adjusted according to those previously derived from the departmental payroll reports.[3/] Through this process, labor cost data for 1974 was derived as well as for 1973 and 1972.

Part of the fringe benefits that is related to labor cost were distributed according to the labor cost in each labor category (i.e., aggregated labor cost in administrative and managerial activities). The remaining fringe benefits were distributed according to headcounts.

1.3 DART

(a) Total Headcount. The only available headcount data was given as in the following Table G-1:

3/The 1974 labor costs distribution were compared with the 5 labor categories of the already derived 1974 data. Then, through an adjustment process, these expenses were made equal to those of the derived set of data. Since the data were given consistently throughout the years, the same adjustment factor can be applied to the years 1972 and 1973.

TABLE G-1. LABOR BREAKDOWN BY TASK PERFORMED FOR DART

Fiscal Year	TOTAL	Officials	Office & Clerical	Skilled Craftsmen	Operatives Semi-Skilled	Laborers Unskilled	Service Workers
1972	127	13	4	10	92	6	2
1973	141	19	5	11	95	4	7
1974	153	17	4	12	101	11	8
1975	178	18	6	14	119	9	12

No distribution among each labor category can be determined to permit labor category disaggregation. A considerable amount of uncertainty as to the distribution of tasks and employees significantly diminishes the disaggregation results. In this situation, an approximation was made according to the assumption that employees are grouped in such a way that the average salary per person under each labor category would be on the same level, i.e., approximately $10,000 per year per employee. This assumption inevitably precludes the fact of different skill/different level of income. Since no additional labor cost information was available, it is very difficult to deal with this problem at this moment. Further discussion about this issue is included in the last section. Based on the above assumption, headcount data were regrouped. An interfunctional breakdown of maintenance labor was made by using the ratio 0.3 : 0.7, derived from SEPTA CTD data in order to maintain the consistency of data processings.

(b) Man-hour Data. The only direct man-hour data available was drivers pay hours (under Direct Transportation Operation). These data were standardized by the multiplier factor 1.26, which closely approximates that of SEPTA operator (1.23). Thus, both overtime and shift work adjustment are assumed to have already been included.

For all other labor categories, further problems arise as to whether to use the same work unit multipliers derived from SEPTA CTD data for each of the labor categories and thus remain homogeneous cross-regionally or to introduce a proxy factor for all the categories so as to retain homogeneity within the system cross-yearly. Considering the various operational characteristics of each system and the probable cross-year productivity changes within each system, it seems to be inappropriate to apply the same factors to different transportation systems. This is especially true when one considers the different level of technology and labor skill structures within each system.

Thus far in this section, the work unit multiplier for full-time employment has been defined as follows:

(365 - weekends (104) - holidays (10) - uncontrollable man-days lost (12.5)[4/])

X 8 hours/day = 226.5 X 8 = 1908.

However, it should be noted that these (approximate) work unit multipliers were calculated on the basis of full-time employees. Certain quantitative modifications could have been made if the percentage of full time and hourly rated employee data were known. For DART, this level of detailed data was not available. In order to derive a set of more accurate man-hour data for DART we used the work unit multiplier (1776 man-hour/year) derived for SEPTA maintenance labor.

All the work unit multipliers were listed. Then, by multiplying these unit factors with all the headcount data (number of employees) for each year, a set of man-hour input data was derived.

(c) Labor Cost. The detailed cost of Labor has been divided in five typical groups, the following:

(1) Direct Transportation Operation. Regular and charter service expenses are included in this expense accounting. The data were given directly from DART.

(2) Labor in Other Primary Operations. These expenses include the costs of transportation supervision and again as above, it includes the supervision costs for regular and charter service operations.

4/This data is derived by averaging all the uncontrollable man-days lost of SEPTA category A: Payroll Employees (Supervision and Managerial Employees).

(3) Labor in Managerial and Administrative Activities. Two expense categories are included here: the first is related to general administrative employee costs (this refers to executive staff and officers) and the second category is labor expenses related to insurance and safety activities.

(4) Labor in Repair and Maintenance Activities. Detailed maintenance labor information necessary for the intra- and inter-functional cost disaggregation and distribution was not available. Therefore, it was assumed that by using a 0.3 : 0.7 expense distribution factor, which had been derived from the 1974 SEPTA CTD data, that primary and support maintenance expenses distributions could be estimated.[5/] Although some arguments might arise questioning the accountability of this disaggregation the limited data permits no other resolutions in this circumstance. Therefore, all of the labor input measures for the Delaware region were calculated using the assumptions itemized above.

(5) Labor in Transportation Promotion and Marketing Activities. The distribution of employee fringe benefits and pensions were again grouped into two categories and then distributed according to either headcounts or labor cost.

1.4 Transport of New Jersey (Southern Division)

The data for TNJ provided no breakdown for the Southern Division. Therefore, it was necessary to follow the procedure stated in the DVRPC report, New Jersey Area, in which the following equation was used to derive the data for the TNJ Southern Division:

$$\text{Total TNJ Measure} \times \frac{\text{Total Vehicle-mile Southern Div.}}{\text{Total Vehicle-mile TNJ System}} = \text{Derived Southern Div. Measure}$$

5/This is derived according to the labor expenses distribution between support maintenance and primary minor maintenance categories.

Therefore, the following measures resulted from applying this ratio for each of the years in the study period.

(a) Total Headcount. All the headcount data were grouped into the five labor categories without too much modification, except in the inter-functional breakdown of maintenance workers. Assumptions had to be made here by using the ratio 0.3 : 0.7 which had been derived from the 1974 SEPTA CTD data to breakdown minor/major maintenance labor.

(b) Man-hours. All of the man-hour data for each labor category were pay-hours instead of actual work-hours. As shown, supervision personnel were paid for 260 days out of one year. That is to say, uncontrollable man-days lost were not included. Thus, the aggregate man-hour data of TNJ might be slightly greater than that of SEPTA, since SEPTA man-hour data had already excluded those uncontrollable man-days lost.

(c) Labor Cost. Since labor cost data were taken from the same data source, very little modification was needed in regrouping these labor costs. The minor/major maintenance labor cost were distributed using the same 0.3 : 0.7 factor derived for SEPTA.

As stated in the data source, fringe benefits and pensions had already been included in each labor category.

2.0 Problems and Issues in Labor Inputs Derivation

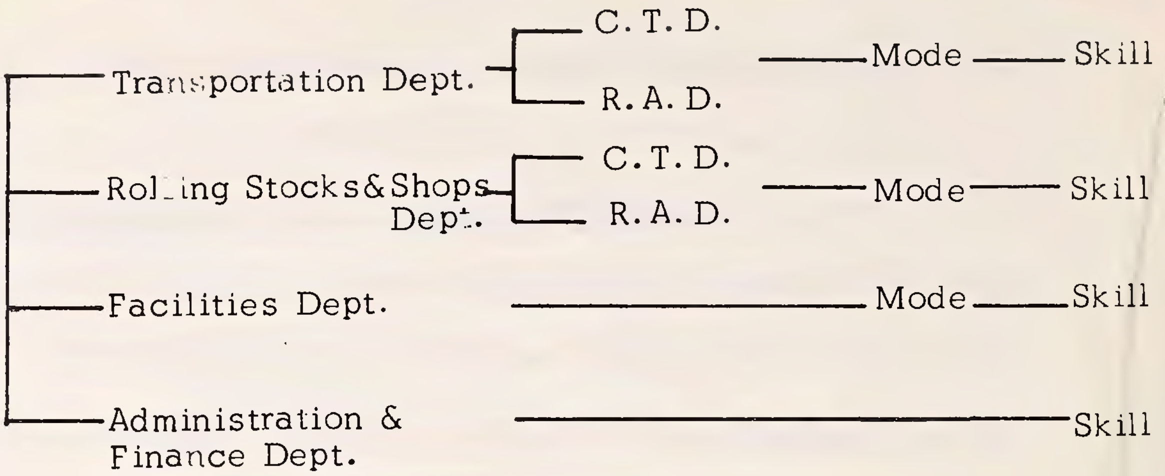
This section focuses on the specific and detailed problems that are usually present when the labor inputs of major regional opèrators of an UPTS are expected to be included in analysing the productivity and efficiency of the primary services and the support functions of the system. The importance of such an analysis is rather obvious when one realizes that labor costs correspond to proportions usually varying between 0.60 and 0.85 of the total operating expenditures of UPTS today.

2.1 Data Requirements. The data collection and reduction problems discussed in the previous parts of this section, particularly with respect to data variations and inconcsistencies, are even more clearly evident in the derivation of a labor data base. This task was pursued in three phases. These are listed below and discussed subsequently:

1. Manpower Data Collection
2. Labor Work Units Structure
3. Labor Cost Calculation

1. Manpower Data Collection. Three steps were required to complete this sub-task. First, it was necessary to inventory all of the operators to extract any and all available data on manpower, labor cost, employee working time, lost time, fringe benefits, etc. Some operators maintained these data by skill categories, others did not, while still others maintained only aggregate data by modes. Due to the wide discrepency in reporting, it was necessary to compile all available data in detail, i.e., their descriptions, sources, year reported, etc.

Second, it was necessary to organize the data into a uniform, efficient and comprehensive format that would consider all the manpower labor inputs and would provide for a more accurate (and efficient) way to reduce and synthesize the raw data. For example, the most comprehensive data we have for any operator is from SEPTA for 1973 and 1974. Therefore, using SEPTA as an example, the following functional breakdown of manpower data was accepted:



In order to derive this classification, several intermediate steps of data disaggregation and synthesis were required. These procedures will be stated later.

Third, from the results of steps 1 and 2, it was possible to set up an intermediate labor matrix based on the finest level of labor disaggregation available for each operator. For SEPTA, this was accomplished by individual skill categories. With this qualitative description of labor, it was then possible to collect and organize Employee Work Time data (i.e., labor work units).

2. <u>Labor Work Units</u>. Data was required on the following items:

a. Suspension or Authorized leave, which includes:

- Sick leave
- Union leave
- Authorized leave
- Vacation leave
- Suspension leave

b. Employee Overtime

c. Shifts of Work time, this information is important when calculating actual employee working time. For example, a Mechanic may stay in the garage for 8 hrs. but actually work 3 hrs. because of delays in supplying tools, material, etc., or he may not finish in time and the vehicle comes out "late" while the driver waits -- these kinds of data would be desirable if available.

From these data it would be possible to calculate actual working units on pay time.

3. Labor Cost Calculations. After the collection of data on employee work time units (either man hours or man days), labor cost can be determined provided that additional data is available on PAYROLL and FRINGE BENEFIT expenditures, i.e., data on:

Employee Cost
- Payroll
- Fringe Benefit
  - •Pensions to retired employees
  - •Pension Funding arrangements
  - •Blue Cross & Blue Shield
  - •Group life insurance
  - •Sick leave
  - •Uniform & Tool allowance
  - •F.I.C.A.
  - •Workman's Compensation
  - •Fringe Benefit Billed

The above data requirements are necessary in order to facilitate the labor cost data calculations discussed below (by sequence):

First Collect payroll and fringe benefits data and place them into the labor matrix. In view of the format of the available data, care must be used, with regard to the number of employees this figure accounts for. Usually Fringe Benefit costs are lump sum data given for one department or mode. What is needed is to specify exactly the recipient of each expense item in order to provide an easy way of cross-checking and to insure against double counting.

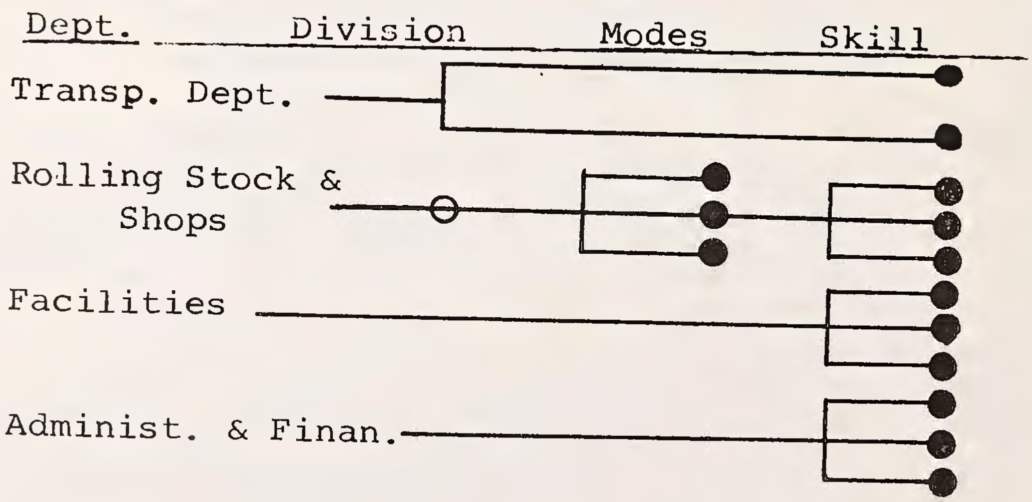
Second In order to reduce possible inaccuracy and improve data consistency, a method needs to be derived that unify data bases, e.g., usually Payroll data are given monthly or on an annual basis. The process of data base unification will be described in the next section.

Third Derive a unit labor cost equation which may be stated in terms of \$/man hour or \$/man day, as follows:

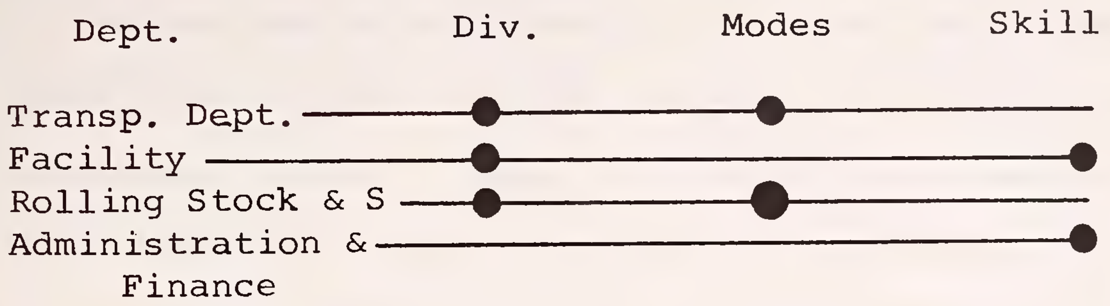
$$\text{Unit labor cost} = \frac{\text{Payroll and Fringe Benefits}}{\text{Employee Pay time (or employee working time)}}$$

Each operator utilizes a different manpower classification structure. Thus the data from the three regions are obviously not ready for a uniform labor input analysis. The data were also, in some cases, internally inconsistent. On the other hand, the available details were frequently variable, i.e., by mode, by division, or by department. It was thus necessary to decide which level of classification should be finally utilized. In order to do this, all the available data including manpower, labor cost, and man-hours inputs were reviewed. This was necessary because if one just formed the classification base on manpower only (number of employees), it would have been impossible to distribute variation of expenses or variation of employee lost time, to each division of the system.

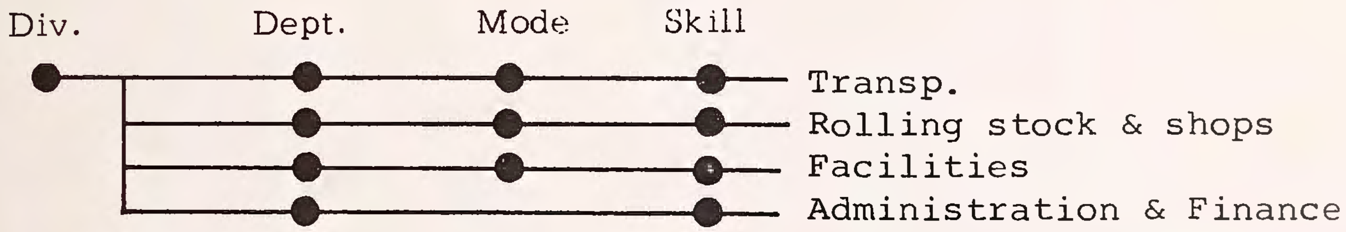
Two major data sources were used: the "Work Unit Manual" and "SEPTA Resources Utilization Plan" for 1973 and 1974. From the "Work Unit Manual" detailed information on manpower, employee lost time, and overtime was broken down first by Department and then by skill. The division of this data was as the following diagram indicates:



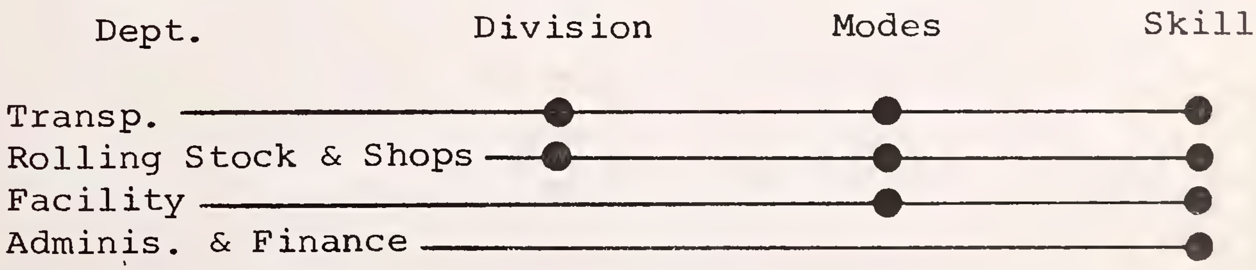
From the "Resources Utilization Plan", manpower data were first broken down by department then by division, then by mode. In Summary:



A third data source, the "City Transit Division Payroll Data" provides details on operating expenses on labor. There, the sequence is as follows:



Thus, in order to derive the most effective & comprehensive way of data processing,the final quantification of labor inputs would have to be achieved from the simultaneous use of these three basic types of data sources.



3.0 Summary

The data problems enumerated represent a considerable task. Clearly, the focus on the SEPTA system, is intended to demonstrate the major complexities and difficulties inherent in formulating the translation of the agency data into useful, tractable and reproducible data. None of the other operators within the three test regions present such problems. The exercise is an important one though. The labor component of the total inputs to any UPTS constitutes the most important segment in any productivity, efficiency and quality of service analysis of UPTS.

Table G-2. LABOR REVENUE VERSUS LABOR EXPENSE
(Bus mode for 1974 for primary labor category (drivers only)).

Operator	Vehicle-Mile /Employee	Revenue /Employee	Salary /Employee	Monetary Differential
CTD	16,902	$19,399	$15,126	+ $4,273
RAD	20,275	$14,685	$13,325	+ $1,360
TNJ	19,500	$21,414	$13,992	+ $7,522
DART	19,800	$13,030	$14,356	- $1,326

Table G-3.

HEADCOUNT FOR SEPTA R.A.D. BY MODE: 1974

	SEPTA R.A.D. 1974	Bus	Trolley Rail	Total
PRIMARY	TRANSPORTATION OPERATION Driver Yardmen Total	269	72	341
	ALL OTHER OPERATIONS			
	Supervision	34	16	50
	Minor Repair & Maint.	47	13	60
	Operate Power Plant	–	–	–
	P/T Check	–	–	–
	Total	81	29	110
	PRIMARY FUNCTION Total	350	101	451
SUPPORT	MANAGERIAL & ADMINISTRATIVE			
	Administration & Finance	–	–	–
	Schedule	–	–	–
	Supervision	–	–	–
	Engineering	–	–	–
	Total	9	6	15
	REPAIR & MAINTENANCE			
	Rolling Stocks Maint.	–	–	–
	Facilities Maint.	–	–	–
	Total	109	32	141
	TRAFFIC PROMOTION	–	–	–
	SUPPORT FUNCTION Total	118	38	156
SYSTEM-WIDE	SYSTEM-WIDE TOTAL.	468	139	607

Table G-4.

HEADCOUNT FOR SEPTA C.T.D. BY MODE: 1974

	SEPTA C.T.D. 1974	Bus	Trolley B.	Trolley R.	Rapid Transit	Total
PRIMARY	TRANSPORTATION OPERATION * Driver * Yardmen					
	Total	2160	164	556	719	3599
	ALL OTHER OPERATIONS					
	* Supervision	150	12	38	52	252
	* Minor Repair & Maint.	270	20	85	130	505
	* Operate Power Plant	0	3	22	64	89
	* P/T Check	7	-	-	16	23
	Total	427	35	145	262	869
	PRIMARY FUNCTION Total	2587	199	701	981	4468
SUPPORT	MANAGERIAL & ADMINISTRATIVE					
	* Administration & Finance	-	-	-	-	395
	* Schedule	-	-	-	-	57
	* Supervision	-	-	-	-	132
	* Engineering	-	-	-	-	60
	Total	344	27	100	173	644
	REPAIR & MAINTENANCE					
	* Rolling Stocks Maint.	427	29	106	211	773
	* Facilities Maint.	73	4	231	376	684
	Total	500	33	337	587	1457
	TRAFFIC PROMOTION	21	2	7	11	41
	SUPPORT FUNCTION Total	865	62	444	771	2142
SYSTEM -WIDE	SYSTEM-WIDE TOTAL.	3452	261	1145	1752	6610

Table G-5.

HEADCOUNT FOR DART BY MODE: 1974

	D.A.R.T. 1974	Headcounts		Man-hour		Labor Cost payroll only	
PRIMARY	TRANSPORTATION OPERATION * Driver * Yardmen						
	Total	101	(1)	278,337	(6)	1,137,906	(7)
	ALL OTHER OPERATIONS						
	* Supervision	-		-		-	
	* Minor Repair & Maint.	-		-		-	
	* Operate Power Plant	-		-		-	
	* P/T Check	-		-		-	
	Total	26	(2)	-		126,914	(8)
	PRIMARY FUNCTION Total	127		-		1,264,820	
SUPPORT	MANAGERIAL & ADMINISTRATIVE						
	* Administration & Finance	-		-		-	
	* Schedule	-		-		-	
	* Supervision	-		-		-	
	* Engineering	-		-		-	
	Total	15	(3)	-		101,448	(9)
	REPAIR & MAINTENANCE						
	* Rolling Stocks Maint.	-		-			
	* Facilities Maint.	-		-			
	Total	9	(4)	-		17,794	(10)
	TRAFFIC PROMOTION	2	(5)	-		9,967	(11)
	SUPPORT FUNCTION Total	26		-		129,209	
SYSTEM-WIDE	SYSTEM-WIDE TOTAL.	153		-		1,393,029	

APPENDIX H

NUMERICAL APPLICATION OF USER COST ESTIMATES

The equations developed in Section (1.0) of Chapter X are the foundation for a complete user cost assessment. However, because of the shortcomings discussed in Sections (1.0) and (2.0) of Chapter X, distinct modifications ought to be made in the system of user costs equations. The following example illustrates how the aforementioned cost accounting method can be applied to one mode over a five-year study period. The High Speed Line of PATCO is chosen for this test of the degree of usage of the cost methodology currently possible.

Access Time Cost. For purposes of computation, access cost includes cost of origin to linehaul mode, and linehaul mode to origin only. For PATCO, the access time cost is defined as the time cost per passenger needed to travel from an origin to a station. We assume an average access time for a PATCO passenger of fifteen minutes (which also applies to the commuter rail modes). For SEPTA CTD and RAD service, the access time is shortened to ten minutes, by postulation.[1/] A recent document from the New Jersey Department of Transportation shows the modal split of access modes to PATCO as follows:[2/]

MODE	ACCESS PER CENT
Auto	79%
Bus	7.7%
Rail	1.0%
Walk	12.3%

1/See Computations Note 1

2/New Jersey, Dept. of Transportation, "New Jersey Public Transportation Study, Phase B, Technical Memorandum," draft, Feb. 23, 1976.

Therefore, knowing the number of passengers using PATCO in 1970,[3/] and using a monetary value for access time developed by Lisco of $7.20 per hour,[4/] the total access cost is $15,580,800. The analysis is applied to all subsequent years by using the "passengers carried" figure for that year.

Access Vehicle Operating Cost. The figures for this category are taken from the [U.S. Department of Transportation paper on automobile costs U.S., Dept. of Transportation, April, 1972]. Essentially the cost breakdown for a compact car (chosen as prototypical of the more common car types) is:

Item	Cost (cents per vehicle mile)
Depreciation	2.70
Repairs & Maintenance	1.79
Tires and accessories	0.39
Gasoline	1.68
Oil	0.11
Insurance	1.30
Taxes	1.03
TOTAL	9.0

In terms of the PATCO case, the average length of the access trip is found to be 5.34 miles.[5/] Knowing the percent of passengers driving from before and multiplying this figure by the trip length gives the 1970 access passenger miles accumulated which is 36,516,201. Dividing the last figure by the average work trip load factor (assumed to be 1.4 from the National Personal Transportation Study, Report #1, U.S. Department of Transportation, April, 1972), gives 26,053,700 access vehicle miles logged.[6/]

3/D.E. Boyce et al. "Impact of Suburban Rapid Transit Station Location, Fare and Parking Availability on User's Station Choice Behavior -- Analysis of the Philadelphia-Lindenwold High Speed Line, Regional Science Dept. Univ. of Pennsylvania, Dec., 1974, pp. 148-149.

4/D.E. Boyce et al. "Impact of Rapid Transit on Fuel Consumption and Cost for Journey to Work--Analysis of the Philadelphia-Lindenwold High Speed Line," Philadelphia, Univ. of Pennsylvania, June, 1975.

5/T.E. Lisco. The Value of Commuters Travel Time: A Study in Urban Transportation, Ph.D. dissertation, Univ. of Chicago, June, 1967.

6/See Computation Notes 2,3, and 4.

Finally, multiplying the vehicle miles by the operating cost gives $2,344,832 for PATCO. For more recent years, the fuel cost is doubled and an inflation factor is applied to the other cost factors. The method outlined above is identically applied to the commuter rail modes presuming the same constant values for the parameters. For the bus and trolley modes, however, it is stipulated that the percentage of access mode split is basically reversed, and the access trip length is 1/8 and 1/3 mile, respectively. For the rapid transit case, the percentage of access mode split is changed somewhat to 80% non-vehicle, 20% vehicle access and the access trip length is postulated to be 1/4 mile.[7/]

Parking Cost. It is known that there are 11,984 toll parking spaces available on a daily basis for PATCO commuters.[8/] Thus finding the average work day access vehicles used as 8832, and assuming 80% park and ride and 80% of those use paid parking spaces, one sees that on a daily basis, 5653 parking spaces are revenue producing. Thus, on an annual basis this number is multiplied by a per cent of $.25 giving $390,749 as the 1970 parking income of those commuters using PATCO.[9/] Following the same reasoning as above, parking costs can be generated for all other modes.

Crime and Social Costs. There was not sufficient data available to compute these costs. Figures for pollutants emitted appear elsewhere in this report. Crime statistics for SEPTA are listed in Appendix F by mode and by type of offenses committed (where data exists).

7/Conversations with Bill Boone and Arlene Steinfield, SEPTA, Feb. 27, 1976.

8/"1974 National Transportation Study, New Jersey Portion," Report # NTS-X-2, Delaware Valley Regional Planning Commission, June, 1973.

9/See Computational Notes 5 and 6.

Accident Costs. Using the relationship of 8.88 accidents per million vehicle miles traveled past an intersection,[10/] and calculating that 0.7% are fatal, 15.7% are injuries and 84% are property damage with an average aggregated 1970 dollar cost of $520 per accident,[11/] one can compute a rough estimate of access vehicle accident expenses to the user. The annual variance for any mode is based on the change in vehicle rules and inflation. For 1970, the accident figure for PATCO is $11,267.[12/]

Transit Time Cost With PATCO. Herein, for 1970 there were 8,656,000 who rode the High Speed Line. The average waiting time (the median value between zero and the average headway) for the Line was five minutes. The average trip length is 9.1 miles, and the average vehicle speed is 40 mph (all figures from the 1974 NTS paper, DVRPC, 1973). Thus, dividing trip length by vehicle speed gives an average travel time per passenger of .23 hour. The total annual passenger hours is the sum of waiting plus travel time (.31 hour) for all passengers[13/] or 2,683,360. Using Lisco's value for travel time of $2.60 per hour[14/] gives an annual, total travel time cost of $6,976,636.

Fare Cost. The annual revenue produced through ridership is found for each mode in the statement of income of each operator. On the other hand,

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10/J.E. Baerwald, ed. Traffic Engineering Handbook, Institute of Traffic Engineers, Washington, D.C., 1965, p. 254.

11/Illinois Dept. of Public Works & Buildings, Div. of Highways, "Cost of Motor Vehicle Accidents to Illinois, 1958," Dec., 1962.

12/See Computational Note 2

13/See Computational Note 8

14/Lisco, Thomas E., The Value of Commuters' Travel Time: A Study in Urban Transportation, PhD. Dissertation, University of Chicago, June 1967.

using figures from Boyce and 1974 NTS paper, the fare-box revenues for PATCO are total passengers carried times the average fare or 8,656,000 X $.50 = $4,328,000.

Crime and Social Costs of Riding PATCO. As with access costs, there are not data available to convert quantities into dollar amounts. Crime statistics are taken from Appendix D of this report and directly entered into the matrix. Pollutants are given elsewhere in the report (although their effects on the user are not).

Accident Costs of Riding PATCO. Using information from two SEPTA sources[15,16] and making certain extrapolations and assumptions where data are unavailable, is developed[17] showing accident rates for all operators and using the consumer price index are applied uniformly to all modes for each year's cost.[18]

15/SEPTA, "1975 Resource Utilization Plan," 1974.

16/SEPTA, "City Transit Division Fact Book," 1974.

17/See Computational Note 3

18/See Computational Note 10

COMPUTATION NOTES OF APPENDIX H

NOTE 1:

Access Cost = x times passengers

where x = ¼ hour access/passenger X $7.20 time value/ hour

x = 1.8 (for PATCO and Commuter Rail)

x = 2.4 (for CTD RAD and TNJ modes)

NOTE 2:

Access Trip Length = 5.34 miles (PATCO and Commuter Rail)

= 1/8 mile (CTD modes of SEPTA excluding rapid transit)

= 1/3 mile (RAD modes of SEPTA and TNJ)

= ¼ mile (CTD - Rapid Transit)

NOTE 3: Access Mode Split

Operator	% Auto	% Non-Auto
PATCO and Commuter Rail	79	21
CTD-- Bus and Trolley	10	90
CTD - Rapid Transit	20	80
RAD - Bus and Trolley	30	70
TNJ	30	70

NOTE 4: Vehicle Mile Calculation

Access Vehicle Miles = (Passengers per line haul mile) XY

$$Y = \frac{\text{(Access vehicle trip length) X (\% Auto Access)}}{\text{Passengers/Access Vehicle}}$$

Access Vehicle Miles = (Passenger per linehaul mode) X Y

where

Y	Operator
6.02	PATCO & Commuter Rail
.018	CTD - Bus & Trolley
.072	CTD - Rapid Transit
.142	RAD - Bus & Trolley
.142	TNJ

NOTE 5: Access Vehicles

$$\text{Access Vehicles} = \frac{\text{(Passengers per linehaul mode) X (\% Auto Access)}}{\text{(passenger/ access vehicle)}}$$

or

Access Vehicles = (Passenger per linehaul mode) X Z

where

Z	Operator
.562	PATCO & Commuter Rail
.072	CTD - Bus & Trolley
.144	CTD - Rapid Transit
.214	RAD - Bus & Trolley
.214	TNJ

NOTE 6: Paid Parking

Parking Cost = (Access Vehicles) X (% Park & ride) X (% Paid Parking spaces used) X (Cost per vehicle)

or

Parking Cost = (Access Vehicles) X P

where

P	Operator
.16	PATCO & Commuter Rail
.224	CTD - Bus & Trolley
.224	CTD - Rapid Transit
.224	RAD - Bus & Trolley
.16	TNJ

NOTE 7: Energy Consumption

The conversion factor for gallons to BTU is
1 gal. gasoline = 138,000 BTU

NOTE 8: Average Transit (In-Vehicle) Travel Time *

Operator	Avg. Waiting Time (Min.)	Avg. Trip Length (mi.)	Avg. Vehicle Speed (mph)	Avg. Movement Time (min.)	Total Travel Time (hours)
SEPTA					
CTD-Bus	9.5	2.38	14	10.2	.33
CTD-Trolley Rail	5	2.16	9.1	14.2	.32
CTD-Trolley Bus	5	1.70	7.1	14.2	.32
CTD-Rapid Transit	3	5.39	21.3	15.2	.30
RAD-Bus	9.5	8.08	14	34.6	.74
RAD-Trolley Rail	6	5.88	21.9	16.1	.37
GCD-PCRR	20	12.4	35.4	21	.68
GCD-RR	25	12.9	30.8	25.1	.84
PATCO					
High Speed Line	5	9.1	40	13.7	.31
TNJ					
Southern Division -Bus	20	1.6	23	41.7	1.00

* 1974 National Transportation Study -- Philadelphia and New Jersey Portions, Report No. NTS-X-2, DVRPC, June, 1973.

NOTE 9: Access Vehicle Capital Expenditure

Capital Cost = (Access Vehicles) X ((8% (new car price) + 14% (used car price)) = Access Vehicles X Q

where

Q	Year
368.55	1970
387	1971
405	1972
437.40	1973
494.10	1974

NOTE 8: Average Transit (In-Vehicle) Travel Time *

Operator	Avg. Waiting Time (Min.)	Avg. Trip Length (mi.)	Avg. Vehicle Speed (mph)	Avg. Movement Time (min.)	Total Travel Time (hours)
SEPTA					
CTD-Bus	9.5	2.38	14	10.2	.33
CTD-Trolley Rail	5	2.16	9.1	14.2	.32
CTD-Trolley Bus	5	1.70	7.1	14.2	.32
CTD-Rapid Transit	3	5.39	21.3	15.2	.30
RAD-Bus	9.5	8.08	14	34.6	.74
RAD-Trolley Rail	6	5.88	21.9	16.1	.37
GCD-PCRR	20	12.4	35.4	21	.68
GCD-RR	25	12.9	30.8	25.1	.84
PATCO					
High Speed Line	5	9.1	40	13.7	.31
TNJ					
Southern Divsion -Bus	20	1.6	23	41.7	1.00

* 1974 National Transportation Study -- Philadephia and New Jersey Portions, Report No. NTS-X-2, DVRPC, June, 1973.

NOTE 7: Energy Consumption

The conversion factor for gallons to BTU is 1 gal. gasoline = 138,000 BTU

NOTE 9: Access Vehicle Capital Expenditure

Capital Cost = (Access Vehicles) X (8% (new car price) + .14% (used car price

= Access Vehicles X Q

where

Q	Year
368.55	1970
387	1971
405	1972
437.40	1973
494.10	1974

NOTE 10: Additional Data of Computations

ITEM	1970	1971	1972	1973	1974
(1) Access Vehicle Operating Cost 1,2/ (per vehicle Mile)	$ 0.09	$0.0945	$0.0981	$0.1053	$0.13
(2) Access Vehicle Purchase Price 1,2/	$2457.00	$2580.00	$2700.00	$2916.00	$3294.00
(3) Access Vehicle Fuel Cost/Per Gal. 1,2/	$ 0.35	$0.3675	$0.3815	$0.4095	$ 0.55
(4) Access Vehicle Annual Accident Cost Per Vehicle 1,3/	$ 520.00	$ 546.00	$ 567.00	$ 608.00	$ 681.00
(5) Annual In-Vehicle Accident Cost Per Vehicle 1,4/	$ 520.00	$ 546.00	$ 567.00	$ 611.00	$ 603.00

1/*Monthly Labor Review*, Vol. 98, No. 1, Jan., 1975.

2/"Costs of Operating an Automobile," U.S. Dept. of Transportation, April, 1972.

3/"Costs of Motor Vehicle Accidents to Illinois, 1958," Div. of Highways, Illinois Dept. of Public Works, Dec., 1962.

4/"City Transit Division--Fact Book," SEPTA, 1975.

NOTE 11: Accident Rate Data
(number of accidents per hundred thousand of vehicle miles)

OPERATOR	1970	1971	1972	1973	1974
SEPTA					
CTD - Bus[1]/	5.2	5.2	5.2	5.2	5.2
CTD - Trolley Rail[1]/	8.0	8.0	8.0	8.1	8.5
CTD - Trolley Bus[1]/	6.0	6.0	6.0	6.0	7.0
CTD - Rapid Transit[2]/	6.6	6.6	6.6	6.6	6.8
RAD - Bus[2]/	1.9	1.9	1.9	1.8	2.2
RAD - Trolley Rail[2]/	2.9	2.9	2.9	2.9	3.5
GCD - PCRR[3]/	1.5	1.5	1.5	1.5	1.5
GCD - RR[3]/	.7	.7	.7	.7	.7
PATCO					
High Speed Line[4]/	.9	.9	.9	.9	.9
TNJ- Southern Div.					
Bus[4]/	1.6	1.6	1.6	1.6	1.6

1/1973-74 data from CTD Fact Book; other years, by extrapolation.

2/Data extrapolated using CTD Fact Book - 1974 and 1975 Resource Allocation Plan. SEPTA.

3/Using 1974 data from 1975 Resource Allocation Plan, other years completed by backward extrapolation.

4/Using 1974 NTS Report (New Jersey Portion) to find base figure, then use as a constant.

APPENDIX I

INPUT AND OUTPUT MATRICES

FISCAL INPUT MATRICES

1) Fiscal Input Matrix, 1973
2) Fiscal Input Matrix, 1974

PHYSICAL INPUT MATRIX

1) Physical Input Matrix, 1973
2) Physical Input Matrix, 1974

OUTPUT MATRICES

1) Output Matrix, 1973
2) Output Matrix, 1974

URBAN PUBLIC TRANSPORTATION SYSTEM — FISCAL INPUT MATRIX 1973

IN CURRENT US DOLLARS

TABLE NUMBER:

Actor / System / Input	Description	PA: SEPTA Bus	SEPTA Trolley Bus	SEPTA Trolley Rail	SEPTA Rapid Transit	C.T.D. Total	SEPTA Bus (RAD)	SEPTA Trolley Rail (RAD)	R.A.D. Total	SEPTA Penn Central	SEPTA Reading Co	G.C.D. Total	Region Total	NJ: PATCO Rapid Transit	T.N.J. Bus	NJ Region Total	DE: CAPT Bus
DISCRETE — OPERATOR	Operator input total/D	E/C	E/C	E/C	E/C	E/C	E/C	E/C	E/C	E/C	E/C	E/C	E/C	E/C	E/C	E/C	E/C
OPERATOR — PRIMARY	Operator primary input total/D	E/C	E/C	E/C	E/C	E/C	E/C	E/C	E/C	E/C	E/C	E/C	E/C	E/C	E/C	E/C	E/C
PRIMARY — OP EXP	Operator primary operating expense total/D	33,491,383	2,349,419	12,166,596	14,825,410	63,592,804	E/C	E/C	4,326,388	10,410,000	8,924,600	19,334,600	88,491,453	2,954,505	E/C	E/C	1,469,799
SUPPORT	Operator support input total/D	E/C	E/C	E/C	E/C	E/C	E/C	E/C	E/C	E/C	E/C	E/C	E/C	E/C	E/C	E/C	E/C
SUPPORT — OP EXP	Operator support operating expense total/D	23,314,357	1,499,019	13,606,067	14,234,149	52,653,592	E/C	E/C	4,241,902	14,179,000	8,913,200	23,092,200	80,001,694	3,192,894	E/C	E/C	1,57[illegible]
NETWORK — CAPITAL	Operator network capital asset total/D										180,200	120,200	180,200	E/C		E/C	
SYSTEM-WIDE	Operator system-wide input totals/D	56,969,740	3,848,424	26,572,663	29,079,559	116,246,396	3,540,000		3,540,000	24,589,000	17,837,800	42,426,800	169,412,846	5,747,399	E/C	E/C	25,095
	Operator S/W energy input total/D	1,203,710	187,273	1,467,182	1,593,391	4,451,556	148,916	263,247	412,163	1,894,000	1,640,677	3,534,677	8,398,396	787,099			
GOVERNMENT	Government input total/D	15,350,000			40,664,250	148,273,000	3,936,000		9,463,000			14,990,000	172,666,000	—	—	—	2,674,[illegible]
GOVERNMENT — PRIMARY	Government primary input total/D	15,350,000			5,370,750	62,632,750	3,936,000		9,163,000			14,520,000	86,365,750				
GOVERNMENT — SUPPORT	Government support input total/D					2,960,000			240,000			470,000	3,670,000				
GOVERNMENT — NETWORK CAPITAL	Government capital input total/D				40,664,250	40,664,250							40,664,250				
GOVERNMENT — SYSTEM-WIDE	Government statewide input total/D	15,354,000			40,664,250	148,223,000	3,536,000		3,536,000			14,990,000	166,749,000				2,446,[illegible]
USER — PRIMARY	Passenger revenue input total/D	39,947,247	2,909,352	12,151,368	20,139,590	75,147,577	3,788,609	1,782,875	5,571,484	12,677,000	8,862,000	21,539,000	102,258,061	5,540,256	12,782,436	19,322,692	1,567,[illegible]
ESTIMATE — OPERATOR	Operator input total/E	98,912,964	5,733,946	50,138,170	85,378,567	240,163,647	14,079,105	16,477,378	30,556,483	24,589,000	19,837,800	42,426,800	287,833,683	38,423,[illegible]	12,053,504	[illegible]	4,8[illegible]
OPERATOR — PRIMARY	Operator primary input total/E	59,771,185	3,580,281	24,946,026	55,169,490	143,466,490	6,867,509	7,090,477	12,897,986	10,410,000	8,924,600	19,334,600	180,695,076	37,772,604	12,924,779	50,6[illegible]	3,4[illegible]
PRIMARY — CAPITAL	Operator primary capital input total/E	26,119,802	1,230,876	12,174,430	40,344,578	79,869,686	3,140,536	5,183,703	8,294,239				38,663,925	35,157,499	124,183	36,3[illegible]	2,3[illegible]
PRIMARY — OP EXP	Operator primary operating expense total/E	D/C	D/C	D/C	D/C	D/C	3,726,973	2,336,738	D/C	D/C	D/C	D/C	D/C	D/C	11,491,496	[illegible]	D/C
PRIMARY — LABOR	Operator primary labor input total/E	38,092,821	2,904,511	10,800,498	14,240,072	65,447,902	4,360,059	1,546,271	5,906,330	D/C	D/C	D/C	71,354,632	934,994	2,444,57	2,579,[illegible]	1,[illegible]
PRIMARY — ENERGY	Operator primary energy input total/E	1,411,116	167,309	1,202,433	1,338,443	3,759,307	125,089	221,127	346,216	1,590,960	1,378,169	2,969,129	7,054,653	661,163	349,163	[illegible]	D/C
SUPPORT	Operator support input total/E	37,877,563	2,085,847	18,222,676	18,445,876	76,361,952	3,596,444	4,097,811	7,694,455	14,179,000	8,913,200	23,092,200	107,138,607	5,149,8[illegible]	5,12[illegible]	10,7[illegible]	1,3[illegible]
SUPPORT — CAPITAL	Operator support capital input total/E	14,263,196	586,828	9,616,609	4,211,727	23,678,360	1,136,841	2,316,212	3,452,553				27,130,913	2,456,932	497,642	2,954,5[illegible]	1,4[illegible]
SUPPORT — OP EXP	Operator support operating expense total/E	D/C	D/C	D/C	D/C	12,161,191	2,460,303	1,381,549	D/C	D/C	D/C	D/C	16,752,490	D/C	4,131,13	2,234,0[illegible]	D/C
SUPPORT — LABOR	Operator support labor input total/E	11,254,457	462,491	5,829,460	9,833,320	27,769,629	1,033,734	915,374	1,999,108	D/C	D/C	D/C	29,728,736	[illegible]	[illegible]	[illegible]	[illegible]
SUPPORT — ENERGY	Operator support energy input total/E	192,593	29,963	234,749	254,943	712,249	23,826	42,119	65,947	303,040	262,508	565,549	1,343,742	125,135	69,784	[illegible]	D/C
NETWORK	Operator network input total/E	1,564,226	67,808	6,974,468	11,742,703	20,349,205	74,952	4,389,090	4,464,042				25,313,247	55,064,[illegible]		55,06[illegible]	
NETWORK — CAPITAL	Existing way capital value / building & station value / fixed equipment value	1,564,226	67,808	6,307,056 / 503,933 / 163,479	4,085,918 / 1,254,260 / 6,402,525	10,392,974 / 3,590,227 / 6,556,004	74,952	3,285,074 / 1,114,812 / 489,204	3,285,074 / 1,114,812 / 564,156				13,678,048 / 4,583,039 / 7,120,160	[illegible]		[illegible]	
SYSTEM-WIDE	Operator S/W capital input total/E	41,947,224	1,885,512	23,765,307	56,299,008	123,897,051	4,851,829	12,359,005	19,210,834	D/C	D/C	D/C	144,107,885	92,578,[illegible]	1,739,285	94,4[illegible]	2,[illegible]
	Operator S/W labor input total/E	49,251,278	3,757,002	16,129,958	24,073,292	93,211,530	5,394,233	2,471,605	7,865,838	D/C	D/C	D/C	101,083,363	[illegible]	[illegible]	[illegible]	[illegible]
GOVERNMENT	Government support input total/E			—													
USER — PRIMARY	User input total/E	100,550,000	7,650,000	30,470,000	45,180,000	183,880,000	23,650,000	5,560,000	29,210,000	35,110,000	28,530,000	61,640,000	274,730,000	9,754,000	29,792,000	39,542,000	4,8[illegible]
	Travel time lane value	99,470,000	7,600,000	30,150,000	43,140,000	180,360,000	22,850,000	5,160,000	28,010,000	30,450,000	26,650,000	57,100,000	265,470,000	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible] cost	1,080,000	50,000	320,000	2,040,000	3,520,000	800,000	400,000	1,200,000	2,660,000	1,880,000	4,540,000	9,26[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PROXY — USER	User input total/P	179,101,400	14,062,800	56,939,800	104,470,000	354,180,000	26,365,200	11,899,600	38,264,900	86,575,000	61,345,000	147,920,000	540,364,800	51,[illegible]	39,[illegible]	[illegible]	[illegible]
USER — PRIMARY — CAPITAL	User primary capital expenditure totals: access vehicle cost	36,511,400	2,869,800	11,441,800	34,835,000	85,628,000	11,117,200	5,016,600	16,133,800	42,486,000	30,108,000	75,594,000	174,355,800	[illegible]	[illegible]	[illegible]	[illegible]
USER — OP EXP	User primary operating expense input total/P	3,470,000	264,000	1,648,000	3,260,000	8,642,000	998,000	463,000	1,451,000	13,089,000	9,267,000	22,356,000	32,449,000	[illegible]	[illegible]	[illegible]	[illegible]
	Access vehicle operating expenditure	2,080,000	164,000	1,160,000	2,200,000	5,604,000	738,000	336,000	1,074,000	12,460,000	8,840,000	21,300,000	27,978,000	[illegible]	[illegible]	[illegible]	[illegible]
	Travel accident cost	1,130,000	80,000	400,000	580,000	2,190,000	60,000	37,000	97,000	69,000	27,000	96,000	2,383,000	[illegible]	[illegible]	[illegible]	[illegible]
	Access accident cost	260,000	20,000	88,000	480,000	848,000	200,000	90,000	290,000	560,000	400,000	960,000	2,098,000	[illegible]	[illegible]	[illegible]	[illegible]
USER — LABOR	User primary labor expenditure totals	139,120,000	10,935,000	43,480,000	66,375,000	259,910,000	14,250,000	6,430,000	20,680,000	31,000,000	21,970,000	52,970,000	333,560,000	[illegible]	[illegible]	[illegible]	[illegible]
SOCIETY — PRIMARY	Society primary externality input totals: air pollution cost	2,660,000	180,000	631,000	1,037,000	4,508,000	197,000	338,000	1,535,000	109,000	77,000	186,000	6,229,[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
AGGREGATE FISCAL INPUTS — SYSTEM-WIDE	System-wide input all actors total	457,835,788	32,071,117	163,346,445	270,669,306	976,199,566	69,075,914	34,657,853	114,940,767	157,060,000	116,534,000	273,893,000	1,231,062,772	[illegible]	[illegible]	[illegible]	[illegible]
	S/W primary input total	397,371,852	28,441,443	124,731,194	225,916,578	783,266,817	65,404,319	27,070,952	101,642,270	142,781,000	107,738,600	250,519,600	1,082,449,176	[illegible]	[illegible]	[illegible]	[illegible]
	S/W support input total	60,891,910	3,594,866	31,813,743	32,720,025	131,989,544	3,596,644	4,097,811	7,934,455	14,179,000	8,713,200	23,092,200	162,876,199	[illegible]	[illegible]	[illegible]	[illegible]
	S/W network input total	1,564,226	62,808	6,974,448	11,742,703	20,349,205	74,952	4,389,090	4,464,042		180,200	180,200	66,152,697	[illegible]	[illegible]	[illegible]	[illegible]
	Categorical: S/W capital input total	93,808,624	4,755,312	35,177,107	131,798,258	314,872,051	23,045,029	17,375,605	40,420,634	42,486,000	30,108,000	72,594,000	425,886,685	[illegible]	[illegible]	[illegible]	[illegible]
	S/W operating exp input total	103,043,007	7,241,786	40,303,031	53,516,149	204,563,973	12,470,885	7,092,248	19,563,133	83,534,000	64,613,200	148,147,200	393,474,956	[illegible]	[illegible]	[illegible]	[illegible]
	S/W labor input total	288,971,278	22,332,042	90,199,958	134,168,292	535,677,530	42,554,233	14,089,605	56,642,838	31,447,000	21,997,000	53,444,000	645,326,363	[illegible]	[illegible]	[illegible]	[illegible]
	S/W energy input total	3,283,310	367,273	1,797,182	2,633,391	7,821,956	969,916	663,747	1,612,163	4,554,000	3,520,677	8,074,677	17,658,[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
DISCRETE	Discrete system-wide input all actors total	78,611,624	4,468,371	25,752,635	75,957,989	234,132,169	E/C	E/C	E/C	12,677,000	9,042,200	21,719,200	E/C	[illegible]	[illegible]	[illegible]	[illegible]
	S/W primary input total/D	55,297,267	2,909,352	12,151,368	20,139,590	137,030,327	E/C	E/C	E/C	12,677,000	8,862,000	21,539,000	E/C				
	S/W support input total/D	23,314,357	1,499,019	13,606,067	14,254,149	55,637,592	E/C	E/C	E/C		180,200	180,200	55,637,592				
	S/W network input total/D				40,664,250	40,664,250							40,664,250				
	Categorical: S/W capital input total/D	18,350,000			40,664,250	103,347,000	7,076,000		7,076,000				110,443,000	[illegible]	[illegible]	[illegible]	[illegible]
	S/W operating exp input total/D	96,918,007	6,757,786	38,524,091	49,219,149	191,443,973	3,785,609	1,782,875	15,377,134	37,266,000	26,499,800	63,765,800	270,756,907	[illegible]	[illegible]	[illegible]	[illegible]
	S/W labor input total/D	E/C	E/C	E/C	E/C	E/C	E/C	E/C	E/C								
	S/W energy input total/D	1,203,710	187,273	1,467,182	1,593,391	4,451,556	148,916	263,247	412,163	1,894,000	1,640,677	3,534,677	8,398,396	[illegible]	[illegible]	[illegible]	[illegible]
ESTIMATE	Estimate system-wide input all actors total	199,462,964	13,383,946	80,608,170	130,558,567	424,043,647	41,513,114	32,820,233	74,340,967	57,677,000	46,167,800	104,044,800	603,351,4[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	S/W primary input total/E	160,321,185	11,260,291	55,411,026	100,349,910	327,342,490	37,842,118	19,943,352	61,842,430	43,518,000	37,454,600	80,978,600	470,163,526	[illegible]	[illegible]	[illegible]	[illegible]
	S/W support input total/E	37,577,553	2,085,847	18,122,676	18,445,876	76,351,952	3,596,644	4,097,811	7,934,455	14,179,000	8,913,200	23,092,200	107,138,607	[illegible]	[illegible]	[illegible]	[illegible]
	S/W network input total/E	1,564,226	62,808	6,974,468	11,742,703	20,349,205	74,952	4,389,090	4,464,042				25,313,247	[illegible]	[illegible]	[illegible]	[illegible]
	Categorical: S/W capital input total/E	4,947,224	1,885,512	23,765,307	56,299,008	123,897,051	4,851,829	12,359,005	19,210,834				144,107,885	[illegible]	[illegible]	[illegible]	[illegible]
	S/W operating exp input total/E	100,550,000	7,650,000	30,470,000	45,180,000	183,880,000	29,337,276	9,678,373	33,015,649	33,110,000	27,930,000	61,040,000	274,[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	S/W labor input total/E	148,727,278	11,152,002	44,279,958	67,213,292	273,571,530	28,244,233	7,631,605	35,875,838	D/C	D/C	D/C	309,447,368	[illegible]	[illegible]	[illegible]	[illegible]
	S/W energy input total/E	1,080,000	10,000	320,000	2,040,000	3,620,000	800,000	400,000	1,200,000	2,660,000	1,880,000	4,540,000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PROXY	Proxy system-wide input all actors total	181,761,400	14,248,800	57,170,800	105,507,000	358,688,000	27,562,200	12,237,600	39,799,800	86,684,000	61,422,000	148,106,000	546,593,800	[illegible]	[illegible]	[illegible]	[illegible]
	Categorical: S/W capital input total/P	36,311,400	2,869,800	11,441,800	34,835,000	85,628,000	11,117,200	5,016,600	16,133,800	42,486,000	30,108,000	72,594,000	174,355,800	[illegible]	[illegible]	[illegible]	[illegible]
	S/W operating exp input total/P	6,130,000	444,000	2,279,000	4,297,000	13,160,000	2,195,000	791,000	2,986,000	13,198,000	9,344,000	22,542,000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	S/W labor input total/P	139,120,000	10,935,000	43,480,000	66,375,000	259,910,000	14,250,000	6,430,000	20,680,000	31,000,000	21,970,000	52,970,000	333,560,000	[illegible]	[illegible]	[illegible]	[illegible]
System-wide actor input totals	S/W operator input total	98,912,964	5,733,946	50,138,170	85,378,567	240,163,647	14,079,105	16,477,378	30,556,483	24,589,000	19,837,800	42,426,800	287,833,683	[illegible]	[illegible]	[illegible]	[illegible]
	S/W government input total	15,350,000			40,664,250	148,273,000	3,536,000		9,463,000			14,990,000	172,666,000	[illegible]	[illegible]	[illegible]	[illegible]
	S/W user input total	319,598,647	24,658,152	99,146,168	169,789,590	613,269,577	53,803,809	19,242,475	73,046,284	134,362,000	98,737,000	233,099,000	919,332,961	[illegible]	[illegible]	[illegible]	[illegible]
	S/W society input total	2,660,000	180,000	631,000	1,037,000	4,508,000	1,197,000	338,000	1,535,000	109,000	77,000	186,000	6,229,000	[illegible]	[illegible]	[illegible]	[illegible]

E/C — Not available
Not applicable
Incomplete Total ▣

URBAN PUBLIC TRANSPORTATION SYSTEM FISCAL INPUT MATRIX 1974

IN CURRENT U.S. DOLLARS

TABLE NUMBER:

ACTOR / SYSTEM / INPUT / DESCRIPTION	PENNSYLVANIA REGION: SEPTA Bus	SEPTA Trolley Bus	SEPTA Trolley Rail	SEPTA Rapid Transit	C.T.D. TOTAL	SEPTA Bus	SEPTA Trolley Rail	R.A.D. TOTAL	SEPTA Penn Central	SEPTA Reading Co	G.C.D. TOTAL	REGION TOTAL	NEW JERSEY REGION: PATCO Rapid Transit	T.N.J. Bus	REGION TOTAL	DELAWARE REGION: DAPT Bus
DISCRETE – OPERATOR	E/C	E/C	E/C	E/C	E/C	E/C	E/C	E/C	E/C	E/C	E/C	E/C	E/C	E/C	E/C	E/C
PRIMARY	E/C	E/C	E/C	E/C	E/C	E/C	E/C	E/C	E/C	E/C	E/C	E/C	E/C	E/C	E/C	E/C
CAPITAL	1,019,600	[illegible]	[illegible]	[illegible]	1,035,000	353,600	[illegible]	383,600	[illegible]	[illegible]	[illegible]	1,238,600	[illegible]	[illegible]	[illegible]	24,600
OP EXP	54,464,775	2,160,548	9,448,425	18,409,988	34,628,648	3,489,414	1,611,024	6,197,409 5,096,448 1,054,203 44,768	11,220,000 11,220,000	10,004,600 10,004,600	21,224,600 21,224,600	21,009,721	3,129,874 3,125,014	E/C	E/C	1,529,289 1,483,663 24,346
SUPPORT – OP EXP	12,078,803	678,909	2,867,449	6,841,444	21,460,540 536,869 20,792,591	1,059,786	1,568,668	5,126,695 3,024,204 148,972 1,648,385 305,134	15,752,000 12,122,000 1,534,000 1,496,000	9,801,400 6,046,400 12,200 1,462,800 2,280,000	28,953,400 19,168,400 2,996,800 3,776,000	44,153,444 605,341 20,722,779	3,262,133 2,624,916 12,000 642,434 30,775	E/C	E/C	1,653,540

URBAN PUBLIC TRANSPORTATION SYSTEM — PHYSICAL INPUT MATRIX 1973

TABLE NUMBER:

Actor / System / Input	Code	Description	Units	PENNSYLVANIA REGION — SEPTA C.T.D. Bus	Trolley Bus	Trolley Rail	Rapid Transit	C.T.D. TOTAL	SEPTA R.A.D. Bus	Trolley Rail	R.A.D. TOTAL	SEPTA G.C.D. Penn Central	Reading Co	G.C.D. TOTAL	REGION TOTAL	NEW JERSEY REGION — PATCO Rapid Transit	T.N.J. Bus	REGION TOTAL	DELAWARE REGION — DART Bus
DISCRETE																			
OPERATOR		OPERATOR Input Totals:																	
PRIMARY		Operator Primary Input Totals:																	
CAPITAL	PDOPNV	NUMBER OF VEHICLES IN FLEET/C	#	1457	131	394	489	2471	191	54	245	243	170	433	3149	75		75	74
	PDOPPV	VEHICLES USED DURING PEAK [illegible]	#	1130	93	271	804	1798											62
	PDOPOV	NO. OF [illegible]	#	1366	131	360	439	2346											
	PDORDV	NO. OF VEHICLES [illegible] DAILY/C	#	1130	93	271	346	1840											
LABOR		Operator Labor Input Totals:																	
	PDOPLT	LABOR HOURS EXPENDED IN DCCT TOTAL/C	HRS	7,951,440	313,236	1,517,526	1,455,841	11,444,043	716,559	304,568	1,021,127				12,465,178	169,999	1,415,620	1,415,670	245,667
	PDOPLD	LABOR HOURS IN DCCT	HRS	7,271,403	457,084	1,290,604	1,047,346	10,072,437	579,742	235,140	814,882				10,887,319		1,195,941	1,365,940	
	PDOPLR	LABOR HOURS RELATED TO DCCT	HRS	680,037	56,152	226,922	408,475	1,371,606	136,817	69,428	206,245				1,577,851		219,679	219,679	
	PDOPET	EMPLOYEES UTILIZED IN DCCT TOTAL/C	#	2385	227	651	1019	4344	334	110	444				4788		610	610	
	PDOPED	EMPLOYEES IN DCCT	#	2013	196	584	790	3585	259	73	332				3917		511	511	
	PDOPER	EMPLOYEES RELATED TO DCCT	#	372	31	127	229	759	75	37	112				871		99	99	
ENERGY		Operator Energy Input Total:																	
	PDOPPK	KWH OF POWER CONSUMED/D	KWH	400.66×10^6	15.9×10^6	124.3×10^6	135.0×10^6	675.9×10^6	49.73×10^6	22.3×10^6	72.03×10^6	109.7×10^6	83.3×10^6	193.0×10^6	941.6×10^6	36.2×10^6	1.02×10^8	138.2×10^6	19.7×10^6
SUPPORT		Operator Support Input Totals:																	
CAPITAL		Operator Capital Input Totals:																	
	PDOSAT	BUILDING FLOOR AREA TOTAL/D	SQ FT																
	PDOSAO	FLOOR AREA OF GENERAL OFFICES	SQ FT																
	PDOSAM	FLOOR AREA OF MAINTENANCE FAC	SQ FT																
	PDOSVB	NUMBER OF REPAIR BAYS/C	#																
	PDOSVG	AVERAGE NUMBER OF VEHICLES IN GARAGE/D	#	91		34		125							125				
	PDOSVP	NUMBER OF PARKING SPACES/D	#				1300	1300				7060	4990	12,050	14,350	8832		8,852	
LABOR		Operator Labor Input Totals:																	
	PDOSLT	SUPPORT LABOR HOURS TOTAL/C	HRS	1,338,450	98,505	722,522	1,233,572	3,302,709	202,011	67,205	269,216				3,571,925		492,424	492,424	
	PDOSLA	MANAG & ADMIN LABOR HOURS TOTAL	HRS	583,660	42,595	184,384	291,831	1,082,130	15,060	11,295	26,355				1,108,485		178,085	178,085	
	PDOSLM	MAJOR REPAIR LABOR HOURS TOTAL	HRS	489,216	15,725	401,856	639,476	1,546,273	122,305	55,910	228,883				2,533,440		203,692	203,692	
	PDOSLR	ROUTINE MAINT LABOR HOURS TOTAL	HRS	265,574	40,185	136,282	302,265	746,306	64,646	13,978	13,978				758,204		110,647	110,647	
	PDOSET	SUPPORT EMPLOYEES TOTAL/C	#	739	55	406	691	1881	115	38	153				2034		195	195	
	PDOSEA	MANAG & ADMIN EMPLOYEES TOTAL	#	307	22	97	193	570	8	6	14				584		86	86	
	PDOSEM	MAJOR REPAIR EMPLOYEES TOTAL	#	280	10	230	365	885	70	24	94				50		58	58	
	PDOSER	ROUTINE MAINTENANCE EMPLOYEES TOTAL	#	152	23	79	173	426	37	8	45				471		51	81	2
NETWORK		Operator Network Input Totals:																	
CAPITAL		Operator Capital Input Totals:																	
	PDONMT	MILES OF TRACK TOTAL/C	MILES			171	58	229		45.2	274.2			265	539.7	33		33	
	PDONMY	MILES OF YARD TRACK TOTAL	MILES				4	4			4				4	4		4	
	PDONMS	MILES OF TUNNEL/SUBWAY TRACK TOTAL	MILES			6	37	43			43				43	5		5	
	PDONME	MILES OF ELEVATED TRACK TOTAL	MILES			0	17	17			17		8	8	25	2		2	
	PDONRM	ROUTE MILES (Two-way)	MILES	1825	41	171	49	2086	614.8	45.2	660			265	925	29		29	
	PDONNS	NUMBER OF STATIONS STOPS/C	#				110	110				97	102	199	309	12		12	
	PDONFA	FLOOR AREA OF STATIONS/D	SQ FT									257,875	20,500	277,875	277,875		2,843	2,843	
SYSTEM-WIDE		Operator System-Wide Input Totals:																	
CAPITAL		Operator Capital Input Total:																	
	PDOWCA	S/W FLOOR AREA TOTAL/C	SQ FT																
LABOR		Operator Labor Input Totals:																	
	PDOWLT	S/W LABOR HOURS TOTAL/C	HRS	9,296,890	611,741	2,240,048	2,627,415	14,746,752	390,472	292,116	1,183,588				15,929,340		1,948,044	1,948,044	
	PDOWET	[illegible]	#	3124	283	1057	1,718	6325	449	148	597				6922		719	719	
USER		USER Input Totals:																	
PRIMARY		User Primary Input Totals:																	
	[illegible]	AVERAGE FARE PAID/C	$	.35	.35	.35	.35	.35	.35	.85	.60	.74	.73	1.47	2.42	.74	.89	0.81	—
	[illegible]	[illegible]	#	1691	117	635	1101	3544			127				3671				
ESTIMATE																			
OPERATOR		OPERATOR Input Totals: [illegible]																	
PRIMARY	[illegible]	[illegible]		1,137,610				1,137,610	170,265		170,265		49,026	49,026	1,356,901		429,514	429,514	64,029
	[illegible]	[illegible]		326.6×10^6	13.4×10^6	104.40×10^6	153.40×10^6	568.64×10^6	41.8×10^6	18.7×10^6	60.5×10^6	92.1×10^6	69.7×10^6	161.8×10^6	790.94×10^6	30.4×10^6	85.86×10^6	116.26×10^6	16.9×10^6
SUPPORT	[illegible]	OPERATOR SUPPORT [illegible]		64.11×10^6	2.52×10^6	19.90×10^6	21.58×10^6	108.27×10^6	7.95×10^6	3.57×10^6	11.52×10^6	17.55×10^6	13.4×10^6	30.95×10^6	150.74×10^6	5.8×10^6	16.32×10^6	22.12×10^6	3.15×10^6
	[illegible]	[illegible]		56.10×10^6	2.20×10^6	17.40×10^6	18.83×10^6	94.72×10^6	6.96×10^6	3.12×10^6	10.08×10^6	15.36×10^6	11.7×10^6	27.06×10^6	131.86×10^6	5.0×10^6	14.28×10^6	19.28×10^6	2.76×10^6
	[illegible]	[illegible]		8.01×10^6	0.32×10^6	2.50×10^6	2.7×10^6	13.55×10^6	0.99×10^6	$.45 \times 10^6$	1.44×10^6	2.19×10^6	1.7×10^6	3.89×10^6	18.88×10^6	$.8 \times 10^6$	2.04×10^6	2.12×10^6	$.39 \times 10^6$
USER / PRIMARY	[illegible]	USER Input Totals: [illegible]		10.2	14.2	14.2	15.2	12.27	34.6	16.1	28.4	21	25.1	22.0	14.4	13.7	41.7	27.4	13
GOVERNMENT / SUPPORT		GOVERNMENT Input Totals:																	
		Government Support Input Totals:																	
LABOR	PGSSLT	GOVERNMENT LABOR [illegible] TOTAL/E	HRS																
	PGSSLT	POLICING & SAFETY LABOR HRS	HRS																
	PGSSLE	LEGAL TRAFFIC [illegible] HRS	HRS																
CONC																			
USER / PRIMARY		USER Input Totals:																	
		User Primary Input Totals:																	
	[illegible]	[illegible] /C																	

KEY: Not Available; Not Applicable; Irrelevant Data

URBAN PUBLIC TRANSPORTATION SYSTEM

PHYSICAL INPUT MATRIX 1974

TABLE NUMBER:

ACTOR / SYSTEM / INPUT	DESCRIPTION	UNITS	PENNSYLVANIA REGION: SEPTA Bus	SEPTA Trolley Bus	SEPTA Trolley Rail	SEPTA Rapid Transit	C.T.D. TOTAL	SEPTA Bus	SEPTA Trolley Rail	R.A.D. TOTAL	SEPTA Penn Central	SEPTA Reading Co	G.C.D. TOTAL	REGION TOTAL	NEW JERSEY REGION: PATCO Rapid Transit	T.N.J. Bus	REGION TOTAL	DELAWARE REGION: DART Bus
DISCRETE — OPERATOR	OPERATOR Input Totals:																	
PRIMARY — CAPITAL	Operator Primary Input Totals:																	
	NUMBER OF VEHICLES IN FLEET/C	#	1462	129	394	489	2474	195	54	249	320	189	509	3252	75		75	94
	VEHICLES SCH'D PEAK ... /C	#	1026	92	348	358	1824	143	41	184	170	145	315	2323	70		70	84
	NO. OF ... VEHICLES/C	#	1348	127	350	489	2311	188	53	241	262	170	432	2984	75		75	94
	NO. OF ... /C	#	1099	92	254	386	1833	149	46	195	185	158	343	1833	72		72	87
LABOR	Operator Labor Input Totals:																	
	LABOR HOURS EXPENDED IN DOCT TOTAL/C	HRS	8,259,884	1,309,765	719,856	1,616,906	11,906,411	738,152	302,065	1,059,217				12,965,628	179,733	1,445,893	1,445,893	338,300
	LABOR HOURS IN DOCT	HRS	7,486,420	1,246,424	460,421	1,149,895	10,341,160	609,856	248,209	857,065				11,198,225		1,248,351	1,428,304	
	LABOR HOURS RELATED TO DOCT	HRS	773,464	63,341	259,435	467,011	1,565,251	148,296	53,856	202,152				1,767,403		217,542	217,542	
	EMPLOYEES UTILIZED IN DOCT TOTAL/C	#	2587	199	701	981	4468	350	101	451	(348)	(283)	(630)	4919		599	599	127
	EMPLOYEES IN DOCT	#	2160	164	556	719	3599	269	72	341	(249)	(265)	(547)	3940		501	547	(0)
	EMPLOYEES RELATED TO DOCT	#	427	35	145	262	869	81	29	110	(98)	(85)	(83)	979	46	98	98	26
ENERGY	Operator Energy Input Total: KWH OF POWER CONSUMED/C	KWH	282.7×10^6	26.92×10^6	127.3×10^6	29.4×10^6	644.32×10^6	28.5×10^6	30.75×10^6	59.25×10^6	96.1×10^6	83.8×10^6	179.9×10^6	880.47×10^6	39.9×10^6	1.02×10^8	141.9×10^6	25.4×10^6
SUPPORT — CAPITAL	Operator Support Input Totals: Operator Capital Input Totals:																	
	BUILDING FLOOR AREA TOTAL/D	SQFT																
	FLOOR AREA OF GENERAL OFFICES	SQFT																
	FLOOR AREA OF MAINTENANCE FAC	SQFT																
	NUMBER OF REPAIR BAYS/C	#																
	AVERAGE NUMBER OF VEHICLES IN GARAGE/C	#	127	2	44	0	173											
	NUMBER OF PARKING SPACES/D	#				1300	1500		710	710	7124	5776	12,900	14,910	8,832		8,832	
LABOR	Operator Labor Input Totals:																	
	SUPPORT LABOR HOURS TOTAL/C	HRS	1,860,678	110,309	797,992	1,376,165	3,844,684	209,270	65,322	274,592				4,119,276		540,865	540,865	
	MANAG & ADMIN LABOR HOURS TOTAL	HRS	687,078	92,661	208,686	350,559	1,299,014	18,825	9,412	28,237				1,327,251		226,526	226,526	
	MAJOR REPAIR LABOR HOURS TOTAL	HRS	866,093	15,725	438,547	697,132	1,797,497	124,051	41,932	165,983				1,963,480		203,692	203,692	
	ROUTINE MAINT LABOR HOURS TOTAL	HRS	307,507	41,923	150,259	328,474	828,173	66,394	13,978	80,372				908,545		110,647	110,647	
	SUPPORT EMPLOYEES TOTAL/C	#	870	62	445	773	2150	119	37	166	469	371	840	2,806		231	231	26
	MANAG & ADMIN EMPLOYEES TOTAL	#	370	29	108	186	693	10	5	15	(51)	(69)	120	708		86	86	17
	MAJOR REPAIR EMPLOYEES TOTAL	#	324	9	251	399	983	71	24	95	(418)	(302)	720	1,038		94	94	6
	ROUTINE MAINTENANCE EMPLOYEES TOTAL	#	176	24	86	188	474	33	8	46				520		51	51	3
NETWORK — CAPITAL	Operator Network Input Totals: Operator Capital Input Totals:																	
	MILES OF TRACK TOTAL/C	MILES			171	68	229		45.2	45.2	269.6	340	609.6	883.4	33		33	
	MILES OF YARD TRACK TOTAL	MILES			19	4	4								4		4	
	MILES OF TUNNEL/SUBWAY TRACK TOTAL	MILES			8	37	43								5		5	
	MILES OF ELEVATED TRACK TOTAL	MILES				17	7					8	8	25	2		2	
	ROUTE MILES (Two-Way)	MILES	1816	41	171	49	2079	576	45.2	621.2	269.6	340	610	3510	29		193	386
	NUMBER OF STATION STOPS/C	#	1429	416	1,018	118	9980	1891	66	1957	144	167	311	12,228	12		12	
	FLOOR AREA OF STATIONS/D	SQFT									251,375	20,500	271,875	271,875		2,843	2,843	
SYSTEM-WIDE — CAPITAL	Operator System-Wide Input Totals: Operator Capital Input Total: S/W FLOOR AREA TOTAL/C	SQFT																
LABOR	Operator Labor Input Totals: S/W LABOR HOURS TOTAL/C	HRS	9,820,962	1,420,014	1,517,348	2,993,071	15,731,095	967,422	367,387	1,333,809				17,064,904		2,006,738	2,006,738	278,700
	S/W ... TOTAL/C	#	2457	261	1166	1794	5618	449	158	607	(969)	(239)	(1698)	7315	272	850	1202	153
USER — PRIMARY	USER Input Totals: User Primary Input Totals: AVERAGE FARE PAID/C	$	.35	.35	.09	.35	.35	.35	.35	.35	.75	.75	.75	.48	.55	.60	.56	.30
	... /C	#	1911	149	697	927	472			158	110	48	159	1388				
ESTIMATE — OPERATOR — PRIMARY	OPERATOR Input Total: Primary; TRANSIT CONTRIBUTION TO POLLUTION/C	LBS	1,198,968				1,198,968	179,109		179,109		1446.9	1446.9	1,379,523.9		434,572	434,572	74,039
	ENERGY CONSUMED IN TRAVEL/C	KWH	199.67×10^6	22.6×10^6	106.9×10^6	209.50×10^6	538.67×10^6	33.9×10^6	25.80×10^6	61.70×10^6	80.70×10^6	70.40×10^6	151.1×10^6	729.47×10^6	33.50×10^6	85.70×10^6	119.20×10^6	4.54×10^6
SUPPORT	OPERATOR SUPPORT ENERGY INPUT TOTAL/C	KWH	58.08×10^6	4.29×10^6	20.34×10^6	39.59×10^6	102.57×10^6	4.56×10^6	4.93×10^6	9.49×10^6	15.40×10^6	13.38×10^6	28.78×10^6	140.84×10^6	6.38×10^6	16.34×10^6	22.72×10^6	4.1×10^6
	OPERATION STATIONS	KWH	34.50×10^6	3.76×10^6	17.80×10^6	34.90×10^6	89.76×10^6	3.99×10^6	4.31×10^6	8.30×10^6	13.50×10^6	11.70×10^6	25.20×10^6	123.26×10^6	5.90×10^6	14.90×10^6	19.88×10^6	3.6×10^6
	REPAIR & MAINTENANCE	KWH	4.75×10^6	0.53×10^6	2.54×10^6	4.99×10^6	12.81×10^6	0.57×10^6	0.62×10^6	1.19×10^6	1.90×10^6	1.68×10^6	3.58×10^6	17.50×10^6	7.98×10^6	3.04×10^6	10.02×10^6	[illegible]
USER — PRIMARY	USER Input Total: Travel; AVERAGE TRIP ... /C	MIN	10.2	14.2	14.2	15.2	12.2	34.6	16.1	28.9	21	25.1	22.7	14.5	13.7	41.7	25.9	12
GOVERNMENT — SUPPORT — LABOR	GOVERNMENT Input Totals: Government Support Input Totals: GOVERNMENT LABOR INPUT TOTAL/C	HRS																
	POLICING & SAFETY LABOR HOURS	HRS																
	LOCAL TRAFFIC ENGINEERING HOURS	HRS																
	LOCAL ADMINISTRATIVE ...	HRS																
CONC. — USER — PRIMARY	USER Input Totals: User Primary Input Totals: FATIGUE OF ... TRAVELING/C																	
	... /C																	

KEY: Not Available / Not Applicable / Incomplete Tot.

TABLE NUMBER:

URBAN PUBLIC TRANSPORTATION SYSTEM

OUTPUT MATRIX : 1973

Regions		System components (primary services / support functions / network / system-wide)	DIRECT OUTPUTS – Operator: Vehicle-miles	Operator: Seat-miles (x10^3)	Operator: Passenger-miles	Operator: Vehicle-hours	Operator: Seat-hours (x10^3)	Operator: Passenger-hours	User: Total person trips completed	User: Rev. passenger trips completed	ESTIMATED OUTPUTS – User	Society: Population served	Society: Employment served	Society: Mobility provision	Society: Area served	Society: Area accessibility to population	Government: Taxes contributed	PROXY (INDIRECT) OUTPUTS – User: Satisfaction from travel	User: Improvement not related to travel	User: Safety gained from travelling with mode	Society: Creation of interaction opportunities	Society: Accessibility to employment	Society: Non-travel use of saved time	Society: Creation of job opportunities	Government: [illegible]	Government: Promotion of gov't's objectives	TOTALLY UNSPECIFIABLE OUTPUTS – Society: Areal organization of space	Government: Defense potential	Government: Requirement for economic growth	Government: National image or prestige	COMMENTS
PENNSYLVANIA REGION (SEPTA)	CITY TRANSIT DIVISION (CTD)	subway	14,324,320	873,764	248,141,020	795,795	48,544	-	56,727,000	55,306,315	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
		trolley rail	8,040,404	402,000	78,270,209	1,006,050	50,250	-	38,069,000	36,236,208	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
		bus	35,499,532	1,775,000	275,926,53[illegible]	5,916,588	295,830	-	124,582,000	115,936,517	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
		trolley bus	2,115,477	97,290	15,491,556	352,574	16,220	-	9,826,000	9,112,678	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
		TOTAL CTD	59,979,733	3,148,054	667,789,341	8,070,007	410,844	N.A.	229,184,000	216,590,718	-	N.A.	N.A.	N.A.	N.A.	N.A.	$ 3,720,000	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	337 million [illegible] citizen [illegible] (peak & off-peak)	N.A.	N.A.	N.A.	N.A.	
	RED ARROW DIV. (RAD)	trolley rail	1,529,370	76,450	31,513,789	-	-	-	6,216,000	5,359,488	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
		bus	5,186,683	259,250	95,964,172	-	-	-	12,300,000	11,876,754	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
		TOTAL RAD	6,716,053	335,700	127,477,961	N.A.	N.A.	N.A.	18,516,000	17,236,242	-	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	[illegible] citizen [illegible] (peak & off-peak)	N.A.	N.A.	N.A.	N.A.	
	GENERAL/CONTRACT OPERATIONS (G.C.D.)	penn central	7,597,233	660,929	206,663,520	-	-	-	17,200,000	17,224,956	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
		reading	6,420,300	532,860	170,861,600	-	-	-	12,200,000	12,204,394	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
		TOTAL GCD	14,017,533	1,193,739	377,525,120	N.A.	N.A.	N.A.	30,316,000 (estimate)	29,426,350	-	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	
	TOTAL SEPTA	TOTAL PENNSYLVANIA REGION (SEPTA)	80,711,319	4,677,493	1,172,792,392	N.A.	N.A.	N.A.	278,000,000	263,253,310	-	3,810,000 (PROJECTED)	1,542,800 (PROJECTED)	1211.7 (DERIVED)	2,185 square miles	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	
NEW JERSEY REGION		patco (rapid transit)	4,080,000	306,000	89,400,000	-	-	-	10,153,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
		tnj (feeder bus)	13,079,000	638,255	171,612,405	-	-	-	9,759,176	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
		TOTAL NEW JERSEY REGION	17,159,000	944,255	261,012,405	N.A.	N.A.	N.A.	19,916,176	N.A.	-	1,994,000 (APPROXIMATED)	N.A.	473.4 (DERIVED)	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	
WILMINGTON REGION		dart (bus)	1,949,739	97,500	-	-	-	-	4,211,436	-	-	442,675 (INTERPOLATED)	-	-	-	-	$ 69,902	-	-	-	-	-	-	-	-	-	-	-	-	-	
		TOTAL WILMINGTON REGION	1,949,739	97,500	N.A.	N.A.	N.A.	N.A.	4,211,436 (EST [illegible])	N.A.	-	442,675 (INTERPOLATED)	N.A.	220.1 (DERIVED)	N.A.	N.A.	$ 69,902	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	

GENERAL GUIDELINES

(1) Any number stated as ⁴ 325,000 ᶜ indicates the source as well as a footnote to it, where the numeral 4 refers to "footnote 4" and the letter C refers to "source C."

(2) All operating statistics are presented on the basis of the calendar year and not the fiscal year.

(3) Data given by source "f" for Wilmington consider only the City and not the total SMSA.

(4) Data given by source "B" were derived data. See internal paper on "Energy Impacts," Dec. 5, 1975.

(5) The following local average vehicular capacity (seats/vehicle) figures were used for determining "seat-miles" and "seat-hours." (a) SEPTA -- subway, 61; trolley rail, 50; bus, 50; trolley bus, 46; Penn Central, 87; and Reading, 83. (b) PATCO -- 73. (c) TNJ -- 48.8. (d) DART -- 50 (taken same as for SEPTA bus). (See source "a_1.")

FOOTNOTES

(1,2) The definition of "person-trips completed" includes the assumption that each "passenger" indicates a single completed person-trip. Transfer passengers are excluded here.

(3) For SEPTA, this data refers to non-agricultural employment.

(4) The indicator for mobility has been suggested as "seat-miles per capita," based on SMSA population.

(5) Accessibility to bus or rail has been defined as the percentage of SMSA population (or employment) within ¼ mile band of bus stops, for bus, or within 4 mile band of rail stops, for rail mode, in any given region.

(6) This refers to "payroll taxes" only. Other forms of contributions would be state gasoline and diesel tax, amortization of bond discount, property taxes, licenses, sales tax on purchase of material, etc. These have not been included since comprehensive data was not available.

(7) Two indicators have been suggested here: (a) Seat-hours per passenger-hour and (b) square feet per passenger divided by 4 square feet.

(8) The indicator suggested for this output is "the number of commercial or noncommercial advertisements in each vehicle in each system."

(9) "Safety gained from travelling" has been defined as "the extent to which the transit system has a better record of accident or incident occurance than other parts of the city (or region)." For instance, if we have transit system record of 5/100,000 user-hours and a housing record of 12/100,000 user-hours, then the system safety output equals (12 - 5) = 7/100,000 user-hours.

(10-18) A satisfactory measure of such conceptual, indeterminate and unspecifiable outputs could not be reached. For further elaboration, see output position paper in Dec. 1 - Dec. 31, 1973 Progress Report.

(19) Data received from Mr. Madison Edgerton (TNJ) on Nov. 10, 1975, in a telephone conversation with Mr. Enrico Bera.

(20) Figures estimated on the basis of data obtained from source a_5.

(21) Assumed approximately same as for 1974.

TABLE NUMBER:

URBAN PUBLIC TRANSPORTATION SYSTEM

OUTPUT MATRIX : 1974

DIRECT OUTPUTS / ESTIMATED OUTPUTS

Regions	System components	Operator: Vehicle miles	Operator: Seat-miles ($\times 10^3$)	Operator: Passenger-miles	Operator: Vehicle hours	Operator: Seat-hours ($\times 10^3$)	Operator: Passenger hours	User: Total person trips completed (1)	User: Rev. person trips completed (2)	Estimated – User	Estimated – Society: Population served	Society: Employment served (3)	Society: Mobility in population (4)	Society: Area served	Society: Area accessibility & population (5)	Government: Taxes contributed (6)
Pennsylvania Region (SEPTA) – City Transit Division (CTD)	subway	15,726,869	959,347	313,630,200	427,801	26,096	–	61,119,000	58,182,425	–	1,935,000	–	–	–	–	Combined figures
	trolley rail	7,765,162	398,250	72,369,458	819,609	44,680	–	57,688,000	35,509,379	–	1,935,000	–	–	–	–	$1,601,232
	bus	34,509,371	1,825,450	274,309,710	3,552,509	177,625	–	134,134,000	115,253,238	–	1,935,000	–	–	–	–	$3,070,624
	trolley bus	2,130,891	98,824	16,593,928	250,244	11,509	–	10,131,000	8,584,664	–	1,935,000	–	–	–	–	$176,747
	TOTAL CTD	62,132,293	3,271,073	674,812,226	5,120,163	259,710	N.A.	262,868,000	215,529,707	–	1,935,000	N.A.	1721.6 (DERIVED)	N.A.	N.A.	$4,849,603
Red Arrow Div. (RAD)	trolley rail	1,614,364	80,700	32,572,598	118,590	5,950	–	6,157,000	5,542,959	–	1,964,620	–	–	–	–	–
	bus	5,456,005	272,700	96,511,156	379,600	18,980	–	13,794,000	11,944,450	–	1,964,620	–	–	–	–	–
	TOTAL RAD	7,068,369	353,400	129,108,754	498,190	24,930	N.A.	19,951,000	17,487,409	–	1,964,120	N.A.	180.1 (DERIVED)	N.A.	N.A	N.A.
General/Contract Operations (GCO)	penn central	7,168,772	623,703	209,435,520	–	–	–	17,309,000	17,453,960	–	3,600,000	–	–	–	–	–
	reading	6,553,700	543,982	179,196,220	–	–	–	12,900,000	12,799,731	–	3,600,000	–	–	–	–	–
	TOTAL GCO	13,722,472	1,167,685	388,631,740	N.A.	N.A.	N.A.	30,252,000 (Estimate)	30,252,691	–	3,600,000	N.A.	324.2 (DERIVED)	N.A.	N.A.	N.A.
Total SEPTA	TOTAL Philadelphia Region (SEPTA)	82,923,274	4,792,158	1,192,631,770	N.A.	N.A.	N.A.	293,057,000	263,269,907	–	4,010,000 (Projected)	1,555,000	1198.0 (DERIVED)	2,200 sq. mi.	N.A.	N.A.
New Jersey Region	patco (rapid transit)	6,354,084	323,550	96,435,932	116,597	–	–	11,110,112	11,100,112	–	456,291	–	–	–	–	$186,752
	tnj (feeder bus)	11,233,000	645,770	150,740,250	946,025 (Estimate)	–	–	10,267,415	10,049,482	–	(Estimate) 1,537,709	–	–	–	–	$786,736 (Estimate)
	TOTAL New Jersey Region	17,587,084	969,320	85,176,182	1,062,622	N.A.	N.A.	12,377,312	21,159,594	–	1,994,000	N.A.	486.9 (DERIVED)	N.A.	N.A.	$973,488
Wilmington Region	dart (bus)	2,574,171	125,700	–	221,191	–	–	4,869,830	–	–	499,493	–	–	–	–	96,935
	TOTAL Wilmington Region	2,574,171	125,700	N.A.	221,191	N.A.	N.A.	4,869,830 (Estimate)	N.A.	–	499,493	N.A.	251.4 (DERIVED)	N.A.	N.A.	96,935

PROXY (INDIRECT) OUTPUTS / TOTALLY UNSPECIFIABLE OUTPUTS

Regions	System components	Proxy – User (2)	User: Independence not related to fears (8)	User: Safety gained from travelling with mode (9)	Proxy – Society (7)	Society: Accessibility & employment (5)	Society (11)	Society: Creation of job opport. (12)	Proxy – Government (13)	Government: Promotion of Govt. & Soc. objectives (14)	Unspecifiable – Society: Area organization of space (15)	Unspecifiable – Government: Defense & ... (16)	Government: Instrument for economic growth (17)	Government: National image or prestige (18)	Comments
Pennsylvania Region (SEPTA) – CTD	subway	–	–	–	–	–	–	–	–	4.2 million Sr. Citizens	–	–	–	–	
	trolley rail	–	–	–	–	–	–	–	–	5.68 million Sr. Citizens	–	–	–	–	
	bus	–	–	–	–	–	–	–	–	37.1 million Sr. Citizens	–	–	–	–	
	trolley bus	–	–	–	–	–	–	–	–	2.19 million Sr. Citizens	–	–	–	–	
	TOTAL CTD	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	49.18 mil. Senior citizen Riders (Peak + Off-peak)	N.A.	N.A.	N.A.	N.A.	
Red Arrow Div. (RAD)	trolley rail	–	–	–	–	–	–	–	–	0.8 million Sr. Citizens	–	–	–	–	
	bus	–	–	–	–	–	–	–	–	2.46 million Sr. Citizens	–	–	–	–	
	TOTAL RAD	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	3.3 mil. Senior Citizen Riders (Peak + Off-peak)	N.A.	N.A.	N.A.	N.A.	
GCO	penn central	–	–	–	–	–	–	–	–	–	–	–	–	–	
	reading	–	–	–	–	–	–	–	–	–	–	–	–	–	
	TOTAL GCO	N.A.	N.A.	N.A.	N.A.		N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	
Total SEPTA	TOTAL Philadelphia Region	N.A.	N.A.	N.A.	N.A	N.A.	N.A.	N.A.	N.A.	N.A	N.A.	N.A.	N.A.	N.A.	
New Jersey Region	patco (rapid transit)	–	–	–	–	–	–	–	–	–	–	–	–	–	
	tnj (feeder bus)	–	–	–	–	–	–	–	–	–	–	–	–	–	
	TOTAL New Jersey Region	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	
Wilmington Region	dart (bus)	–	–	–	–	–	–	–	–	–	–	–	–	–	
	TOTAL Wilmington Region	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	

GENERAL GUIDELINES

(1) Any number stated as "325,000 [4][c]" indicates the source as well as a footnote to it, where the numeral 4 refers to "footnote 4" and the letter C refers to "source C."

(2) All operating statistics are accounted on the basis of the calendar year and not the fiscal year.

(3) Data given by source "f" for Wilmington consider only the City and not the rural area.

(4) Data given by source "P" were derived data. See internal paper on "Energy Impact," Dec. 5, 1975.

(5) The following total average vehicular capacity (seats/vehicle) figures were used for determining "seat-miles" and "seat-hours." (a) SEPTA -- subway, 61; trolley rail, 50; bus, 50; trolley bus, 48; Penn Central, 87; and Reading, 83. (b) PATCO -- 75. (c) TNJ -- 49.8. (d) DART -- 50 (taken same as for SEPTA bus). (See source "a_1.")

FOOTNOTES

(1,2) The definition of "person-trips completed" includes the assumption that each "passenger" indicates a single completed person-trip. Transfer passengers are excluded here.

(3) For SEPTA, this data refers to non-agricultural employment.

(4) The indicator for mobility has been suggested as "seat-miles per capita," based on SMSA population.

(5) Accessibility to bus or rail has been defined as the percentage of SMSA population (or employment) within ¼ mile band of bus stops, for bus, or within 1 mile band of rail stops, for rail mode, in any given region.

(6) This refers to "payroll taxes" only. Other forms of contributions would be state gasoline and diesel tax, amortization of bond discount, property taxes, licenses, sales tax on purchase of material, etc. These have not been included since comprehensive data was not available.

(7) Two indicators have been suggested here: (a) Seat-hours per passenger-hour and (b) square feet per passenger divided by 6 square feet.

(8) The indicator suggested for this output is "the number of commercial or non-commercial advertisements in each vehicle in each system."

(9) "Safety gained from travelling" has been defined as "the extent to which the transit system has a better record of accident or incident occurrence than other part of the city (or region)." For instance, if we have transit system record of 5/100,000 user-hours and a housing record of 12/100,000 user-hours, then the system safety output = equals (12 - 5) = 7/100,000 user-hours.

(10-18) A satisfactory measure of such conceptual, indeterminate and unspecifiable outputs could not be reached. For further elaboration, see output position paper in Dec. 1 - Dec. 31, 1975 Progress Report.

(19) Data received from Mr. Madison Edgerton (TNJ) on Nov. 10, 1975, in a telephone conversation with Mr. Barton Bate.

(20) Figures estimated on the basis of data obtained from source a_1.

(21) TNJ (Southern Div.) figure estimated by proportioning data according to bus-miles served in the Southern Div. relative to the value for total TNJ system (see source "a_1.")

(22) Data for fiscal year 1974.

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(7) FARE Project. Forms of Wage and Salaries for High Productivity, UMTA.

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(3) 1974 National Transportation Study Data, Pennsylvania portion. (Bus includes: Colonial Coach, Huntington Valley, North Penn, Pottstown Transit, Reeders, Schuykill Valley Lines, SEPTA, Short Lines, TX, Wertz)

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