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**THE DEVELOPMENT OF AN
EVALUATION FRAMEWORK
FOR
TRANSPORTATION SYSTEM MANAGEMENT STRATEGIES**

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16. Abstract This report addresses the problem of evaluating alternate TSM strategies to be implemented within metropolitan areas. The requirement of a TSM Element has caused significant confusion among urban transportation planners which were generally indoctrinated in the traditional long-range planning process, and lack knowledge of the consequences of TSM Strategies. In addition, the division of responsibility between implementing agencies and MPOs clouds the TSM planning process even further. This research applied a systems analytic approach to construct an evaluation framework for TSM Strategies. The framework includes the setting of goals and objectives, the identification of measures of effectiveness, the identification of potential TSM Strategies, and the monitoring of those strategies. In order to test this framework, a case study of TSM evaluation within the Omaha-Council Bluffs metropolitan area was undertaken. Based on the review of other TSM Elements and this case study, an implementation program for the framework was proposed. This program includes the identification of the evaluation tasks, an identification of the specific roles for each implementing agency and MPO, and a recommended TSM information system which encompasses data generation, data retention and retrieval, and data transmission.					
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Table of Contents

Acknowledgements	ii
List of Tables	v
List of Figures	vi
	Page
 PART I: SETTING THE DECISION PROBLEM	 1
CHAPTER I: INTRODUCTION	2
Problem Statement	2
Scope of This Project	3
Organization of This Report	5
CHAPTER II: DEFINING THE COMPONENTS	7
Systems Analytic Approach	7
Guidelines For Identifying Operational Objectives and Measures of Effectiveness	8
Identifying TSM Objectives and Measures of Effectiveness For Medium-sized Metropolitan Areas	18
Discussion of TSM Strategies	22
Geographical Orientation of Evaluation	30
Summary	31
CHAPTER III: BACKGROUND OF COST-EFFECTIVENESS AND UTILITY- BASED MODELS	33
Introduction	33
Cost-Effectiveness Models	33
Rank-Based Expected Value Method	35
Value Matrix	37
Utility-Based Evaluation Models	39
An Additive-Utilities Model	40
Strengths and Weaknesses of the Additive Model	43
A Recommended Decision Model	44
CHAPTER IV: MONITORING TSM STRATEGIES	49
Introduction	49
Technique Selection Considerations	49
Monitoring Techniques	51
Simulation	57
Applying the Monitoring Techniques	59
Transit Strategies	59
Computerization of Signal Control	61
Summary	64
 PART II: THE OMAHA-COUNCIL BLUFFS METROPOLITAN AREA: A CASE STUDY IN TSM EVALUATION	 65
CHAPTER V: PROFILE OF THE METROPOLITAN AREA	66
Introduction to Part II	66
Description of the Metropolitan Region	67
Regional Transportation Planning and Programming	73
CHAPTER VI: APPLICATION OF A UTILITY-BASED DECISION MODEL TO EVALUATE ALTERNATE TSM PACKAGES	82

	Page
Introduction	82
Operational Objectives and Measures of Effectiveness	
For the Omaha-Council Bluffs Metropolitan Area	82
Simulation of the TSM Packages	90
Determination of the Weights on the TSM Attributes	93
Specification of the Utility Functions	95
Computation of Total Utility For Each Package	96
Comments on the Additive Model	101
 CHAPTER VII: CARPOOL PROGRAM CASE STUDY	 102
Introduction	102
Background of Metro Area Carpool (MAC)	102
Program Goals and Objectives	104
Program Operations	104
Current Monitoring of MAC Program	106
Instrumentation (questionnaire)	107
Evaluation Methodologies for Marketing Studies	109
Additional Monitoring Techniques and Extended Evaluation	112
SRI Study Data Crosstabulations	112
SRI Study Data Regression Analysis	116
Transportation Zone Analysis	116
Employers Survey Analysis	118
Auto Occupancy as a Measure of Effectiveness	119
Measures of System Performance	120
Summary and Recommendations	125
 PART III: A PROPOSED IMPLEMENTATION PROGRAM	 128
 CHAPTER VIII: SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS	 129
Setting the Decision Problem	129
A Case Study in Evaluation	132
Developing a TSM Information System	134
Integrating the TSM Evaluation Framework Into the "3C"	
Planning Process	143
 APPENDIX A: THE QUANTIFICATION OF A UTILITY-BASED EVALUATION MODEL	 147
 APPENDIX B: CARPOOLING MONITORING AND EVALUATION	 158
 BIBLIOGRAPHY	 164

LIST OF TABLES

<u>Number</u>	<u>Title</u>	<u>Page</u>
1	A Tentative Classification of Verbs Used In Objective State-ments	13
2	TSM Objectives and Measures of Effectiveness	19
3	TSM Strategies	24
4	Matching TSM Strategies With TSM Objectives	29
5	Example of a Value Matrix For a Transportation Plan	38
6	Example of Utility and Effectiveness Values for Certain Objectives	42
7	Examples of Urban Transportation Planning Computer Programs to Simulate Selected Measures of Effectiveness	58
8	A Partial List of COATS Technical Advisory Committee Members	75
9	Transportation Evaluation Criteria for the COATS Year 2000 Plan	78
10	Justification For TSM Project Selection	80
11	Simulated Attributes For Five Abstract TSM Packages	92
12	Ratings and Normalized Weights For the 13 TSM Attributes	94
13	Utility Values Taken Directly From Utility Functions	100
14	Demographic Profiles of Survey Respondents	110
15	Demographic Data Comparisons	115
16	Example of a Statement of Responsibility For a TSM Element: Alternate Form 1	140
17	Example of a Statement of Responsibility For a TSM Element: Alternate Form 2	141
18	Example of a Transportation System Status Report	142
19	Example of a Package of Alternatives: Capital Improvement and Service Oriented	145
A-1	Determining the Weights on Each Attribute	149
A-2	Simulated TSM Attributes	150
B-1	Metro Area Carpool Sample Response Variables	159
B-2	Transportation Zone Sample Data	160
B-3	Employer Survey Sample Response	161
B-4	Employer Auto Occupancy Summary	162
B-5	Crosstabulation: Mode To Work By Work Trip Length	163

LIST OF FIGURES

<u>Number</u>	<u>Title</u>	<u>Page</u>
1	A General Goal Hierarchy	9
2	Example of a Utility Function	45
3	Location Map of the Study Area	68
4	The Omaha-Council Bluffs Standard Metropolitan Statistical Area	69
5	COATS Year 2000 Planning Process	77
6	Graphical Representation of the 13 Single Attribute Utility Functions	97
7	MAC Organizational Structure	105
8	Per Cent Participants By Vehicle Occupancy	120
9	Program Participant Carpooling Subgroups	121
10	Application of the TSM Evaluation Framework	135
A-1	Examples of Utility Functions	153
A-2	Sketches of Your Utility Functions	154

PART I: SETTING THE DECISION PROBLEM

CHAPTER I: INTRODUCTION

Problem Statement

"Congestion," "Energy Crisis," "Fiscal Crisis," and "Environmental Degradation" are common terms used day to day with regard to the performance of many urban transportation systems throughout the nation. The recognition of such problems spurred the enactment of the 1962 Federal-Aid Highway Act which mandated that a long-range transportation plan be prepared for urban areas over 50,000 population (the "3C" planning process). In general, these long-range plans were oriented toward the highway mode and aimed toward the construction of large-scale capital facilities. As these planned facilities were implemented, it became apparent that many adverse by-products are associated with the continuous expansion of our transportation infrastructure and that "something" should be done to improve the efficiency of our urban transportation systems.

One of the earliest concentrated efforts to improve transportation efficiency was made through the enactment of the federal TOPICS¹ program directed toward improving roadway efficiency. However, this effort focused on a single mode and was generally geared toward improving the efficiency of spot locations rather than directed toward a broader geographic area.² The enactment of mass transportation legislation in the mid-sixties and early seventies gave new impetus to the planning of urban transit facilities; but again this program was chiefly a capital improvement program. Environmental legislation, especially the 1970 Clean Air Act Amendments, encouraged planners to consider non-capital intensive projects which could be implemented

¹Traffic Operations Program To Improve Capacity and Safety.

²Some Corridor Demonstration Projects were part of the TOPICS program.

within short-time periods in order to improve the environment.

This overall direction toward improving system-wide efficiency within a multi-modal context combined with a significant money "crunch" eventually led to the requirement of a Transportation Systems Management (TSM) Element as part of the overall urban transportation planning process. The scope of this element is to plan non-capital intensive projects to improve the operation, regulation, and management of existing transportation systems. The requirement of a TSM Element has caused significant confusion among urban transportation planners which were generally indoctrinated in the traditional long-range planning process. Unlike a well-defined capital-intensive facility such as an interstate expressway, a TSM-type project is nebulous and often defies a clear-cut definition. This ambiguity combined with limited experience of the consequences of TSM projects makes it difficult to plan and evaluate such projects. Add to this a division of responsibility which includes local agencies at the implementation level and Metropolitan Planning Organizations (MPO's) at the coordination level, the planning process then becomes even cloudier.

After one examines this problem of planning for TSM projects, it becomes clear that the short-range planning process must be placed on a par with the traditional long-range process. Of course, such a process includes functions such as data collection, forecasting, and evaluation and all of these steps need to be investigated with regard to TSM planning. This report, however, examines only one aspect of the planning process; that is, the evaluation phase. But, the evaluation framework developed herein can be used as an "umbrella" for the entire TSM planning process.

Scope of This Project

The overall purpose of this project was to develop a framework for the evaluation of transportation system management strategies. The general intent

of the research was to construct a practical framework which can be easily integrated into the current urban transportation planning process and which can also be adapted to previously established institutional arrangements within medium-sized metropolitan areas. For this, a systems analytic approach was applied to build the specific components which must comprise the framework. Based on this approach, six specific tasks were undertaken to construct such a framework:

1. The identification of specific transportation objectives which can be achieved through various TSM strategies.
2. The construction of a set of TSM performance measures or measures of effectiveness which are sensitive to TSM objectives.
3. The identification of a set of techniques to monitor the performance of TSM strategies.
4. The development of a decision rule which when given the TSM objectives, measures of effectiveness, and strategies, can be used to evaluate overall performance of TSM strategies.
5. The testing of monitoring techniques for various TSM strategies.
6. The development of an information system for the collection, retention, and retrieval of TSM information.

The scope of this project can be divided into two primary aspects. On the one hand, the research involved the development of a general evaluation framework which can be adapted to specific metropolitan areas. On the other hand, the project scope encompassed the testing of a framework within a "real-world" context. As part of this testing aspect, the evaluation framework was partially applied within one case study area: The Omaha-Council Bluffs Metropolitan area. The testing portion of this project was carried out on the decision rule (see research task 4) and on selected monitoring techniques (see research task 5). Based on the general investigation and the specific case study, a program was developed to implement the evaluation framework within a Metropolitan Planning Organization (MPO).

Organization of This Report

This report is presented in three parts. The first part, "Setting the Decision Problem," outlines the methodology used to construct the evaluation framework. This part discusses the specification of TSM goals and objectives, measures of effectiveness, and strategies and examines how these components can be linked together. Moreover, Part I reviews various evaluation models in respect to their application to the comparison of alternate TSM strategies. As a result of this investigation, it is suggested that an additive-utilities model be further investigated to determine its potential as a TSM evaluation tool. The final component of the framework to be discussed consists of the various TSM monitoring techniques.

Part II, "A Case Study In Evaluation," presents the application of the evaluation framework within the Omaha-Council Bluffs Metropolitan Area. The purpose of this case study was to examine how well the components of the framework fit into the existing institutional arrangements and to assess the potential for integrating the framework into the current transportation

planning process. In order to get a better perspective on the problem a profile of the metropolitan area is presented which includes a description of the metropolitan transportation system and the on-going planning process. Also, a utility-based evaluation model is applied to evaluate alternate "simulated" TSM packages. This test application helped to bring the entire framework into proper perspective with respect to a "real-world" situation. Next, the monitoring of the current carpool matching program within the metropolitan region is analyzed in detail. As a result of this investigation, several recommendations are made to improve the monitoring of a carpool program as a TSM strategy.

The information outlined in the first two parts is brought together in Part III, "An Implementation Program," as a practical instrument which can hopefully be applied within various metropolitan areas. Part III presents an overall summary of the framework, a TSM Information System, and a delineation of evaluation tasks by agencies involved in the process. Furthermore, this part presents a discussion on how the evaluation framework can be integrated into the current urban transportation process.

CHAPTER II: DEFINING THE COMPONENTS

Systems Analytic Approach

The primary purpose of this chapter is to define the specific components which are involved in the general problem and to present the reader with a methodology which he can apply to his specific problem with regard to evaluating TSM strategies. To accomplish this, a systems analytic approach is applied in order to develop an overall evaluation framework for TSM strategies. Systems analysis is a "catch-all" phrase referring to an explicit, theoretical, and deductive approach to problem solving which may have both quantitative and qualitative aspects. A systems analytic framework can be subdivided into four major phases: (1) formulation, (2) search, (3) interpretation and evaluation, and (4) verification. The first phase, the formulation or conceptual phase, identifies the problem or problems and the actors involved in the problem. The problem identification phase concerns the delineation of the system under consideration and the various functional subsystems. Moreover, the formulation phase breaks down the overall problem into a set of desirable goals and objectives along with specific measures of effectiveness.

During the search phase, the analyst selects a set of potential actions which can achieve the goals and objectives laid out in the formulation stage. This process entails the identification of the characteristics of each action and the linkage of those characteristics to the specific objectives. In regard to this linkage, one should attempt to recognize those actions which compliment or conflict with one another in order to narrow the range of potential actions.

Interpretation and evaluation involves the prediction of the consequences of the potential actions and the weighing of those consequences

against the goals and objectives. This phase ends in the actual selection of an action or a set of actions to be implemented to solve the particular problem at hand.

The verification phase encompasses the monitoring of the "real-world" consequences in order to check the actual effectiveness of the implemented actions in achieving the stated objectives. For this, the impact of the actions on the system or subsystem must be carefully measured and compared to the predicted consequences. Also, the overall systems analytic framework should be continuously reviewed and revised according to any weaknesses which are identified in this phase.

Guidelines For Identifying Operational Objectives and Measures of Effectiveness

The heart of the problem formulation stage is the establishment of an explicit goal hierarchy which acts as an "umbrella" for the entire problem solving process. Such a hierarchy is an order of elements which includes: Values, goals, objectives, criteria, requisites, and measures of effectiveness (see Figure 1). These six elements of the goal hierarchy guide the analyst in his search, interpretation and evaluation, and verification, and permit him to fine tune the entire process.

Values represent society's ideals and aspirations which are dynamic in nature and continuously change due to external forces. Examples of societal values are equality, freedom, and affluence. Within a basic value system, a goal is an ideal end or model to which society strives toward to satisfy its value system. Goals are generally broad in scope, have long-range implications, and are something that society reaches for but never obtains. An example of a goal is: To improve the quality of life.

In contrast to a goal, an objective is a specific means to achieve a given end. Objectives are more narrow in scope than goals, they have short-range implications, and they are generally attainable. For instance, the following objective is directed toward the improvement of the quality of

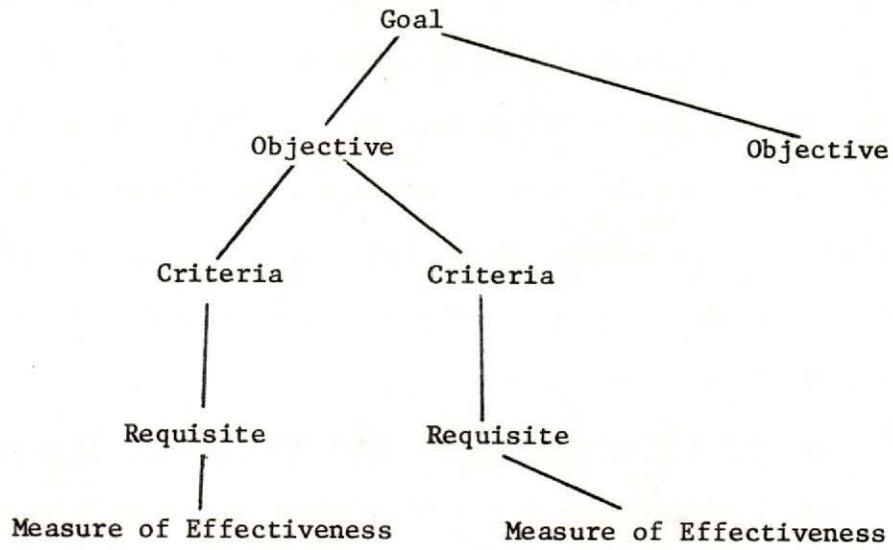


Figure 1. A General Goal Hierarchy

life: To reduce air pollution. Although this objective is more specific than the overall goal, the achievement of the objective is not easily measured. Therefore, in order to measure the achievement of this objective it is necessary to state a specific criterion or a set criteria.

A criterion is a system attribute which can be measured either directly or indirectly in order to determine if an objective is achieved by some action. Following the previous example, one possible criterion to measure the reduction of air pollution would be the number of parts per million of carbon monoxide emitted from a highway vehicle. As Figure 1 illustrates, several criteria or attributes may be associated with a given objective. For example, it may be desirable to measure the number of parts per million of nitrous oxides (NO_x) as well as the level of carbon monoxide. In general, criterion can be quantified as an indicator or as a forecast. An indicator is a descriptor of a current or past value of a given system attribute which may be measured in the field or simulated by a model. On the other hand, a forecast is a predictor of a future value of an attribute which is generally estimated from a mathematical modelling process.

The next element to address within the goal hierarchy includes a statement of requisites which defines the limits of particular criteria. One type of requisite statement, the standard-type requisite, is a normative statement of a given criterion. A standard is an upper or lower threshold of an objective expressed in specific terms. For instance, 5ppm of carbon monoxide emissions may be a standard set for vehicle emissions. Another type of requisite statement is the criterion-type which does not set a specific value for an objective. Thus, the requisite is satisfied if the performance of the system achieves the objective no matter what the degree of attainment. For example, the system performance will be accepted in regard to the objective to reduce air pollution no matter if the pollution

is reduced by 1ppm, 2ppm, or by any amount as long as it is reduced.

The primary purpose of transportation system management is to insure efficient and productive transport operations. As the federal regulation states:¹

The objective of urban transportation system management is to coordinate...individual elements through operating, regulatory and service policies so as to achieve maximum efficiency and productivity for the system as a whole.

Therefore, a TSM objective should be related to the operation, regulation, and service functions and contribute to the efficiency of the transport system.

Within the transportation system management process, a TSM objective should exhibit several important characteristics in order to be fully operational. In the first place, a TSM objective should be clear, concise, and be output oriented, i.e., the objective must connote some action which results in a definitive outcome state or states. A second characteristic, linked to definitive outcome states, is the measurability of the objective. In the ideal objective statement, the outcome would be tangible and could be measured in quantifiable terms. However, in a comprehensive analysis, there will probably be objectives whose outcomes are intangible and must be measured in subjective terms.

In order to better understand the first two characteristics of an operational objective, consider the following simplistic objective statement:

Improve the level of service of the transport system
by reducing the average travel time in the system.

Note that this statement connotes action by the verbs to improve and to re-

¹U.S. Federal Register, "Transportation Improvement Program,"
September 1975, p. 42979.

duce on the system attributes level of service and travel time, respectively. A tentative list of verbs which can be used to connote action in an objective statement is presented in Table 1. Note that certain verbs may be associated with standards (standard-type) while other verbs may be associated with the relative attainment of a criteria (criteria-type). For instance, the verb to reduce in the example refers to the relative attainment of a criteria. That is, the system performance with regard to travel time will be accepted if the average travel time is merely reduced from the existing base by some action. If a decision maker desires to set a standard for this objective, he could rephrase the statement as follows:

Improve the level of service of the transport system
by attaining an average travel time of 25 minutes.

Thus, a definite level of performance is specified and the success in attaining the standard could be measured. It is important to realize that, at this time, one should not be overly interested in how the objective will be attained, but more concerned with whether the objective is measurable or not. In this case, travel time is a tangible criteria which can be directly measured from the system.

Given an objective statement which can be measured, the next question to ask is: Can this objective be attained through the actions of the agencies responsible for the overall TSM process? In general, local agencies will be responsible for implementing TSM actions and therefore, the objectives should be within their authority and control. Along this line, ideally the objective statement should indicate which agency is responsible for the attainment of the object. Related to this characteristic is the range of the objective such as systemwide, corridor, link, or spot application. The characteristics just mentioned could be stated explicitly in the statement, or be reflected in the types of actions to achieve a given objective.

TABLE 1. A TENTATIVE CLASSIFICATION OF VERBS
USED IN OBJECTIVE STATEMENTS

RELATED TO STANDARDS (STANDARD-TYPE)

Accommodate	Attain
Serve	Delimit
Meet	Manage
Prevent	Insure
Operate	Shape
(Not) penetrate	Order
(Not) destroy	Have
(Not) interfere	Is, Equals
Provide	Structure

RELATED TO RELATIVE ATTAINMENT OF A CRITERIA (CRITERIA-TYPE)

Induce	Expand
Promote	Maximize
Reduce	Absorb
Minimize	Alleviate

RELATED TO BOTH CASES

Give
Offer
Guide
Enhance

Source: Boyce, 1972, p. 82

Although a TSM objective is directed toward the effective management of a transport system, specific objectives should be consistent with the entire set of regional transportation goals and objectives. In other words, a TSM objective statement must be developed within a framework of a more extensive set of transportation goals and objectives which reflect physical changes in the system as well as management strategies. Moreover, since TSM actions are generally short-range in scope, a TSM objective should be attainable within a reasonable time period, that is, the objective should be achievable through a short term action or strategy. Ideally, a maximum time limit should be placed on the implementation of the TSM action to achieve a given objective. It is important to note that although TSM actions are short-range in scope they may have long-range consequences. For instance, the success of an intensive carpooling could reduce the need for additional highway facilities. Therefore, the long-range plan for a given metropolitan area could be significantly altered by short-range TSM actions and it is imperative that TSM planning be incorporated into the long-range planning process.

Based on the previous discussion of the characteristics of TSM objective, the following questions should be asked when defining a TSM objective:

1. Is the objective directed toward the operation, regulation, or service functions?
2. Is the objective stated in clear and concise terms and output oriented?
3. Can the objective be measured directly or indirectly, and can it be measured within existing resources?
4. Is the objective within local authority and control?
5. Is the objective consistent with the stated regional transportation goals and objectives?

6. Is the objective attainable within a reasonable time?

Once a definitive set of TSM objectives is established, the next step is to identify specific measures of effectiveness which can be used to determine the degree of objective attainment by any given strategy. For example, although the reduction in the attribute travel time has been identified as a TSM objective, one could use a myriad of measures to determine whether travel time was in fact reduced. He could measure the point-to-point travel time, door-to-door travel time, or he could measure the average speed of automobiles on a section of highway. In order to select the most suitable measure for his specific purpose the analyst must answer two important questions. First, "How well does this measure describe the degree of objective attainment of a given strategy?" Second, the analyst must ask himself: "How difficult is it to either measure or simulate the particular measure of effectiveness?"

Both questions can be answered by analyzing specific characteristics of each measure of effectiveness.² The first question which reflects the level of importance of the measure can be divided into four facets: relevancy, understandability, responsiveness, and uniqueness. It is important that a measure of effectiveness is a relevant descriptor of objective attainment. In general, a measure of effectiveness which directly describes the objective is more relevant than one which indirectly describes the objective. For example, the average point-to-point travel time may be a more relevant evaluator of whether or not travel time is reduced than is perceived travel time. Since the object here is to develop a framework to be used by the decisionmaker, a desirable measure of effectiveness is one which is readily understood. Most decisionmakers probably understand the concept of volume-to-capacity (v/c) ratio, but would have difficulty in understanding the concept of acceleration noise as a descriptor of traffic

²This scheme is based on that used by JHK & Associates, Measures of Effectiveness for Multimodal Urban Traffic Management, November 1977.

flow. A third facet of the level of importance is how responsive the measure of effectiveness is to relatively minor changes in the system caused by the implementation of a TSM strategy. For example, one could attempt to model the level of air quality for the entire metropolitan region, but such a model would most likely be insensitive to variations in the pollution levels caused by a TSM strategy. On the other hand, the direct measurement of pollutants on the street level could be responsive to minor changes such as traffic improvements. Finally, the measure of effectiveness should be a unique descriptor of an objective and not overlap with other objectives. To better understand this facet consider the following two objectives: (1) to reduce travel time, and (2) to improve comfort and convenience. It seems reasonable that point-to-point travel time could be used to measure both objectives, but this would be redundant. Rather it would be more relevant to search for another measure to describe comfort and convenience such as the level of privacy.

After the analyst determines the level of importance of each measure of effectiveness, he must then determine how feasible it is to gather information on each measure. For this determination, he can examine four characteristics of each measure: (1) the ease of quantification, (2) the ease of modelling, (3) the ease of data collection, and (4) the appropriate level of detail. The first characteristic refers to how simple it is for one to express each measure in quantitative rather than qualitative terms. For example, the measure of effectiveness perceived security may be fairly difficult to quantify whereas the number of crimes per year is easily quantified. The ease of modelling refers to the feasibility of developing a mathematical model for a measure within the current state-of-the-art in transportation modelling. Such measures as travel time or v/c ratio can be routinely modeled with current traffic assignment models within reasonable

time and budget constraints, but other measures such as perceived comfort and convenience requires sophisticated modelling techniques which are not yet fully operationalized. Ideally, data collection techniques for a measure of effectiveness should be relatively inexpensive with limited time requirements. For example, an analyst can generally acquire data on the number of accidents without great difficulty, but data on the number of hazardous maneuvers would require sophisticated data collection techniques and necessitate highly trained personnel to interpret the data. The fourth characteristic which is related to the ease in data collection refers to the level of detail required for the particular measure of effectiveness. For example, a 24-hour count is a low-level technique, a 15-minute intersection turning-movement count is a moderate-level technique, and a lane occupancy count is a high-level technique. In general, a low-level technique would be more desirable than a high-level technique because data would be easier and cheaper to obtain and the interpretation would be a routine matter.

Of course, the most suitable measure of effectiveness is one which is both highly important and feasible. But, it is highly unlikely that many measures can be found which fulfill both of these qualities. Rather, it is more likely that the analyst must make trade-offs between importance and feasibility of a particular measure. Moreover, the analyst will be confronted with the problem of how to use each measure of effectiveness according to his specific problem. In this regard, one could structure each measure according to several characteristics of the transportation system such as: (1) mode, (2) time of day, (3) trip purpose, and (4) system component, i.e., route, corridor, or network. For example, the average travel time per mile during the peak hour might be selected as a more relevant descriptor of travel time than the average travel time during the entire day.

It is important to note that the degree of importance and feasibility of a given measure of effectiveness will generally vary from one metropolitan area to another due to different geographic, demographic, and institutional characteristics. Organizations within some metropolitan areas will be more capable to perform certain planning and monitoring functions which other organizations may not be able to carry out. Likewise, the importance of a measure of effectiveness will depend upon the various attitudes within a metropolitan area and the existing state of the transport system. Thus, the transportation practitioners within each metropolitan area must identify the measures which are uniquely relevant to that area.

Identifying TSM Objectives and Measures of Effectiveness For Medium-Sized Metropolitan Areas

Based on the above guidelines, scores of objectives and hundreds of measures of effectiveness³ were reviewed in order to construct a relatively small set of TSM objectives and measures of effectiveness which might be applied to medium-sized metropolitan areas (see Table 2). As used in this report, medium-sized refers to a Standard Metropolitan Statistical Area (SMSA) that has an urbanized area population between 200,000 and 1,000,000. According to the U. S. Bureau of Census (1970) this classification would encompass approximately 78 cities including New Orleans, LA, Indianapolis, IND, Hartford, CT, and Omaha, NE. Of course each metropolitan area is a unique entity, but Table represents a broad range of objectives and measures of effectiveness which should be applicable to this general size of a metropolitan area.

The objectives and measures of effectiveness shown in Table 2 were

³See JHK & Associates, Measures of Effectiveness for Multimodal Urban Traffic Management, November, 1977 for an extensive list of measures of effectiveness.

TABLE 2 . TSM OBJECTIVES AND MEASURES OF EFFECTIVENESS

To Reduce Travel Time

1. Point-to-point travel time
2. Speed
3. Delay time by type of delay

To Reduce Travel Costs

1. Out-of-pocket door-to-door cost
2. Total cost of vehicle operation
3. Generalized door-to-door cost

To Increase Vehicle Occupancy

1. Vehicle occupancy, persons per vehicle
2. Total number of passengers

To Increase Facility Capacity

1. Number of vehicles per hour
2. Level of service, V/C

To Increase Non-Motorized Traffic

1. Number of pedestrians per hour
2. Number of bicycles per hour

To Improve Safety

1. Number of accidents
2. Number of hazardous movements
3. Number of conflicts

To Improve Security

1. Number of in-vehicle crimes
2. Number of crimes waiting for a transit vehicle

To Improve Comfort and Convenience

1. Frequency of service
2. Number of complaints
3. Level of privacy

To Improve Reliability

1. Variance in point-to-point travel time

To Reduce Noise Impacts

1. Number of households within certain noise level contours
2. Number of noise-related complaints
3. Noise levels at certain distances

Table 2 (cont'd)

To Improve Air Quality

1. Number of households within various concentration contours
2. Concentration of particulates by area
3. Emission factors

To Reduce Energy Consumption

1. Total energy consumption
2. Number of gallons of gasoline saved by strategy

To Provide Service to the Transportation Disadvantaged

1. Number of disadvantaged served
2. Percent of total population served

Source: Adapted from JHK & Associates, Measures of Effectiveness for Multimodal Urban Traffic Management, November 1977

identified during the course of the Omaha-Council Bluffs case study (see Chapter VI). The components are presented in a reduced form, but may be combined into a more comprehensive objective statement for inclusion on a TSM Element. An example of such a statement would be:

To improve the quality of transportation service within the metropolitan area by reducing the average point-to-point travel time during the peak hour.

The above statement gives a clear and concise outline of the objective and identifies exactly how the obtainment of that objective will be monitored. The construction of statements such as the above as part of the TSM Element should provide a strong foundation for the evaluation of alternate TSM strategies. The next section discusses specific strategies which can be implemented to achieve the stated objective.

Discussion of TSM Strategies

Once the basic components of the goal hierarchy have been identified, the analyst can search for potential actions in order to achieve the stated goals and objectives. As noted earlier, the type of actions which will be selected are clearly dependent upon the specific TSM objectives and the overall scope of TSM. One of the problems an analyst is confronted with when looking at the realm of TSM possibilities is that no pat definition of a TSM strategy exists. As used in this report, a TSM strategy is a single-focus regulatory operation or management act which is implemented on the transportation system to improve efficiency and/or productivity. In general, a TSM-type strategy deals with a specific transportation network which will basically remain physically unchanged such as the widening of an intersection. Thus, one is analyzing non-capital intensive alternatives rather than capital-intensive facilities. Also, when considering

TSM alternatives an analyst is generally searching for strategies which can be implemented within a short-time duration rather than the standard 10 to 15 years for capital-intensive facilities. In summary, the general characteristics of a TSM strategy are:

1. Relatively low to a moderate implementation costs.
2. Short-implementation time requirements.
3. A management, regulatory, and/or operation action implemented on the transportation system.
4. An action directed toward the achievement of one or more TSM objectives.

Four broad categories of TSM strategies have been identified in the U. S. Federal regulations issued jointly by the Urban Mass Transportation Administration (UMTA) and the Federal Highway Administration (FHWA) (23 CFR Part 450 and 49 CFR Part 613). These are (1) strategies to maximize the efficient use of existing road space; (2) strategies to reduce automobile usage; (3) strategies to improve transit service; and (4) strategies to increase transit management efficiency. Table 3 presents an array of potential strategies which fall within these four broad categories and which have been broken into several subcategories. A further classification of these subcategories is given below.

Traffic Operations. This particular type of strategy includes the traditional "TOPICS-type" improvement such as an intersection widening or a one-way street. The primary purpose of traffic operation projects is to maximize street capacity and minimize congestion. Except for intersection widenings and shoulder construction the bulk of the projects are regulatory in nature.

Traffic Signalization. Improvements to traffic signals ranging from single controllers to area-wide computerized systems can significantly

improve traffic flow.

Parking Management. This is a broad classification of strategies which includes various types of schemes to control passenger-vehicle parking. These strategies are directed either at the control of parking spaces or parking charges both on-street and off-street.

Commercial Vehicles. Basically, the purpose of this type of strategy is to effect better control of delivery vehicles to improve traffic flow. This could entail on-street and/or off-street controls.

Work Schedules. A work-schedule strategy is a non-transportation strategy which can be implemented to reduce peak-hour traffic. The most common work-schedule strategies are the implementation of staggered work hours and the establishment of the four-day work week.

Pricing Policies. Such policies are either monetary incentives or disincentives directed toward reducing automobile usage. The range of policies extends from enacting peak-hour roadway tolls to reducing off-peak transit tolls.

Ridesharing Programs. This is a type of management strategy with the express purpose of increasing automobile occupancy rates. Ridesharing strategies can be either management oriented such as a carpool matching program or regulatory oriented such as a taxi/group riding program.

Paratransit. This classification captures the direct special services provided for the elderly or handicapped including special vans and carpools. Also, included within this category is the coordination of private social service transportation (16b(2)) provided by certain transit authorities.

Pedestrian/Bicycle Measures. These measures are oriented toward improving pedestrian and bicycle facilities in order to provide an adequate

TABLE 3 . TSM STRATEGIES

Maximize the Efficient Use of Existing Road Space

Traffic Operations

- Intersection Widening
- One-way Streets
- Turn Lane Installation
- Turning Movement Restrictions
- New Freeway Lane Using Shoulder
- Exclusive Bus Lane
- Bus Only Street
- Contra-flow Bus Lane
- Reversible Lane Systems
- Freeway Bypass
- Exclusive Bus Freeway Lane and Roadway
- Residential Traffic Control
- Area Licensing
- Freeway Diversion and Advisory Signing
- Freeway Surveillance and Control

Traffic Signalization

- Signal Controller Improvement
- Arterial Signal System
- Area Signal System
- Ramp Metering System

Parking Management

- Curb Parking Restrictions
- Residential Parking Control
- Off-Street Parking Restrictions
- Long-term Parking Charge
- Preferential Rates for Vehicles
- Preferential Rates for Shoppers
- Preferential Spaces for Vehicles

Commercial Vehicles

- Provide On-street Loading Zones
- Provide Off-street Loading Areas
- Prohibit Peak-hour On-street Loading

Table 3 (cont'd)

Reduction In Automobile Usage

Work Schedules

Staggered Work Hours and Flex-time
Four-day Work Week

Pricing Policies

Peak Hour Tolls
Low-occupancy Tolls
Gasoline Tax
Peak/Off-peak Transit Fares
Elderly and Handicapped Fares
Reduced Transit Fares

Ridesharing Program

Carpool Matching Programs
Vanpool Programs
Taxi/Group Riding Programs

Paratransit

Elderly and Handicapped Service
Dial-a-Ride
Coordination of Social Service

Pedestrian and Bicycle Measures

Provide sidewalks
Widen sidewalks
Pedestrian grade separation
Pedestrian malls
Provide bikeways
Provide bike routes
Provide bike storage

Improved Transit Service

Transit Operations

Bus Route and Schedule Modifications
Simplified Fare Collection
Express Bus Service
Bus Traffic Signal Preemption
Bus Terminals

Intermodal Coordination

Park-Ride Facilities
Transfer Improvements

Table 3 (cont'd)

Increased Transit Management Efficiency

Transit Management

Marketing Program
Maintenance Improvements
Vehicle Fleet Improvement

Source: Adapted from JHK & Associates, Measures of Effectiveness for Multimodal Urban Traffic Management, November 1977

alternative to the automobile. Such measures include the construction and widening of sidewalks, signing bus routes, and the provision of pedestrian malls.

Transit Operations. Such strategies are implemented to improve the operation of transit service including bus route and schedule modifications, simplified fare collection, and express bus service.

Intermodal Coordination. This is another subcategory of strategies to improve overall transit service which is specifically geared toward the improvement of the interfacing between modes. Two examples of this type of strategy are the provision of park-and-ride facilities and the improvement of line-haul transfers.

Transit Management. This type of strategy is aimed toward improving the overall management of existing transit service which includes a marketing program and maintenance improvement.

Linking TSM Strategies to TSM Objectives

Given a set of potential TSM strategies, the analyst can link those strategies to the stated TSM objectives. This linkage will help him to identify the most relevant strategies with respect to all the objectives. To better understand how candidate strategies can be screened out to be included in the TSM Element, consider the matching of strategies and objectives shown in Table 4. In this case, thirteen TSM objectives have been matched with the twelve subcategories of strategies described above using these classifications of linkage. These are (1) a potential positive impact of strategy on an objective; (2) a potential negative impact of a strategy on an objective; and (3) no impact of a strategy on an objective. As an example as shown in Table 4, traffic operation strategies are expected to have a positive impact on the objective: to

reduce travel time. On the other hand, pedestrian/bicycle measures are expected to have a negative impact on the same objective. This overall linkage among strategies and objectives will help to identify strategies which have the potential to achieve certain objectives and to pinpoint strategies which may be complementary or conflicting. Thus, the analyst can narrow the range of strategies which will undergo further testing.

Two points must be made with regard to this screening process. First, since the state-of-the-art in forecasting the consequences of TSM strategies is in a relatively early stage, the screening process relies on the subjective judgement of the analyst. Second, the judgement as to the type of impact of a strategy has on an objective is clearly dependent upon the intensiveness of the strategy and the geographic scope of the strategy's application. For instance, a sole intersection widening would not significantly affect travel time on a corridor level. However, at this point in the analysis, the intensiveness of various strategies and their geographic application probably will be unknown, and, at best, this screening is a "jumping off" place for the remainder of the analysis.

Geographical Orientation of Evaluation

If every TSM strategy impacted the transport system on the same geographic scale, the intercomparison of different strategies would be a much easier task. But this is not the case since various strategies do have varying geographical impacts. As an example, a carpool matching program has a system wide impact whereas an arterial signal system has a corridor impact. The first step toward attaching this problem of geographical scope is to identify the basic components of the system. One such classification of the components include (1) nodes; (2) links; (3) corridors; (4) subareas; and (5) the network. Furthermore, several modes of trans-

TABLE 4. MATCHING TSM STRATEGIES WITH TSM OBJECTIVES

Objective \ Strategy	Traffic Operations	Traffic Signalization	Parking Management	Commercial Regulations	Work Schedule Changes	Pricing Policies	Ridesharing Program	Paratransit	Pedestrian/Bicycle Measures	Transit Operations	Intermodal Coordination	Transit Management Techniques
Reduce Travel Time	+	+	-	0	+	+	+	0	-	+	+	+
Reduce Travel Costs	+	+	-	0	+	-	+	0	+	+	0	+
Increase Vehicle Occupancy	0	0	0	0	0	+	+	+	0	+	+	+
Increase Facility Capacity	+	+	+	+	+	+	0	0	+	+	0	+
Increase Non-Motorized Traffic	0	0	0	0	0	0	0	0	+	0	0	0
Improve Safety	+	+	0	+	0	0	0	+	+	+	0	+
Improve Security	0	0	0	0	0	0	+	+	0	+	0	+
Improve Comfort and Convenience	0	0	0	0	0	0	-	+	0	+	+	+
Improve Reliability	+	+	0	0	0	0	0	0	0	+	0	+
Reduce Noise Impacts	+	+	0	0	+	0	+	0	+	+	0	+
Improve Air Quality	+	+	0	0	+	0	+	0	+	+	0	+
Reduce Energy Consumption	+	+	0	0	+	0	+	-	+	+	0	+
Provide Service to Disadvantaged	0	0	0	0	0	+	0	+	+	+	0	+

- + Potential Positive Impact of Strategy on Objective
- Potential Negative Impact of Strategy on Objective
- 0 No Impact of Strategy on Objective

portation operate on the system such as (1) the private automobile; (2) taxi; (3) truck; (4) bus, (5) rail; (6) pedestiran; and (7) bicycle. The system can be further broken down into subsystems such as the highway, transit, and pedestrian networks. Given the realm of geographic possibilities in examining transportation performance, the analyst must address several questions.

1. What are the specific measures of effectiveness for the system on the whole?
2. What are the specific measures of effectiveness for the basic components and subsystems? Are they different than those for the system?
3. How can component or subsystem performance be related to system performance?
4. How can performance of a component be measured across the various modes?
5. How can performance be measured across all the components?

It is beyond the scope of this research to answer each one of the above questions in detail; for a detailed analysis of these questions, the reader is referred to Tomazinis (1975). However, two examples are presented to give the reader a guide toward addressing these problems. First, consider the problem of measuring performance across the various modes of transportation. One could approach this problem by identifying common measures for each mode. For example, the analyst could compare the number of passengers per link-mile or the cost per link-mile for both the automobile and transit modes. Next, consider the problem of relating performance at the component level to the system level. In this case, the analyst could use measures which apply to the link level as well as the system level. For example, he could compare passengers per link-mile on a particular link to the average passengers per link-mile over the entire

transit network.

The varying geographic implications of TSM strategies makes the comparison of strategies on a one to one basis practically meaningless. Thus, it is necessary to group the strategies into TSM "packages." For this, the TSM strategies could be grouped by type of component such as by corridor. The analyst could then construct alternative TSM "packages" and each package could be compared with the other packages. A hypothetical example of a TSM package would be composed of (1) a high level carpool matching program; (2) a moderate level CBD computerized signal system; and (3) a moderate level of businesses participating in a staggered work hours program. Note that the adjectives high and moderate connote the relative intensiveness of the particular strategy with respect to the level of coverage and participation.

Summary

The systems analytic approach can be a helpful technique to construct an overall TSM evaluation framework. This chapter discussed two phases of the systems analytic framework as applied to evaluate alternate TSM strategies; (1) the problem formulation phases; and (2) the search phase. The problem formulation stage involves the identification of an appropriate goal hierarchy which includes goals, objectives, and measures of effectiveness. Furthermore, as part of this stage, the analyst must specify the geographical scope of the transport system under consideration, and he must identify the system component such as highway links or corridors. The search phase is the actual screening of all possible TSM strategies in regard to the goal hierarchy in order to construct a reasonable sized set of strategies to undergo further analysis. This chapter presented an array of TSM objectives, measures of effectiveness, and strategies which might

be applied to medium-sized metropolitan areas. Of course, each metropolitan area is unique in character and some of the components identified herein will not be applicable to certain areas, and others not included in this report might be added as deemed necessary by the analyst. In such cases, the guidelines presented in this chapter for specifying the specific components can be used by transportation practitioners with regard to their specific context.

Assuming that the problem stage has been set and a potential set of TSM strategies has been identified, the next stage is the detailed evaluation of the strategies in order to produce a recommended set of TSM strategies to be implemented. Along this line, the following chapter gives a background of various cost-effectiveness and utility-based evaluation models as applied in various transportation contexts as a result of the investigation of these evaluation models, the research team suggested that an additive-utilities model be further investigated as a tool to evaluate TSM strategies.

CHAPTER III: BACKGROUND OF COST-EFFECTIVENESS
AND UTILITY-BASED MODELS

Introduction

As Manheim (1972, Part A, p. 45) notes, the general problem of evaluation is "How to bring about in the community a course of action from among the many alternatives, when those alternatives have a differential incidence of gains and losses." Thus, the transportation analyst must weigh the consequences generated by a set of projects against the community values in order to select one course of action. This selection process generally involves the careful sifting and sorting of reams of data on transportation goals, objectives, and impacts. In order to better manage this "sifting and sorting" process, many evaluation techniques have been developed over the past few decades and applied to various transportation problems. These techniques range from the traditional benefit-cost analysis to the multi-criterion goal-matrix analysis.¹ To review all these models would require a book by itself. Hence, only two broad categories of models which are deemed the most pertinent to this research are reviewed here. The models discussed below can be separately classified as either cost-effectiveness or utility-based models although there is only a subtle distinction between the two types. Both types of models are based on a systems analytic approach which entails the specification of goals, objectives, and evaluation criteria.

Cost-Effectiveness Models

Cost-benefit analysis is a popular evaluation technique used to measure

¹See Stopher (1976) and Manheim (1972) for further discussion of evaluation models. Also, see Hill (1973) for a presentation of the goals-matrix approach.

the economic efficiency of public works projects. As Mishan (1973, p. 11) notes:

The general question that a cost-benefit analysis sets out to answer is whether a number of investment projects should be undertaken and, if investible funds are limited, which one, two, or more, among these specific projects that would otherwise qualify for admission should be selected.

The traditional single goal of a cost-benefit analysis is to achieve economic efficiency within a given range of projects by selecting the one project among all the alternatives which has the greatest net benefit. To illustrate, consider four highway projects which could link points A and B and which would generate net benefits of 1.0, 1.5, 0.5, and 0.9 million dollars, respectively. According to the above criterion, the project which generated 1.5 million dollars in net benefits would be chosen as the most economically efficient. In order to determine the net benefit of a particular project, the monetary costs and benefits are forecast for each year over the expected service life of the project. The costs and benefits for each year are then discounted to some base year using an assumed rate of interest. Finally, the net benefit is computed by subtracting the sum of the discounted costs from the discounted benefits; or a benefit cost (B/C) ratio is computed by dividing the discounted benefits by the discounted costs. In this latter case, the project yielding the highest B/C ratio would be chosen as the most economically efficient.

A major weakness of the traditional cost-benefit analysis is that this technique measures project efficiency strictly in economic terms while neglecting other tangible and intangible factors. To offset this weakness,

a decisionmaker can evaluate the set of alternatives within a cost-effectiveness framework. As defined by Schofer (1974, p. 103):

Cost-effectiveness analysis is an extension of the traditional cost-benefit approach to include non-monetary impacts and to relate the impacts to the attainment of goals and objectives, i.e., effectiveness. It focuses on a comprehensive assessment of goal-achievement rather than simply capturing only the easily-measured benefits and costs.

Thus, this type of analysis is aimed at achieving a stated objective at the lowest cost. For this, two primary requisites must be met. First, the objectives must be explicitly stated and definite criteria must be enunciated to measure the degree of objective attainment by each course of action. For example, the number of bus miles could be a measure of the objective: to increase bus route coverage. Since more than one objective will generally be stated, the decisionmaker must rank order the importance of each objective and, preferably, put the measures of effectiveness in a common metric. The second requisite of a cost effectiveness analysis is that a monetary cost must be assigned to each alternative under study. Therefore, the end result of the analysis will be the ratio of the weighted effectiveness of each project in obtaining all the stated objectives to the cost of the alternative. The alternative with the highest ratio would be selected as the "best" plan. Two examples of cost-effectiveness analysis applied within a planning context are presented below to illustrate the overall concepts.

Rank-Based Expected Value Method

The Southeastern Wisconsin Regional Planning Commission (SEWRPC) applied this technique to incorporate non-quantifiable as well as quantifiable

factors in the evaluation of regional transportation plans (Robertson, p.6). For this method, the planning staff explicitly stated the regional transportation objectives and ranked each objective according to its importance. Once the alternative plans were developed, each plan was ranked according to its effectiveness in achieving certain standards for each objective. Next, an initial plan value was determined by multiplying the rank of each objective by the rank for the plan's effectiveness in obtaining that objective and then summing the product across all the objectives. Since implementation generally involves uncertainty, the probability of implementing each plan was then multiplied by the initial value to obtain a final plan value. Finally, the plan with the highest final value was chosen as the "best" plan.

The model can be mathematically stated as:

$$V(a) = P(a) \sum_{i=1}^n R_i^O R_i^a \quad (1)$$

where $V(a)$ = the final value of plan a

$P(a)$ = the probability of implementing plan a

R_i^O = the rank of objective i

R_i^a = the rank of plan a in achieving objective i

n = the total number of objectives

Conceptually, this method includes the primary components of a comprehensive evaluation technique: (1) a set of transportation objectives, (2) a set of standards, (3) measures of effectiveness, and (4) the inclusion of uncertainty. On the other hand, the model has some serious weaknesses which blur its viability as a decision-making tool. One such weakness is the use of a ranking scheme rather than a rating scheme. This is a weakness because the ranks for two different plans on the same objective may not

reflect the true difference in the performance of the plans. For example, if five plans, A, B, C, D, and E, yield values for a given time standard of 50, 25, 35, 45, and 20 minutes, the plans would be ranked as follows: A=5, B=2, C=3, D=4, and E=1, where 1 indicates the best score. Thus, according to the ranking scheme, the interval between A and D of 1 is equivalent to the interval between B and C although the respective differences in the standard are 5 minutes and 10 minutes. As a result of using ranks, this evaluation model distorts the true differences among plans.

Value Matrix

An extension of the rank-based expected value method, the value matrix technique, is rooted in a systems analytic approach (Robertson, p. 9). The heart of the analysis lies in the articulation and weighting of the transportation goals, objectives, and evaluation criteria for the system under study. For this, the particular weights can be determined by the use of various ranking, rating, or successive comparison schemes. An important part of this method is the specification of evaluation criteria for each objective, either in monetary terms, other quantifiable, or qualitative terms. Once the criteria are specified, each plan can be rated with respect to each objective. As before, a composite plan score can be determined by multiplying each objective weight by the plan rating and summing the values across all the objectives.

The following example will help the reader to better understand this technique. Table 5 presents a value matrix which consists of three broad goals, six objectives within the stated goals, and seven evaluation criteria for one transportation plan. As an example, one of the three stated goals is to provide efficient economical transportation, and two objectives which

TABLE 5. EXAMPLE OF A VALUE MATRIX FOR A TRANSPORTATION PLAN

Goal	Provide Efficient Economical Transportation		Enhance Environmental, Sociological, and Esthetic Values			Provide a Safe System		Plan Score
Objective	Minimize User Cost	Minimize Indirection	Minimize Air Pollution	Minimize Dislocation		Provide Esthetics	Minimize Accidents	
Evaluation Criteria	User Cost (000)	VMT (000)	VHT (000)	D.U.	B.U.	Rate Plans	Accidents	
Weight	1.3	1.9	1.1	0.7	0.4	1.0	3.6	
Raw Data	\$200	1,820	5,030	0	0	4	4,440	
Rating	0	6	4	10	10	4	3	
Composite Score	0	11.4	4.4	7.0	4.0	4.0	10.8	42

VMT = Vehicle-miles traveled
 VHT = Vehicle-hours traveled
 D.U. = Dwelling units taken
 B.U. = Business units taken

Source: Robertson, undated, p. 12.

are fundamental in obtaining this goal are (1) to minimize user cost and (2) to minimize indirection. The evaluation criteria for objectives (1) and (2) are user costs, expressed in thousands of dollars, and vehicle miles traveled expressed in thousands, respectively. The reader will note that the weights of the two evaluation criteria are 1.3 and 1.9, respectively. Also note that in this example the higher weight assigned to an objective indicates a greater importance of that objective and that the sum of all the objective weights equals 10. The ratings for this particular plan represent the effectiveness of that plan in achieving the stated objective; these ratings are based on an integer scale of 0 to 10 with 10 representing complete effectiveness of the plan in achieving an objective. For example, the plan illustrated in Table 5 has a zero rating with respect to user costs when compared to the other alternatives; on the other hand, since no dwelling units are taken, this plan scores a 10 for this objective. Thus, the plan is successful in achieving some objectives but fails to achieve other objectives. The contribution of this plan to the achievement of each objective is determined by multiplying the objective weight by the rating. For example, the value of plan A with respect to the number of dwelling units taken is $(0.7 \times 10) = 7$. Finally, the total plan score is found by summing the individual values across the six objectives; in this case, the total score is 42.

In order to select the best plan, the decisionmaker must enumerate the scores for all the plans and determine the monetary cost for each plan. His decision rule will be to pick the plan with the highest effectiveness at the lowest cost.

Utility-Based Evaluation Models

The two examples of cost-effectiveness analysis cited above are both

value based; i.e., the decisionmaker's primary goal is to find the plan with the greatest value. Utility-based decision models take these techniques one step further through a more rigorous treatment of utility theory as the basis for making comparisons among alternative courses of action. For this report, a detailed discussion of utility theory will not be presented. However, the overall concept of the utility-based models can be easily summarized. The brunt of the problem is that decisionmakers are generally confronted with many courses of actions which can be implemented to solve a particular problem. Each action, in turn, results in a specific consequence or consequences that may be either desirable or undesirable in nature. In order to weigh the significance of each consequence with respect to solving his overall problem, the decisionmaker assigns a utility, or level of satisfaction, to each consequence. He must then apply a decision model, whether additive, multiply, or another form, to determine the total utility of each alternative with respect to all the consequences. His decision rule will be to select the alternative which yields the highest expected utility.

An Additive-Utilities Model

Schimpeler (1972) presents a utility-based model which incorporates specific utility values for a criterion associated with a specific objective. Furthermore, the model includes effectiveness values which define the performance of an alternative plan with respect to each stated objective.

As a first step in the application of this model to evaluate alternate regional plans for metropolitan Louisville, Kentucky, a task force established a hierarchy of regional planning goals, objectives, and criteria. Given this overall framework, the task force next assigned a numerical utility value, u_j , to each j th objective within a set of n objectives. More speci-

fically, the task force identified 35 specific objectives within a set of ten general community goals; one of the specific objectives identified for this region is to insure safe public facilities (see Table 6). Based on a rating technique, the task force assigned a utility value of 0.0270 to this objective. By definition, the sum of all the utility values was set equal to one. That is,

$$\sum_{j=1}^n u_j = 1 \quad (2)$$

where u_j = the utility of the j th objective

n = the total number of objectives

The next step in the construction of the specific decision model was the identification of effectiveness values; as used here, the effectiveness e_{ij} is an estimate of the probability that objective j can be achieved if a given plan i is implemented (Schimpeler, 1972, p. 244). For example, the three transportation plans under consideration in the Louisville study were assigned effectiveness values for the objective, to insure safe public facilities, of 0.24, 0.56, and 0.82, respectively (refer to Table 6). Alternatively stated, the individuals involved in this study were of the opinion that there was a 24 percent chance, a 56 percent chance, and an 82 percent chance that plan 1, plan 2, and plan 3 would achieve the objective, respectively.

Given the specific utility values, u_j , and effectiveness values, e_{ij} , the following additive model was applied to determine the total utility of a given alternative:

$$U_i = \sum_{j=1}^n u_j \cdot e_{ij} \quad (3)$$

where U_i = total utility of plan i in achieving all the objectives

u_j = the utility value assigned to the objective j

e_{ij} = the effectiveness of plan i in achieving objective j

n = the total number of objectives

For a set of m plans, the model can be stated in a vector notation as:

$$\begin{array}{cccccc}
 e_{11} & e_{12} \cdots & e_{1n} & u_1 & U_1 & \\
 e_{21} & e_{22} \cdots & e_{2n} & u_2 & U_2 & \\
 \cdot & \cdot & \cdot & \times & \cdot & = \\
 \cdot & \cdot & \cdot & \cdot & \cdot & \\
 \cdot & \cdot & \cdot & \cdot & \cdot & \\
 e_{m1} & e_{m2} & e_{mn} & u_{jn} & U_m &
 \end{array} \tag{4}$$

or,

$$U = E u \tag{5}$$

where $U = (u_1, u_2, \dots, u_m)^T$ is a column vector whose components represent the total utility of each plan

E = the $m \times n$ matrix whose components represent the effectiveness values for each plan

$u = (u_1, u_2, \dots, u_n)^T$ is a column vector whose components represent the utility values associated with each criterion

TABLE 6. EXAMPLE OF UTILITY AND EFFECTIVENESS VALUES FOR CERTAIN OBJECTIVES

Criterion (Objective Statement)	Utility Value	Effectiveness Value		
	u_j	Plan 1	Plan 2	Plan 3
Insure safe public facilities	0.0270	0.24	0.56	0.82
Provide for adequate safety regulations and their enforcement	0.3260	0.32	0.76	0.64
Provide for the removal of contaminants (solid, liquid, gaseous)	0.3350	0.30	0.44	0.62
Minimize maintenance costs of	0.0280	0.44	0.60	0.62

Adapted from Schimpeler (1972, pp. 266-267).

Given the above decision model, the decisionmaker would select the plan with the highest total utility among all the alternatives. For the Louisville study, transportation plans 1, 2, and 3 achieved total utility values of 0.38, 0.52, and 0.60, respectively; therefore, according to the above criterion, plan 3 was selected as the "best" plan among the three plans.

Other transportation analysts have applied alternate forms of the additive-utilities model to the evaluation example. Yu (1975) applied an additive model constructed within a cost-effectiveness framework in order to evaluate alternate airport site locations. In a similar type of application, Keeney and de Neuville (Keeney 1976) developed a utility-based evaluation model on the fundamentals of expected utility theory in order to analyze alternate airport development plans for the Mexico City metropolitan area. Also, Boske (1977) presented a linear impact model designed for the evaluation of statewide rail plans. More recently, Wilson and Schofer (1978) used an additive model to develop a regional highway improvement program.

Strengths and Weaknesses of the Additive Model

Of course, similar to all mathematical models, the additive-utilities model has both strengths and weaknesses. The particular strengths of all models are:

1. The model can incorporate an array of objectives and measures of effectiveness.
2. The model is based on expected consumer behavior theory.
3. The application of the model is a relatively simplistic process

But, these particular strengths are countered by certain weaknesses in the model structure including:

1. The specification of the utility values is a subjective process
2. The possible overlapping of the utility values may cause 'double counting' in the model and produce artificial results.

The impact of the model's weaknesses on the final outcome can be minimized by the careful selection of the input parameters and the proper application of the model's results. The analyst must remember that any model is only a tool in the evaluation and the final selection of TSM strategies is basically a political decision. However, the model can be used to narrow the range of choices opened to the decisionmaker and help him to wade through the data.

A Recommended Decision Model

Based on the various types of models studied during the course of this research, the following additive-utilities model is suggested as a tool for evaluating alternate TSM packages:

$$U(x_1, \dots, x_n) = \sum_{i=1}^n w(x_i) u(x_i) \quad (6)$$

where $U(x_1, \dots, x_n)$ = the total utility of a TSM package with regard to all the TSM attributes x_n

$w(x_i)$ = the weight or utility of attribute x_i

$u(x_i)$ = the utility function defined at the attribute value of x_i

n = the total number of attributes

For the above model, each utility function represents the worth or effectiveness of each strategy with respect to a given attribute. For example, consider the utility function shown in Figure 2 for the attribute travel time as measured in minutes per mile. Assume that an infinite number of TSM "packages" exist which can be implemented to reduce travel time.

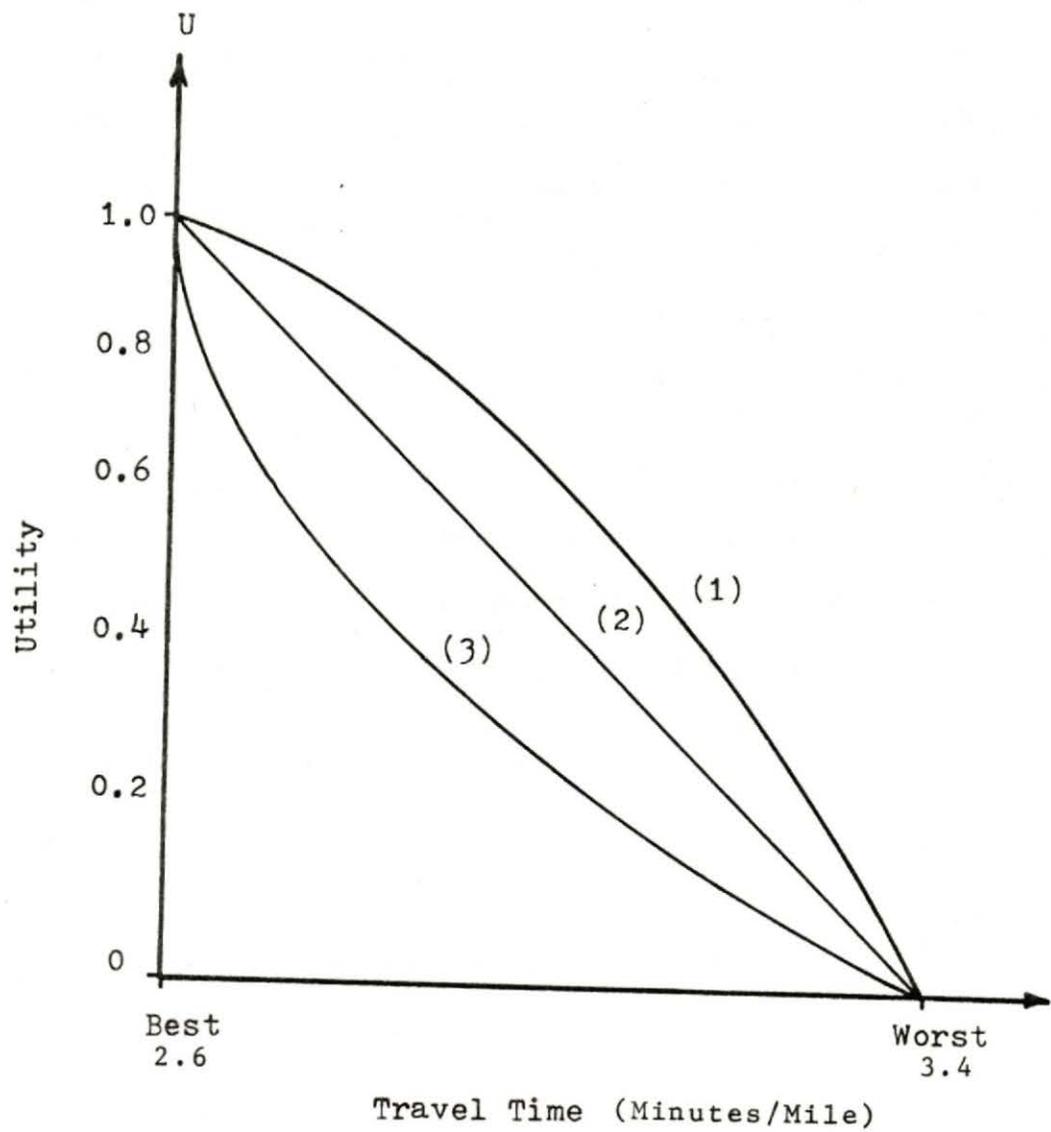


Figure 2. Example of A Utility Function

However, the implementation of the best package will generate an average travel time on the transportation system of 2.6 minutes per mile whereas the worst package generates an average travel time of 3.4 minutes per mile. All other strategies generate travel times which lie between the low of 2.6 and the high of 3.4 minutes per mile. The boundary conditions of this utility function are:

$$u(2.6) = 1$$

$$u(3.4) = 0$$

Thus, the utility function for travel time decreases from one at 2.6 min/mile to zero at 3.4 min/mile. But not all utility functions will decrease as the attribute increases; for example, the utility function for vehicle occupancy will increase as the occupancy rates increase. Therefore, the following general rule for specifying the boundary conditions of the utility functions can be applied either for increasing or decreasing functions.

$$u(\text{best } x) = 1$$

$$u(\text{worst } x) = 0$$

Given the boundary conditions for each utility function, various methods can then be used to define the specific form of the utility function. One simplistic method is as follows: A group of individuals (judges) are asked to assign the values of the attributes at utilities of 0.25, 0.50, and 0.75. In the above example, values of 3.25, 3.05, and 2.85 min/mile are assigned for utilities of 0.25, 0.50, and 0.75, respectively. The analyst could take the mean response among all the judges in order to construct one utility function for each attribute.

The weight $w(x_i)$ on a given attribute represents the strength of preference of an individual or individuals for that attribute. This may be determined through the use of various ranking or rating techniques. As pointed out in the discussion on cost-effectiveness models, rating techniques

are generally superior to ranking techniques for specifying individuals' preferences. One such rating technique can be applied as follows: An individual (judge) assigns a rating to an attribute on a scale between zero and ten with zero indicating that the attribute is of no value and a ten indicating that the attribute is of the highest value. Once each judge has assigned a rating to each attribute, normalized weights ranging between zero and one are computed as:

$$w(x_i) = \frac{\sum_{j=1}^m R_{ij}}{\sum_{i=1}^n \sum_{j=1}^m R_{ij}} \quad (7)$$

where $w(x_i)$ = the weight placed on an attribute; $0 \leq w(x_i) \leq 1$
 R_{ij} = the rating assigned to attribute x_i by judge j ;
 $0 \leq R_{ij} \leq 10$
 n = the total number of attributes
 m = the total number of judges

Once the input parameters for the model have been quantified, the total utility for each TSM "package" with regard to all the attributes can be computed from equation 6. The decision rule for the model is to select the package which yields the highest utility among all the packages. The procedure can be extended to include certain maximum and minimum constraints on the model outcome if the analyst desires. For example, the decision rule could be:

$$\begin{aligned} \max U(x_1, \dots, x_n) \text{ subject to} & \quad (8) \\ w(x_i)u(x_i) & \leq a \\ w(x_i)u(x_i) & \geq b \end{aligned}$$

where a = an upper bound
 b = a lower bound

Another constraint to the selection of a particular package is the direct implementation costs of the package. The analyst must, therefore, attempt to minimize the utility subject to a budget constraint.

The steps involved in applying this model can be summarized as:

1. Determine the objectives and measures of effectiveness
2. Assign weights to the TSM attributes
3. Develop alternate TSM packages
4. Estimate the values of each attribute for each package
5. Determine the shape of the utility function for each attribute
6. Compute the utility of each package from equation 6 subject to predetermined constraints
7. Select the package which yields the highest utility subject to a budget constraint

CHAPTER IV: MONITORING TSM STRATEGIES

Introduction

Monitoring is an essential part of the continuing urban transportation planning process. It provides to the process the information needed to:

- * Define the transportation system and its components
- * Assess socioeconomic and land-use developments and their impacts on the system
- * Identify transportation problems and the need for various transportation system improvements
- * Evaluate the effectiveness of transportation system improvements that have been implemented
- * Develop and refine transportation planning models used to forecast the consequences of transportation system improvement alternatives

In addition to these problem definition and evaluation functions, another aspect of monitoring is process monitoring, which involves observing the operation and progress of the planning process itself.

All of the aspects of monitoring indicated above are pertinent to the incorporation of a TSM element into the urban transportation planning process. However, the scope of this study is confined to the monitoring of TSM strategies for the purpose of evaluating their performance. In this chapter considerations for selecting appropriate TSM performance monitoring techniques are presented, and a basic set of techniques is outlined.

Technique Selection Considerations

There are a number of factors that must be considered in the development of a set of techniques to monitor the performance of TSM strategies. A brief discussion of some of these considerations follows.

- * Measures of Effectiveness - The measures of effectiveness used to evaluate TSM strategies limit the choice of monitoring techniques to those that are designed to provide data pertinent to the assessment of those measures. Any technique that does not provide such information relative to at least one of these measures of effectiveness should not be included in the set. The measures of effectiveness that are included in the evaluation framework developed in this study are shown in Table 2.
- * TSM Strategies - In general a monitoring technique is linked to a specific TSM strategy via the objectives to which the strategy is matched. The objectives to which the strategy is linked determine the measures of effectiveness that must be measured and which in turn indicates the monitoring techniques that should be used. The linkage between TSM strategies and objectives are shown in Table 4 .
- * Geographical Orientation - The geographical scope of the impacts of TSM strategies range from specific-location to system-wide effects. Consequently the set of monitoring techniques employed must also be applicable over this range. For some measures of effectiveness, the same techniques could be used on a system-wide basis as well as on a corridor, link, or specific-location level. But for other measures of effectiveness, more than one technique must be applied in order to properly assess the geographical scope of strategy impacts.
- * Resource Requirements - The selection of monitoring techniques is constrained by the availability of resources. Techniques that require the use of sophisticated equipment and/or highly-trained personnel are likely to exceed budget, time, and staff resources that are usually

available for monitoring urban transportation system improvements.

Therefore, preference should be given to those techniques that provide the data required with a minimal expenditure of resources and that are compatible with the surveillance activities and capabilities that normally exist within medium-sized metropolitan areas.

In terms of the above factors each urban area is different, the particular set of techniques employed in one area may not be suited to another. Therefore, the set of techniques presented in this report is intended to exemplify the scope and nature of the techniques to be used to monitor the performance of TSM strategies in order to apply the evaluation framework developed in this study.

Monitoring Techniques

Techniques that can be used to monitor the performance of TSM strategies with respect to the set of TSM objectives presented in this study were identified. Those techniques which seem to be particularly applicable to monitoring TSM strategies in medium-sized metropolitan areas are briefly described below.

Traffic Counts

Traffic counts are conducted to determine the number of traffic units (e.g., vehicles, pedestrians, passengers) that pass a given point or a particular facility (e.g., highway, bikeway, sidewalk) per unit time (e.g., hour, day, year). The two basic methods of taking traffic counts are:

- (1) Mechanical counts in which traffic volumes are counted using some mechanical/electrical means for detecting the movement of traffic past the point of interest.
- (2) Manual counts in which traffic volumes are counted by observers stationed at the location of interest.

Mechanical counts merely provide at tabulation of the number of vehicles whereas manual counts can provide additional detailed information pertaining to the

traffic units such as vehicle classification, direction of travel, turning movements, and vehicle occupancy. However, manual counts are only practical for relatively short study periods because of the amount of manpower involved. Therefore, mechanical counts are used for measuring traffic volumes over extended periods of time and to monitor the temporal and geographical patterns of traffic volumes, which can be used to expand the results obtained from the shorter manual counts.

Traffic counts can be used to monitor the following TSM measures of effectiveness identified in this study:

- * Vehicle occupancy, persons per vehicle
- * Total number of passengers
- * Number of vehicles per hour
- * Level of service, v/c
- * Number of pedestrians per hour
- * Number of bicycles per hour

In addition, the volume data provided by traffic counts can be used in the computation of the following TSM measures of effectiveness:

- * Generalized door-to-door costs
- * Number of households within certain noise level contours
- * Noise levels at certain distances
- * Number of households within various concentration contours
- * Concentration of particulates by area
- * Emission factors
- * Total energy consumption
- * Number of gallons of gasoline saved

Traffic counts are applicable to all modes and all geographical orientations.

Also, both traffic count methods are regularly used by transportation engineering agencies in all medium-sized metropolitan areas to collect traffic volume data as a basis for planning, designing, and operating the urban transportation system. Therefore, the use of these methods in the monitoring of TSM strategies is compatible with the surveillance activities and capabilities that normally exist within medium-sized metropolitan areas.

Travel Time and Delay Study

The travel time and delay study using the test vehicle technique of data collection can be used to monitor the following TSM measures of effectiveness identified in this study:

- * Point-to-point travel time
- * Speed
- * Delay time by type of delay
- * Variance in point-to-point travel time

In addition, the above measures can be used in the computation of the following TSM measures of effectiveness:

- * Out-of-pocket door-to-door cost
- * Total cost of vehicle operation
- * Generalized door-to-door cost
- * Number of households within certain noise level contours
- * Noise levels at certain distances
- * Number of households within various concentration contours
- * Concentration of particulates by area
- * Emission factors
- * Total energy consumption
- * Number of gallons of gasoline saved by strategy

Data collection involves the use of a test vehicle which is driven over the specified route in a series of runs at speeds judged to be representative of the traffic stream speed. During each run, elapsed times to designated control points are recorded and the durations and types of delays are noted.

This technique is applicable to all modes. And although it is primarily used in the evaluation of projects with link and corridor geographical orientations, this technique can also be applied on a specific-location or system-wide basis. Also, most local traffic engineering agencies in medium-sized metropolitan areas commonly use this technique to evaluate traffic engineering improvements and to provide speed-delay data input to the surveillance element of the continuing urban transportation planning process. Therefore, this technique is compatible with the surveillance activities and capabilities that normally exist within medium-sized metropolitan areas.

Accident Study

Analyses of accident report files maintained by police agencies can be conducted to determine the numbers of accidents by type and location for the purpose of evaluating TSM strategies with respect to the safety TSM objective identified in this study. Accident studies are applicable to all modes and all geographical orientations.

In most medium-sized metropolitan areas, accident record systems are routinely maintained by local transportation agencies to provide a basis for identifying high-accident locations and evaluating transportation system improvements. Therefore, the use of accident studies to monitor TSM strategies is compatible with the surveillance activities and capabilities that normally exist within medium-sized metropolitan areas.

Traffic Conflicts Analysis Technique

Traffic conflicts are defined as any potential accident situations, and are of two types: (1) evasive actions taken by drivers and (2) traffic violations. The traffic conflicts analysis technique is a traffic engineering study designed to measure the accident potential at particular locations by counting the number of traffic conflicts that occur. Thus, this technique can be used to monitor TSM strategies in regard to the safety objective identified in this study.

The traffic conflicts analysis technique is usually used to study the accident potential at specific locations. However, the study results for a number of locations could be aggregated to provide link, corridor, and system-wide geographic orientations. And, as is the case with the other monitoring techniques discussed up to this point, this is a monitoring technique that is commonly used by local traffic engineering agencies, and therefore, it is compatible with the surveillance activities and capabilities that normally exist within medium-sized metropolitan areas.

Noise Level Monitoring

Traffic generated noise can be monitored by direct measurement with a portable sound level meter. Many local governments currently use such devices regularly. However, measurement procedures must state the exact location of the device so that readings made at different times and by different personnel can be compared.

An alternative to the direct measurement of noise levels is the prediction of noise levels by employing computer programs such as the Michigan Version of the NCHRP 117 Noise Predictor Program. Inputs to these programs include traffic volumes, travel speeds, and percent of trucks, which are data that can be provided by the traffic-count and travel-time-and-delay monitoring techniques previously discussed.

Air Quality Monitoring

Governmental agencies regularly monitor overall air quality, the relative amounts of component pollutants, and the geographical distribution of air pollution within metropolitan areas. Although many industries also emit pollutants into the atmosphere, these data can be analyzed to obtain an average areawide level of transportation-related pollutants.

Transportation-related pollutants can also be measured directly by systematically gathering air samples along heavily traveled links. By analyzing these samples, it is possible to identify areas with serious concentrations of pollutants, and thus monitor the effects of TSM strategies on air quality.

An alternative to the direct measurement of air quality is the use of computer programs to predict the amounts of transportation-related pollutants (e.g. The transportation model and emissions model contained in the FHWA PLANPAC Package). In addition to a description of the transportation network, inputs to such programs include traffic volumes, vehicle type distribution, and average vehicle speeds, which can be obtained from the use of the traffic-count and travel-time-and-delay monitoring technique previously discussed.

Energy Consumption Monitoring

Gasoline consumption can be estimated in a number of ways. The following methods are some that seem to be applicable to the monitoring of TSM strategies:

- * Gasoline Sales Tax Revenues - Total tax revenues are divided by average tax per gallon to yield gallons of gasoline sold. This method is applicable to all modes, but it has an areawide geographical orientation.
- * VMT Estimates - Gasoline consumption is estimated based on estimates of total vehicle miles traveled by vehicle type multiplied by average per mile fuel consumption rates for each vehicle type. This method can be applied on a link, corridor, or system-wide basis.

*Delay/Stops Algorithm - Gasoline consumption is computed as a function of the reduction in vehicle delay and the reduction in the number of stops required. This method is limited to estimates of automobile fuel consumption, but can be applied over the range of geographical orientations from specific location to system wide.

In addition to the methods presented above, transit fuel consumption can be obtained from the records maintained as part of the UMTA FARE reporting requirement. Also, computer programs contained in the FHWA and UMTA urban transportation planning packages can be used to simulate energy consumption on a link, corridor, or system-wide basis.

Simulation

Simulation can be considered a monitoring technique in the context of the planning and evaluation of TSM strategies. As indicated in the discussion of monitoring techniques presented above, there are a number of urban transportation planning computer programs that can be used to simulate some of the TSM measures of effectiveness identified in this study. Some additional examples are shown in Table 7. The computer programs are commonly used in the urban transportation planning process. Therefore, their use in the planning and evaluation of TSM strategies is compatible with the planning resources that are typically available in medium-sized metropolitan areas.

Besides the transportation computer programs, certain measures of effectiveness can be simulated by less sophisticated mathematical algorithms. For example, highway capacity graphs can be used to compute V/C ratios and Environmental Protection Agency (EPA) emission factors can be used to compute transportation emissions. A further discussion on how specific measures of effectiveness can be measured and modeled is presented in Chapter VI.

Table 7 . Examples of Urban Transportation Planning Computer Programs to Simulate Selected Measures of Effectiveness

Measure	Geographical Basis		
	Link	Corridor	System
Travel Time	CAPRES	SUMPED	CAPRES
Travel Cost	LNKCOST	LNKCOST	LNKCOST
Facility Capacity v/c	CAPRES	SCREEN	SCREEN

Note: Computer Packages are a part of the FHWA PLANPAC Package.

Applying the Monitoring Techniques

The most important question to be addressed in TSM monitoring does not appear to be: Can this measure of effectiveness be monitored?, or even, What specific technique should be used? But, rather, the most important question to answer is: How can a given measure of effectiveness be tied to a specific TSM strategy or a package of TSM strategies through the application of various monitoring techniques? The ultimate objective of TSM monitoring, then, is to determine what affect a strategy or group of strategies has on a particular measure of effectiveness. In order to achieve this objective, three fundamental concepts should be followed. First, monitoring should be carried out in a systematic manner such that measures of effectiveness and specific monitoring techniques are consistently applied to the various types of strategies. Second, monitoring should be carried out within a geographic stratification of the transport system including nodes, links, corridors, and subareas. Third, monitoring should be periodic and conducted on a continuous basis beginning with some base condition and a base year.

In order to better understand these three concepts which should be followed in TSM monitoring, two examples are presented. The first example discusses the monitoring of transit strategies and the second example discusses the monitoring of a computerized traffic signal system.

Transit Strategies

This is a hypothetical example to illustrate how a transit authority should monitor various transit TSM strategies. Since the FARE system (Financial Accounting and Reporting Elements) is a monitoring requirement which must be met to receive federal transit funds, this comprehensive monitoring technique easily fits into the overall framework. FARE encompasses surveys and field measurements which are carried out on a periodic basis

with respect to many transit related measures of effectiveness including: (1) point-to-point travel time, (2) speed, (3) delay time, (4) vehicle operation costs, (5) number of persons per vehicle, (6) total number of passengers, (7) number of bus accidents, and (8) energy consumption. The important point is that the FARE system requires that a transit authority monitor the transit system with regard to many of the TSM measures of effectiveness which are identified in this report.

Given that the FARE system is a mechanism to collect certain measures of effectiveness, the real need is to relate this mechanism to transit related strategies. In order to achieve this, the transit authority should define a base condition which consists of the existing network, routes, fleet, operation standards, and a mix of TSM strategies. This will set a reference point and year for evaluating the effect of any future strategies on the measures of effectiveness. It is vital that the transit network be broken down into geographic components and that each strategy be associated with a particular component. For example, an express bus route might be associated with Corridor A and a park-and-ride lot might be associated with Corridor B of the network.

Once the base transit condition is defined, the measures of effectiveness can be monitored for some base period. This should be done in a systematic pattern over the entire network and should be referenced according to time of year, time of day, and climatic conditions. Due to the nature of certain TSM strategies, the base condition will fluctuate to some degree. For example, an authority might institute a "dime-day" before the measures of effectiveness can be monitored for the base condition. Thus, it will be necessary to schedule these strategies "around" the monitoring activities when appropriate.

Since the FARE system provides for periodic monitoring, trends can be established for the measures of effectiveness over time. If a new transit TSM package is implemented then the strategies in that package should be treated the same as those for the base package. Thus, continuous monitoring can be carried out which is sensitive to the measures of effectiveness, strategies, and the overall transit network.

Computerization of Signal Control

The monitoring of traffic signal system improvements should relate to the specific goals and objectives identified for the strategy. As previously established, these goals and objectives are quantified through identification of the change in given measures of effectiveness over a period of time. The monitoring of signal improvements will relate directly to the type and physical scale of the improvement. For example, the installation of a traffic-actuated controller may provide maximum intersection efficiency when measured at an isolated location. However, if efficiency is measured on a link or system basis, the improvement may not provide link progression, and thus become a system deficiency.

The implementation of a computerized traffic signal system has link and network impacts, and as such the monitoring provided should reflect those impacts. For example, in the City of Omaha the type of monitoring used for evaluation of the impacts associated with the installation of a computer signal control was based on the changes in link measures of effectiveness. More specifically, those measures of effectiveness were traffic volumes, vehicle stops, travel time, and accidents. The need to establish a data base is obvious for a "before and after" comparative analysis. However, any preliminary data collection needed to establish a base condition should be qualified within the context of the existing system. More simply,

is the conventional control equipment along the sample link operated efficiently in the first place? Thus, it is necessary to determine the level of signal coordination previously provided to establish the actual impact of the new action.

The efficiency of the "before" system is directly related to the monitoring of vehicle stops and travel time. Again, in the City of Omaha, vehicle stops and travel time were monitored for changes in the before and after study using the moving vehicle method.

The most noticeable change improvement to the motoring public was the improved traffic flow resulting in less congestion, fewer stops and reduced travel time. Fewer stops and reduced travel time directly benefited the motorist by reducing travel costs. The collected data indicated that after computerization, an average decrease of 18% in travel time and a 52% reduction in stops were achieved. (Krajicek, 1978).

Also, for the Omaha system traffic volumes which are monitored on a periodic basis and traffic accidents which are monitored continuously provide an effective data base for comparative analysis. In this case, a reduction in traffic accidents was achieved which can be attributed to the computer system. However, the recorded change in traffic volumes between before and after conditions was not significant.

The actual evaluation of a computerized signal system cannot be completely quantified by system measures of effectiveness alone. This unique type of TSM strategy provides for continuous system monitoring of operational functions (i.e., volume, occupancy, speed, stops, and delays) and provides automatic reporting of system failures. The computerized traffic

control system incorporates the desirable attributes of signal interconnected systems and volume-density signal controllers. This represents an area-wide coordination of a traffic responsive system.

System efficiency can be improved through a reduction in the system volume (V) to capacity (C) measured over time. The desired effects of transit TSM strategies is to reduce the volumes on the street thereby reducing the V/C ratio. In contrast, the computerized traffic control system provides for an increase in capacity and a corresponding reduction in the V/C ratio. The resultant reduction in stops and vehicle delay provide for increased safety, reduced energy consumption, and a reduction in pollutants to some degree. The effectiveness of computerized signal control, while ever changing to adapt to the traffic environment, is constrained by the physical conditions of the roadway; thus, changes in the measures of effectiveness will stabilize over time.

In sum, one interesting point about a computerized signal system is that it is both a TSM strategy and a TSM monitoring technique. It can be implemented to change certain measures of effectiveness and it can be used to collect data on those measures. Moreover, computerized signal control fulfills the three fundamental requirements of a monitoring technique: it is systematic, geographic, and periodic.

Summary

This Chapter presented various techniques to monitor TSM strategies and the factors which an agency must consider in order to select a specific technique. Literally, hundreds of techniques exist which could be used to monitor the measures of effectiveness identified in Chapter II; only a small subset of those techniques was discussed here. In looking back on the examination of these techniques, the primary constraint in selecting one technique over another appears to be the time and money resources which are available within a given metropolitan area. Within specific resource limitations, the key to successful TSM monitoring appears to be the manner in which monitoring is carried out within the metropolitan area. In this regard, this research recommends that TSM monitoring should be (1) carried out systematically with respect to the measures of effectiveness and the specific techniques; (2) based on a geographic stratification of the transportation system; and (3) conducted periodically beginning with some base year.

PART II

THE OMAHA-COUNCIL BLUFFS METROPOLITAN AREA:

A CASE STUDY IN TSM EVALUATION

CHAPTER V. PROFILE OF THE METROPOLITAN AREA

Introduction to Part II

The primary purpose of this segment of the research effort was to apply the general framework presented above to evaluate alternate TSM strategies within one case study area: the Omaha-Council Bluffs metropolitan area.

The scope of this case study included:

1. A descriptive analysis of the metropolitan transport system and the ongoing regional transportation planning and programming process.
2. The application of a utility-based decision model to evaluate alternate TSM strategies. This included the identification of 13 TSM objective statements, the simulation of five TSM "packages," and the quantification of the model parameters.
3. The analysis of current techniques used to monitor the metropolitan area carpool (MAC) matching program and the investigation of other monitoring techniques such as questionnaires and field surveys.

The intent of this case study was to assess the potential for integrating the general framework into the current urban transportation planning process and to explore candidate TSM monitoring techniques which can be adapted to the current institutional framework. However, the results of this case study are limited due to data constraint, and time and budget restriction. Thus, a thorough analysis is lacking of the complete framework beginning with the setting of objectives and ending with the monitoring of the strategies. But, the examination of some of the 'pieces' of the frame-

work did provide an adequate picture of the evaluation process in order to construct a suggested implementation program (Part III).

Description of the Metropolitan Region

The Omaha-Council Bluffs metropolitan area is a major midwestern region centrally located within the United States (refer to Figures 3 and 4). The Standard Metropolitan Statistical Area (SMSA) is composed of Douglas and Sarpy Counties, Nebraska, and Pottawattamie County, Iowa, and includes over 20 incorporated cities, towns, and villages (MAPA, 1971, p. 5). Among these municipalities, the three most important are the Cities of Omaha and Bellevue in Nebraska and the City of Council Bluffs in Iowa. The Missouri River, a primary inland waterway, divides the region into the Nebraska and Iowa portions, and the Platte River borders the southwestern portion of the region. Within the SMSA, the physical terrain is a gently rolling landscape with only a few natural barriers to urban development; the most prominent are the flood plains of the Missouri and Platte Rivers and the wind-deposited loess hills on the east bank of the Missouri River.

As a result of limited physical restrictions on growth and intense agricultural activity, the SMSA grew in population from 100,000 inhabitants in 1870 to over 600,000 by 1976 (MAPA, 1971, pp. 14-15, and MAPA, 1976, p.17). Historically, urban growth concentrated in the City of Omaha which currently accounts for over 60 percent of the total SMSA population¹, but more recently the pattern of growth has shifted to the southwestern portion of the region, primarily concentrating in the City of Bellevue and Sarpy County. Although the Omaha-Council Bluffs area has undergone significant urban development, the amount of developed land accounts for only ten percent of the total land area. Hence, the SMSA remains oriented toward agriculture which continues to

¹The legal boundaries of the City of Omaha have continuously expanded and literally captured the outward population growth.

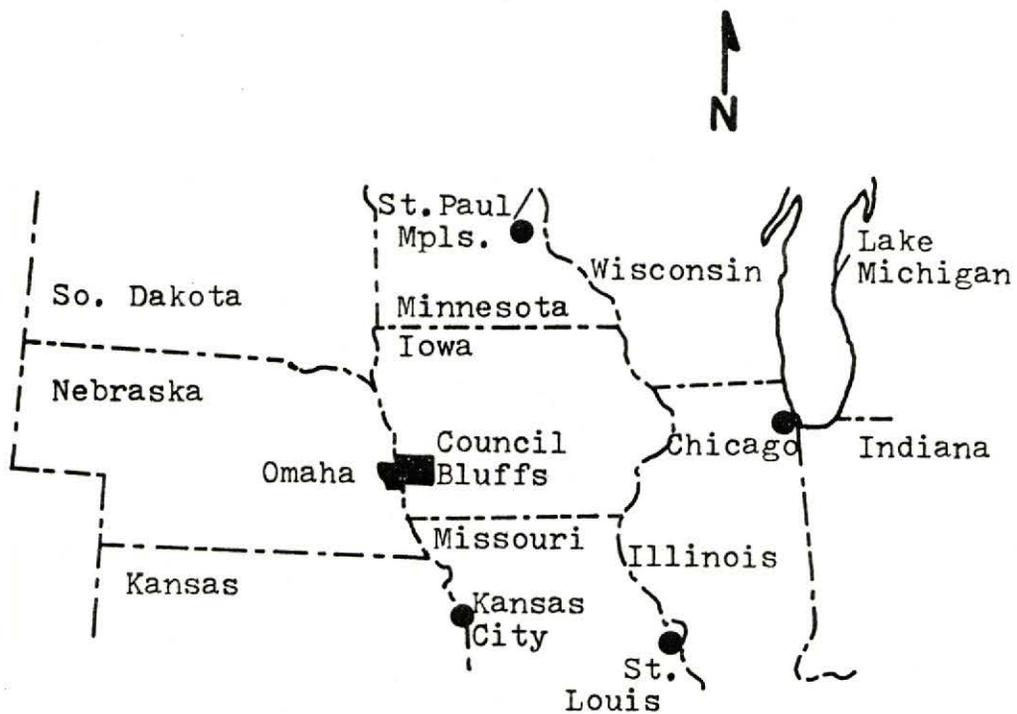


Figure 3. Location Map of the Study Area

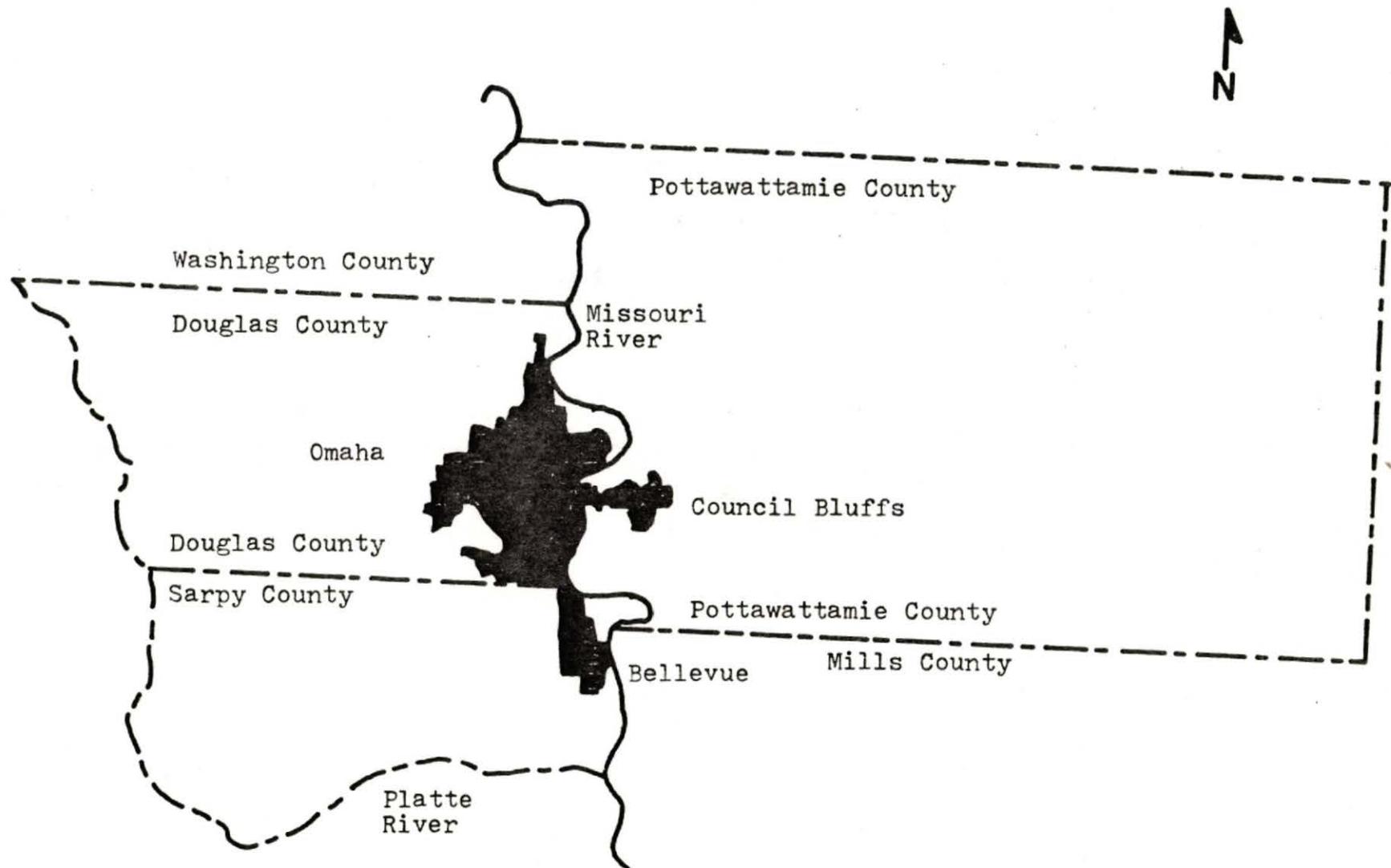


Figure 4. The Omaha-Council Bluffs Standard Metropolitan Statistical Area

be the economic mainstay of the region. However, since 1950, agriculturally-oriented employment has declined, and employment in the trades and services has grown (MAPA, 1971, p. 44).

The urban core of the region consists of the central business districts (CBD's) of Omaha and Council Bluffs and their adjacent residential areas. Downtown Omaha is a prominent regional center for retail, government, and medical services which has recently undergone extensive renewal, including new private and civic office buildings, a new library, and a new pedestrian mall. Council Bluffs has undergone a similar renewal effort but to a lesser extent than Omaha's effort. Despite this revitalization of the downtown areas, urban development continues to extend outward from the core areas. This extension has been in a north-south direction in Iowa and an east-west direction in Nebraska, resulting in an egg-shaped pattern with the narrow end of the egg located on Omaha's western bounday. In general, development has "...sprawled outward in a low density pattern being serviced by lineal commercial development" (MAPA, 1971, p. 9). Moreover, this growth has been accompanied by the outward movement of large-scale office buildings and the formation of suburban shopping centers and industrial parks. Hence, the activities within this region, similar to activities in other regions throughout the nation, are widely dispersed and poorly linked together. One report has clearly summarized the impacts of this outward urbanization:

A subdivision springs up outside of a community and requests extension of utilities or annexation with its accompanying tax burdens. An inner city neighborhood slowly decays and its residents move out leaving behind expensive and underutilized public facilities

in the form of streets and sewers. Suburban shopping centers develop around the fringes of a metropolitan area attracting regular customers away from the central business district of the communities and older established shopping centers (MAPA, 1977, p. iii).

Of course, the transportation system is an integral part of the urbanization process which has taken place within the Omaha-Council Bluffs metropolitan area. But, because a "chicken-and-egg effect" is present, it is difficult to assess the exact relationship between land development and the existence of transportation facilities. That is, one may say that the construction of transportation facilities is followed by land development; or one may say with equal accuracy that land development is followed by the construction of transportation facilities. In any event, the two happenings are inextricably linked together within the overall urbanization process, and the linkage between land use and transportation is clearly evident in this metropolitan area. If one maps the present and projected urban growth within the region, he will notice a distinct clustering around the major interstate expressways, I-80, I-480, I-680, and I-29. The generally well-developed radial and circumferential expressway system has significantly increased the accessibility to the outlying portions of the region; thus, the outward expansion has been encouraged by the increase in transportation capacity. Furthermore, the influence of the expressway system on the growth process has been aided by the arterial grid system although the system is plagued by connectivity problems. But the "sprawling" of regional development has placed severe burdens on the east-west transportation links. Moreover, the outward movement of development has resulted in significant excess highway capacity in the core areas.

The burden on the transportation system is further increased by low automobile occupancy rates which have been encouraged by the ubiquitous highway system, sprawling growth, and high automobile ownership². Compared with a national average for work trips of 1.4 persons per vehicle (U.S. Department of Transportation, 1974, pp. iv-5), the occupancy rate for the same trip purpose in the Omaha-Council Bluffs area is relatively low at 1.27 persons per vehicle (Ridel, 1977, p. 10). Over the years, the growing usage of the automobile has contributed to the deterioration of the regional transit system as well as the highway system. In 1946, bus transit accounted for approximately 41 percent of the total person trips in the metropolitan area; however, this percentage declined to about 14 percent by 1956 and further declined to about two percent by 1971 (COATS, 1973, pp. 2-3). At present, this decline in importance of bus transit as a transportation mode has apparently "bottomed out," and it is anticipated that the percentage of total person trips will remain at the two percent level.

The overall state of the metropolitan transportation system can be capsulized by several generalized statements. First, highway capacity is unevenly distributed such that the east-west links are generally below a desirable level of service, and the north-south links as well as the downtown street system exhibit excess capacity. Second, automobile occupancy rates on the system are low, and alternate modes to the automobile, including mass transit and pedestrian walks, are severely limited. Third, noise pollution, air pollution, and energy waste are undesirable by-products of the "sprawling" development. Fourth, the arterial system lacks connectivity and continuity.

²The number of automobiles per person in the SMSA has increased from 0.38 in 1960 to 0.50 in 1976 (MAPA, 1976, p. 17).

At the route of these "inefficiencies" are issues concerning how transportation facilities are planned and how resources are allocated among transportation facilities. Specifically, these issues include the long-range planning process, the institutional arrangements within the region, the evaluation methodology used to select projects, and the linkage of long-range planning to short-range implementation. The following section presents a description of the current regional transportation planning and programming process as a background to how these issues are addressed in the Omaha-Council Bluffs metropolitan area.

Regional Transportation Planning and Programming

Within the Omaha-Council Bluffs metropolitan area, the Continuing Omaha-Council Bluffs Metropolitan Area Transportation Study (COATS) is the designated Metropolitan Planning Organization (MPO) to carry out the "3C" planning process. This multi-agency organization is structured along the traditional "3C" organizational pattern which consists of a policy committee, a technical committee, a technical staff, and a citizens' advisory committee. Since COATS is an integral part of the Metropolitan Area Planning Agency (MAPA),³ this agency's board of directors acts as the Policy Committee to the transportation study. Furthermore, MAPA provides the lead technical staff for the regional transportation planning process as well as the overall comprehensive planning process with additional technical assistance provided by the Nebraska Department of Roads and the Iowa Department of Transportation. The members of the Technical Advisory Committee function as advisors to the technical staff, and they also act as coordinators between the staff and the local implementing agencies.⁴ A partial listing of the members of this

³The MAPA planning region includes the SMSA plus Washington County, Nebraska, and Mills County, Iowa. The COATS transportation study includes the urbanized portion of the SMSA.

committee is given in Table 8. In addition to the advice given by the technical committee, a Citizen's Transportation Committee provides a review and comment function to the MAPA staff.⁵

All major items within the transportation planning and programming process, including the setting of goals and objectives and the establishment of evaluation criteria, are reviewed by the technical committee which gives either favorable comment to the item or returns the item to the staff for further work. If favorable comment is given by the committee, the item is forwarded to the policy committee (MAPA's Board of Directors) for its action. For some items of major significance, the Board then forwards its action to the Council of Officials for formal adoption. Of course, if a regional plan or program is up for adoption, a series of public meetings will be held prior to the adoption by the Council of Officials.

The COATS process involves a variety of tasks: (1) the coordination of transportation activities throughout the metropolitan region; (2) the development of a long-range regional transportation plan; (3) the development of a short-range transportation plan in the form of a Transportation System Management (TSM) Element; and (4) the preparation of a Transportation Improvement Program (TIP) consisting of an Annual Element and a subsequent five-year element.⁶ At present, the COATS 1995 Interim Transportation Plan, adopted in 1974 and as subsequently amended, is the official long-range plan which guides local and state decisionmakers in the allocation of available resources. Based on the 1995 plan, both highway and transit projects are selected, prioritized, and placed on the TIP. In addition to projects

⁴It is important to note that MAPA is a planning agency only and does not have implementation powers. These powers lie within the local jurisdictions.

⁵This committee is a working committee of the larger Citizens' Advisory Board.

Table 8. A Partial List of COATS Technical
Advisory Committee Members

Council Bluffs Planning Department
Council Bluffs Public Works Department
Douglas County-Surveyor-Engineer
Federal Aviation Administration
Federal Highway Administration
Iowa Department of Transportation
Iowa Office of Planning and Programming
Metro Area Transit
Mills County
Nebraska Department of Roads
Nebraska Office of Planning and Programming
Omaha Airport Authority
Omaha Public Works Department
Pottawattamie County
Sarpy County
Washington County

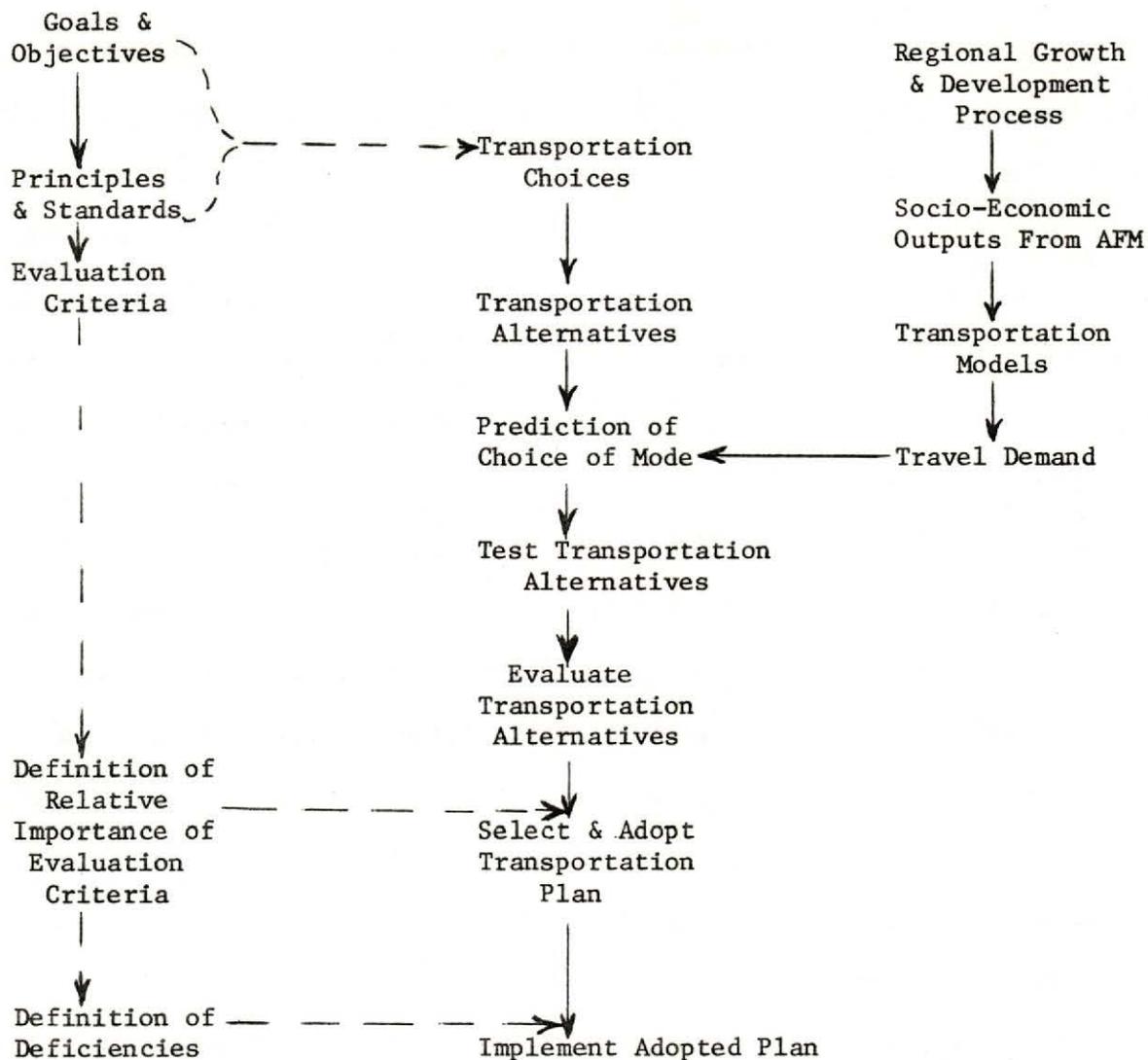
Source: MAPA, Transportation Annual Report, 1976, p. 21.

selected from the long-range plan, the TIP includes projects listed in the TSM Element of the transportation plan. Once a project is placed on the TIP, the responsible agency or agencies will generally initiate work leading toward the implementation of the project.

Of course, the success of the TIP as an efficient allocation mechanism depends on how long-range and short-range projects are evaluated within the transportation planning process. To better understand how this evaluation is handled in the Omaha-Council Bluffs area, consider the on-going year 2000 planning process (see Figure 5). The preparation of this plan is a major update of the 1995 plan and "... is designed to enable elected officials, technical personnel, planners, and citizens to re-evaluate socio-economic trends, transportation policy and technology, environmental issues, and energy availability so that previous long-range plans may be modified as necessary" (MAPA, 1976, p. 7). To date, the MAPA staff has completed the initial steps of the plan and is preparing to test a wide range of transportation alternatives. Each alternative will be evaluated according to a comprehensive set of criteria based on the regional goals, objectives, transportation principles, and standards (see Table 9).⁷ Before a "best" plan can be selected, it will be necessary to define a level of importance for each evaluation criteria so that a decisionmaker implicitly assigned a weight to each evaluation criterion based on his assessment of what was best for his constituents. At present, it is difficult to determine whether

⁶A TIP and a TSM Element are required by federal regulations as part of the "3C" process. See U.S. Federal Register, "Transportation Improvement Program," September 1975.

⁷The evaluation criteria used for the 1995 plan was not as comprehensive with respect to alternate transportation modes. Also, some criteria were not included in the 1995 plan. For example, energy consumption was excluded.



Source: COATS, Year 2000 Transportation Plan, Technical Memorandum
 TM-T-1, 1977, p. 2.

Figure 5. COATS Year 2000 Planning Process

Table 9. Transportation Evaluation Criteria

For the COATS Year 2000 Plan

Travel Analysis

Highway System

Volume/Capacity (V/C) Ratio
Average Speed
Vehicle Miles Traveled

Transit System

System Coverage
System Performance

Parking Facilities

Number of Facilities

Accessibility

Economic Analysis

Capital Costs

Operating Costs

User Costs

Impacts

Social Analysis

Displacements

Neighborhood Cohesion

Service to the Transportation Disadvantaged

Safety

Environmental Analysis

Air Quality

Noise Impacts

Energy Consumption

Source: Adapted from COATS, Year 2000 Transportation Plan Technical Memorandum TM-T-1, 1977.

the evaluation criteria will be explicitly weighted or left unweighted for the Year 2000 plan. In any event, a period of negotiation among the decisionmakers and special interest groups will undoubtedly be necessary before a final plan can be adopted by the council of officials.

As part of the overall regional transportation planning process, the Transportation System Management (TSM) Element serves "... to find better and more efficient uses for existing investments in the transportation infrastructure by considering a wide range of actions with low capital investment requirements that can improve service in the short term" (COATS, 1977, p. 3). Since TSM planning is a relatively new requirement in the ongoing urban transportation planning process, the methodology used to select TSM projects is less formalized than the methodology used to select long-range projects. Basically, as outlined in the COATS 1977 TSM Element, three steps are taken to select TSM projects. First, transportation problems and deficiencies within the system are identified either by the MAPA staff or by a local agency. Also, the regional transportation goals and objectives as previously stated⁸ are linked to projects within the four general categories of TSM actions delineated in the federal regulations. These actions are: (1) actions to ensure the efficient use of existing road space; (2) actions to reduce vehicle use in congested areas; (3) actions to improve transit service; and (4) actions to increase internal management efficiency. After the projects are linked to the transportation objectives, the final step is to select a project based on a combination of criteria and justifications listed in Table 10. Subsequently, the projects are prioritized and placed on the TSM Element of the TIP.

⁸A special Transportation Goals Committee was established to select a set of goals and objectives to guide the planning process.

Table 10. Justification For TSM Project Selection

To Improve Traffic Operation

To improve traffic flow, decrease delays

To improve traffic circulation

To Provide Improved Safety

To improve traffic safety

To improve inadequate sight distance or other special conditions

To provide for safe pedestrian movement

To improve rideability

To eliminate confusion

To provide for safe turning movements

To provide for acceptable standards of lighting

To eliminate the need for transit vehicles driving into opposing
traffic and increase maneuverability of transit vehicles

To Increase Roadway or Corridor People-Carrying Capacity

To Improve Flexibility and Responsiveness in Routing, Scheduling, and
Dispatching of Transit Vehicles

To Improve Transit Management Efficiency

Source: COATS, Transportation Systems Management Element, May 1977, p. 10.

As Meyer (1976, p. 35) notes, the standard procedure throughout the nation in the preparation of the TSM Element has been for the local agencies to carry out the planning process:

In most cases, the evaluation of a TSM project occurred within the planning process of an implementing agency after which the project was sent to the MPO where it was accepted as a 'needed' project to be listed in the TSM.

The evaluation procedure is similar within the Omaha-Council Bluffs metropolitan area since each implementing agency such as Metro Area Transit and Omaha's Traffic Engineer evaluates and selects its own projects for inclusion on the TSM Element. As a result, a comparison between and among TSM strategies on a regional level is lacking. Also, each agency is responsible for the monitoring of the projects within its own jurisdiction to determine the success rate in achieving the transportation objectives.

CHAPTER VI. APPLICATION OF A UTILITY-BASED DECISION MODEL TO
EVALUATE ALTERNATE TSM PACKAGES

Introduction

The purpose of this portion of the case study was to test the additive-utilities model, as presented in Chapter III, within an actual decision making context. This test consisted of the identification of TSM objectives and measures of effectiveness for the Omaha-Council Bluffs metropolitan area and the specification of the weights, $W(x_i)$, and the utility functions, $u(x_i)$, for the additive-utilities model. Since the state-of-the-art in forecasting the consequences of TSM strategies is not well developed, five simulated TSM packages were used as a basis for testing the model. Although simulated strategies were used here, care was taken to structure the modelling process in such a way as to replicate the process which would be carried out in "real-world" situations.

Operational Objectives and Measures of Effectiveness For The Omaha-Council
Bluffs Metropolitan Area

The intent of this application of the model was to compare alternate TSM packages on a system-wide basis using common measures of effectiveness. Since the packages are compared on a system-wide basis, the COATS transportation system, which includes the urbanized portion of the SMSA, is the geographical basis of the analysis. Also, this analysis covers the automobile, transit, and pedestrian/bicycle modes of transportation. The viewpoint of the analysis is one of the users and nonusers rather than the operators of transportation services, and, as a result, the packages are compared on the basis of impacts on the users and nonusers, and not on the impacts on the operators. This is not to suggest that impacts on the operators are not

important, but rather that different types of strategies should not be compared on the basis of how well the operator delivers his service. Thus, it is assumed that each operator delivers his transportation service in an efficient manner, and, of course, each operator must evaluate the cost-effectiveness of each strategy in achieving stated objectives. In order to better distinguish between impacts on the users and nonusers, and impacts on the operators consider the example of carpool program. Such a program may be highly effective in increasing the average vehicle occupancy rate on the system for the work trip, but the overall management of the program might be improved to reduced operating costs.

An extensive literature search was conducted in order to identify objectives and measures of effectiveness which might be appropriate for the Omaha-Council Bluffs metropolitan area. A set of TSM objectives and a set of TSM measures of effectiveness were presented to the COATS Technical Advisory Committee for its review and comment. Once the committee members' comments were received, the following 13 TSM objective statements were constructed to serve as a basis for quantifying the additive-utilities model:

1. To improve the quality of transportation service within the metropolitan area by reducing the average point-to-point travel time during the peak hour.
2. To improve the economic efficiency of the transportation system by reducing the total out-of-pocket costs per year.
3. To improve the productive efficiency of the transportation system by increasing the average vehicle occupancy rate for work trips.
4. To improve the productive efficiency of the transportation system by reducing the average volume capacity ratio during the peak hour.
5. To improve the productive efficiency of the transportation system by increasing the percentage of pedestrian-bicycle trips per day.

6. To improve safety of traveling on the transportation system by reducing the total number of accidents per year.
7. To improve the security of traveling on the transportation system by reducing the total number of transit-related crimes per year.
8. To improve the comfort and convenience of transportation service by reducing the average transit wait time per day.
9. To improve the reliability of transportation service by reducing the average variance in transit trip times per day.
10. To improve the environmental quality within the metropolitan area by reducing the average noise level within 100 feet of a transportation facility.
11. To improve the environmental quality within the metropolitan area by reducing the number of pounds of carbon monoxide emitted per day.
12. To improve the productive efficiency of the transportation system by reducing the number of gallons of gasoline consumed per day.
13. To improve the quality of transportation service by increasing the number of transportation disadvantaged persons who receive special service.

Although the above 13 objective statements have been stated in concise terms of the TSM measures of effectiveness, further elaboration on the application of the measures is required. For this, the following descriptions will help the reader to better understand why each attribute and its measure of effectiveness have been chosen and how each measure is applied herein. Also, each measure is described with regard to how it can be measured and/or mathematically modeled.

Travel Time. This TSM attribute is an important measure of the quality of transportation service which describes the ease in moving people and goods from one point to another. For this study, the average point-to-point travel time measured in minutes per mile has been selected as an evaluator

of the objective to reduce travel time. As used here, the average point-to-point travel time represents both highway and transit modes. Data collection on travel times can be easily obtained through direct field measurement and through trip surveys such as a transit on-board survey. Furthermore, point-to-point travel times can be easily modeled using current Federal Highway Administration and Urban Mass Transportation Administration computer packages PLANPAC and UTPS, respectively. For example, the program LOADVN contained in the PLANPAC computer package can provide travel times on selected network links.

Travel Costs. This attribute is a traditional descriptor of transportation efficiency; thus, for this study, the total yearly out-of-pocket costs have been chosen as the evaluator of travel costs. Such costs include automobile operation and maintenance costs, transit fares, and accident costs resulting from property damage and personal injury. However, the direct measurement of travel cost is a difficult process which requires detailed data collection techniques. But travel costs can be indirectly estimated based on other information such as vehicle miles traveled, vehicle operation characteristics, and travel time worth. Also, computer programs such as LNKCOST (PLANPAC) give the analyst an opportunity to input his own speed-cost curves in order to estimate travel cost for a given highway link.

Vehicle Occupancy Rate. The number of persons per automobile is an important descriptor of the productive efficiency of a transportation system. However, data collection on this measure requires significant time and money resources. The lack of current data on vehicle occupancies within the Omaha-Council Bluffs metropolitan area is evidence that such data collection involves substantial amount of work. But this should not preclude a periodic evaluation, say every five years, of vehicle occupancy rates on the metro-

politan system. Until such data is made on a periodic basis, automobile occupancy models can be used to indirectly measure this attribute; however, one must remember that such models rely on historical data for their calibration.

The researchers chose to concentrate on the average automobile occupancy rate for the work trip. This is not to suggest that transit occupancy rates are not important with regard to system efficiency. Rather, the concentration on automobile occupancy rate reflects the nature of the Omaha metropolitan area in that any substantial change in vehicle occupancy rates in the system will probably be made by the automobile mode. But certainly one could measure the number of persons per bus-hour as well as the number of persons per automobile and could easily add it to this framework.

Facility Capacity. The volume/capacity (v/c) ratio is a common indicator of the productive efficiency of highway facilities. Thus, this study uses the average v/c ratio during the peak-hour to indicate the overall level at which the system is operating. Here, a v/c ratio of 1.00 refers to a level of service "C" which is a desirable level of service for highway design. Volume-capacity ratios can be easily computed from data on traffic volumes and roadway characteristics; and such data can be collected for an intersection, roadway section, and/or corridor. Besides directly measuring v/c ratios, this indicator can be modeled for highway links using such computer programs as CAPRES (PLANPAC).

Pedestrian/Bicycle Travel. The consideration of this attribute in the evaluation of transportation systems is relatively new to the planning profession, but recent federal regulations call attention to this aspect of

people movement.¹ However, this is not an easy indicator to measure for this type of low-density metropolitan area because activities are dispersed throughout the region. At present, the most suitable means to measure pedestrian/bicycle travel appears to be by a comprehensive trip survey. But this entails complex and expensive data collection which can be undertaken only every 10 or 15 years. Based on historical data, modal split models for the walk mode can be developed to estimate the percent of pedestrian and bicycle trips. Of course, pedestrian volumes could be measured directly, but this may not provide an adequate picture on the system level. Despite data collection limitations, the writer has chosen the percentage of pedestrian/bicycle trips of total person trips per day as an indicator of this attribute.

Security. As applied here, the term security refers to an individual's personal safety with regard to criminal incidents. Although automobile related incidents exist, transit related incidents are probably more prevalent. Thus, the total number of transit-related crimes per year is used as a measure of the level of security within the system. In contrast to accident data, data on transit-related crimes is not easy to obtain because of deficiencies in reporting incidents to the authorities, nor is it easy to model.

Comfort and Convenience. This attribute, plus reliability, are two of the most difficult system attributes to measure. Literally scores of evaluators can be identified for comfort and convenience including the

¹U.S. Federal Register, "Pedestrian and Bikeway Facilities", 26 April 1978, p. 17814.

level of privacy, rideability of bus transit, and the transit wait time per day. Granted this measure is somewhat narrow in scope because it focuses only on the transit mode rather than all the other modes, but the level of comfort and convenience of the automobile might be better reflected by other attributes such as the total travel time. Information on transit wait times requires moderate level data collection techniques such as on-board surveys which do not pose any special problems.

Reliability. This is another difficult attribute to measure which again appears to be related more to the transit mode than any other mode. Here, the average variance in transit trip times per day is used as an evaluator for reliability. One problem arises in that this measure is related to the average wait time for transit; that is, generally, as the adherence to transit schedules diminishes, the wait time increases. Thus, one may say that the two evaluators measure the same thing. But the intent here is to measure reliability from the perspective of the total trip, not just the wait portion. Thus, this measure was retained to test for importance in comparing TSM strategies. Information on trip variance can be obtained by periodic checks on bus arrival and departure times.

Noise Pollution. The preservation of environmental quality is a high ranking goal for the metropolitan area, and the reduction of noise pollution is one objective toward achieving this goal. For this study, the researchers chose the average noise level within 100 feet of a transportation facility measured in decibels on the A level scale (dBA). Such an evaluator can be directly measured with noise meters and can also be modeled using sources such as the National Cooperative Highway Research Project Report 117 (Gordon, 1971).

Air Quality. Since the enactment of the 1970 Clean Air Act, transportation planners are more cognizant of the impact of the transportation system on air quality. As a result, the modeling and monitoring of air quality has become a routine matter in most metropolitan areas. For example, the Kansas Air Pollution Package (KAPP) has been applied to evaluate the COATS 1995 Interim Transportation Plan. Due to the relative ease in measurement and modeling, Carbon Monoxide (CO) Emissions measured in thousands of pounds per day has been selected to evaluate air quality. For this, air pollution analyzers can record CO emissions on a daily basis, and emission factors measured in grams per mile of pollutant can be used to compute daily emissions. Because the Omaha-Council Bluffs area does not have any special adverse atmospheric conditions with regard to Hydrocarbons, Carbon Monoxide has been singled out as the primary evaluator of air quality. But one could also measure the total amount of pollutants, or he could measure the daily amounts of each pollutant on a separate basis.

Energy. The Arab Oil Embargo of the early 1970's emphasized the importance of conserving the nation's oil reserves which was hitherto generally disregarded by transportation planners. The lack of energy as an evaluator for the 1995 plan is evidence that the conservation of energy was previously ignored. But, for this study, energy consumption is evaluated by the number of thousands of gallons consumed per day by both the automobile and bus modes. The most practical method of measuring energy consumption is to apply statistics concerning vehicle characteristics and vehicle mix to such traffic characteristics as vehicle miles traveled and volume-capacity ratios. The practicality of using the current battery of urban transportation models to evaluate the impact on energy consumption by various strategies has been demonstrated by Carrier (1975).

Service to the Disadvantaged. The Urban Mass Transportation Act of 1964, as amended by Section 16(b), provides federal monies to both public and private entities for expenditures on public transportation for the elderly and handicapped. In this regard, Metro Area Transit has made strides in providing and coordinating special services to the disadvantaged within the metropolitan area. The percentage of the number of disadvantaged receiving special service has been selected to evaluate if this segment of the population is obtaining adequate transportation. But this is often a difficult indicator to measure since the term "disadvantaged" is not itself concisely defined. Moreover, the lack of historical data makes it difficult to model this evaluator, but ongoing research efforts should provide some means of modeling in the near future.

Simulation of the TSM Packages

Since the state-of-the-art of forecasting the outcomes of TSM strategies is in a relatively early stage, the research team simulated the values for the 13 TSM measures of effectiveness. However, in order to maintain a sense of realism with respect to the specific values, local planning and design reports were reviewed to determine a reasonable range of values for each evaluator with regard to the COATS transportation system. For example, previous planning forecasts provided data on travel costs, volume-capacity ratios, and vehicle occupancy rates. However, certain pieces of data were not readily available from local sources; thus, technical reports were relied on for information in these cases.

The specific TSM attribute values were determined using Monte-Carlo methods of simulation. First, random numbers were generated, and then random normal variates were computed based on a mean μ , standard deviation σ and a normal probability density function $f(x) \sim N[\mu, \sigma]$. Based on the information obtained above, 20 numerical values were generated by assuming a

single-variate normal distribution $N[u,\sigma]$ across each evaluator. To illustrate, consider the evaluator of out-of-pocket costs measured in \$ Millions; in this case, 20 values were generated assuming the distribution $N[600,25]$. Once the 20 values were simulated, the range of values was inspected for reasonableness. If the range of an evaluator was judged too high or too low in comparison to other data for the attribute, a new mean and standard deviation were specified, and a new set of values was generated. An abstract TSM package was then constructed by choosing the corresponding values for each measure of effectiveness.² For example, if 3.1 minutes per mile was the fifth value simulated for travel time and 633.7 was the fifth value simulated for travel costs, both of these numbers were selected for the fifth TSM package. Thus, each package was constructed having attribute values which are stochastically independent. But in reality some of the attributes are dependent upon one another; thus, the original set of 20 alternatives was reduced to five of the most logical packages. This reduction was made by examining the following four relationships: (1) travel time versus travel costs; (2) v/c versus travel costs; (3) v/c versus air quality; and (4) v/c versus travel time.

Table 11 presents the five abstract TSM packages which are used as a basis for testing the additive-utilities model. Package 1 is a base alternative which represents the existing transportation system operating under existing TSM strategies of a low level carpool matching program, a CBD computerized traffic signal system, a low level of participation in a staggered work hours program, and a low level of special services to the disadvantaged. The second package generates only minor variations in the evaluators from

²An abstract TSM package is uniquely defined by the specific values for the evaluators.

TABLE 11. SIMULATED ATTRIBUTES FOR FIVE ABSTRACT TSM PACKAGES

	1	2	3	4	5
<u>Travel Time</u>					
Av. minutes per mile during peak-hour travel	3.4	3.1	3.0	3.0	2.6
<u>Travel Costs</u>					
Total out-of-pocket costs per year (\$ Millions)	634.2	633.7	596.7	606.0	624.3
<u>Vehicle Occupancy</u>					
Persons per automobile for the work trip	1.4	1.4	1.4	1.5	1.4
<u>Facility Capacity</u>					
Av. V/C ratio during the peak hour	1.0	1.1	1.0	1.0	0.9
<u>Pedestrian/Bicycle Travel</u>					
% of total person trips	9.2	11.2	12.0	11.9	11.1
<u>Safety</u>					
Total # of accidents per year	15,732	15,825	15,866	15,970	16,073
<u>Security</u>					
Total # of crimes per year	205	194	201	200	182
<u>Comfort and Convenience</u>					
Av. Transit Wait Time, min.	4.8	6.4	8.5	5.8	11.2
<u>Reliability</u>					
Av. Transit Trip variance, min.	2.0	2.3	2.5	2.6	0.9
<u>Noise Level</u>					
Av. Noise level, dBA within 100 ft. of facility	75.0	75.4	73.7	77.1	69.5
<u>Air Quality</u>					
CO (1,000 lbs/day)	197.0	200.3	189.8	194.3	186.2
<u>Service to Disadvantaged</u>					
% of Disadvantaged receiving adequate service	44.9	61.8	65.7	43.9	42.2
<u>Energy</u>					
Gasoline (1,000 gal/day)	410.0	413.7	399.2	374.6	407.8

Package 1 represents a base transportation system.

those in Package 1. The primary differences are an increased number of pedestrian/bicycle trips and more service to the disadvantaged. Package 3 offers the lowest out-of-pocket travel costs which could be a result of increased service to the disadvantaged, low energy consumption, and high usage of the walk and bicycle modes. The fourth TSM package generates the second lowest out-of-pocket costs which could be caused by increased vehicle occupancy rate on the system. Alternative 4 could represent a package which includes a high level carpool matching program. The fifth package offers the best quality of service with regard to overall travel time and v/c ratio. However, travel costs on the system are high compared to Packages 4 and 5 probably because the number of accidents per year are high.

Determination of the Weights on the TSM Attributes

Given the five TSM packages, five individuals (judges), four transportation planners on the MAPA staff and one research team member, were asked to assign ratings to the 13 TSM attributes on a scale of zero to ten.³ For this scale, a rating of zero indicates that the attribute is of no value and a rating of ten indicates that the attribute is of extreme importance. After the judges rated each attribute, the means and standard deviations of the ratings were computed, and, then, each judge was asked to reconsider his response for an attribute if his rating varied ± 2 points from the mean rating. Once this "second round" was completed, a set of normalized weights $w(x_i)$ was computed such that the sum of the weights is equal to one. These weights along with the second round ratings, means, and standard deviations are presented in Table 12.

³Appendix A presents the questionnaire used to determine the weights and the utility functions. This questionnaire also includes tests for determining dependencies among the weights and among the utilities.

TABLE 12. RATINGS AND NORMALIZED WEIGHTS FOR THE 13 TSM ATTRIBUTES

	<u>High Rating</u>	<u>Low Rating</u>	<u>Mean Rating</u>	<u>Standard Deviation</u>	<u>Weight $w_i(x_i)$</u>
Travel Time	9	5	7.2	1.48	0.111
Travel Costs	9	7	8.2	0.83	0.127
Vehicle Occupancy	6	4	5.0	1.41	0.077
Facility Capacity	6	4	5.0	1.41	0.077
Pedestrian/Bicycle Traffic	6	2	3.6	2.36	0.056
Safety	5	3	4.2	0.62	0.065
Security	4	1	2.6	1.29	0.040
Comfort & Convenience	6	3	4.0	1.41	0.062
Reliability	7	1	5.4	2.72	0.083
Noise Level	5	2	3.4	1.48	0.052
Air Quality	5	3	4.2	0.63	0.065
Energy	9	5	6.8	1.65	0.105
Service to Disadvan- taged	7	4	5.2	1.30	0.080

Figures shown represent second round ratings.

In general, the quality and efficiency attributes such as travel time and travel costs were rated as highly important by all the judges. Also, the judges were in fairly close agreement in their individual ratings of the first four attributes. The judges considered the environmental attributes of noise, air quality, and energy to be only moderately important with energy rated the highest and noise level rated the lowest among these three attributes. Moreover, both comfort and convenience and reliability were rated on about the same level as the environmental factors. However, as the standard deviation for the ratings on reliability indicates, the judges differed considerably in their attitudes toward this attribute. The judges were in strong agreement that safety was only moderately important as an evaluator of system performance and that security was not important. Similarly, pedestrian/bicycle traffic was considered to be of some importance, but the ranges in the individual ratings for this attribute were fairly widespread.

Specification of the Utility Functions

The next step in the quantification of the additive-utilities model involved the specification by the five judges of each utility function, $u(x_i)$, for the 13 TSM attributes.⁴ Given the range of attribute values among the five packages (see Table 11), the boundary conditions for each utility function were determined as:

$$u(\text{best } x) = 1$$

$$u(\text{worst } x) = 0$$

where "best x" is the most preferred value attribute x among the five packages,

⁴See Appendix A for a detailed description of how the utility functions were specified.

and "worst x" is the least preferred value. For example, \$596.7 million/year (Package 3) is the most preferred value for cost, whereas \$634.2 million/year (Package 1) is the least preferred value. Each judge was then asked to assign values to each attribute at corresponding utilities of 0.25, 0.50, and 0.75. Subsequently, the mean value of each attribute was computed and one composite utility function was determined for each attribute. The 13 utility functions determined in this manner are illustrated in Figure 6, and the utility values for each package are shown in Table 13.

Computation of Total Utility For Each Package

The total utility of any given TSM package is computed from the following additive model:

$$U_A = \sum_{i=1}^n w(x_i) u(x_i)$$

where U_A = the total utility of package A

Or, in matrix form:

$$U = wu$$

where U = a column matrix of total utilities for m packages

w = a column matrix of weights $w(x_i)$ for n attributes
from Table 12)

u = an m x n matrix of utility values $u(x_i)$ (from Table 13).

For this case study, the total utilities were computed to be 0.23, 0.34, 0.57, 0.56, and 0.54, for Packages 1 thru 5, respectively. Thus, according to the highest utility criterion, the packages are ordered according to decreasing utility as 3, 4, 5, 2, 1. Ordinarily, the "best" package would be selected within a budget constraint; however, since simulated packages were used here, implementation costs were not assigned.

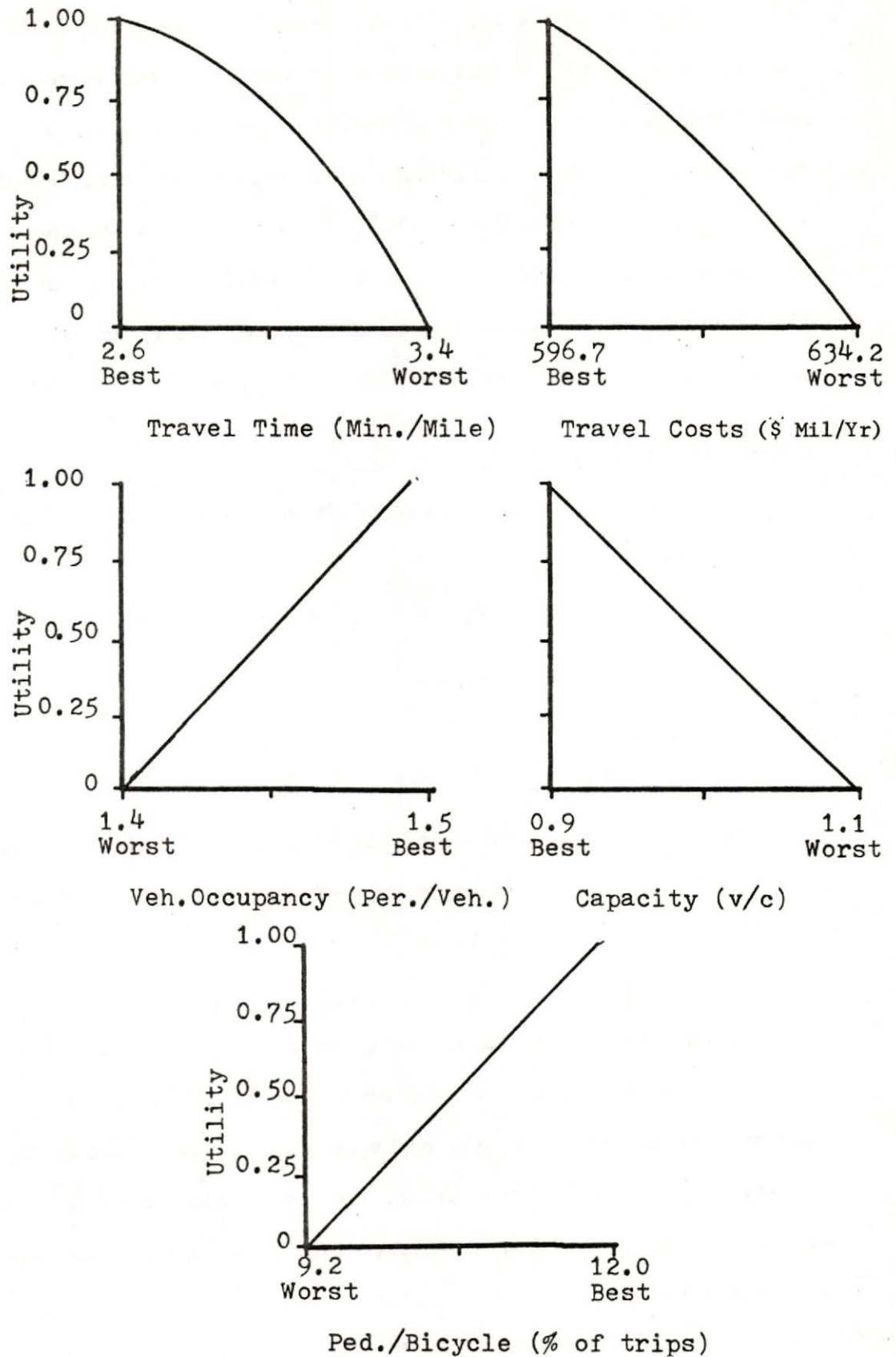


Figure 6. Graphical Representation of the 13 Single Attribute Utility Functions

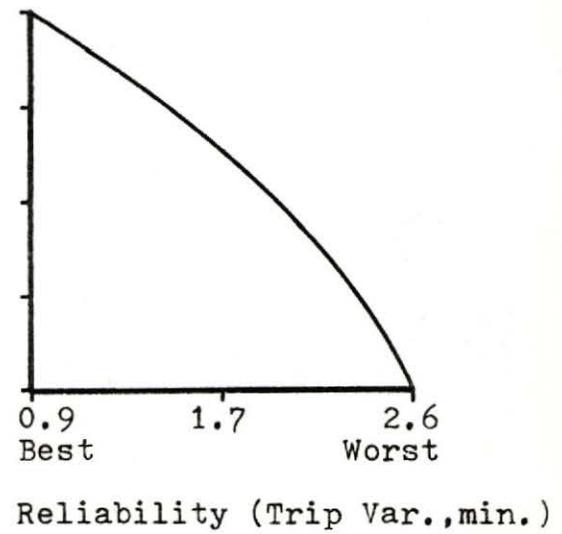
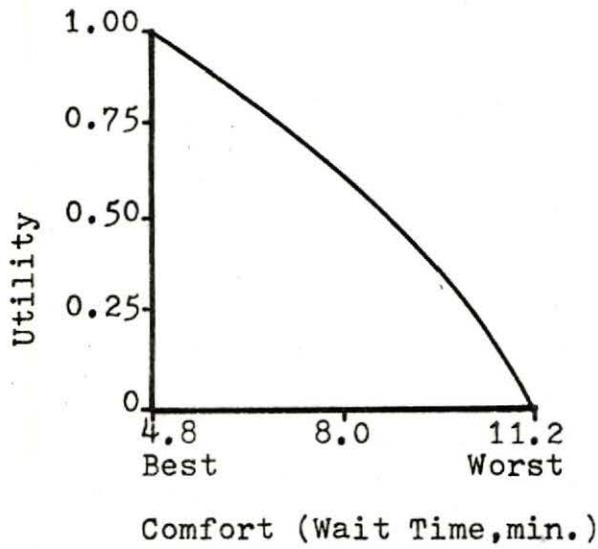
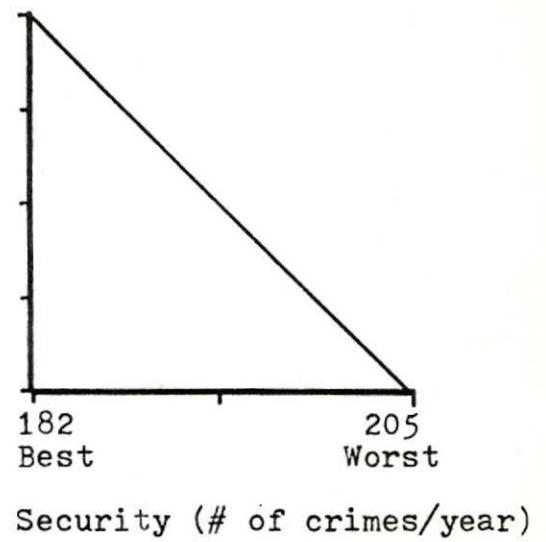
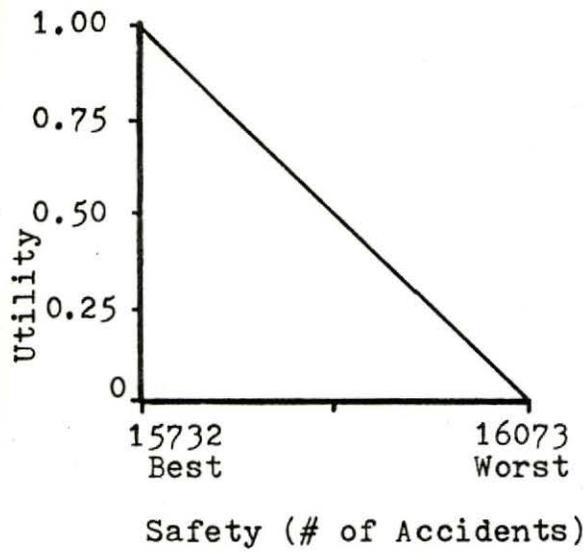


Figure 6 (cont'd)

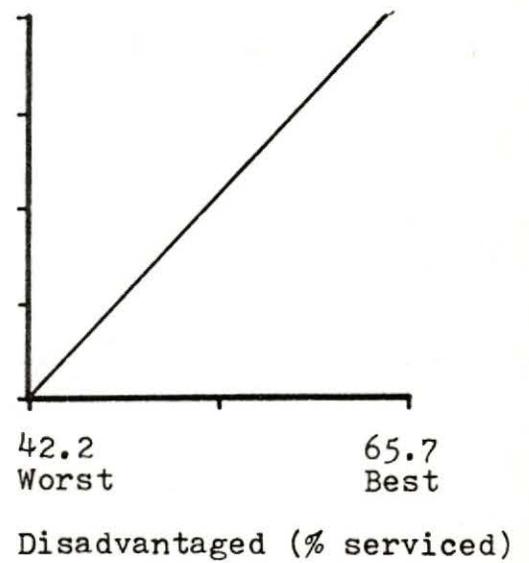
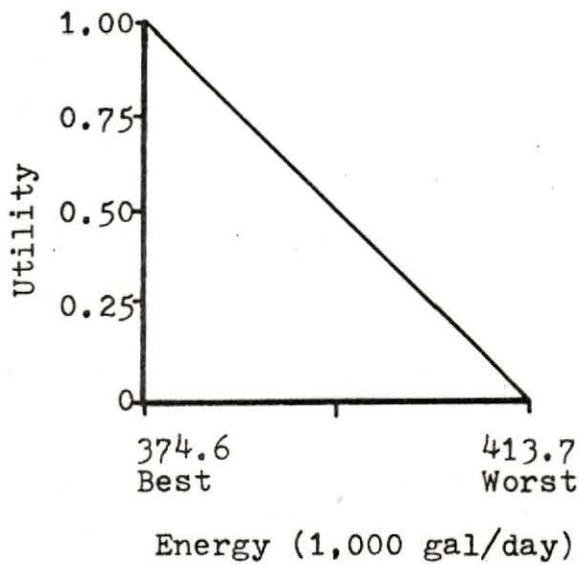
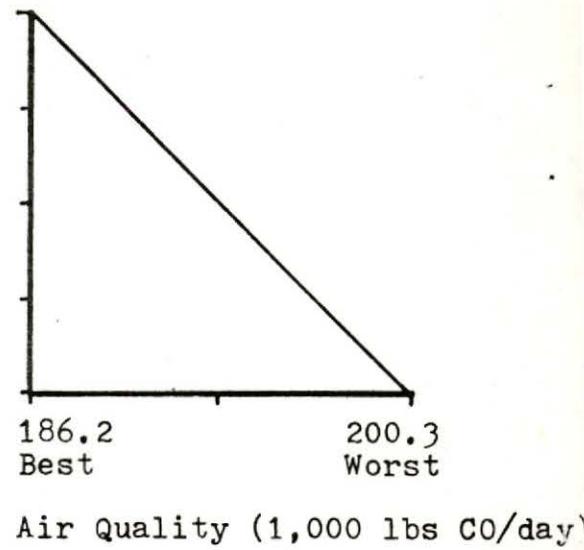
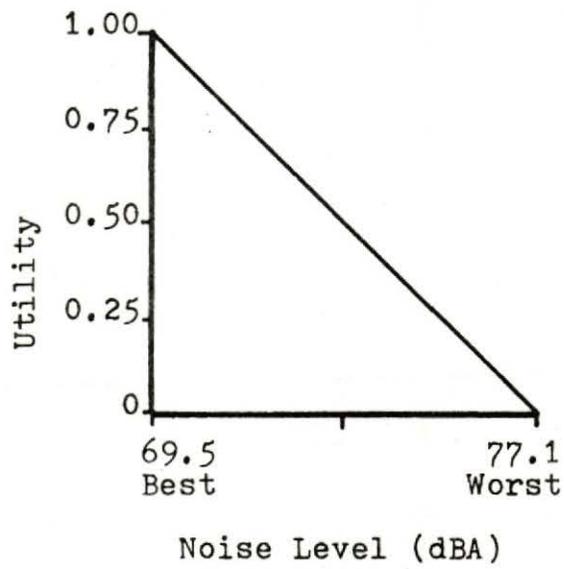


Figure 6 (cont'd)

TABLE 13 . UTILITY VALUES TAKEN DIRECTLY FROM UTILITY FUNCTIONS

<u>Attribute</u>	<u>Simulated TSM Package</u>				
	1	2	3	4	5
Travel Time	0.00	0.60	0.70	0.70	1.00
Travel Costs	0.00	0.05	1.00	0.80	0.40
Vehicle Occupancy	0.00	0.00	0.00	1.00	0.00
Facility Capacity	0.50	0.00	0.50	0.50	1.00
Pedestrian/Bicycle Traffic	0.00	0.75	1.00	0.99	0.74
Safety	1.00	0.66	0.56	0.27	1.00
Security	0.00	0.50	0.17	0.22	1.00
Comfort	1.00	0.80	0.50	0.87	0.00
Reliability	0.06	0.40	0.10	0.00	1.00
Noise	0.28	0.22	0.45	0.00	1.00
Air Quality	0.23	0.00	0.74	0.42	1.00
Energy	0.25	0.00	0.37	1.00	0.15
Service to Disadvantaged	0.01	0.83	1.00	0.07	0.00

Comments on the Additive Model

The following observations on the application of the model were made throughout the modelling process:

1. The modelling procedure is relatively straight forward and simple to apply to TSM strategies.

2. The process of assigning weights and specifying utility functions encouraged the participants to give a hard look at their preferences with regard to evaluation criteria.

3. In general, the current battery of urban transportation planning models appears to have potential for estimating outcomes of alternate TSM packages.

4. Grouping the TSM strategies into packages appears to be the most satisfactory way of analyzing the strategies. By grouping the strategies into packages, the synergistic effects of one strategy on another can be accounted for in both the modelling and monitoring process.

5. The outcome of the additive model is sensitive to the specific weights and utility functions; therefore, a diverse group of individuals should be used to quantify the model.

Overall the potential for integrating the additive-utilities model is fairly high. However, since the outcome of the model is based on the subjective attitudes of various individuals, the model should be used only as a "tool" to guide the decision makers in their negotiation process for developing the TSM Element.

CHAPTER VII. CARPOOL PROGRAM CASE STUDY

Introduction

As noted in the previous chapters, car ownership has increased, transit patronage has dropped, and auto occupancies have been steadily declining within the Omaha-Council Bluffs area. The combined effect is an ever increasing number of vehicle-miles traveled. While energy resources are limited, today's concerns also include problems of pollution, congestion, and parking; all of these problems stem from inefficient use of the private automobile. Thus, in addition to conserving the fuel supply, there are other equally substantial incentives for finding effective ways to reduce auto travel and increase average auto occupancy.

This chapter discusses the objectives, approach, and current status of the Metro Area Carpool Programs. The relationships common to Metro Area Carpoolers are investigated and system performance and carpool potential evaluated. Carpool monitoring and evaluation techniques are examined for possible future program applications.

Background of Metro Area Carpool (MAC)

During the energy crisis of 1973-74 the federal government encouraged voluntary conservation as far as possible and involved state and local organizations in the promotion and supervision of efforts. In the greater Omaha regional area local employers, with substantial employment forces, voluntarily implemented programs to encourage shared rides to work in response to the national energy crisis. For example, the Northern Natural Gas Company started a program called ECCO (Energy Conservation Carpool Operation) and developed broad support by working with the Omaha Jaycees. Encouraged

by the success of local voluntarily implemented programs, the local Jaycees Chapter undertook sponsorship of an expanded regional carpool program, to provide employer information and to promote carpooling locally.

At the beginning of 1974, during the height of the energy crisis, The Department of Transportation announced inauguration of a nation-wide effort to promote the use of carpools for the daily work trip. Through the joint efforts of The Federal Highway Administration and the Urban Mass Transportation Administration a program to promote, encourage and facilitate the use of carpools in all urbanized areas was organized. As one report notes:

Financial aid under the Unified Transportation Assistance Program was made available on a 90-10 basis to regions submitting an approved program for organizing carpool formation services. The FHWA conducted a series of regional training seminars for personnel of federal and state highway offices and regional planning councils to familiarize them with the available techniques and materials for promotion and organization of carpools.¹

Metro Area Carpool is an outgrowth of The Federal Urban Aid Program. MAC has assumed all responsibility for regional coordination of ridesharing projects which includes promotional, informational, and computer match services. The Metro Area Carpool Program was organized in June 1974 and began operation the following October. Metro Area Transit (MAT) has assumed overall management responsibility for the demonstration program in cooperation with the Federal Highway Administration, Nebraska Department of

¹U. S. Department of Transportation, Carpooling Status and Potential, Washington, D. C., June 1975, p.1.

Roads, city of Omaha, Douglas County, and the Metropolitan Area Planning Agency. (Crowley 1975, p. 1).

Program Goals and Objectives

Assuming that the number of person-trips that must be accommodated by the urban transportation system is constant, one method of reducing the vehicular demand on the system is to increase the number of person-trips per vehicle. Therefore, the primary goal of the Metro Area Carpool Program is to ultimately improve urban transportation through reducing the number of vehicles on the road and subsequently reducing vehicle miles traveled (VMT). Relatively minor reductions in VMT during peak hours return high potential rewards in reducing congestion, lowering automobile emissions and conserving fuel. Accentuating these positive transportation impacts helps achieve a fuller understanding of the current and future importance of ride-sharing as an essential element of the urban transportation improvement process.

The Metro Area Carpool demonstration program has concentrated effort on two objectives: (1) Building a service to employers to assist working commuters in forming carpools and (2) Building a means through which carpools can be sustained once they are formed. The long-range objectives of the program are to conserve fuel, reduce traffic congestion during rush hours, and improve the use of public transit. (Crowley 1975, p. 1, 2). These long-range objectives will help facilitate implementation of MAPA's year 2000 Transportation Plan Update, along with state and national goals encouraging energy conservation.

Program Operations

Carpool service is typically door-to-door, no transfer, low cost, avoids waiting in inclement weather, provides a guaranteed comfortable seat, requires

fewer driving days and potentially provides service to the handicapped and non-drivers. To form convenient carpools, matching services must extend beyond friends and associates to virtually all employees at specific locations. This requires a high level of communication and cooperation with employers, which is the major emphasis of the Metro Area Carpool Program.

The success of ongoing area programs, and trends established through national research efforts, encouraged expansion of employer-based operations. The carpool staff provides the following essential services to employer programs: (1) Coordination of efforts to actively promote carpooling among employees, (2) Computerized carpool matching for employees and a system for updating matching information, (3) Establish through the company personnel office an ongoing carpool information service available to employees.

Figure 7 demonstrates the importance of employer interaction in the overall organizational framework.

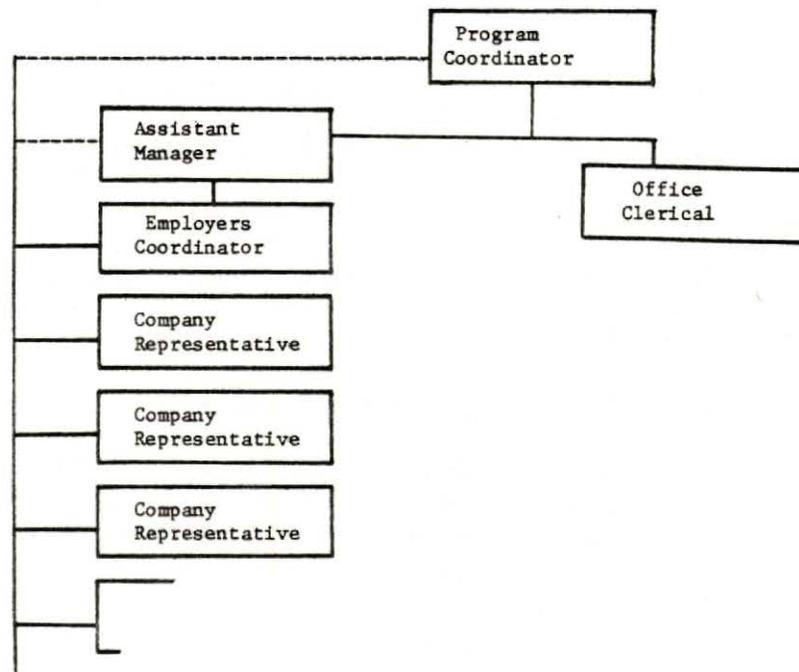


Figure 7. MAC Organizational Structure

The employer-based operations have provided a firm foundation for program expansion to the general population. In addition to the maintenance of existing programs and computer grid matching services, the staff has undertaken a marketing program. This advertising and promotional aspect of the MAC program is necessary to provide for public awareness of the project and procedure for participation.

Current Monitoring of MAC Program

As part of the TSM planning process, the monitoring of actions and the evaluation of performance is necessary to supply information on the effectiveness of project implementation. The federal government has mandated that "reasonable progress be shown" in the development of TSM projects. While it is difficult to organize a planning program around cause and effect statements, this type of program examination may provide for continuation of needed funding; monitoring provides the needed basis for future program direction.

Prior attempts to measure the effectiveness of the Metro Area Carpool program were inconclusive, as information requested was insufficient and participant response was poor. Recognizing the need to evaluate the effectiveness of certain aspects of the Metro Area Carpool program and the objectiveness that would be established through an independent study, the staff contracted for a marketing analysis with Selection Research, Inc. (SRI).

The objectives of SRI, as provided in the project general study description, primarily sought to:

- Determine the awareness, image, and receptiveness of the MAC program.
- Conduct a demographic analysis of program participants and non-participants, identifying variables that either support or disprove carpooling as a work trip alternative to driving alone. Additionally, determine

the effectiveness of the MAC staff in meeting the objectives of specific program functions.²

The research project was designed to collect attitude and behavior information from both the general community population and the MAC program participants for analysis and comparisons.

The general community information was provided through a stratified random sampling of the general population based on current projections of demographical characteristics. The stratified sample allows for a reduced number of interviews and may be conducted in conjunction with other studies of a similar nature. This commonly used survey technique provides a cost effective method of data collection for marketing analysis. For the program participant phase of the study the sample population was randomly selected from a list of all program participants. Mature and experienced interviewers were utilized in a telephone survey for both study elements.

Instrumentation (questionnaire)

A review of survey instruments utilized by other communities for similar program evaluations was conducted to establish weaknesses, strengths, and question areas for study. Questions were selected that were commensurate with the objectives of the study, and a pilot test was conducted to insure workability of the sample survey instrument. While the questionnaire provides a data source for characteristics identification, comparative analysis was difficult to facilitate due to the categorization of question response. Response categories were not consistent between the program participants survey and the general community resident survey as shown in Table 14 .

²Selection Research, Inc., "A Marketing Evaluation Study of the Metro Area Carpool Program", Omaha, Nebraska, June 1977.

If a comparative analysis is to be conducted either between study elements or with previously collected data, the survey instrument should provide for uniform response categories. Additionally, the geographical study areas should provide for consistency and be comprised of aggregates of commonly used data regions (i.e. census tracts, transportation zones) for which comparative data would be readily available. Four question study areas have been identified from previous similar studies and an evaluation of the SRI study elements. Questionnaires for future studies should provide for, but not be limited to the following study areas:

I. Study Areas Common to Both Program Participant Surveys and General Community Surveys

- A) Employment status
- B) Demographic (sex, age, income, residential and work locations)
- C) Vehicle ownership (size, work needs, number at household)
- D) Work trip (mode, distance, time, location, alternate modes)

II. Study Areas Common to General Community Surveys

- A) Awareness of program existence (program name identification, source of awareness)
- B) Program evaluation (need to meet objectives, program need)
- C) Prior history of pooling

III. Study Areas Common to Program Participant Surveys

- A) Source of program awareness
- B) Evaluation (rate program, alternative improvement options)
- C) Contact with program representative (type, contact list reception, list contact, pool formed)

IV. Study Areas for Populations Identified as Pooling in Both Sample Population Groups

- A) Work trip history (prior mode, prior pooling experience, duration of pool)
- B) Number in pool and driving frequency
- C) Reason for pooling
- D) Extent of alternate use of freed vehicle

Questionnaire response is affected by the additional considerations of survey question structure and identification of survey respondent. For example, a negative indication of employment by a respondent may not be indicative of the actual household employment situation. Questions should be carefully structured to avoid confusion, or to lead a response, such as, "The main purpose of the Metro Area Carpool is to conserve the total amount of fuel consumed in Omaha, and reduce traffic congestion during rush hour. How much does the Omaha community need this service?" Does the wording of this question require an evaluation of program objectives or an evaluation of the program itself?

Evaluation Methodologies for Marketing Studies

In the analysis of the information gathered, from both the general community survey and the program participant survey, the relationships between demographic characteristics and other general question areas were examined in an effort to identify possible marketing trends. This type of analysis additionally provided for frequencies and percentages of various categories of question response. Table 14 provided a summary of the participant and general community profiles identified in this study.

Comparisons (crosstabulations) of demographic characteristics (age, income, sex, and location) with work trip characteristics, program awareness, and program evaluation provided an effective method of market area analysis. This type of comparative analysis proved useful in identifying relationships between response variables as demonstrated by the figures provided in Appendix Table B-1. The SRI study provided analysis for the following crosstabulations in an effort to establish various relationships.

General Community Survey: Demographical by, (program identification, organizational name identification, program awareness, media of awareness, program need, carpooling history, carpooling frequency, work trip mode, employment status, and demographical)

Table 14. Demographic Profiles of Survey Respondents.

Program Participants Sample Profile			General Community Resident Sample Profile		
Characteristics	Frequency	Percentage	Characteristics	Frequency	Percentage
Sex:			Sex:		
Male	170	56%	Male	142	46%
Female	131	44%	Female	170	54%
Age:			Age:		
Under 30	92	30%	18 to 24	51	16%
30 to 50	153	51%	25 to 44	135	43%
50 and above	56	19%	45 and above	126	41%
Household Income:			Household Income:		
Under \$7,000	11	04%	Under \$7,000	46	15%
\$7,000 to \$14,999	88	30%	\$7,000 to \$14,999	104	35%
\$15,000 to \$25,000	150	52%	\$15,000 to \$25,000	117	40%
Over \$25,000	40	14%	Over \$25,000	29	10%
Area (Divided by Dodge and 72nd Streets):			Area (By Zipcode 681--)		
Northeast	54	18%	West (14,24,44,54,64)	64	21%
Southeast	91	30%	North Central (04,34)	75	24%
Northwest	59	20%	Northeast (11,12,42)	39	13%
Southwest	79	26%	East (02,10,31,32)	48	15%
Iowa	18	06%	South Central (05,06,08)	49	16%
			South (07,17,27)	36	11%
TOTAL:	301	100%	TOTAL:	312	100%

(Source: Selection Research Inc., "A Marketing Evaluation Study of the Metro Area Carpool Program," Omaha, Nebraska, June 1, 1977.)

Program Participant: Demographical by, (program contact, type of contact, receive match list, list contact, work trip length, work trip mode, media of awareness, household vehicle ownership, vehicle type, program evaluation, alternative mode acceptability, and demographical)

Program Participants Carpooling: Demographical by, (reasons for carpooling, carpooling status, carpool size, mileage change, alternative household vehicle use, alternative vehicle use mileage, and driving frequency)

Crosstabulations provided frequencies and percentages with respect to demographic characteristics for each for the response variables previously listed. While this comparative analysis identifies categorical trends within, and between study elements for marketing considerations, the frequencies established allowed for a more quantitative analysis of the carpool program. The following example shows how frequency analysis provided information useful in identification of participant and carpool auto occupancies. Auto occupancy is a load factor which is simply obtained by dividing the summation of auto occupants by the summation of the autos the occupants were in, (Σ auto occupants/ Σ autos). Utilizing the frequencies provided in Appendix Table B-1 participant carpool auto occupancies equals,

$$\frac{[(52 \times 2) + (35 \times 3) + 18 \times 4) + (8 \times 5) + (1 \times 6)]}{(52 + 35 + 18 + 1)} = \frac{325}{148} \text{ or } 2.85$$

Adding in the single occupancy drivers identified in the participant survey, the overall program participant auto occupancy equals,

$$\frac{325 + 148}{114 + 148} = 1.80$$

If the carpool occupancies for the general community would have been identified consistent with the program participant method, the computation of the general community auto occupancies could have been facilitated. However, the 1.80 auto occupancy established by the program participants survey represents a 44 percent increase over the general population occupancy identified in a 1966 count survey of 1.25.

From a marketing analysis perspective it is important to quantify both program awareness and program image. One such measure, advertising effectiveness,

is obtained through identification of program sources or media through which information was transferred. Essentially the awareness findings re-enforce the employer based program emphasis, as employers in Omaha played a key role in informing the community and increasing the participation levels of support. For additional analysis a ratio of market reached, to market actually obtained, or to marketing cost would provide a method to compare marketing techniques against each other and further provide for year to year comparisons. However, this type of evaluation should be used with caution as many advertising variables are very difficult to quantify.

In retrospect, the SRI study provided for the survey objectives, as previously identified in the marketing analysis. While the level of characteristic identification did not prove exceedingly valuable, several conclusions could be drawn from the overall frequency findings of the research project. The study established a data base for additional and subsequent analysis, and identified problem areas requiring further refinement.

Additional Monitoring Techniques and Extended Evaluation

The purpose in providing for additional analysis was to identify other data or data sources which could provide information on the measures of effectiveness. More specifically, further analysis sought to:

1. Establish relationships between and among the attitudes, demographic characteristics and work trip characteristics, of selected segments of the regional area population data bases.
2. Establish linear relationships between the percentage of MAC participants within transportation zones and the socioeconomic and land use characteristics of those zones.
3. Establish linear relationships between the percentage of MAC participants at selected places of employment with employee and work trip characteristics.

SRI Study Data Crosstabulations

The SRI study, in establishing relationships of demographic characteristics generated tabular reports of frequency and percentage distribution. With

this understanding of the characteristics of the variables, further relationships between several sets of variables were investigated. Comparisons were established using a crosstabulation procedure which produces a two-way table displaying the joint frequency distribution of two variables.³ The following additional crosstabulations were provided for the SRI survey data.

General Community Survey: Demographical by, (work trip mode, pooling frequency, program need.) Program need by, (pooling frequency)

Program Participant Survey: Work trip mode by, (type of contact, receive match list, list contact, work trip length, household vehicle ownership, vehicle type, program evaluation, alternative mode acceptability, and demographic.) Demographical by, (household vehicle ownership, demographic.) Work trip length by, (household vehicle ownership, vehicle type, alternative mode acceptability, and demographic.) Reasons for pooling by, (demographic) Mileage change by, (alternative household vehicle use.)

The crosstabulations calculated with the SPSS program express frequency as a percentage of row total, column total, and table total. This information was useful in identifying additional areas of interest or concern and proved valuable in evaluation of program measures of effectiveness. Narrative analysis is provided for those results found to be of importance to the MAC Program.

1. The southeast quadrant of the city was identified as having the largest propensity to carpool and also the shortest work trip length. This did not seem to be consistent with work trip patterns established elsewhere in the area, and without expanded analysis is meaningless. Supplementary analysis demonstrated that the high rate of participation and short work trip length was credited to the proximity of a substantial sized housing subdivision to a large military installation, with that installation having

³ Statistical Package for the Social Sciences (SPSS) was the computer program used for crosstabular analysis (CROSSTABS). CROSSTABS permits the user to produce n-way crosstabulations of variables and to compute a variety of nonparametric statistics based on those tables.

having a very active carpool program.

2. Crosstabulations identified that at least 10 percent of the program participants are carpooling without the aid of computer matching services as is indicated by the program participants' indication of contacting or being contacted by others to form a carpool. More specifically, slightly more than half of program participants recall receiving a match list of potential poolers. This might indicate a need for additional contact subsequent to initial match list mailings.
3. The frequency of work trip length compared with work trip moded allowed for estimates of program participant's average work trip length. The median one way distance to work for those program participants identified as pooling was 9.6 miles. This is a slightly longer distance than the participants driving alone to work. However, the difference in distances was not significant enough to establish a direct relationship between work trip length and propensity to carpool. Calculation of the work trip length is necessary for evaluation of program measures of effectiveness. A comparison with the general community perceived work trip length is not possible as this item was not addressed in the general community survey.
4. If the household vehicle(s) that are left available by the formation of carpools are subject to alternate household use, it is valuable to know the extent of that use for the evaluation of program measures of effectiveness. For the purpose of analysis the assumption will be made that all alternative household trips are generated by vehicle availability. Comparative analysis indicated that of the vehicles available for alternative household use, 16 percent are being utilized, averaging 16.5 miles use a week per auto. However, over 62 percent of the identified carpoolers offered no response to the availability of alternative vehicle use and

84 percent offered no response to the extent of vehicle use. This would indicate the identified 16 percent alternate household vehicle use is probably low.

5. In the evaluation of the socioeconomic data the frequency distributions allow for computation of the following demographic data for comparative analysis. The most obvious comparisons indicate program participants

Table 15. Demographic Data Comparisons

Demographic Data	General Community	Program Participants		
		Ride Alone	Carpool	All Part.
Sex, % male	46%	54%	64%	56%
Age, median	36	37	36	37
Income, median	\$14,900	\$16,700	\$17,000	\$16,700
Residential location, mean	N. Central	-	S. East	South

have a larger percent male population and have a higher average family income than the general community. The high male participation and carpool propensity rates may be attributed to characteristics common to the work force. Assuming that the total work force was 2/3 males, females would have a larger participation to work force ratio than males.

6. While low question response and some confusion with questions was obvious, several interesting relationships between variables were identified. Although the significance of the results are in question, due to poor response, the following additional relationships would appear to draw some conclusions and may warrant supplementary consideration.

- A) Identified the potential number of participants (65%) willing to consider the bus as an alternate mode to work.

- B) As work trip length increased, the bus was more likely to be considered as an alternate mode to work.
- C) Twice as many female program participants as male participants are presently using the bus as a mode to work.
- D) Multi-vehicle households are much more likely to have longer work trip lengths.

SRI Study Data Regression Analysis

This subsequent analysis of the SRI study data was beyond the scope of service required by Selection Research Inc.. Comparative analysis was used in an effort to establish relationships between variables and provide information necessary to calculate various measures of effectiveness. Additionally, multiple regression analysis was used to study the linear relationships between sets of independent variables and established dependent variables. The goal of this type of analysis is to produce a linear combination of independent variables that highly correlate with the dependent variable. This linear combination could then be used to predict values for the dependent variable. The application of multiple regression analysis reinforced the conclusions reached through comparative analysis by identifying significant variables. However, no significant correlations could be established through regression analysis due to the low R^2 values obtained. Computation of R^2 values ranged from .07 to .19 and from .02 to .07 for the general community and the program participants surveys respectively, thus indicating a low correlation between variables.

Transportation Zone Analysis

Transportation zone information was utilized in an effort to establish a linear relationship between land use and socioeconomic characteristics and the propensity to be a MAC program participant. This required the identifi-

cation of the current MAC program participants by residential grid location. Since the transportation zones⁴ and the carpool grid coordinates⁵ are not comprised of aggregate areas, an overlay process was used to identify program participants by transportation zone of origin.

Multiple regression analysis was again used to identify correlations between variables with some degree of success. R^2 values indicated a strong correlation exists between isolated transportation zone variables and a particular area's propensity to participate in the MAC program. Significant variables identified the propensity to participate in the MAC program as a function of, population, multi-family residential acres, households, single-family residential acres, income, and autos. Further analysis of this finding could provide for a more refined linear correlation which could be used as an indicator of the potential to participate in given transportation zone areas.

Concomitant to this study of all program participants a study was conducted to compare the characteristics of only the program participants identified in the SRI survey. However, the small sample size which was identified by specific residential location did not produce a sample large enough to give validity to any additional analysis. The mapping exercise did prove useful in identification of residential location and clustering of carpool program participants in various grid areas and transportation zones. This

⁴Transportation zone information includes 20 sub-classifications of socio-economic factors and land use in acres; this information in turn is used in origin-destination studies to determine trip generation for a given area. (See Appendix B-2)

⁵Program participants are grouped into areas on a 1/2 mile grid coordinate basis to facilitate computer match list based on the proximity of program participant's residential locations to each other.

type of cluster pin mapping allowed for the visual identification of area relationships such as, the proximity of the large housing subdivision to Offutt Air Force Base which accounted for the high participation and short work trip length in the southeast quadrant of the Omaha area.

Employers Survey Analysis

Since emphasis in the MAC program is placed on employer contact an attempt was made to identify relationships between MAC participants at selected places of employment and the employee work trip characteristics. A survey of participating employers was conducted by the Metro Area Carpool staff in conjunction with this study element. The companies selected to participate in this survey actively promote MAC's program, have a designated company carpool representative and have three or more employees registered in the MAC program. The following question areas were addressed to the individual company representatives.

1. Number of employees
2. Number of participants
3. Work hours (type, number of shifts, hours)
4. Type of work (classification)
5. % needing car during work day (personal vehicles)
6. Incentives to carpoolers
7. Average trip length (one-way)
8. Number of carpools formed (if available)

Employers should be encouraged to monitor this type of information for program self evaluation. Examples of employer furnished survey data are included in Appendix Table B-3, overall the employers provided a very broad range of response to questions presented.

Employment size, trip length, and percent needing car were identified through regression analysis as the most significant variables relating to

the employers percentage of program participation. However, R^2 values were too low to establish a significant correlation between variables. Employment size and population were identified as significant factors in predicting employer percentage program participation, as opportunities increased so did percent participation. A direct relationship exists between propensity to carpool and distance traveled as was previously established. However, in the employers survey, estimation of the work trip length was a judgment on the part of the employer's contact and may have little relationship to actual sample representation. No significant correlations were established between type of work and employer participation, but visual observation notes a very low participation among medical professionals. This may be a reflection on work hours or personal vehicle need.

Auto Occupancy as a Measure of Effectiveness

Occupancy studies were conducted at select locations in an effort to establish a relationship with employer based data, and provide a method for monitoring the changes in average auto occupancy as related to the work trip. Several methods exist to provide for continued monitoring of auto occupancies depending on the type of trip to be monitored. The monitoring of auto occupancies should be approached with the knowledge that occupancies fluctuate with the time of day, trip purpose, seasonal changes, and weather conditions. Such auto occupancies are not very sensitive to measuring program effectiveness over a short duration of time, but may prove extremely valuable to long term evaluation.

Since the work trip constitutes the largest portion of peak period travel and remains the major MAC program emphasis, selected employer parking lots were monitored in conjunction with the furnished employer survey data. Peak hour counts were conducted in an effort to provide average auto occupancies for multiple occupant vehicles and total vehicles, at sample employer lot locations.

A study summarization is provided in Appendix Table B-4. Comparative analysis of per cent of total employees participating⁶ in the MAC program or other programs with the total vehicle occupancy rate of selected employer lots suggest a direct relationship exists as provided in Figure 8.

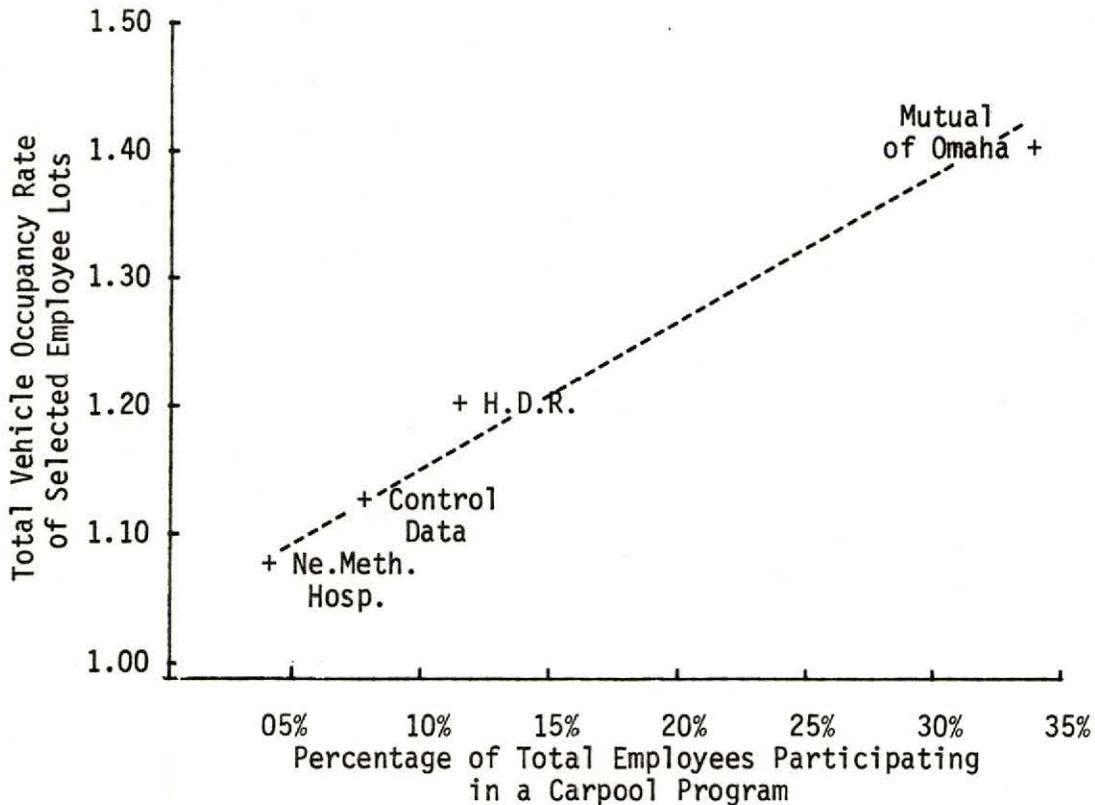


Figure 8. Percent Participants By Vehicle Occupancy

The study results by themselves are not conclusive due to the small sample size of employers and the extreme range of results, but the study indicates a direct correlation may exist which additional monitoring could substantiate.

Measures of System Performance

The level of auto occupancy and transit usages have a significant effect on the future need for road network improvements. Effective monitoring can accommodate

⁶Percentage of total employees participating was calculated from employer survey data. Number of identified MAC program participants divided by the total number of employees, for each employer location.

historical trending from which future needs can be projected. Since vehicle miles traveled (VMT) can be used to calculate related measures of effectiveness, what is needed is a method of establishing and projecting the reductions in VMT that are directly accountable to the carpool program efforts.

Most program evaluations make the assumption that all program participants identified as pooling previously drove alone to work, neglecting the fact that poolers may have been diverted from other modes of previous pooling. This type of analysis will become more evident in the computation of program cost benefits. Often, actual program impacts on area wide ridesharing are difficult at best to identify; such as the effects that program advertising efforts have on diverting traffic to carpools outside of the matching program.

By making a few assumptions, a reasonable estimate of VMT reductions directly accountable to program efforts can be achieved. Calculation of program impacts requires the identification of the program participant carpooling subgroups.

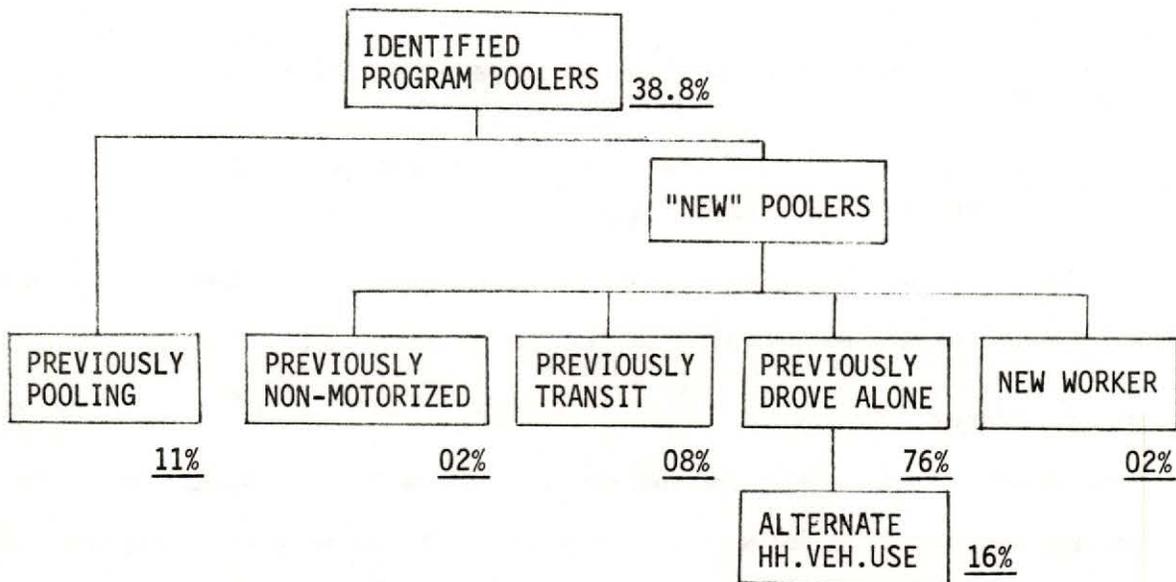


Figure 9. Program Participant Carpooling Subgroups

Information provided through the program participants survey facilitated identification of the subgroups comprising the program poolers. Cross-tabulations of "mode to work" with "prior mode to work" has provided a percentage dispersement of carpooling subgroups as given in Figure 9. The frequency distribution associated with mode to work indicated that 38.8 percent of program participants are currently carpooling. (See Appendix B-5) The subgroups of the program participants identified as carpooling will be examined on an individual basis to determine their effect on percentage change in VMT.

Subgroup impacts will be equal to the differences in the change between individual impacts. For example, assuming the present general populations multiple auto occupancy to be 2.20, any one individual's impact will be one over the multiple occupancy or $\frac{1}{2.20} = .45$. The program multiple occupancy was previously identified as 2.85, the impact of any one individual equals $\frac{1}{2.85} = .35$. The total impact achieved was the difference between the individual impacts, $.45 - .35 = .10$ or a 10% change. The following relationships are established to determine subgroup impacts of program poolers on the system.

Previously carpooling: This subgroup impact will represent an increase in multiple occupancies and a reduction in VMT, as given by the equation;

$$\left[\left(\frac{1}{\text{Prior Mult. Occp.}} \right) - \left(\frac{1}{\text{Prog. Mult. Occp.}} \right) \right] (\% \text{ Previously Pooling})$$

Previously Transit: This impact represents a slight decrease in program effectiveness. Even with transit vehicles operating at capacity during peak hour a shift from transit to private vehicle represents a change in system performance that can not be justified by existing auto seat availability. Therefore, this impact is calculated as follows;

$$\left[\left(\frac{1}{\text{Avg. Tran. Veh. Occp.}} \right) - \left(\frac{1}{\text{Prog. Mult. Occp.}} \right) \right] (\% \text{ Previously Transit})$$

Previously Non-Motorized: While the percentage of commuters walking or bicycling to work is small any shift to motorized travel will have a negative system effect as illustrated by the following equation:

$$(0) - \left(\frac{1}{\text{Prog. Mult. Occup.}} \right) (\% \text{ Previously Non-motorized})$$

Previously Drove Alone: This subgroup represents the major emphasis of the program to remove or more fully utilize the single occupant vehicle. This impact is measured as follows:

$$\left(\frac{1}{\text{Single Occp.}}\right) - \left(\frac{1}{\text{Prog. Mult. Occup.}}\right) (\% \text{ Drove Alone})$$

Previously Not Working: Recognizing that carpooling provides an additional benefit of an expanded employee market, a conservative assumption is made that those previously not working would have an auto occupancy consistent with that of the general community, thus indicating the following impact:

$$\left(\frac{1}{\text{Gen. Comm. Veh. Occp.}}\right) - \left(\frac{1}{\text{Prog. Mult. Occp.}}\right) (\% \text{ Not Working})$$

Impacts of Alternate Vehicle Use: While ridesharing to work has the additional benefit of reducing peak hour congestion, in terms of vehicle miles traveled any alternate use of vehicles freed through program participation indicates an increase in VMT. The percentage of the new poolers, who previously drove alone to work, indicated the amount of alternate vehicle use for their vehicles. The system impacts on VMT are given by the following:

$$\left[\left(\frac{\text{Prior Veh. Use} - \text{Alt. Veh. Use}}{\text{Prior Veh. Uses}}\right) - 1\right] (\% \text{ Alt. Veh. Use})(\% \text{ Drove Alone}) =$$

$$\left(\frac{\text{Alt. Veh. Use}}{\text{Prior Veh. Use}}\right) (\% \text{ Alt. Veh. Use})(\% \text{ Drove Alone})$$

VMT Summary Calculations

Impact of Prior Modes

<u>Carpool^a:</u>		
	$\left[\frac{1}{\text{Prior Mult. Occup.}} - \frac{1}{\text{Prog. Mult. Occup.}}\right] (\% \text{ Prior Pooling}) =$	
	$\left[\frac{1}{2.20} - \frac{1}{2.85}\right] (11) =$	+ 1.10
<u>Transit^b:</u>		
	$\left[\frac{1}{\text{Ave. Tran. Veh. Occp.}} - \frac{1}{\text{Prog. Mult. Occup.}}\right] (\% \text{ Prior Transit}) =$	
	$\left[\frac{1}{45} - \frac{1}{2.85}\right] (8) =$	- 2.64
<u>Non-Motorized:</u>		
	$\left[0 - \frac{1}{\text{Prog. Mult. Occup.}}\right] (\% \text{ Prior Non-Motorized}) =$	
	$\left[0 - \frac{1}{2.85}\right] (2) =$	- 0.70
<u>Drove Alone:</u>		
	$\left[\frac{1}{\text{Single Occp.}} - \frac{1}{\text{Prog. Mult. Occup.}}\right] (\% \text{ Drove Alone}) =$	
	$\left[\frac{1}{1} - \frac{1}{2.85}\right] (76) =$	+ 49.40
<u>Not Previously Working^c:</u>		
	$\left[\frac{1}{\text{Gen. Comm. Veh. Occp.}} - \frac{1}{\text{Prog. Mult. Occup.}}\right] (\% \text{ Not Working}) =$	
	$\left[\frac{1}{1.25} - \frac{1}{2.85}\right] (2) =$	+ 0.90

Alternate Vehicle Use^d:

$\left(\frac{\text{Alt. Veh. Use}}{\text{Prior Veh. Use}}\right) (\% \text{ Alt. Veh. Use})(\% \text{ Drove Alone})$		
$\left(\frac{16}{96}\right) (.16)(76) =$		- 2.03
		Total Impacts + 46.03
<u>Reduced Daily VMT</u>		
$(\text{Prog. Impact})(\% \text{ Part. Pooling})(\text{No. of Part.})(\text{Avg. Dist. To Work} \times 2) =$		
$\left(\frac{46.03}{100}\right) (.388)(5,000)(9.6 \text{ miles} \times 2) =$		<u>17,134 Veh. Miles</u>
<u>Reduced Yearly VMT</u>		
$(\text{Total Reduced Daily VMT})(\text{No. of Work Days}) =$		
$(17,134 \text{ Veh. Miles})(230 \text{ Work Days}) =$		<u>3,940,838 Veh. Miles</u>
<u>Alt. - Alternate</u>	<u>Gen. - General</u>	<u>Prog. - Program</u>
<u>Avg. - Average</u>	<u>Mult. - Multiple</u>	<u>Tran. - Transit</u>
<u>Comm. - Community</u>	<u>Occp. - Occupancy</u>	<u>Veh. - Vehicle</u>
<u>Dist. - Distance</u>	<u>Part. - Participant</u>	

^aCarpool: Prior multiple occupancy is estimated at 2.2 persons per multiple occupancy vehicle. Program participant multiple occupancy was previously calculated to be 2.85 persons per multiple occupancy vehicle.

^bTransit: Average transit vehicle occupancy is assumed to be 45 persons per vehicle during peak hour.

^cNot Previously Working: The general community auto occupancy is estimated at 1.25 persons per auto.

^dAlternate Vehicle Use: Is based on previously identified distances projected on a weekly basis.

Through an increased frequency in carpooling, the resulting reductions in vehicle miles traveled help achieve many transportation system goals: relief of congestion, lowering transportation cost, reduction in need for new transportation and parking facilities, pollution emission reductions, and lowering energy consumption. The Department of Transportation identifies the following impacts and benefits associated with carpooling from the standpoint of individual and private employers, and from the perspective of the local transportation system's goals and objectives.⁷

- A. Individual Benefits accruing from shifting to a carpool depends on several factors:
1. Carpool size
 2. Trip length, time
 3. Continued vehicle maintenance required, alternate vehicle use.
- B. Employer Benefits depends on the size, location, and other characteristics of the employer's facility, and on the nature of the employer's carpool program. Included among employer carpooling benefits are the following:
1. Reduced facilities cost; parking and traffic access capacity
 2. Expands labor market
 3. Improved employee morale and performance; management's interest, lower absenteeism.
 4. Enhanced community relations; reduced facility congestion, community image.
- C. Transportation System Benefits of encouraging carpooling to work relate directly to area goals and objectives as follows:

⁷ U.S. Dept. of Transportation, Carpool Incentives and Opportunities, P. 85-93, Washington, D.C., Feb., 1975.

1. Congestion cost savings; reduced vehicle delay, increased speed, travel time, driving stress
2. Reduced pollution emissions; carbon monoxide, hydrocarbons, particulates
3. Fuel consumption reduction
4. Reduced facility cost; parking and transportation network needs
5. Minor accident reductions

Several methods have been identified for calculating carpooling benefits. Due to differences in individual travel patterns most benefits are determined on a average or network system basis. Most system benefits can be quantified as functions of vehicle miles traveled (VMT). For example, reduced energy consumption can be calculated with the aid of the following information: average fuel consumption, reduced VMT, weight of additional passengers and increased trip length incurred by passenger pick up and delivery.

Continued monitoring will provide for the measuring of program effectiveness on a comparative annual basis. Current carpool program evaluation efforts will allow for estimates of program effects such as those previous discussed. The magnitude of the comparative carpool program impacts will provide measures of effectiveness for a comparative evaluation with alternate transportation system management strategies of the area.

Summary and Recommendations

The purpose of this case study was to examine problems inherent to monitoring and evaluating carpool programs in general, and the MAC program specifically. Existing or available data sources were investigated for their potential in providing comparative or additional support analysis. Current monitoring techniques were explored from the standpoint of data collected and methods for additional program analysis. Also, an attempt was made to relate monitoring and

analysis to various system measures of performance which would facilitate comparative analysis with alternative system actions.

Carpooling monitoring and analysis provides a basis for measuring program levels of effectiveness and additionally serves a supplementary function of providing data to determine regional area travel characteristics. Characteristics identification can demonstrate areas for future program emphasis, and evaluation can facilitate implementation of cost effective strategies.

Marketing analysis sought to answer specific questions related to advertising promotion, public acceptability and program effectiveness. The data that was provided allowed for additional analysis beyond that provided in the marketing survey but for some areas question response suggested that the analysis be interpreted with caution. Some questions did not facilitate comparative analysis due to non-consistent categorical responses, unclear questions, and inconsistencies between survey instruments for the general community and program participant questionnaires.

Poor response to questions on several occasions suggest a reluctance to respond, or an unclear question. A consistent data format should be established between study elements in an effort to provide categorical data consistene with other available data bases (i.e. transportation zones), and more specifically, the questionnaire should distinguish areas of origin and destination (i.e. CBD fringe, suburban, rural) for comparative analysis.

Conclusions drawn from the calculations of VMT indicate that new carpoolers are attracted primarily from those previously driving alone to work. If a significant number of commuters are attracted from transit to carpool, VMT will not decrease and transit revenues will decline. It is important to insure that policies designed to promote ride sharing do not result in an overall increase in auto commuters. Ridesharing programs can assume complementary functions such

as matching potential poolers to transit when possible or encouraging flextime.

Comparative analysis of using transportation zone regions uses data that may be heterogenous within zones. Differences in geography, population density, income, etc. within zones are hidden by aggregation. The resulting analysis may be biased and should be interpreted with caution. However, it is recommended that further research and analysis of transportation zone data be conducted due to the correlations discovered.

Auto occupancy studies should be implemented in conjunction with the local or regional planning agencies. Information that would be made available through this type of monitoring would provide for historical trending and serve as an indication of both program success and transportation system needs. On a smaller scale employer base auto occupancies can be compared on a before and after basis, or by monitoring non-participating employers to serve as control groups for comparison with participating employers.

Administratively, to provide for community input in establishing a successful program it is suggested that a regional carpool policy committee be created with representation from governing agencies, labor and business, transportation operators, and clubs or chambers of commerce. The results would provide a support base for future contacts and help in assuring continuity of funding.

PART III
A PROPOSED IMPLEMENTATION PROGRAM

CHAPTER VIII. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Setting the Decision Problem

Transportation systems management (TSM) strategies have the potential to improve the performance of metropolitan transportation systems throughout the nation with respect to a wide range of efficiency, social, economic, and environmental issues. However, the evaluation of TSM strategy performance in regard to these issues has proved difficult to the participating agencies since the overall TSM process is a relatively new concept and the state-of-the-art in TSM planning is in an early stage of development. This research sought to improve the evaluation phase of the TSM planning process by applying a systems analytic approach to the construction of a TSM evaluation framework. The basic components of this framework include: (1) TSM goals and objectives; (2) TSM measures of effectiveness; (3) TSM strategies; (4) a decision model to evaluate strategy performance, and (5) techniques to monitor strategy performance.

Because each metropolitan area is unique in character and institutional arrangements, the individual agencies responsible for strategy implementation and regional transportation planning must identify the specific components for that metropolitan area. The following conclusions were drawn with respect to how these agencies should identify the basic components of the evaluation framework:

1. TSM objective statements should be constructed which clearly identify the TSM objectives and the measures of effectiveness which will be used to measure the degree of objective obtainment.

2. All the identified TSM strategies should be screened against the objectives in order to develop a set of potential strategies for that metropolitan area.

3. The potential TSM strategies should be grouped into alternate TSM packages.

4. The set of alternate TSM packages should be evaluated and monitored according to a geographical stratification of the transportation system; i.e., corridor, subarea, link.

Once these basic components are identified for a given metropolitan area, the next problem is to compare each TSM package against the other packages. Chapter III analyzed several techniques which have been applied to evaluate various types of transportation facilities. These techniques include the traditional cost-benefit analyses; cost-effectiveness analysis; and utility-based analysis. This research recommended that an additive-utilities model be used as a TSM decision model for several reasons:

(1) the model is based on expected consumer behavior theory; (2) the model can incorporate TSM measures of effectiveness which are both economic and non-economic in nature; and (3) in general, the model is relatively easy to apply. The mathematical form of the model is:

$$U(x_1, \dots, x_n) = \sum_{i=1}^n w(x_i) u(x_i)$$

where $U(x_1, \dots, x_n)$ = the total utility of a TSM package with regard to all the TSM attributes x_n

$w(x_i)$ = the weight or utility of attribute x_i

$u(x_i)$ = the utility function defined at the attribute value of x_i

n = the total number of attributes

The recommended steps to apply this model are:

1. Determine the TSM objectives and measures of effectiveness
2. Assign weights to the TSM attributes
3. Develop alternate TSM packages
4. Estimate the values of each attribute for each package
5. Determine the shape of the utility function for each attribute
6. Compute the utility of each package from the above equation subject to any predetermined constraints
7. Select the package which yields the highest utility subject to a budget constraint

Since the specification of the weights and the utility functions are based on subjective judgments, it is recommended that the model be used only as a tool to narrow the range of the TSM packages. Ultimately the final selection of a "best" TSM package will be accomplishment through negotiation among implementing agencies, planning agencies, and citizens.

Of course, the adequacy of the overall evaluation process clearly depends on the type and the detail of available information on the measures of effectiveness. Thus, it is important that each implementing agency, or any other agency concerned with a particular measure of effectiveness, monitor the transportation system with respect to the stated TSM measures of effectiveness. In regard to this monitoring, the following conclusions were made:

1. A monitoring technique must be tied to a particular TSM objective and measure of effectiveness.
2. The monitoring of TSM strategies should be carried out according to geographical component, i.e., corridor or link.

3. The monitoring of TSM strategies should be conducted on periodic basis. In general, it will be necessary to establish a base condition and time period for each measure of effectiveness.
4. The monitoring of the various types of strategies must be coordinated on a regional level to insure consistency.

A Case Study In Evaluation

A case study was carried out in order to apply the general framework to evaluate alternate TSM strategies within the Omaha-Council Bluffs metropolitan area. This low density midwestern region is predominantly oriented toward the automobile mode and pedestrian/bicycle and transit usage within the area is low. The regional transportation system has several major inefficiencies: (1) highway capacity is unevenly distributed throughout the system; (2) automobile occupancy rates on the system are low; and (3) noise pollution, air pollution, and energy waste are by-products of the sprawling development. In general, the evaluation of TSM strategies within the area has not been conducted at the same level of detail as the traditional "long-range" projects. This research examined the feasibility of applying the evaluation framework to TSM strategies in order to upgrade the TSM evaluation process.

Thirteen TSM objective statements were identified for the Omaha-Council Bluffs area to serve as an "umbrella" for TSM evaluation. In addition, the case study examined how each measure of effectiveness could be monitored in the field as mathematically modeled. Transportation planners on the MAPA staff were then asked to determine the weights and utility functions for 13 TSM attributes, identified in the objective statements, with respect to five simulated packages. Given these packages weights and utility functions, the additive-utilities model was used to compute the expected utilities of each model in order to construct a priority listing for all

five packages.

The following conclusions about the additive-utilities model were made:

1. The modelling procedure is relatively straight forward and simple to apply to TSM strategies.

2. The process of assigning weights and specifying utility functions encouraged the participants to give a hard look at their preferences with regard to evaluation criteria.

3. In general, the current battery of urban transportation planning models appears to have potential for estimating outcomes of alternate TSM packages.

4. Grouping the TSM strategies into packages appears to be the most satisfactory way of analyzing the strategies. By grouping the strategies into packages, the synergistic effects of one strategy on another can be accounted for in both the modelling and monitoring process.

5. The outcome of the additive model is sensitive to the specific weights and utility functions; therefore, a diverse group of individuals should be used to quantify the model.

As part of this case study, a detailed analysis of the Metro Area Carpool Program was undertaken to determine how the monitoring of this one TSM strategy should be carried out within the overall evaluation framework. For this, existing or available data sources were investigated for their potential in providing information for comparative analysis. In addition, the specific pieces of data were related to the various system measures of effectiveness such as auto occupancy. Several recommendations were made as a result of this examination.

1. Auto occupancy rates should be monitored on a periodic basis at spot locations and on a system level.

2. It is imperative that the carpool data collected be consistent with other planning data and it is important that carpool data be collected on the same geographical basis as planning data; i.e., transportation zones.

3. A carpool policy committee should be established within metropolitan areas to coordinate carpool activities and monitoring techniques.

Developing a TSM Information System

Although this report discussed some of the types of actors which are involved in the TSM evaluation process, the bulk of the discussion focused on the mechanics of evaluation rather than the actual implementation of the framework within a given metropolitan area. This section now presents a recommended program to implement the TSM evaluation framework. As Figure 10 illustrates, the implementation of the framework requires the interaction between the agencies involved in the TSM process¹ and the evaluation components. This interaction can be provided by a TSM information system which provides a clear flow of information from the stating of goals and objectives through all the evaluation functions. The information system can be subdivided into three major functions; (1) data generation; (2) data processing; and (3) information transmission. The data generation functions encompasses the development of TSM information including goals and objectives, measures of effectiveness, strategies, and evaluation information. The data processing function entails the physical retention and periodic retrieval of TSM information. This retrieved information is then conveyed to decisionmakers and to the public via prepared statements and visual displays.

Three issues need to be addressed in order to develop an information

¹The list of agencies shown is only a representative sample of the types of agencies involved in the TSM process.

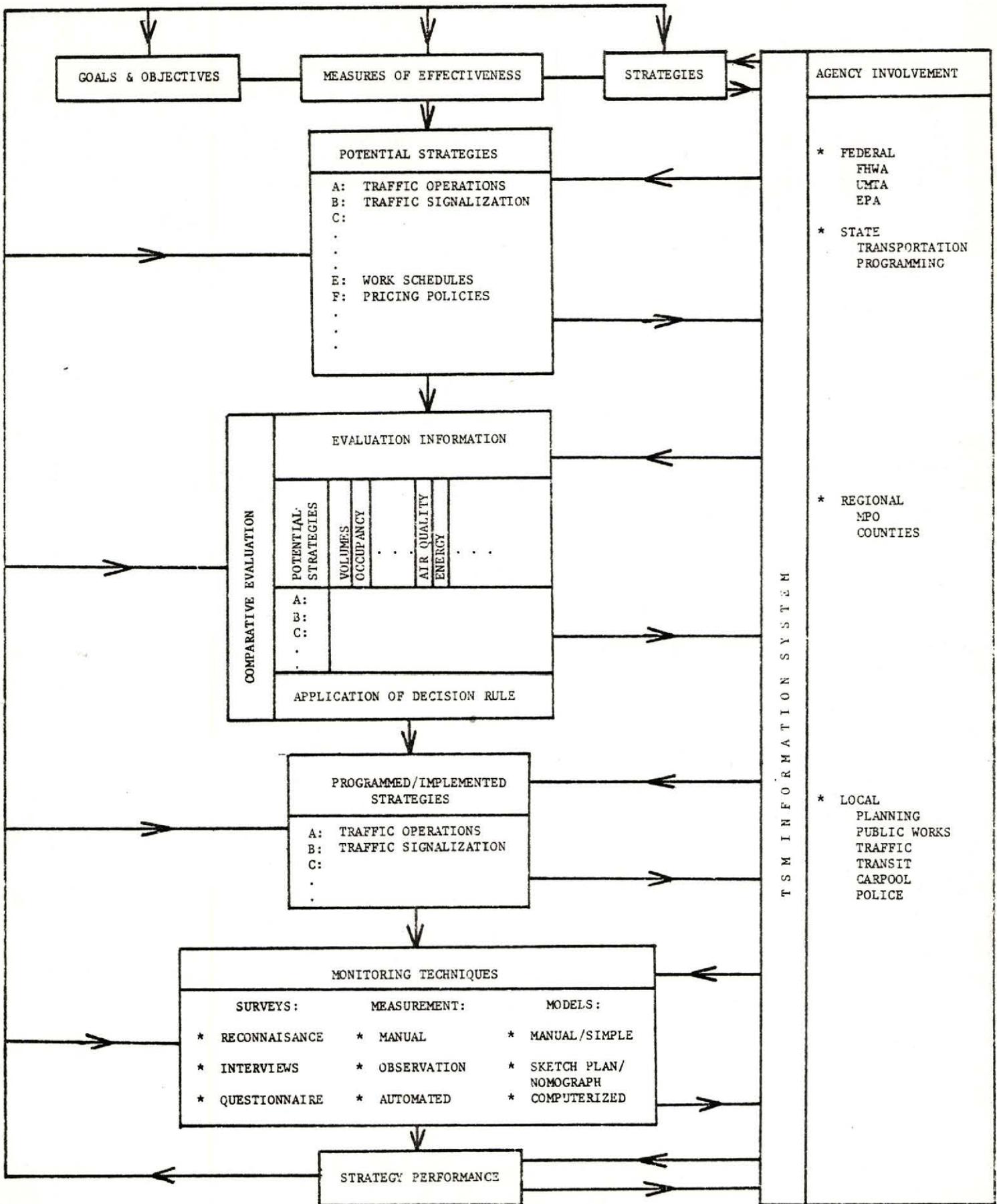


Figure 10. Application of the TSM Evaluation Framework

system for a particular metropolitan area. First, what specific generation, processing, and transmission functions need to be performed? Second, what role will each implementing agency and the MPO take in each function? Third, what specific information product or products are necessary to establish a clear line of information throughout the evaluation process? A proposed information system which includes specific functions, roles, and information products is presented below.

Function: The MPO takes the lead role in setting TSM objectives and determining measures of effectiveness to insure consistency among the various implementing agencies. In addition, the MPO delineates the transportation system into geographical components to establish a consistent geographical basis for evaluation and monitoring. Furthermore, the MPO takes the lead role, with support from the implementing agencies, in developing the format to be followed in data collection.

Product: A statement of TSM goals and objectives, a list of TSM measures of effectiveness, a geographical compartmentation of the transportation system, and a specific data format.

Function: Each implementing agency, with the support of the MPO, identifies the potential TSM strategies which are within its jurisdiction. Each agency then groups these strategies into alternate TSM packages according to its area of responsibility such as a Traffic Operations Package or a Transit Management Package.

Product: A set of TSM packages delineated according to implementing agency.

Function: The MPO groups the individual TSM packages into more compre-

hensive packages which compare all types of TSM strategies and encompass all the implementing agencies. Moreover, the MPO constructs these packages according to geographical components previously defined.

Product: A set of alternate TSM packages which will be tested on a system-wide basis.

Function: The MPO predicts the consequences of the alternate TSM packages with respect to the TSM measures of effectiveness. The prediction of the consequences should be made according to the geographical component.

Product: The estimated values for the TSM measures of effectiveness by geographical component for all the alternate TSM packages.

Function: Each implementing agency then develops a priority listing of the alternate TSM packages according to a utility-based decision rule. The weights and utility functions used in the model will reflect the preferences of the decision makers and constituency of that agency.

Product: A priority listing of TSM packages for each implementing agency.

Function: The MPO develops a priority listing of the alternate TSM packages according to the same decision rule used by the implementing agency. However, the weights and utility functions will reflect the regional perspective rather than the local perspective.

Product: A priority listing of TSM packages with regard to a regional perspective.

Function: The MPO negotiates with the implementing agencies in order to develop a final priority listing of packages. The "best" package is then selected according to a total budget constraint, and a time schedule is set for the implementation of each strategy.

Product: A "best" TSM package to be implemented according to a proposed time schedule.

Function: Each implementing agency determines which strategies it will monitor and the monitoring technique it will use for each strategy within the TSM package. Each agency will also set a tentative time schedule for monitoring the strategies. In some cases, certain agencies other than the implementing agencies will collect data on particular measures of effectiveness. The MPO should identify these agencies, and request that they forward the data to the MPO.

Product: At this point, the TSM Element is prepared. The document should include a statement of responsibility for each TSM strategy which identifies the following items: 1) the implementing agency, 2) the implementation time schedule, 3) the monitoring agency, 4) the monitoring technique and geographical basis for monitoring, and 5) the monitoring time schedule. Tables 16 and 17 illustrate two example forms for a statement of responsibility. Alternative Form 1 is for a single strategy and Alternative Form 2 is for a package of strategies. In addition, the TSM Element should include summary tables showing time schedules and status for both

strategy implementation and monitoring.

Function: The appropriate agencies monitor the strategies according to the time schedule and forward the data on each measure of effectiveness to the MPO. The MPO then processes this data in a central file (transportation system performance inventory) according to specific measures of effectiveness and geographic delineation. It is recommended that the MPO processes this data using the set of urban transportation planning computer packages which it utilizes for "3C" planning. For example, the MPO would update the network link cards on a periodic basis in order to construct a current model of the transportation network.

Product: A computerized transportation system performance inventory which is updated on a periodic basis.

Function: The MPO retrieves the data semi-annually to produce a status report on the system with regard to all the measures of effectiveness.

Product: A computerized status report which lists the following items:

- 1) the measure of effectiveness;
- 2) the system component monitored;
- 3) the monitoring status;
- 4) the performance status of selected components; and
- 5) an update of the transportation network as a whole according to a planning computer program.

Table 18 presents an example format of a transportation system status report. In addition, visual displays are prepared which illustrate the performance of the system components with respect to each measure of effectiveness; for example, travel time contours for major facilities on the network.

TABLE 16 . EXAMPLE OF A STATEMENT OF RESPONSIBILITY FOR
A TSM ELEMENT: ALTERNATE FORM 1

TSM Objective: To reduce travel time

Strategy: Major Intersection Improvement: 72nd & Dodge St.

Implementation Date: Summer 1980

Lead Implementing Agency: Omaha Public Works Department

Geographical Basis For Monitoring Effectiveness

Corridor: Not Scheduled

Subarea: Not Scheduled

Link: Speed and Delay Study/Dodge St. - 30th St. to 84th St.

Node: Intersection Delay Study

Lead Monitoring Agency: Omaha Traffic Engineer

Monitoring Period: Before Implementation Study - Fall 1978
After Implementation Study - Fall 1982

TABLE 17 . EXAMPLE OF A STATEMENT OF RESPONSIBILITY FOR A TSM ELEMENT;
ALTERNATE FORM 2

Objective: To reduce point-to-point travel time

Strategy: Traffic Operations Package 6

Implementation Date: Phase 1 - Summer 1980
Phase 2 - Winter 1982
Phase 3 - Winter 1985

Lead Implementing Agency: Omaha Traffic Engineer

Geographical Basis For Monitoring Effectiveness Speed & Delay Study

Corridor: Dodge St. Corridor - 30th St. to 60th St.
Subarea: Not Scheduled
Link: Not Scheduled
Node: Not Scheduled

Lead Monitoring Agency: Omaha Traffic Engineer

Monitoring Period: Before Implementation Study - Fall 1978
After Implementation Study - Fall 1987

TABLE 18. EXAMPLE OF A TRANSPORTATION SYSTEM STATUS REPORT

Measure of Effectiveness: Point-to-Point Travel Time

System Component Monitored:

1. 72nd St. Corridor
2. 30th St. Corridor

Monitoring Status

1. Speed and Delay Study Completed August 1980
2. Speed and Delay Study Completed November 1980

Performance Status

<u>N-S Corridor</u>	<u>Average Travel Time (min/mile)</u>
72nd St.	3.8
30th St.	3.0

COATS System Update

<u>N-S Corridor</u>	<u>Estimated Travel Time (min/mile)</u>
30th St.	3.0
72nd St.	3.8
90th St.	3.5
120th St.	3.5

NOTE: Travel times are estimated for 90th and 120th St. corridors from capacity restraint assignment on COATS Network

Integrating the TSM Evaluation Framework Into the "3C" Planning Process

Several issues have restricted the full integration of the overall TSM planning process into the traditional "3C" planning process. One such issue concerns the definition of a TSM strategy. As mentioned in Chapter II, the definition of a TSM strategy is often ambiguous whereas the traditional capital improvement project is well defined. As a result of this difference in the degree of definition, the two types of projects have been generally analyzed at two separate levels of detail. For the most part, the primary difference between the two types of projects is that capital improvement projects are construction oriented and TSM strategies are service oriented.¹ In reality, a "gray area" exists between a project which is clearly construction oriented and a project which is clearly service oriented. For example, a computerized traffic signal system, which may require significant capital outlay and which is largely service oriented, lies within this gray area. The exact categorization of a project as either construction or service oriented may not be all that important in the planning process. The important point is that both types of projects impact the transportation system with respect to certain measures of effectiveness. Although this report has focused on TSM measures of effectiveness and TSM strategies, both construction and service oriented projects should be grouped into packages of transportation alternatives which are planned and evaluated with respect to common measures of effectiveness. If this is done, the set of measures of effectiveness needs to be expanded to include objectives other than strictly TSM objectives. For example, the following objective would relate more to a construction oriented project than to a service

¹The term "service oriented" is applied here as defined by Gackheimer (1978).

oriented project: to minimize residential dislocations. By grouping capital and service oriented projects together into alternate packages, the "best" transportation system can be selected which yields the highest utility with respect to all the regional goals and objectives.

A second issue, closely related to the first issue, involves the stigma of long-range versus short-range projects. In general, capital improvement projects are associated with long-range consequences whereas service oriented projects are associated with short-range consequences. However, both types of projects have both long-range and short-range consequences. Therefore, the packages of transportation alternatives should be planned and programmed on a time-staged basis with construction and service oriented projects having common interim projections. The concept of planning capital and service oriented projects on a time-staged basis is illustrated by Table 19.

A third issue which restricts the implementation of the evaluation framework concerns the forecasting of TSM strategy consequences. Over the past few decades, the state-of-the-art in forecasting the consequences of capital improvement projects has improved significantly; however, the state-of-the-art in TSM forecasting is at an early stage of development. Extensive research is needed to answer some vital questions with regard to TSM forecasting: (1) How can a TSM strategy, such as a carpool program or staggered work hours program, be simulated? (2) What modifications must be made to the current battery of urban transportation computer programs to forecast the consequences of TSM strategies? (3) What are the mathematical relationships between measures of effectiveness at one geographical level and those at another geographical level? and (4) How can TSM strategies be grouped together into alternate packages and how can the

TABLE 19. EXAMPLE OF A PACKAGE OF ALTERNATIVES: CAPITAL IMPROVEMENT AND SERVICE ORIENTED

	<u>Project</u>	<u>Proposed Time Staging</u>		
		<u>Yr 2000</u>	<u>Yr 1990</u>	<u>Yr 1980</u>
Capital Improvement ↓ Service	4L Expressway 2.2 mi	Complete	PS & E	Programmed
	Widening 2L to 4L 25.0 mi		Phase 1 15.0 mi	Planned
	New 2L Arterial 1.5 mi		Complete	Prelim. Design
	Intersection Widening 20 Major Intersections		Phase 1 10 inter.	Planned
	Computerized Arterial Signal System 2.0 mi		Complete	Programmed
	Intensive Carpool Matching Program (20,000 participants)		Phase 2 (10,000 part.)	Phase 1 (5,000 part.)
	Staggered Work Hours Program (50 businesses)		Phase 2 (30 buss.)	Phase 1 (15 buss.)

consequences of those packages be forecasted?

Another issue which needs to be addressed is the method of funding of TSM strategy implementation and TSM monitoring. In many cases, the funding for a purely service oriented strategy is not available. For example, an agency may desire to establish a staggered work hours program or even a carpool program, but may not be able to obtain funding for the program. The Surface Transportation Act currently under consideration by Congress would be a step toward providing definite categories of funding which would be available for implementation and monitoring.

A fifth issue concerns the responsibility for TSM planning and evaluation. In essence, the MPO has no authority except that of a "coordinator." However, in order to be an effective coordinator, the MPO needs to be given a positive role in various evaluation functions as noted in the recommended TSM information system. Also, the local implementing agencies should be required to monitor specific TSM strategies which are placed in the TSM Element.

APPENDIX A

THE QUANTIFICATION OF A UTILITY-BASED EVALUATION MODEL

BACKGROUND

Various types of decision models can be used to evaluate alternate TSM strategies. But we have chosen only one to test for the Omaha-Council Bluffs metropolitan area: an additive utilities model. The basic premise of this model is that the total utility of a given TSM strategy is a linear function of the importance placed on an attribute, e.g., travel time, and the utility received from a strategy with regard to each attribute. Mathematically stated:

$$U_A = \sum_{i=1}^n w_i(x_i) u_i(x_i)$$

- where U_A = the total utility of strategy A with regard to all the attributes
- $w_i(x_i)$ = the importance or weight placed on the attribute x_i
- $u_i(x_i)$ = the utility function defined over the values of x_i
- n = the total number of attributes

Each utility function is, in essence, a scaling function which reflects the performance of a strategy over a range of attribute values. The strategy with the highest total utility is the most preferred alternative; the strategy with the next highest utility would be the second preferred alternative, and so forth.

In order to quantify the model, we must first determine the weights, and, next, we must define each utility function. Also, to minimize the effect of overlapping attributes on the model outcome, we must verify assumptions of independence. Since data is scanty, we will simulate the

values of the attributes for five "abstract" multi-modal alternatives for the existing COATS transportation study area. For this, means and standard deviations have been selected for the attributes based on available sources such as the COATS 1995 plan. Subsequently, values of the attributes were simulated using the means and standard deviations as inputs into a normal distribution.

You will be asked to respond to two parts of this questionnaire. The first part is the determination of the weights, and the second part is the specification of the utility functions. Upon completion of each questionnaire, we will compute the means and variance of each response for all participants. We will then furnish you with the results including your own responses. Next, if one or more of your responses is significantly different from the mean, you will be asked to either change your response or defend your answer.

I. DETERMINING THE WEIGHTS ON TSM ATTRIBUTES

The purpose of this part is to determine your preferences for the various TSM attributes listed in Table A-1 and to find out if your preference for an attribute is dependent on the values of the other attributes. For this, consider the five simulated alternatives with the attribute values shown in Table A-2. (Note: You are considering weights only with regard to the range of values shown.) Now, examine alternative 1 and rate each attribute on a continuous scale of zero to ten with zero indicating that the attribute is of no importance and a ten indicating that the attribute is of extreme importance. Place your rating in column (1). For example, one may give travel time a rating of eight because he considers this attribute to be very important. If his preference for cost was equally as strong, he would also assign an eight to this attribute. Thus, he would use the same

TABLE A-1. DETERMINING THE WEIGHTS ON EACH ATTRIBUTE

<u>TSM Attribute</u>	<u>Column (1)</u>	<u>Column (2)</u>
Travel Time	_____	_____
Travel Costs	_____	_____
Vehicle Occupancy	_____	_____
Facility Capacity	_____	_____
Pedestrian/Bicycle Traffic	_____	_____
Safety	_____	_____
Security	_____	_____
Comfort and Convenience	_____	_____
Reliability	_____	_____
Noise	_____	_____
Air Quality	_____	_____
Energy	_____	_____
Service to Disadvantaged	_____	_____

Are your preferences independent of the values shown in Table A-2?

Yes _____ No _____. If not, why do they change?

TABLE A-2. SIMULATED TSM ATTRIBUTES

	1	2	3	4	5
<u>Travel Time</u>					
Av. minutes per mile during peak-hour travel	3.4	3.1	3.0	3.0	2.6
<u>Travel Costs</u>					
Total out-of-pocket costs per year (\$ Millions)	634.2	633.7	596.8	606.0	624.3
<u>Vehicle Occupancy</u>					
Persons per automobile for the work trip	1.4	1.4	1.4	1.5	1.4
<u>Facility Capacity</u>					
Av. V/C ratio during the peak hour	1.0	1.1	1.0	1.0	0.9
<u>Pedestrian/Bicycle Travel</u>					
% of total person trips	9.2	11.2	12.0	11.9	11.1
<u>Safety</u>					
Total # of accidents per year	15,732	15,825	15,866	15,970	16,073
<u>Security</u>					
Total # of crimes per year	205	194	201	200	182
<u>Comfort and Convenience</u>					
Av. Transit Wait Time, min.	4.8	6.4	8.5	5.8	11.2
<u>Reliability</u>					
Av. Transit Trip variance, min.	2.0	2.3	2.5	2.6	0.9
<u>Noise Level</u>					
Av. Noise level, dBA within 100 ft. of facility	75.0	75.4	73.7	77.1	69.5
<u>Air Quality</u>					
CO (1,000 lbs/day)	197.0	200.3	189.8	194.3	186.2
<u>Service to Disadvantaged</u>					
% of Disadvantaged receiving adequate service	44.9	61.8	65.7	43.9	42.2
<u>Energy</u>					
Gasoline (1,000 gal/day)	410.0	413.7	399.2	374.6	407.8

scale for rating each attribute and assign the same number to the attributes which he considered equally important.

Now consider alternative 5. Will any of your weights in column (1) change? If so, place the revised weight in column (2) and indicate the reason in the space provided. If not, could you say with confidence that your preferences for these attributes are independent of the attribute values?

II. SPECIFYING THE UTILITY FUNCTIONS

The objective here is to define utility functions for each one of the 13 attributes shown in Table A-1. The term utility refers to the level of satisfaction which you receive from a given level of an attribute. For example, among a set of strategies a V/C ratio of 1.00 for one alternative might be assigned a utility value of 0.60. But, in general, before a specific utility value can be assigned to an attribute, we must first consider the range of values generated by all the alternatives. Then we can arbitrarily assign a utility of one to the most preferred value and a utility of zero to the least preferred value. You will be asked to assign utilities to attribute values between these two extreme points.

Figure A-1 illustrates three possible utility functions defined over the range of travel times for the ten simulated alternatives shown in Table A-2. In this case, the function decreases as travel time increases, but a utility function for other attributes may increase as the attribute value increases. For example, you may expect the utility function for the attribute reliability to increase as reliability increases. The three curves shown in Figure A-1 exhibit certain properties with regard to how marginal utility changes with change in the attribute values. For curve 1, for each unit reduction in travel time, the marginal utility diminishes. However, for curve 2, for each unit reduction in travel time, the marginal utility is constant. Finally, for curve 3, for each unit reduction in travel time, the marginal utility increases. All the curves shown in Figure A-1 are monotonically decreasing with increasing values of travel time. That is, a smaller value of travel time is always preferred to a larger value within the range shown. But there may be situations where this may not be true, and this possibility must be checked.

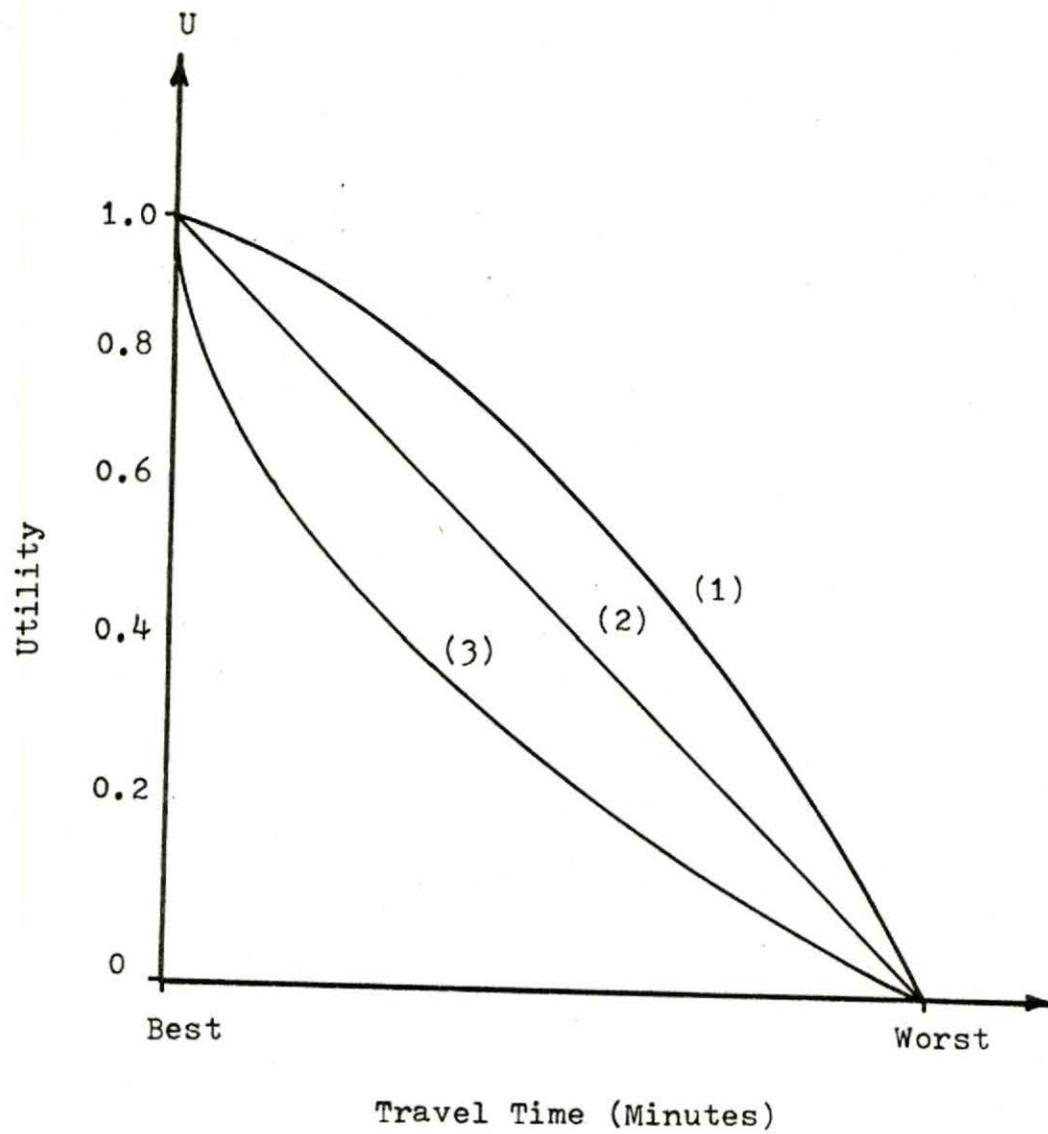


Figure A-1. Examples of Utility Functions

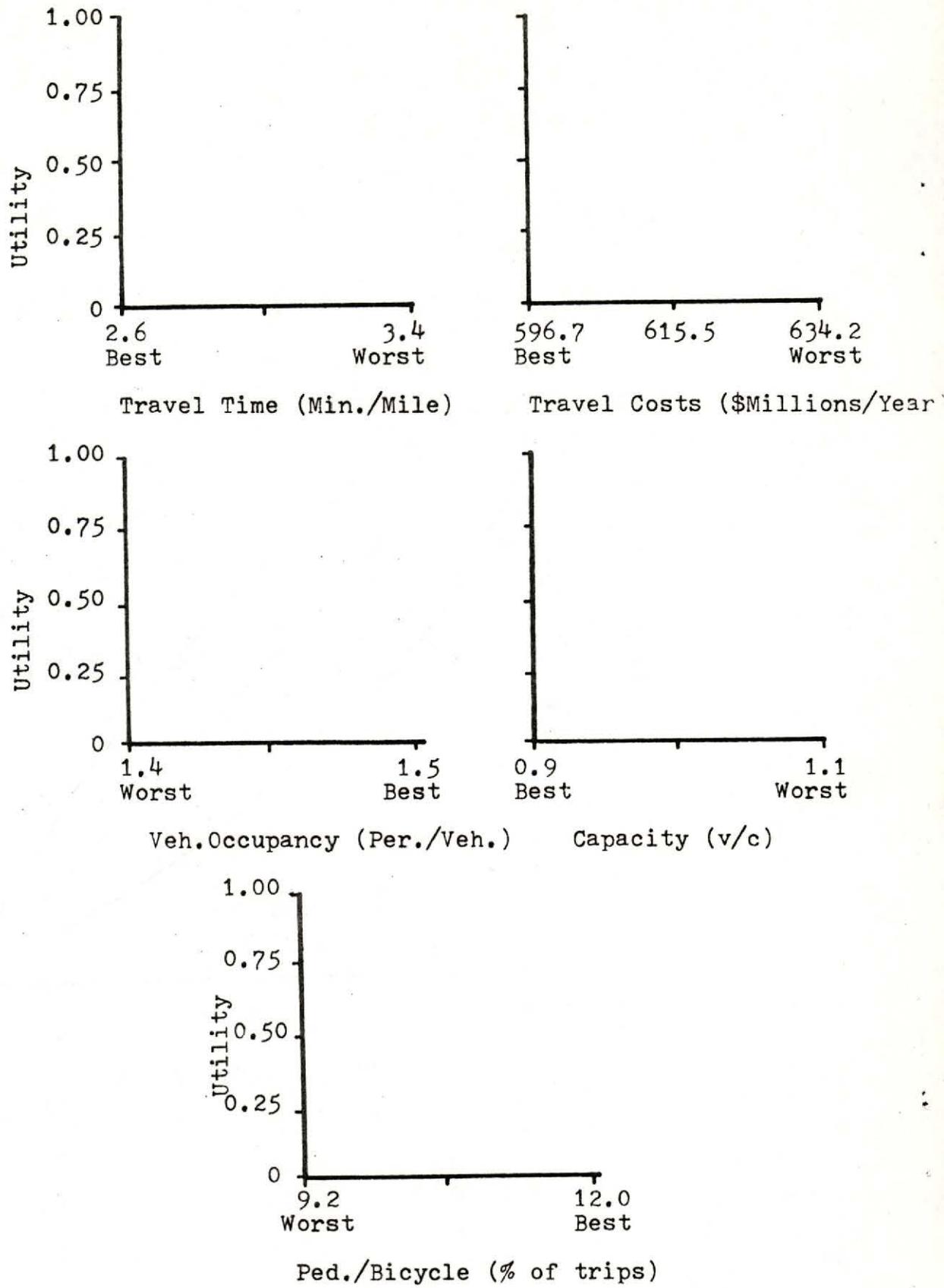


Figure A-2. Sketches of Your Utility Functions

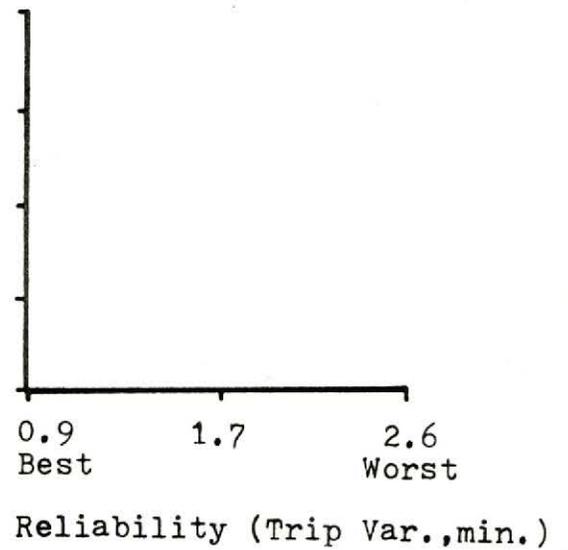
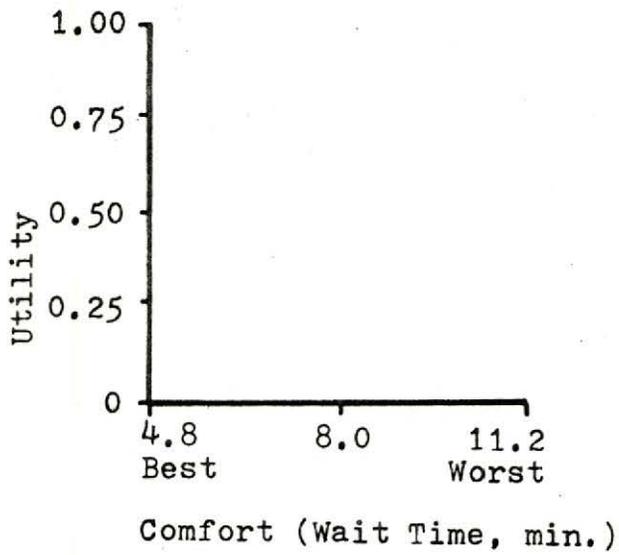
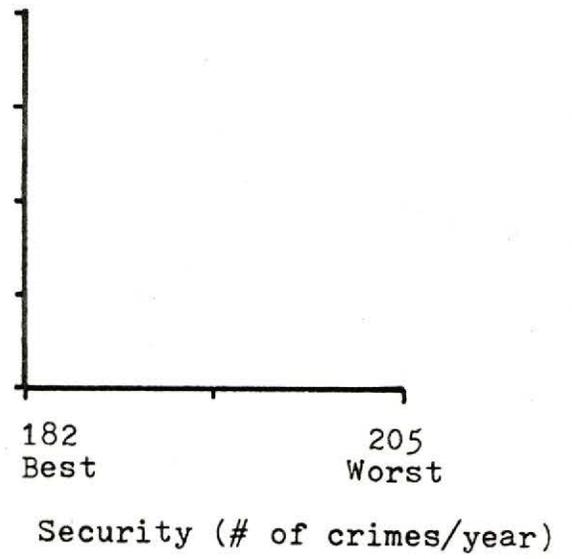
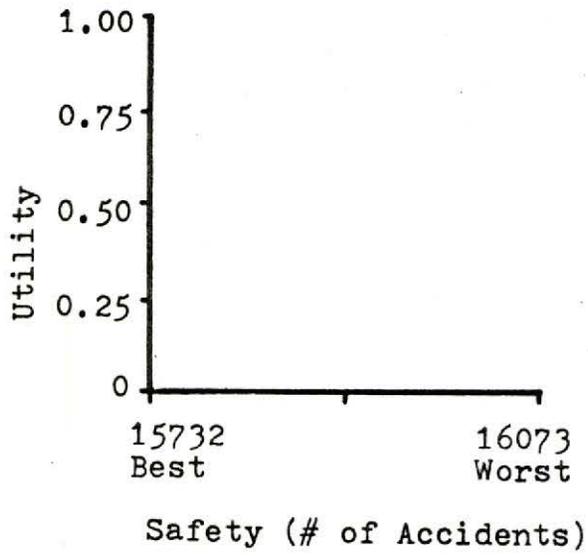


Figure A-2 (cont'd)

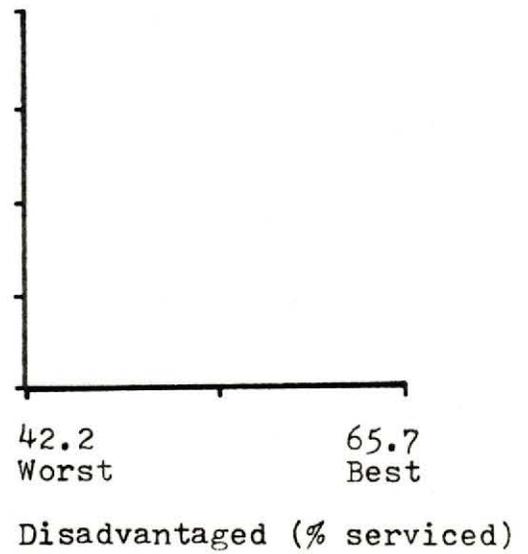
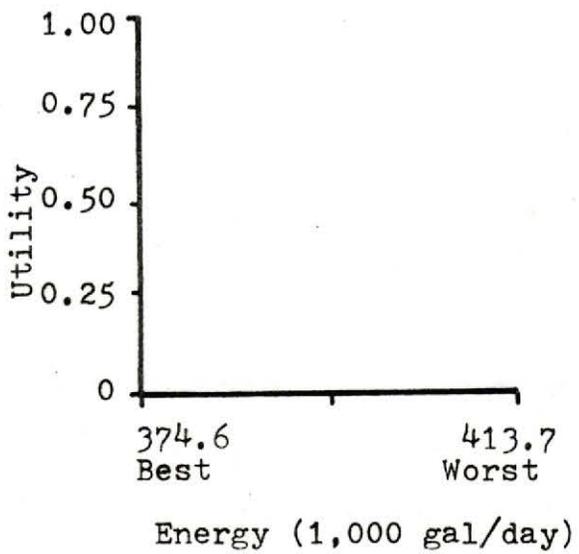
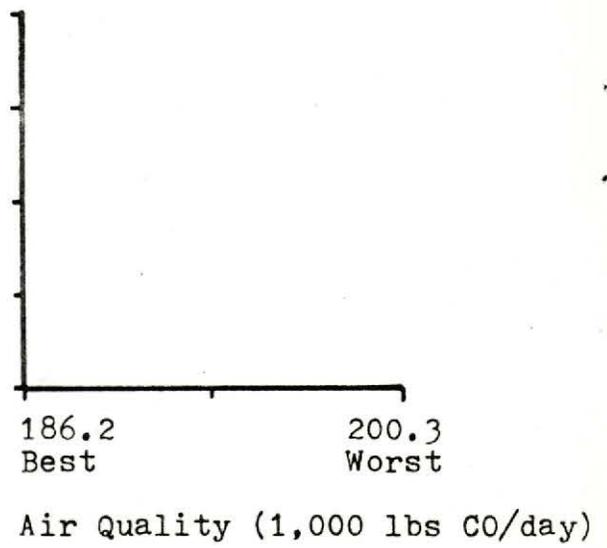
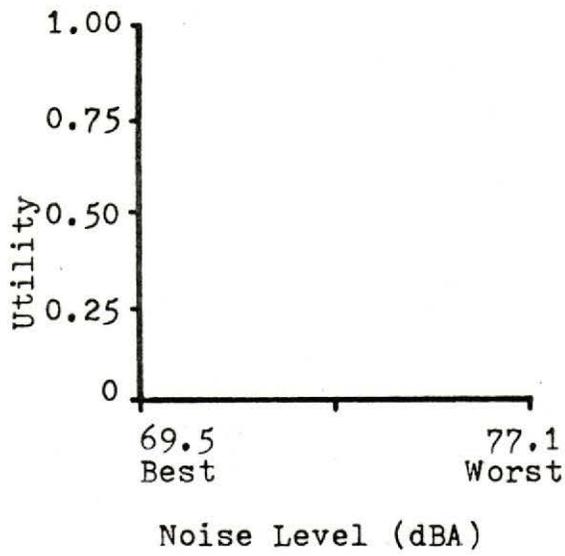


Figure A-2 (cont'd)

Now, using the above discussion as a guide, we will ask you to sketch the utility functions for each one of the 13 attributes on the axes provided. To help, first assign an attribute value at a utility values of 0.25, 0.50, and 0.75, and then sketch in the curve. Please show the values on the Figure A-2.

Can you imagine a situation in which the utility function for any attribute could both increase and decrease within the range of values?

If so, please explain why. _____

Now, consider the five simulated alternatives as you did in the first part of the questionnaire. First, examine alternative 1, then examine alternative 5. Will any of your utility functions change as the attribute values change? If so, why? _____

APPENDIX B

CARPOOLING MONITORING AND EVALUATION

The following information is provided as supplementary support for analysis provided in Chapter VII "Carpool Program Case Study." The following tables include information pertinent to the SRI response output, transportation zone information, employer survey, auto occupancy summary, and crosstabulation example.

TABLE B-1. METRO AREA CARPOOL SAMPLE RESPONSE VARIABLES

GENERAL COMMUNITY SURVEY

RESPONSE VARIABLE: WHAT METHOD OF TRANSPORTATION DO YOU USE TO AND FROM WORK

CLASSIFICATION CODES	DRIVE OR RIDE IN A CARPOOL	RIDE THE BUS	DRIVE ALONE IN A CAR OR TRUCK	WITH A FAMILY MEMBER	WALK	OTHER
INCOME						
NO ANSWER	14. ^a 1	0. 0	57. 4	29. 2	0. 0	0. 0
UNDER \$7000	8. 1	0. 0	58. 7	0. 0	25. 3	8. 1
\$7000-\$15000	20. 11	2. 1	62. 34	5. 3	9. 5	2. 1
\$15000-25000	14. 10	3. 2	71. 49	6. 4	1. 1	4. 3
OVER \$25000	21. 4	0. 0	79. 15	0. 0	0. 0	0. 0
TOTAL	17. 27	2. 3	67. 109	6. 9	6. 9	3. 5

PROGRAM PARTICIPANTS SURVEY

RESPONSE VARIABLE: HOW DO YOU USUALLY TRAVEL TO WORK

CLASSIFICATION CODES	CARPOOL	DRIVE ALONE	BUS	MOTORCYCLE	OTHER
INCOME					
NO ANSWER	42. 5	50. 6	0. 0	0. 0	8. 1
UNDER \$7000	36. 4	36. 4	18. 2	0. 0	9. 1
\$7000-\$15000	33. 29	50. 44	10. 9	0. 0	7. 6
\$15000-25000	41. 61	50. 75	2. 3	2. 3	5. 7
OVER \$25000	44. 17	49. 19	8. 3	0. 0	0. 0
TOTAL	39. 116	49. 148	6. 17	1. 3	5. 15

RESPONSE VARIABLE: INCLUDING THE DRIVER, HOW MANY PEOPLE ARE IN YOUR CARPOOL

CLASSIFICATION CODES	TWO	THREE	FOUR	FIVE	SIX OR MORE
INCOME					
NO ANSWER	60. 3	20. 1	0. 0	0. 0	0. 0
UNDER \$7000	50. 2	50. 2	0. 0	0. 0	0. 0
\$7000-\$15000	54. 15	29. 8	11. 3	4. 1	4. 1
\$15000-25000	42. 25	29. 17	20. 12	8. 5	0. 0
OVER \$25000	39. 7	39. 7	11. 2	11. 2	0. 0
TOTAL	46. 52	31. 35	16. 18	7. 8	1. 1

^a14.1 - percentage frequency

Table B-2. Transportation Zone Sample Data

1975 Socio-Economic Activity

<u>Activity</u>	<u>Zone</u>		
	<u>81</u>	<u>82</u>	<u>83</u>
Retail Employment	415	2022	187
Manufacturing Employment	0	0	0
Other Employment	141	674	942
Total Employment	556	2696	1129
Population	2837	3055	4653
Households	809	863	1717
Housing Units	970	910	1797
Autos	1643	2711	2473
Trucks	25	15	9
Income	12579	23818	9280

1975 Existing Land Use

(Acres)

Industrial	10.0	0.0	0.0
Commercial	70.3	85.8	28.3
Institutional	0.0	0.0	25.0
Multi-family	43.2	8.0	67.2
Single-family	100.5	87.2	194.8
Transportation	121.4	102.1	94.7
Recreation	156.8	13.6	17.6
Water	2.2	0.0	0.0
Vacant	321.6	157.4	136.6
Total	826.0	454.0	584.0

TABLE B-3 EMPLOYER SURVEY SAMPLE RESPONSE

Northern Natural Gas N05 0029
2223 Dodge
Omaha, Nebraska 68102
Company Contact - Bill Zimmerman, 348-4000

1. No. of employees - 1,200
2. No. of participants - 42
3. Work hours - flextime - any 8 hours between 6:00 a.m. - 6:00 p.m.
4. Type of work - Office & Clerical, Administrative
5. % needing car during workday - 2%
6. Incentives - preferential parking - 92 stalls
7. Average trip length - 5 miles

Northwestern Bell N06 0T33(DFD)
100 South 19th
Omaha, Nebraska 68102
Company Contact - Sally McGuire, 422-8288

1. No. of employees - 4,200
2. No. of participants - 531
3. Work hours - 8:00 a.m. - 5:00 p.m.; 7:30 a.m. - 4:30 p.m.
4. Type of work - Office & Clerical, Administrative
5. % needing car during workday - 0%
6. Incentives - None
7. Average trip length - 12 miles

Offutt A.F.B. 001 0A36
Omaha, Nebraska 68113
Company Contact - Sgt. Peterson, 294-3259

1. No. of employees - 20,000
2. No. of participants - 1,133
3. Work hours - 7:00 a.m. - 5:00 p.m. for majority
4. Type of work - Military, Transportation
5. % needing car during workday - 1%
6. Incentives - Preferential parking, Vanpool program
7. Average trip length - 8 miles

TABLE B-4 EMPLOYER AUTO OCCUPANCY SUMMARY

LOCATION	DATE	DAY	TIME	NUMBER OF OCCUPANTS IN VEHICLE							MULTI-OCCUPANCY VEHS. (M.O.V.)			TOTAL VEHICLES (T.V.)			
				1	2	3	4	5	6	+	TOTAL VEHS.	TOTAL OCCUPANTS	AVERAGE OCCUPANCY	TOTAL VEHS.	TOTAL OCCUPANTS	AVERAGE OCCUPANCY	
NE.METHODIST HOSP.*	6-13	Tues.	0630-0830														
Farnam / North Lot				250	13	-	2	-	-	-							
South Lot				230	11	-	-	-	-	-							
-TOTAL-				480	24	-	2	-	-	-	26	56	2.15	506	536	1.06	
NE.METHODIST HOSP.*	6-13	Tues.	1530-1650														
Farnam / North Lot				211	14	1	-	-	-	-							
South Lot				110	16	4	-	-	-	-							
-TOTAL-				321	30	5	-	-	-	-	35	75	2.14	356	396	1.11	
H.D.R.	6-14	Wed.	0730-0830														
East Lot				44	20	2	-	-	-	-							
West Lot				78	4	1	-	-	-	-							
-TOTAL-				122	24	3	-	-	-	-	27	57	2.11	149	179	1.20	
H.D.R.	6-14	Wed.	1630-1730														
Combined Lot				132	24	4	-	-	-	-	28	60	2.14	160	192	1.20	
MUTUAL of OMAHA *	6-15	Thur.	0630-0830														
33rd Harney /E.Lot				36	10	2	4	1	-	-							
W.Lot				40	11	1	-	-	-	-							
-TOTAL-				76	21	3	4	1	-	-	29	72	2.48	105	148	1.41	
CONTROL DATA	6-16	Fr1.	0630-0830	436	59	1	-	-	-	-	65	137	2.11	501	573	1.14	

TABLE B-5 CROSSTABULATION: MODE TO WORK BY WORK TRIP LENGTH

PARTICIPANT SURVEY

FILE NONAME (CREATION DATE = 05/18/78)

***** CROSSTABULATION OF *****
 MODE MODE TO WORK BY WTLN WORK TRIP LENGTH

MODE	COUNT ROW PCT COL PCT TOT PCT	WTLN						ROW TOTAL
		0-5 MILES		5-9 MILES		10-19 MILES		
		0.1	1.1	2.1	3.1	4.1	5.1	
0.	I	0	0	2	0	0	0	2
	I	0.0	0.0	100.0	0.0	0.0	0.0	0.7
	I	0.0	0.0	2.0	0.0	0.0	0.0	
CARPOOL	I	0	35	35	40	7	1	118
	I	0.0	29.7	29.7	33.9	5.9	0.8	38.8
	I	0.0	38.5	35.0	44.0	41.2	25.0	
DRIVE ALONE	I	0	42	55	40	9	2	149
	I	0.7	28.2	36.9	26.8	6.0	1.3	49.0
	I	100.0	46.2	55.0	44.0	52.9	50.0	
BUS	I	0	6	5	6	0	0	17
	I	0.0	35.3	29.4	35.3	0.0	0.0	5.6
	I	0.0	6.6	5.0	6.6	0.0	0.0	
MOTORCYCLE	I	0	2	0	1	0	0	3
	I	0.0	66.7	0.0	33.3	0.0	0.0	1.0
	I	0.0	2.2	0.0	1.1	0.0	0.0	
OTHER	I	0	6	3	4	1	1	15
	I	0.0	40.0	20.0	26.7	6.7	6.7	4.9
	I	0.0	6.6	3.0	4.4	5.9	25.0	
COLUMN TOTAL		1	91	100	91	17	4	304
TOTAL		0.3	29.9	32.9	29.9	5.6	1.3	100.0

CHI SQUARE = 16.48013 WITH 25 DEGREES OF FREEDOM SIGNIFICANCE = 0.8998

163

BIBLIOGRAPHY

- Boske, Leigh B., and Mark J. Wolfgram. "A Social Decision-Making Framework for Analyzing Rail Service Abandonment Impacts." Transportation Journal. Chicago: American Society of Traffic and Transportation, Inc., Summer 1977.
- Boyce, David E. "Toward a Framework for Defining and Applying Urban Indicators in Plan-Making." Decision-Making in Urban Planning: An Introduction to New Methodologies. Ira M. Robinson, Editor. Beverly Hills: Sage Publications, 1972, pp. 61-83.
- Carrier, Roger E. Energy Conservation Through Urban Transportation Planning. University Park, Pa.: The Pennsylvania Transportation Institute, 1975.
- COATS (Continuing Omaha-Council Bluffs Metropolitan Area Transportation Study). 1995 Interim Transportation Study: Transit Study. Omaha: COATS, September 1973.
- _____. 1995 Interim Transportation Study: Volume 2. Omaha: COATS, November 1977.
- _____. Transportation Goals, Objectives, Principles, Standards, and Evaluation Criteria. Year 2000 Transportation Plan Technical Memorandum TM-T-1. Omaha: COATS, 1977.
- _____. Transportation Systems Management Element. Omaha: COATS, May 1977.
- Crowley, M. Metro Area Carpool Progress and Evaluation Report. Omaha Metro Area Carpool, December 1975.
- Fishburn, Peter C. Utility Theory for Decision Making. New York: John Wiley & Sons, Inc., 1970.
- Gakenheimer, Ralph and Meyer, Michael. Transportation System Management: The Record and a Look Ahead (Summary Report). Cambridge: Massachusetts Institute of Technology, January 1978.
- Gordon, Colin G., William J. Galloway, Andrew B. Kugler, and Daniel L. Nelson. Highway Noise: A Design Guide for Highway Engineers. National Cooperative Highway Research Program Report 117. Washington, D.C.: Highway Research Board, 1971.
- Hill, Morris. Planning for Multiple Objectives: An Approach to the Evaluation of Transportation Plans. Philadelphia: Regional Science Research Institute, 1973.
- Hoel, Lester, Michael Demetsky, and Mark Virkle. Criteria for Evaluating Alternative Station Designs. Charlottesville: University of Virginia, February 1976.

- Institute of Transportation Engineers. Manual of Traffic Engineering Studies, 4th Edition. Arlington, Virginia: Institute of Transportation Engineers, 1976.
- JHK & Associates and Peat, Marwick, Mitchell & Company. Measures of Effectiveness for Multimodal Urban Traffic Management. Working Paper No. 7: Recommended Measures of Effectiveness for TSM Tactics. Prepared for Federal Highway Administration Office of Research, November 1977.
- JHK & Associates. A Selected Bibliography and Reference Document in Transportation System Management. Prepared for the Federal Highway Administration, May 1977.
- Jones, David W., Jr. "The Politics of Metropolitan Transportation Planning and Programming--Implications for Transportation System Management." Berkeley: Institute of Transportation Studies, University of California at Berkeley, November 1976.
- Keeney, Ralph L. and Howard Raiffa. Decisions with Multiple Objectives: Preferences and Trade-offs. New York: John Wiley & Sons, Inc., 1976.
- Kendall, Donald C. Carpooling Status and Potential. Washington, D.C.: U. S. Department of Transportation, June 1975.
- Krajicek, C. MOVITE JOURNAL, Missouri Valley Section of the Institute of Transportation Engineers. March 1978, pp. 39-40.
- Lifson, M. W. Decision and Risk Analysis for Practicing Engineers. Boston: Cahners Books, 1972.
- Lin, Feng-Bor, and Lester A. Hoel. "Structure of Utility-Based Evaluation Approaches." Transportation Engineering Journal of ASCE. New York: American Society of Civil Engineers, March 1977, pp. 307-320.
- Manheim, Marvin L. "The Emerging Planning Process: Neither Long-Range Nor Short-Range, but Adaptive and (Hopefully) Decisive." Presented at the Annual Meeting of the Transportation Research Board, Washington, D.C., January 1977.
- _____. Fundamentals of Transportation Systems Analysis. (Preliminary Edition) Cambridge: Massachusetts Institute of Technology, August 1972, Parts A and B.
- MAPA (Omaha-Council Bluffs Metropolitan Area Planning Agency). Goals for the MAPA Region. Omaha: MAPA, 29 July 1976a.
- _____. Metropolitan Area Comprehensive Plan: Phase One. MAPA, April 1971.
- _____. Regional Growth and Development Plan: The New Direction Plan. Omaha: MAPA, December 1977.
- _____. Transportation Annual Report. Omaha: MAPA, 1976b.

- Maximan, Robert J., and Darwin G. Stuart. Sensitivity Analysis of Selected Transportation Control Strategies. Presented at the Annual Meeting of the Transportation Research Board, Washington, D.C., January 1978.
- "Measures of the Quality of Traffic Service." Highway Research Board Special Report 130. Washington, D. C.: Highway Research Board, 1972.
- Meyer, John R., and Jose A. Gomez-Obanez. Improving Urban Mass Transportation Productivity. Final Report. Cambridge, Massachusetts: Harvard University, February 1977.
- Meyer, Michael. A Review of Transportation System Management Plans Submitted In Response to New Federal Policy. Cambridge, Massachusetts: Center for Transportation Studies, Massachusetts Institute of Technology, October 1976.
- Mikolowsky, William T., William L. Stanley, and Bruce F. Goeller. "Effectiveness of Near-Term Tactics in Reducing Vehicle Miles of Travel; Case Study of Los Angeles Region." Transportation Research Record 574. Washington, D.C.: Transportation Research Board, 1976.
- Mishan, E. J. Economics for Social Decisions: Elements of Cost-Benefit Analysis. New York: Praeger Publishers, 1973.
- Nicholson, Walter. Microeconomic Theory: Basic Principles and Extensions. Hinsdale, Illinois: The Dryden Press, Inc., 1972.
- Nie, Norman H., et al. Statistical Package for the Social Sciences. 2nd Ed. New York: McGraw Hill, 1975.
- Orski, C. Kenneth. "Transportation Systems Management in Perspective." Traffic Engineering, November 1976, pp. 36-37.
- Ostrofsky, Benjamin. Design, Planning, and Development Methodology. Englewood Cliffs, N.J.: Prentice-Hall, Inc. 1977.
- Peat, Marwick, Mitchell & Company. Measures of Effectiveness for Multimodal Urban Traffic Management. Working paper Number 3 prepared for the Federal Highway Administration, June 1977.
- Pignataro, L. J. Traffic Engineering Theory and Practice. Englewood, N.J.: Prentice-Hall, Inc., 1973.
- Pratch, Lew. "Carpools: The Underutilized Resource." Civil Engineering Magazine. New York: American Society of Civil Engineers, January, 1974.
- Proposed Urban Transportation Data Reporting Requirements for States and Metropolitan Planning Organizations. Report prepared for the U.S. Department of Transportation, Washington, D. C. Transportation Research Board, 1976.
- Ridel, Frederick. "Auto Occupancy Calibration." COATS Technical Advisory Committee Memorandum. Omaha: COATS, 16 September 1977a.
- _____. "Transportation Impact Analysis for the Regional Growth and Development 'New Direction Plan'." COATS Technical Advisory Committee

Memorandum. Omaha: COATS, 9 December 1977b.

Robertson, Sydney R. "Evaluation of Alternative Transportation Systems." Lecture 14. Urban Transportation Planning Short Course. Washington, D. C.: Federal Highway Administration (undated).

Robinson, Ira M., Editor. Decision-Making in Urban Planning: An Introduction to New Methodologies. Beverly Hills: Sage Publications, 1972.

Scheibe, Mark H., and Neal J. Pedersen. "Predicting the Effectiveness of Transportation System Management Measures." Presented at the Annual Meeting of the Transportation Research Board, Washington, D. C., January 1978.

Schofer, Joseph L., and Darwin G. Stuart. "Evaluating Regional Plans and Community Impacts." Journal of the Urban Planning and Development Division. New York: American Society of Civil Engineers, March 1974, pp. 93-109

Selection Research, Inc. A Marketing Evaluation Study of the Metro Area Carpool Program. Omaha: Selection Research, Inc., June 1977.

Shimpeler, Charles G., and William L. Grecco. "Systems Evaluation: An Approach Based on Community Structure and Value." Chapter 11. Decision-Making in Urban Planning: An Introduction to New Methodologies. Ira M. Robinson, Editor. Beverly Hills: Sage Publications, 1972, pp. 241-268.

Stopher, Peter R., and Arnim H. Meyburg. Transportation Systems Evaluation. Lexington, Massachusetts: Lexington Books, 1976.

Tarnoff, Philip S. "The Results of FHWA Urban Traffic Control Research: An Interim Report." Traffic Engineering. April 1975, p. 27.

Texas Transportation Institute. Alternatives For Improving Urban Transportation. Prepared for the U. S. Department of Transportation. Washington, D. C. Texas Transportation Institute, 1977.

Thomas, Edwin N., and Joseph L. Scholfer. Strategies for the Evaluation of Alternative Transportation Plans. National Cooperative Highway Research Program Report 96. Washington, D. C.: Highway Research Board, 1970.

Thrasher, Edward J., and John B. Schnell. "Scope of Crime and Vandalism on Urban Transit Systems." Transportation Research Record 487. Washington, D. C.: Transportation Research Board, 1974.

Tomazinis, Anthony R. "Planning Urban Transportation Systems for Productivity, Efficiency, and Quality of Services." Transportation Research Record 491. Washington, D. C.: Transportation Research Board, 1974, pp. 52-59.

Productivity, Efficiency, and Quality in Urban Transportation Systems. Lexington: D. C. Heath and Company, 1975.

- Transportation Research Board. Special Report 152. Motor Vehicle Noise Control. Washington, D. C.: Transportation Research Board, 1975.
- _____. Special Report 172. Transportation Systems Management. Washington, D. C.: Transportation Research Board, 1977.
- _____. Transportation Decision-Making: A Guide to Social and Environmental Considerations. National Cooperative Highway Research Program Report 156. Washington, D.C.: Transportation Research Board, 1975.
- U. S. Department of Transportation. Carpool Incentives and Opportunities. Washington, D. C.: U. S. Department of Transportation, February 1975.
- _____. Federal Highway Administration. Computer Programs for Urban Transportation Planning: PLANPAC/BACKPAC. Washington, D. C.: U. S. Department of Transportation, April 1977.
- _____. 1974 National Transportation Report: Summary. Washington, D.C.: U.S. Department of Transportation, December 1974.
- _____. Transportation System Management: Bibliography of Technical Reports. Washington, D. C.: U.S. Department of Transportation, May 1976.
- _____. Transportation System Management: State of the Art. Washington, D.C.: U.S. Department of Transportation, February 1977.
- U.S. Federal Register. "Transportation Improvement Program." Washington, D.C.: U.S. Government Printing Office, 17 September 1975, pp. 42976-42981.
- _____. "Pedestrian Facilities and Bikeways." Washington, D.C.: U.S. Government Printing Office, 26 April 1978, pp. 17814-17815.
- _____. "Uniform System of Accounts and Records and Reporting System." Washington, D.C.: U.S. Government Printing Office, November 22, 1976, pp. 51536-51543.
- Vodrazka, Walter C., Charles C. Schimpeler, and Joseph C. Corradino. "Citizen Participation in Louisville Airport Site Selection." Transportation Research Record 555. Washington, D.C.: Transportation Research Board, 1975.
- Wagner, F. A. "Evaluation of Carpool Demonstration Projects." Washington, D.C.: U.S. Department of Transportation, November 1977.
- Weiner, Paul, and Edward J. Deak. Environmental Factors in Transportation Planning. Lexington: Lexington Books, D.C. Heath and Company, 1972.
- Wilson, David I., and Joseph L. Schofer. "A Decision-Maker-Defined Cost-Effectiveness Framework for Highway Programming." Presented at the Annual Meeting of the Transportation Research Board, Washington, D.C., January 1978.
- Winnie, R.E., and Harry P. Hartry. Measuring the Effectiveness of Local Government Services: Transportation. Washington, D.C.: The Urban Institute (undated).

Yu, Jason C., and Ahmet Ulusoy. "Cost-Effectiveness Analysis of Air Traffic Control System Improvements." Transportation Research Record 529. Washington, D.C.: Transportation Research Board, 1975.

Zakaria, Thabet. Transportation Systems Evaluation: Toward a Method and Set of Criteria for Evaluating Alternative Transportation Plans for Urban Regions. Unpublished Ph.D. Thesis, University of Pennsylvania, 1968.

