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THE USE OF MODELS IN URBAN TRANSPORTATION PLANNING

William G. Barker

DEPARTMENT OF TRANSPORTATION ★ UNITED STATES OF AMERICA ★

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16. Abstract

The report describes the most commonly used models in urban transportation planning. A background on urban transportation planning is given including changes in planning objectives and the effects of Federal legislation. General concepts and problems in the use of the models are also presented. An assessment of the situation is made and recommendations for improvement are suggested.

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PREFACE

This report was prepared within the Systems Analysis Division at the Transportation Systems Center for the Office of Transportation Planning Assistance, Department of Transportation.

The document is intended to provide background information on modeling in urban transportation planning and does not reflect the official policy of the U.S. Department of Transportation. The preparation of this report is one of the work items on the project entitled Urban Model Assessment for Transportation Planning sponsored by the U.S. Department of Transportation's Office of Transportation Planning Assistance.

Mr. Gene Tyndall, Chief of the Planning and Coordination Division in the Office of Transportation Planning Assistance, provided valuable guidance in his role as DOT monitor of the project. TSC Task Manager for the project was Mr. K.H. Schaeffer who provided technical direction to the overall study. The research for this report and its preparation was the responsibility of William G. Barker.

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1. INTRODUCTION

Urban transportation planning as it is practiced today relies heavily on computer analysis. The amount of information which is considered in order to plan a city's transportation system in a comprehensive manner is enormous*, and the only appropriate method of using this large quantity of data is through some form of automatic data processing. But the computer permits more than the efficient handling of large amounts of information. It allows an urban transportation planner to explore these data for patterns and trends and to postulate explanations of these regularities in the form of mathematical models. These models thus represent theories of urban transportation. The computer is, therefore, both a means for developing and testing urban transportation theories and a tool for assisting planners in assessing the impacts of major transportation decisions.

Computer models have been and are being used in hundreds of urban transportation studies to plan the investment of billions of dollars in transportation facilities throughout the United States. It is estimated** that approximately $70 million is spent annually for urban transportation planning in the United States. Moreover, it would not be unreasonable to expect that some 20% of this amount went to direct computer costs and to the salaries of programmers and computer operations personnel.[1]

In addition, the United States has become an urban nation. Almost three-quarters of the population of the country now reside in urban areas, and the transportation planning in a major metropolitan area impacts literally millions of people.

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*In his book, Urban Transportation Planning (University of Illinois Press, 1970), Creighton notes that the not-particularly-large Niagra Frontier Transportation Study used a file of 6,000,000 pieces of information.

**Conversation with Dr. R. B. Dial, Urban Mass Transportation Administration

Thus, the models used in urban transportation have a definite influence on the investment of large amounts of capital and the lives of the majority of the country's citizens. It is very sensible therefore, to continually assess the models used in urban transportation planning to ensure that this planning, with so much at stake, is performed at the best level of technical capability. This report is the result of one such assessment.

1.1 OBJECTIVE

The objective of this study is to describe the existing urban transportation planning models in terms of their usefulness in the planning process. The validity, ease of use, and applicability are examined, all in relation to the urban transportation planning process. The study is part of the general assessment of the role and usefulness of computer modeling in the urban transportation planning process being conducted by the Office of the Secretary, Federal Highway Administration (FHWA), and Urban Mass Transportation Administration (UMTA).

1.2 SCOPE

In any study of this nature, a trade-off must be made between the scope or number of the models considered and the depth at which the investigation is to be made. Initially, all DOT-sponsored models were to be examined. This, it was found, defines too large a universe to consider. The Department of Transportation, especially through highway trust funds allocated to state highway departments, directly or indirectly supports scores of model development efforts. In addition, the Urban Mass Transportation Administration, through its planning grant programs, supports model development at the urban level. It was decided therefore to place an emphasis on the FHWA Battery and the HUD Transit Planning Package. These software packages, distributed by the FHWA, are the most influential and the most widely used in urban transportation planning in the United States today. Other models and packages are discussed in this report, but are not analysed to any extent.

1.3 APPROACH

In preparing this report, heavy use was made of the literature in determining the validity of the theories contained in the models. For information on the performance of these models, discussions were held with several urban transportation planners and model developers*. This report attempts to present a summary of the current thinking of professionals involved with all aspects of modeling in urban transportation planning.

During this project, emphasis was placed on two aspects of urban transportation modeling. One was the models themselves, and the other area was the context in which models are used. The evaluation presented in this report results from the comparison of the modeling needs of the urban transportation planners and the capabilities of the current models.

1.4 REPORT CONTENTS

Section 2 to follow establishes the setting of urban transportation planning in the United States including a discussion of the historical background, types of activities, and planning objectives. Section 3 details the models commonly used in urban transportation planning. A descriptive evaluation of the models is also made in Section 3. Conclusions and recommendations are contained in the final section, Section 4.

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*See the Appendix for a list of the personal contacts made during the course of this study

2. SETTING OF URBAN TRANSPORTATION PLANNING

This study is primarily concerned with the use of models in urban transportation planning. It became obvious at the initiation of this project that in order to adequately evaluate model usage in this area, some understanding of urban transportation planning itself was needed. The purpose of this section is to establish the setting in which urban transportation models are used. The discussion is not intended to be a comprehensive presentation of the urban transportation planning scenario. Urban transportation is a rich enough topic for study in its own right. This section will attempt, however, to provide some background on the subject for those who are not engaged in urban transportation planning.

2.1 GENERAL

2.1.1 Activities in Urban Transportation Planning

For the purposes of this study it is convenient to divide urban transportation planning activities into two broad categories: long-range planning and short-range planning. Long-range planning is defined here as planning which deals with a planning horizon of several years. Such planning is necessarily of the strategic type, and macroscopic analytical approaches are generally most appropriate for this kind of activity. Such long-range planning usually results in a "master plan" for an urban area in a target year 10 or 20 years from the time of the plan formulation. While it has become generally recognized that a master plan cannot be both ridged and meaningful over such long periods of time, long-range urban transportation planning efforts still produce plans for the spatial distribution of land-use and major transportation facility types and locations.

Short-range urban transportation planning, on the other hand, is primarily concerned with aiding decisions on more immediate and specific topics. The design of a bus route structure is a good example of the output of a short-range planning effort. Such a plan can be implemented within a period measured in months. The FHWA TOPICS Program which encourages short-range improvements to traffic flow is another area to which short-range planning is applied.

2.1.2 Relationship with Urban Planning

The relationship between urban planning and urban transportation planning is very close. In fact, as Levin[2] has pointed out, area transportation planning has been used as a method for achieving comprehensive metropolitan plans. Today, it is generally recognized that transportation is only part of the integrated whole of the urban system. Other elements of the urban system often considered are land use, water resources, pollution, parks and recreation, and public services such as police, health, and fire protection.

2.1.3 Organization for Planning

Urban transportation planning today is conducted or sponsored by metropolitan review agencies, metropolitan planning agencies, metropolitan governments, metropolitan councils of governments, county governments and similar organizations. Sometimes planning agencies, such as the review agencies, lack the authority to implement the plans. In general, the planning is actually done by various agencies (e.g., highways by the state highway department, transit by the local transit authority, airports by the local airport authority, parks and sewers by the city, etc.) in a complex arrangement involving several levels of government (often including more than one Federal agency) and with varying degrees of coordination. The evolution of the complex governmental structure which is responsible for today's urban transportation planning is an important area worth noting.

In the nineteenth century, the limited transportation planning which existed was performed primarily by private organizations. As Creighton[3] notes:

> Most of the mass transportation facilities that were built in the nineteenth century, both between and within cities, were planned and built as single facilities without consideration of how they would link up and work together as parts of a total transportation system. Even the terminals were, many of them, in separate places. Sometimes the single lines were directly competitive with one another; in other cases franchises were handed out which gave a single company a monopoly in a certain territory. In planning these facilities, profit was the main criterion while the hard practicalities of grade, subsoil, river crossings, and (in the case of canals) water supply acted as the chief constraints.

After the turn of the century, plans were made to coordinate the individual transit operations in the major cities in order to provide better service. But the use of the automobile rapidly expanded, and by the 1920's, automobile congestion became a major city problem. Since city government controlled the streets, transportation planning became a local government activity.

The states had been responsible for farm-to-market roads, and the Federal government first entered the transportation planning picture to help the states. The Hayden-Cartwright Act of 1934 set the precedent of providing Federal highway funds for research and planning. Holmes and Lynch[4] write:

> Beginning with the Federal-aid Highway Act of 1934, Congress has provided that 1 1/2 percent of the amount of Federal-aid funds apportioned for any year to any state might be used for surveys, plans, engineering and economic investigations of projects for future construction.
>
> Starting in the autumn of 1935, the states, one by one, took advantage of this provision in the Federal law, and entered into an agreement with the Public Roads Administation relative to the conduct of a comprehensive highway planning survey. By 1940 all of the states had begun to participate and all are continuing to do so.

Since at that time Federal aid was available only for rural highways (with the exception of some public works programs during the Depression), none of this money went towards planning urban highway systems. Significant help to the cities first came in the 1944 Highway Act. As Creighton[3] notes:

> The great change in road planning came during World War II. Here was an opportunity - when lack of men and materials forced slow-downs of construction - for rethinking the direction of road construction. The cities up to this time had received very little aid, yet vehicular congestion was greatest in cities. City finances were incapable of paying for anything significant in the way of road improvements. The states and the Federal government had to intervene and bring both the powers of superior tax resources and their much larger engineering and highway-building organizations to bear if anything significant was to be accomplished. This policy change was passed in the Federal Aid Highway Act of 1944.

Thus, the Hayden-Cartwright Act of 1934 not only marked the involvement of the Federal government in transportation planning, but also set the route through which Federal aid for urban highway planning would flow in the 1944 Highway Act, namely, through the state highway departments. This arrangement has continued essentially the same since 1944.

But this arrangement existed to provide only for urban highway planning. As automobile usage continued to climb, concern developed in the cities over public transportation and urban transportation planning. The first major ad hoc study, i.e., an urban transportation study conducted by a group outside state and local government formed solely to conduct the study, was the Detroit Metropolitan Area Traffic Study started in 1953. Although this was essentially a highway planning study, the precedent was set for performing such studies by an ad hoc body separate from, but strongly related to, various governmental agencies at all levels.*

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*Some of these were: Detroit Metropolitan Area Traffic Study (1953-55), Chicago Area Transportation Study (1955), Pittsburgh (1958), Penn-Jersey (1959), Niagara Frontier (1961), and Tri-State Transportation Committee (1962).

Federal support for public transportation and/or total urban transportation planning did not come until 1954. Under the Housing Act of 1954, $5 million in matching grants was provided for urban and mass transportation planning. This was the first Federal assistance to urban transit planning. However, it apparently did not aid in the development of significant urban transportation planning. Levin and Abend[5] report on the results of some studies in the early 1960's:

> The same studies implied that neither Section 701 of the Housing Act of 1954 nor the 1.5 percent provision of the highway legislation was generating much area wide transportation planning. The 701 projects were primarily general planning studies with only a minor focus on transportation. Furthermore, most of them were conducted in small towns and medium-sized cities rather than in the nation's largest urban areas.

This time planning funds, although limited, went directly to the cities instead of being routed through the states. More Federal aid to public transportation was to come with the Housing Act of 1961. By that year, 70 percent of the Nation's population lived in urban areas, and, since World War II, more than 300 cities and towns had lost all of their public transportation due to private company cutbacks or bankruptcies.[5]

Possibly the legislation with the most impact on urban transportation planning was the Federal-Aid Highway Act of 1962. This Act specified that in order for urban areas of more than 50,000 population to receive Federal aid for road-building projects, these projects must be based on a comprehensive, continuing, and cooperative transportation planning process. Further, this requirement had to be met by July 1, 1965. Thus hundreds of cities* were required to develop plans through a process based on the three "C's" (cooperative, comprehensive, and continuing) in just three short years.

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*Some 230 urban areas were involved.[6]

For a period of about one year beginning in May 1962 (approximately six months before the passage of the 1962 Act), the American Municipal Association (AMA), the American Association of State Highway Officials (AASHO), and the National Association of County Officials (NACO) sponsored a program to discuss the planning requirements of the Act with local and state officials, many of whom were being introduced to this type of planning for the first time. Although the concepts developed in the earlier ad hoc planning efforts were generally accepted and, indeed, were part of the basis of the 1962 Act, the fact that this type of planning was new to many of the officials who would be responsible for the planning studies coupled with the resulting shortage of talent to perform the planning would create problems in meeting the July 5, 1965 deadline.

In 1964 "...The Bureau of Public Roads prepared a list of seventy-nine metropolitan areas which, according to the Bureau, were in danger of highway project disapprovals after July 1, 1965, unless they sufficiently 'accelerated' their planning processes."[6] But changes in construction schedules and improvements in the progress of the planning efforts solved the problems. "In the two years following the July 1, 1965 deadline, no interstate highway project delays could be attributed to failure of a state highway department and metropolitan area to meet the terms of the planning requirement of the 1962 Highway Act."[6]

The 1962 Act not only authorized Federal planning funds for urban transportation planning done cooperatively between state and local agencies, but did a great deal to "institutionalize" the planning methodology developed up until the passage of the Act. In order to be sure that the planning would be completed prior to the deadline and that the plans would be acceptable, local and state agencies responsible for the planning naturally used "tried and true" methods. Some state highway departments contractually required their consultants to use the BPR software.

A planning methodology is strongly linked to the planning objectives. Once goals are determined and are translated into objectives, the planning methodology must be capable of aiding the planner to determine how well a given plan meets the objectives. The goals and objectives of urban transportation planning is therefore, the next topic for discussion.

2.2 THE GOALS AND OBJECTIVES OF URBAN TRANSPORTATION PLANNING

Before getting into a discussion of the suitability of the models used in urban transportation planning, it is important to review the goals and objectives of such planning. After all, the value of a model will depend in part on its ability to help the planner reach his planning goals and objectives.

2.2.1 Historical Notes

As discussed earlier, urban transportation planning of the nineteenth century for the most part had one objective - profit for the public transportation operators. As the automobile gained wide usage in the beginning of the twentieth century, the relief of automobile congestion was a primary objective.

In the 1950's and the early 1960's it appeared that automobiles and highways would dominate future urban transportation plans for two reasons. First, the automobile became the primary means of transportation for an increasing proportion of the population, and accordingly mass transportation patronage dwindled. The second reason for the heavy emphasis on highways for cities was the lack of funding for mass transportation. Cities were offered attractive Federal funding arrangements for highway construction. The goal of transportation planning under such circumstances was the design for an efficient highway system for the urban area. The Chicago Area Transportation Study (CATS) of the late 1950's synthesized a plan evaluation scheme based on transportation costs by translating such things as accidents and travel time to costs.[3] By combining these costs with capital and operating expenses, a minimum cost transportation network could be designed.

The results of such objectives can and sometimes have become plans with straight-as-an-arrow freeways rapidly moving privately-owned automobiles from one area of a city to another. However, people began to question, among other things, the assumption that a few minutes decrease in travel time was more important than the integrity of an established neighborhood. In order to justify building more expensive transportation facilites, it was necessary to add to the objectives of the planning effort. The Eastern Massachusetts Regional Planning Project, for example, had twelve objectives which were to be maximized. These included increased jobs; recreational, and shopping opportunities; reduced physical blight; flexibility for long-term growth; retainment of regional core activities. This progression to broader objectives and values which are difficult to quantify has been under way for several years now. The Organization for Economic Co-operation and Development Consultive Group on Transportation Research recently stated[7] the general goal of urban transportation planning as it is currently understood:

> Today the best design for a transportation system is no longer necessarily the one which results in the lowest capital costs or in lower user costs, or which produces the biggest reduction in travel time. Rather, it is that design which yields the highest social return on the investment and which reconciles most effectively the conflicting interests of the individuals and various groups in the community affected by the proposed projects.

While this goal is simply stated, the mechanism for implementing this goal has not been developed. A generally acceptable definition of the social return on the transportation investment does not exist nor has a satisfactory means of identifying and resolving the community interests evolved. In short, the clear, quantified goals of early urban transportation planning have become obsolete without a recognized alternative set of goals taking their place.

2.2.2 The Influence of Federal Legislation

Federal legislation has broadened the objectives of urban transportation planning process to explicitly include consideration of the environment, the urban disadvantaged, and intermodal integration of systems. Major recent legislation affecting planning goals include:

2.2.2.1 Department of Transportation Act - The 1966 Department of Transportation Act not only formed the Department, but included a policy declaration on the environment:

> It is hereby declared to be the National policy that special effort should be made to preserve the natural beauty of the countryside and public park and recreation lands, wildlife and waterfowl refuges, and historic sites.[8]

Section 4 of the Act prohibits the Secretary from approving any project which is not in keeping with the policy stated above. Thus, transportation planning must include consideration of certain environmental impacts.

The Act also instructs the Secretaries of DOT and HUD to "...jointly study how Federal policies and programs can assure that urban transportation systems most effectively serve both national transportation needs and the comprehensively planned development of urban areas."[8]

2.2.2.2 National Environment Policy Act of 1969 - The purposes of this act are among others "to declare a national policy which will encourage productive and enjoyable harmony between man and his environment (and) to promote efforts which will prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare to man." One provision of this Act provides for environmental impact statements with every recommendation or report on proposals for legislation and other major Federal actions significantly affecting the quality of the human environment. In addition, the Act requires that all Federal agencies shall "study, develop and describe appropriate alternatives to recommended courses of action in any proposal which involves unresolved conflicts concerning alternative uses of available resources." Since urban transportation systems impact not only the traveling public but also the environment through which they are routed, the provisions of the Act affect directly the urban transportation planning process.

2.2.2.3 Federal-Aid Highway Act of 1970 - This act places particular emphasis on urban transportation. The Act specifically encourages the use of public mass transportation systems on highways and declares: "The establishment of routes and schedules of such public mass transportation systems shall be based upon a continuing comprehensive transportation planning process..."[9] The Act requires that the Urban Area Traffic Operations Improvement Programs should also be based on the planning process.

2.2.2.4 Urban Mass Transportation Assistance Act of 1970 - This Act provided a significant increase in Federal financial assistance to urban mass transit. It also declares it to be National policy, "...that elderly and handicapped persons have the same right as other persons to utilize mass transportation facilities...", and that, "...special efforts shall be made in the planning and design of mass transportation facilities and services so that the availability to elderly and handicapped persons of mass transportation which they can effectively utilize will be assured..."[10]

2.2.2.5 Airport and Airway Development Act of 1970 - This act permits the Secretary to approve airport development projects only if he is satisfied that, among other things, the project is consistent with the plans of the area planning agencies and will contribute to the accomplishment of the purposes of these plans. Here, progress can be seen in the attainment, at least as far as

Federal legislation is concerned, of true comprehensive urban transportation planning incorporating all modes.

These are real planning objectives because Federal funding can be withheld if urban transportation plans do not allow for these factors, but they are external factors in that they do not necessarily coincide with local policies and concerns. Generally, locally perceived issues dominate the development of transportation plans.

2.2.3 Planning in Response to Problems

One of the objectives of urban transportation planning is to improve the urban situation, i.e., to alleviate urban problems.

Many problems of the city have been identified, but for the purposes of this report, the eight urban problem areas identified in the 1968 summary report of the "new systems" study sponsored by HUD* will be discussed. The eight urban problem areas identified which relate to transportation are:

- Equality of access to urban opportunity;
- Quality of services;
- Congestion;
- Efficient use of equipment and facilities;
- Efficient use of land;
- Urban pollution;
- Urban development options;
- Institutional framework and implementation.

A discussion of each of these items follows.

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*The report Tomorrow's Transportation: New Systems for the Urban Future[11] is the summary of an intensive 18-month program undertaken by HUD in accordance with the Urban Mass Transportation Amendments of 1966. The various studies conducted under this program are still relevant although four to five years old.

2.2.3.1 Equality of Access to Urban Opportunity - There seem to be many facets to this problem. For one, there is the concern of providing transportation to the young, the old, the poor, and the handicapped. Recently, this concern has resulted in a national policy declaration in the Urban Mass Transportation Assistance Act of 1970 that the elderly and the handicapped have the right to utilize mass transit facilities.

Another aspect of the problem appears to be bringing mobility to particular socio-economic groups in the urban community in an attempt to solve social problems such as unemployment. For example, Washinton, D.C. recently conducted such a project in which it was noted, "inadequate reverse commuter bus facilities have long compounded the problem of transporting inner city under-employed persons to suburban areas of greatest hiring potential".[12]

A basic underlying cause to all of this is the overwhelming reliance on the auto-driver/highway system as the transportation system for personal transportation in our cities. This has isolated those who are not auto drivers whether by choice or not. As Plowden[13] has noted, consciously or unconsciously our aim over the years has been:

> to allow as many people as would like to use cars to do so. This is an attractive statement, since certainly it is a reasonable aim that people should do what they like as far as possible, but is hard to see why it is more important to allow as many people as want to use cars than to make an attractive and convenient system available for those who are unable or unwilling to use cars. Nor is it easy to see how one can tell, or even how the individuals themselves could tell, who would want to use cars without knowing what the possible alternatives might be.

Providing transportation to those who cannot drive a car has become possibly the primary transportation concern of small cities. While small cities are generally free of the automobile congestion experienced by larger cities, they may also experience difficulty in supporting a bus system.

2.2.3.2 Quality of Service - This problem primarily relates to current mass transportation systems. Excessive walking distances, infrequent service, poor connections, crowding, noise, and other characteristics are commonly used to describe mass transit. Obviously, the improvement of the quality of service requires a combination of engineering and planning.

2.2.3.3 Congestion - Although congestion is considered undesirable because it results in loss of time to the traveler, the HUD report notes that with the congestion problem "too often the 'solutions' are expensive in dollars and landtaking, destroying the urban environment in the process." Congestion is not always a problem. It can be an effective tool of urban design in shaping the urban form. It may not even be a transportation problem at all, for as Owen[14] writes:

> ...the long-standing nature of urban congestion and its world-wide scope suggest, despite a variety of forms, that underlying factors may be universal and only partially related to modern methods of transport. Basic causes appear to be excessive crowding of population and economic activity into small areas of land and the disorderly arrangement of land uses that has maximized transport requirements.

2.2.3.4 Efficient Use of Equipment and Facilities - Although the HUD report addresses the efficient use of mass transit facilities, the efficient use of the automobile and the highway network is also a problem. Excess capacity exists due to the design of facilities to meet peak demands. As the DOT policy statement[15] emphasizes, this excess capacity situation is not peculiar to just urban transportation but is characteristic of transportation as a whole. For example, automobiles themselves carry, on the average, only one-half to one-fourth of their capacity while in use. Furthermore, the Niagara Frontier Transportation Study found that in the highest six-minute period of auto usage, only 24 percent of all the cars in an urban area were being used, i.e., were not parked.

For mass transit, improved planning offers increased efficiency through the determination of better routing and scheduling. The HUD paper identifies improved planning as a primary means to increase operating efficiency.

2.2.3.5 Efficient Use of Land - Owen[14] writes, "In most cities one-third of all the land is devoted to streets, railroad yards, terminals, airports, and parking facilities. Much of this space is required by urban street systems designed primarily for property access rather than for traffic." The HUD report states "more rational urban land use made possible by new forms of transportation might help reduce travel demands, aid in substituting communications for urban transportation, and achieve greater total transportation services for the amounts of land required."

2.2.3.6 Urban Pollution - The statistics vary, but transportation systems are a large, if not the largest, sources of air pollution. Recent studies,[16,17] have shown that urban transportation planning can result in transportation plans which reduce this pollution. Noise and esthetic pollution are also problems to which transportation contributes in a significant way.

2.2.3.7 Urban Development Options - Transportation is a primary tool in the shaping of the urban form. It should be recognized that while a transportation system can influence the development of a metropolitan area, the system may not be designed to support the resulting spatial distribution of urban activities. The HUD report states, "present urban transportation is often not appropriate for the modern city: service is generally inadequate or unavailable for low and medium density areas, for cross haul trips and reverse commuting and for circulation within activity centers and satellite cities." Further, the report states, "urban transportation service should provide for choice in living styles and in location as well as choice among modes of transportation."

2.2.3.8 Institutional Framework and Implementation - Finally, but certainly not last in importance, are the legal, financial, governmental, and intergovernmental aspects of transportation. Solutions to many urban transportation problems lie in the improvement of the institutional framework of urban transportation and not necessarily in better technical planning or new technology. The HUD report does note, however, that better analyses of the investment, financing and pricing considerations or urban transportation systems could contribute to the reduction of some of the problems found in this area. The need for better evaluation techniques is also identified.

2.2.4 The Flux of the Matter

It should be clear to the reader at this point that what prevents the solidification of a set of objectives for urban transportation planning is that our goals change over time. Lang[18] has written:

> ...transportation is all bound up with the fundamental goals and objectives of our society. These goals and objectives are changing in complex and uncertain ways. Thus, our planning efforts must work within a value structure which is at best uncertain, a problem rendered more difficult by the unusually long lead times associated with many critical transportation decisions.

A very good example of the effects of changing goals and objectives can be seen with the Nation's newest rapid transit system the Bay Area Rapid Transit (BART) system. BART took a decade to plan and another decade to construct. As parts of the system neared completion, it was deemed necessary to retrofit stations with elevators to meet the policy requirement regarding the accessibility to mass transit by the elderly and handicapped in the Urban Mass Transportation Assistance Act of 1970.

Indeed, in the light of changing goals and objectives, there must be a strategy to urban transportation planning which keeps the whole exercise meaningful in this context of change. Accordingly, rigid master plan development has given way to more flexible planning approaches. Different cities with different problems necessarily have sought individual planning solutions to fit their needs.

2.3 HOW MODELS ARE USED IN URBAN TRANSPORTATION PLANNING

Just as cities differ, urban transportation planning approaches differ from city to city. A full discussion of the variations in approaches to urban transportation planning is not within the scope of this study, but the following remarks will provide the reader with a general understanding of the process.

2.3.1 General Approach

The complexity of the urban transportation planning process naturally lends itself to the techniques of operations research and systems analysis. Central to these approaches to complex problem-solving is some type of model of the system under study.

The use of models, whether computer models or in some other form, is necessary for the planning of urban transportation. The planner cannot try different highway networks in an actual city in order to determine the best network. The disruption to activities in the city would be enormous, the expense would be prohibitive, and the planner would still be uninformed as to the long range desirability of his selections. The process of using a model to determine the performance of a system under various conditions is called "simulation," and as Creighton[3] has noted:

> As a process, transportation planning is unusually dependent upon simulation as its means of testing plans. Other kinds of planning may employ intuition or "conventional" reasoning or a series of simplistic calculations. But these are not adequate in a situation where the mutual interdependence of facilities is so great, and where changes in facilities can so easily cause a redirection of travel, a change in habitual origins and destinations or even a choice of mode of travel. No

> means other than simulation offers the ability to determine the ramifications of kinds of actions proposed to be taken in urban systems.

Simulation is used in the evaluation of a transportation plan. To perform this evaluation, forecasts are made of the demographic and economic characteristics of the urban area, and activity allocation models (sometimes called "land-use models") are used to determine the resulting densities and spatial distribution of the forecasted urban activities. The characteristics of the trip-making in the urban area can be estimated from this forecasted layout of the area.

The transportation system is then modeled under these forecasted conditions in an effort to test or evaluate the performance of the proposed transportation system.

Depending on the study, variations are made in land use policies or the transportation system or both to develop alternative plans for the city. The best alternative plan is usually selected through a formal set of criteria.

The general approach can be represented by the diagram in Figure 2-1. Variations in approaches usually are characterized by differences in the methods by which the alternative plans are developed. There seem to be two broad method categories: those methods in which alternative plans are generated as the result of the simulation of a previous plan and those methods in which alternative plans are constructed independently of the evaluation simulation.

Using models in this manner requires that the models produce performance measures of the system which can be rated by the evaluation criteria in the plan selection process. Another requirement is the necessity of simulating all reasonable alternatives so that there is no chance that the best alternative will not be evaluated. Naturally, there must also be some assurance that the model is a valid one, i.e., it truly behaves as the real system behaves.

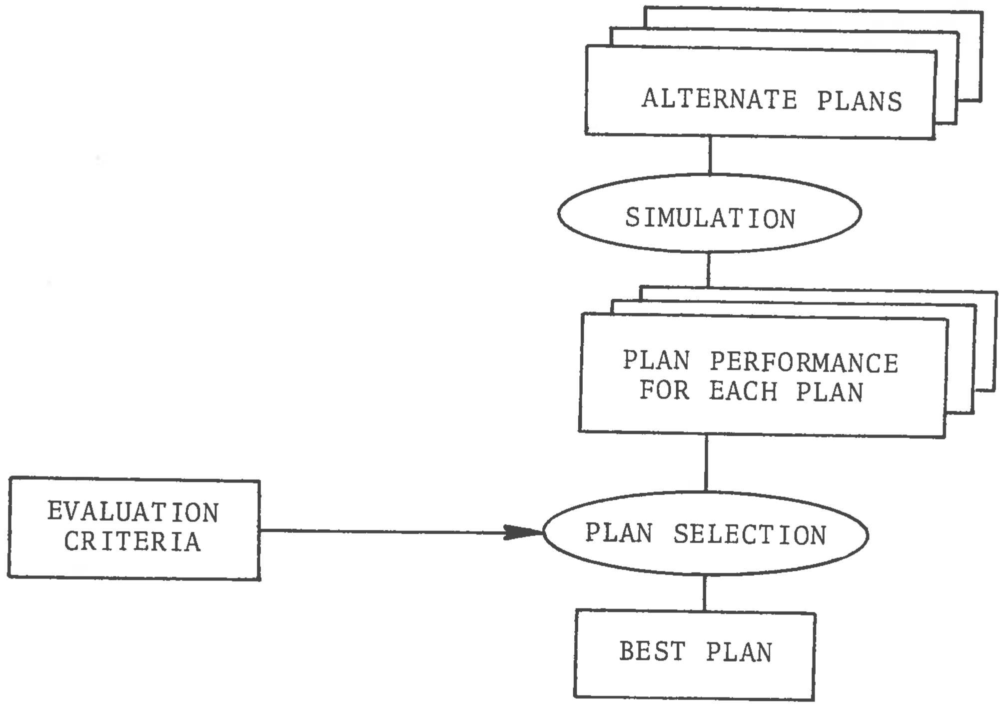


Figure 2-1 General Approach

These requirements are essential to a valid analysis, and they imply an order to the work preliminary to the actual simulation process. The very first task preliminary to simulation is a statement of the problem, i.e., what performance measures are to be used in the evaluation of the plan. Next, a model is constructed which will produce these performance measures, and the model is tested to verify that it performs correctly. Finally, some methodology is constructed which will assume that all reasonable alternatives will be investigated.

In practice, the total urban system is decomposed for analysis into the various urban subsystems, and the separate performance measures are later combined into a set of system performance measures which are then evaluated to determine the best plan for the urban area. The simulation of the transportation subsystem is of interest here.

2.3.2 Simulating the Transportation System

Under the auspices of the FHWA and its predecessor the Bureau of Public Roads, a somewhat standardized method has evolved for the simulation of urban transportation systems. The general approach of this method is diagrammed in Figure 2-2. Here, an alternative plan is introduced as the "Future Land Uses" and the "Future Network"; the plan performance in terms of network loadings, is the output of the "Assignment" task. The evaluation criteria and plan selection are part of "Transportation System Analysis".

The steps taken within this framework to estimate network loadings from a given land use/network plan are of particular interest. A series or battery of computer programs, some of which are models, is provided by the FHWA to accomplish this portion of the plan-making process. Because a particular analytical approach is implicitly contained in this battery of programs, it will be called the "Battery approach." Technically, this approach consists of four steps (see Figure 2-3). The steps in this approach are as follows:

- Trip generation - This is an estimation of the number of trip-ends (trip origins and destinations) for each zone of the urban area.
- Trip distribution - The outcome of this step is an estimation of the number of trips between each zone pair.
- Modal split - This is a prediction of the number of trips made by each mode of transportation between each zone pair.
- Traffic assignment - The amount of travel is loaded onto the transportation network during this step to determine the network performance.

These steps are executed in the order listed above with exception of modal split. Modal split may be made part of the

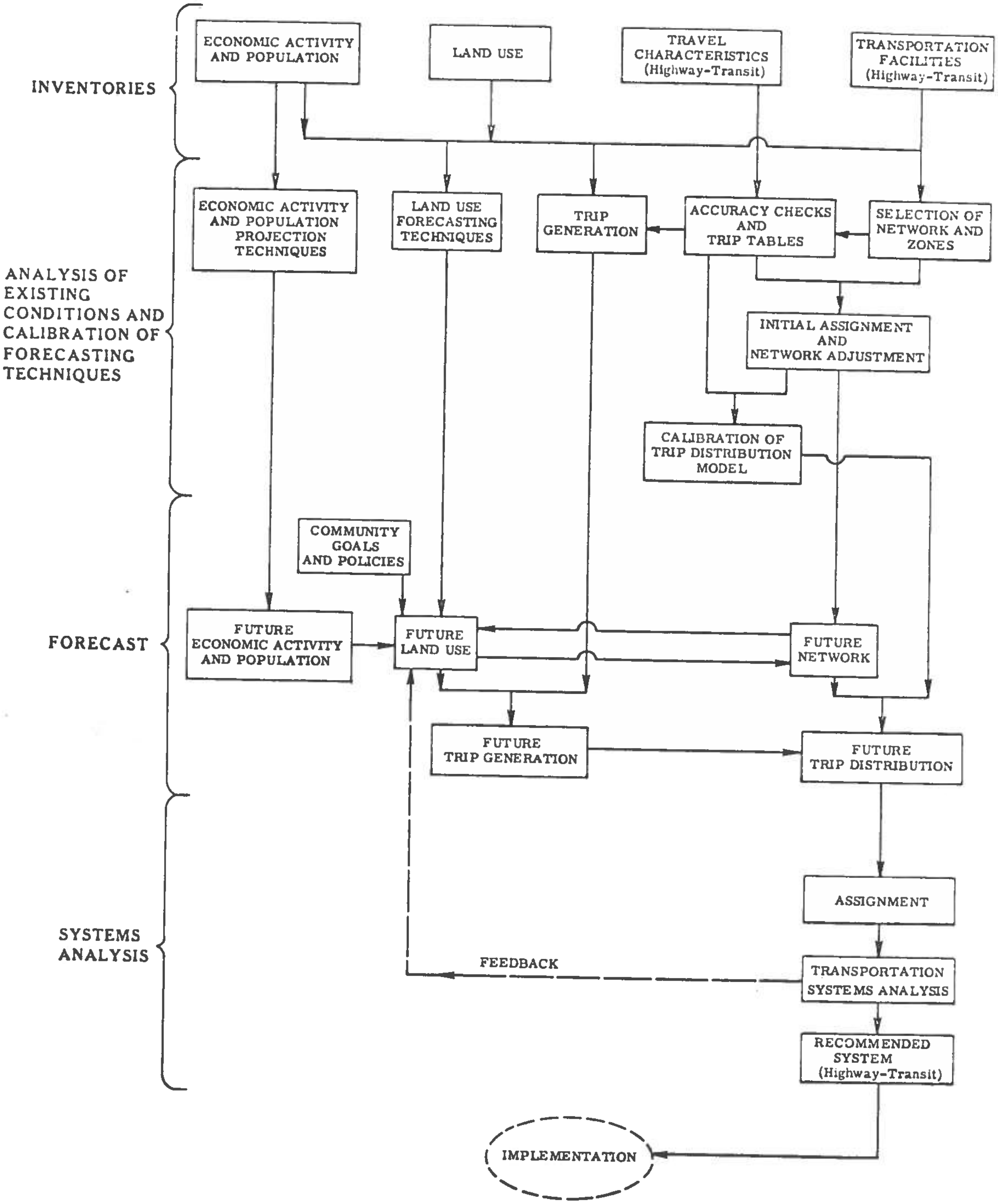


Figure 2-2 Urban Travel Forecasting Process[19]

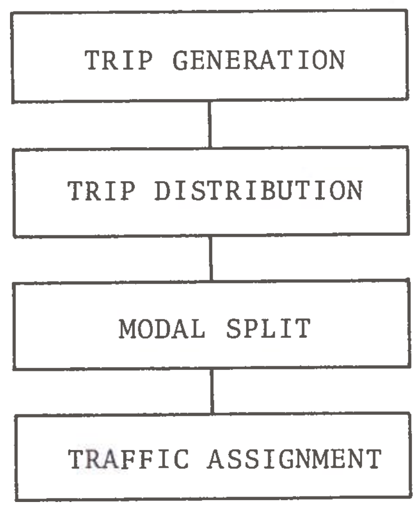


Figure 2-3 The Battery Approach

trip generation step or may be accomplished between the trip generation and trip distribution steps instead of its location in the list above. In addition, modal split is sometimes not performed at all when the interest is in only one mode of transportation.

In those studies where more than one mode is considered, the modes are usually considered separately once the modal split has been made. For example, transit networks and highway networks are loaded by separate traffic assignments.

These basic steps of the Battery approach, and the associated models, are discussed more fully in the next section of this report.

3. MODELING IN URBAN TRANSPORTATION PLANNING

In this section, a more detailed description of the basic models commonly used in urban transportation planning will be presented. A set of criteria for evaluating these models will be developed and an evaluation presented.

3.1 A DESCRIPTION OF THE METHODOLOGY

The term "Battery approach" is used to describe the methodology shown in Figure 3-1. This approach is used widely and is known also as the "transportation plan evaluation process" and the "urban transportation planning process". The objective of the process is to estimate the amount of travel on specific portions of the transportation network. Through this means, the efficacy of various land use plans and transportation network plans can be determined.

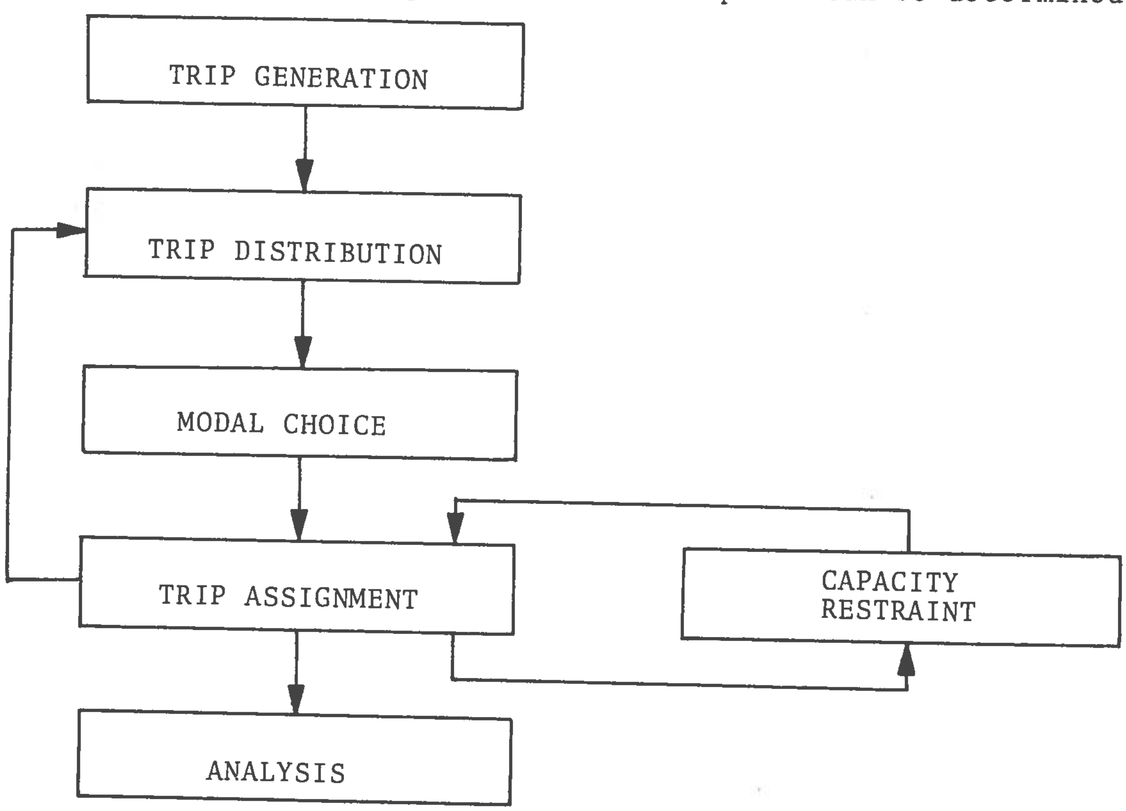


Figure 3-1 The Battery Methodology

The FHWA distributes two packages of programs which are designed to support this methodology. These two sets of programs are called the "FHWA Battery" and the "HUD Package." The FHWA Battery is designed to address all of the steps of analysis with the exception of the modal choice step for which the HUD Package is used. The FHWA Battery was first released by the BPR in the early 1960's. In 1966-67, the Department of Housing and Urban Development contracted for a package of mass transit planning programs but did not provide support for this software. Since both types of planning programs are needed for urban transportation planning the FHWA performed a needed role by distributing the HUD Package.

Returning to Figure 3-1, estimates are made of the numbers of trip origins and destinations in all zones of the urban area in the "trip generation" step in the process. These estimates are based upon information on the activities in each zone such as housing information, retail floor space, and population characteristics. The Battery contains no models for this task but does offer general statistics programs which may be used to develop statistical relationships.

In the "trip distribution" process, a kind of matching takes place between the trip origins and the trip destinations calculated in the trip generation process to produce estimates of the numbers and lengths of trips from one zone to another in the study area. The Battery provides a choice of three models to perform this task: a gravity model, an intervening opportunities model, and the Fratar model. The gravity model is the most widely used of the trip distribution models. It works on the premise that the amount of travel between two zones in a city is proportioned to the amount of activity in the two zones and inversely proportional to the impedance to travel (a function of time, cost, distance, etc.) between the two zones.

The intervening opportunities model was originally developed for use in the Chicago Area Transportation Study. More difficult to calibrate than the gravity model, the intervening opportunities model assumes that trips originating in a zone will terminate in the nearest zone which satisfies the purpose of the trip. This model is considered to have a stronger theoretical foundation than any of the other common distribution models,[20,21] but recent figures[22] indicate that the model has declined in popularity. The program used to calibrate this model has been dropped from the Battery.

The Fratar model simply applies growth factors to the trip productions and attractions in each zone and resolves these growth factors with an initial trip distribution. When applied to stable areas, i.e., areas not undergoing land use or transportation changes, the Fratar model is comparable in accuracy to the other distribution model and computationally more efficient.[23]

The HUD package contains programs which support the development of a modal choice or modal split model. In the "modal choice" step, this model will "split" the trip interchanges calculated in the trip distribution step into transit trips and auto trips.

The application of modal split has been tried in a number of places in the process. Besides the location after trip distribution, the modal split has also been done before the trips are distributed. Modal split models which allocate a portion of origins and destinations to different modes before distribution are called "trip end" models. Those models which perform the split after distribution are called "trip interchange" models. The HUD package supports the trip interchange approach.

At this point in the process, the planner now has estimates of the number of trips by auto and transit between each pair of zones in the urban area. These estimates are called "trip tables". In the trip assignment step, these trips are loaded onto a potential transportation network. The HUD package provides programs for loading transit trips on a transit network, and the Battery contains programs for loading auto trips (converted from person trips) onto the road network.

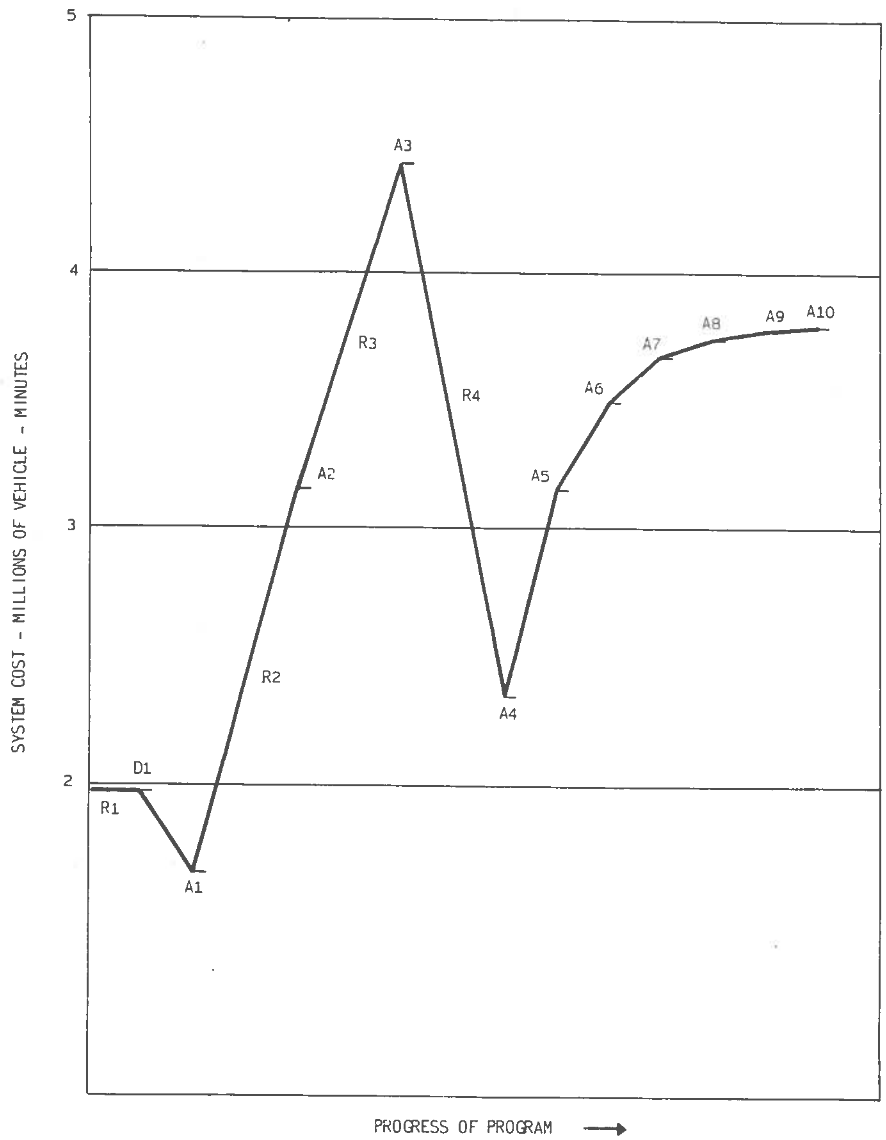
The analyst now proceeds with the "capacity restraint" task in which auto trip times are adjusted according to the volumes of traffic assigned to the links of the road network. Travel times on the road network links are increased as the traffic volume on these links increases. These changes in travel times between zones may cause drivers to use different road routes in order to reduce their trip times, so the "trip assignment" process is repeated for the auto trips to redistribute the traffic on the road network with the adjusted link travel times.

When the Battery user is satisfied that enough iterations of the capacity restraint/trip assignment cycle have been completed, the resulting zone to zone travel times are input into the trip distribution calculation to repeat the steps of the approach with more realistic travel times. Finally, in the "analysis" step the resulting information from the previous steps in the process is used to determine the performance of the existing or proposed transportation network. Various programs in the HUD package and the Battery can be used to aid in this task.

The structure shown in Figure 3-1 is not rigid. Local and state planners are free to modify the process. Depending on the highway network input and the level of accuracy desired, the capacity restraint function can be dropped. Some studies even drop the feedback of congested travel times from assignment back to distribution. This is unfortunate since this is the opportunity for the system to reach a balance between trip distribution and traffic congestion. The graph in Figure 3-2 shows the variance in total system cost (in vehicle-minutes) for one city through several iterations of the assignment/distribution process. Note that the total system cost is nearly twice the original total cost after the system reaches a balance.

3.2 EVALUATION CRITERIA

In order to evaluate the models discussed in terms of validity, ease of use, and applicability, some criteria must be used. The selection of criteria for the evaluation here is constrained



Source: N.A. Irwin, Norman Dodd, and H.G. Von Cube, "Capacity Restraint in Assignment Programs," Highway Research Board Bulletin Number 297, 1961.

Figure 3-2 Balance of Traffic Congestion and Traffic Distribution by the lack of sufficient information about the models in some cases. An example of this is in evaluating the validity of the models. Ideally, one would like to examine the accuracy of the travel forecasts which the models produce. Unfortunately, such an investigation apparently has never been performed. Examinations of model accuracy have been limited to the models' ability to reproduce existing travel. The accuracy of the models in reproducing base year travel patterns will by determined by comparing travel volume errors with the expected errors due to sampling.

The validity of the models in forecasting cannot be determined solely by this criteria, however. In order to have confidence that the models will forecast the correct travel under conditions other than those existing in the base year, the model system must be based upon acceptable assumptions and develop forecasts logically from these assumptions. Thus, the second criteria of model validity is that the model is logically consistent.

In the area of ease of use, two criteria have been identified: documentation and resource requirements. Documentation is those materials needed to intelligently apply the theory embodied in the models as well as program documentation, i.e., the instructional material needed to run the programs. The extent to which quality documentation exists for the models will be noted. The breakdown of costs in an urban transportation study will be examined in order to evaluate the resource requirements of using the models.

The investigation of the applicability of the models can be interpreted as an attempt to determine the extent to which the models aid in the analysis which supports urban transportation planning. In Figure 3-3 a breakdown of the inputs and outputs of such an analysis are shown. The catagories into which these inputs and outputs are placed are extremely broad, and some planners would perhaps disagree with the specific groupings shown in the figure. The diagram points out, however, that the basic controlable variables are policies and facilities. Further, the purpose of the analysis is to determine the impacts (in the broad areas

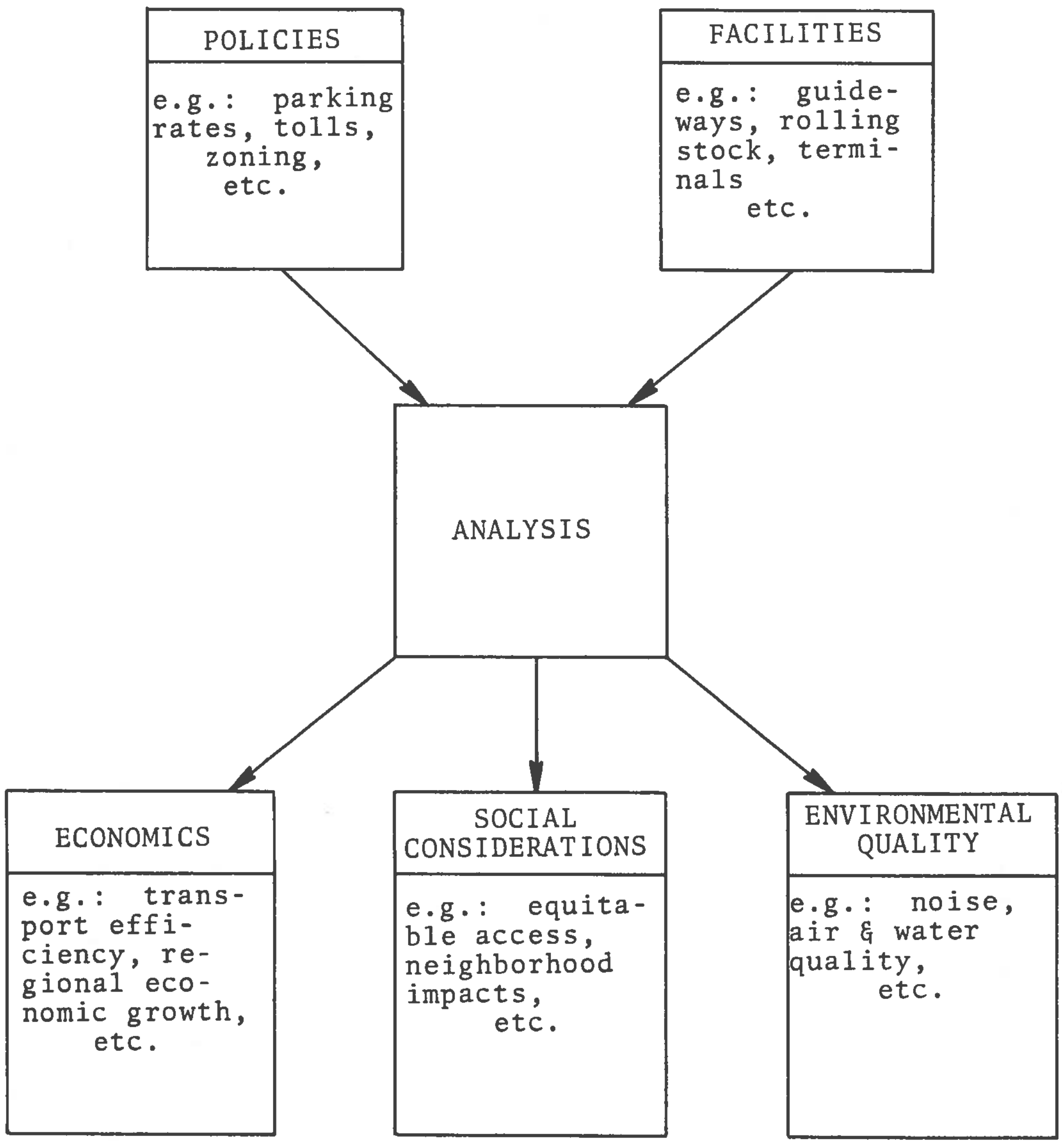


Figure 3-3 Inputs and Outputs of an Urban Transportation Planning Analysis

of economics, social considerations, and environmental quality) that a given set of policies and facility plans will have on the urban area. To assess the applicability of the models, an attempt will be made to discuss how well the models can accept variations in the input parameters, viz., policies and facilities, as well as the appropriateness of the modeling approach in estimating impacts in the three broad areas identified.

Finally, the ability of the models to permit planners to distinguish between the alternative plans will be examined. It can be argued that regardless of the accuracy of the estimates produced by the models, the models are useful if they permit planners to distinguish between plans.

3.3 AN EVALUATION OF THE MODELS

With the set of criteria developed previously, an evaluation of the models can now be performed. How well the models meet the criteria will be discussed below.

3.3.1 Validity

3.3.1.1 Reproducing Existing Travel Patterns - There is limited published information on this topic. One report[24] investigates the accuracy of the models in reproducing the traffic volumes in Sioux Falls, South Dakota in 1963*. The metropolitan area was subdivided into 183 internal zones (66 more than the actual Sioux Falls study). The population of the metropolitan area in 1963 was approximately 84 thousand.

Since only 1% of the person trips were transit trips, no attempt was made to reproduce transit trip patterns. A cross-classification procedure for four trip purposes was used for trip generation. The gravity model was used to distribute the trips which were then assigned to the highway network.

*The case of Sioux Falls is commonly used in the classes conducted by the FHWA in the use of the Battery.

The study area zones were than aggregated to 14 districts. A comparison of the traffic volumes between districts from the original data and the model predictions is shown in Figure 3-4. Figure 3-4 is a schematic corridor map showing volumes to the downtown district. Table 3-1 shows the model errors in predicting traffic volumes from all districts to the downtown district. With a few exceptions, the errors (% RMSE in the Table) in the model outputs are close to the 12 1/2% root-mean-square volume errors expected for the sample rate used in the dwelling unit survey. For those volumes with unusually large errors, the volume of the traffic is small compared to what could be considered a need for expanded transportation facilities.* Since auto traffic volumes are low for this relatively small city, the instances of errors up to 68% in the model results generally present no problem to planning. Thus, for the case of Sioux Falls, the models appear to adequately replicate existing auto travel patterns.

A more comprehensive investigation of the accuracy of the Battery approach for a large city was performed by CONSAD Research Corporation under contract to the BPR in 1968.[25] In this study, an attempt was made to compare the accuracy of the models in reproducing 1958 Pittsburgh travel patterns with particular attention to the propagation of sample errors throughout the modeling process.

In the CONSAD study, the 1958 Pittsburgh Area Transportation Study (PATS) internal inventory was used. The area was composed of 226 zones from which a 4% sample yielded over 16,000 home interviews.

For trip generation, CONSAD used a trip production model developed by PATS. CONSAD developed a trip attraction model for the study. Both models were based on linear regression. The gravity model was used for trip distribution. Linear regression on characteristics of the origin and destination zones and the

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*A two lane urban arterial can carry from 3-9 thousand vehicles in the peak direction

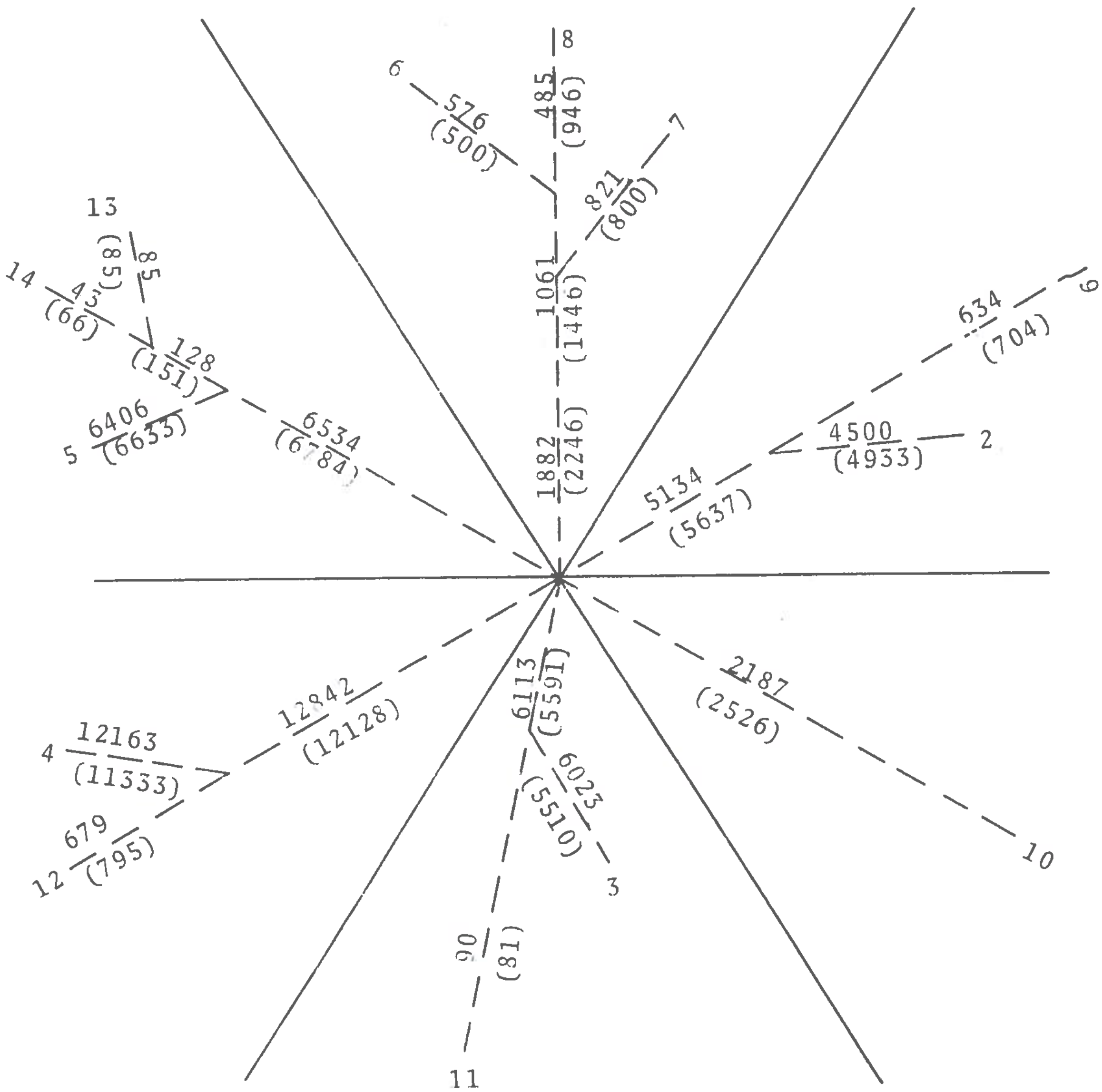

Figure 3-4 Schematic Corridor Map for Sioux Falls

TABLE 3-1 COMPARISON OF DISTRICT TO DISTRICT TRAFFIC VOLUMES FOR SIOUX FALLS

Traffic Volume Group	Frequency	Average Volume	% of Total Volume	Mean Difference	Root Mean Square Error	Standard Deviation	% RMSE
0 - 499	165	110	73	22	74	71	68
500 - 999	16	731	7	83	167	150	22
1,000 - 1,999	21	1,427	9	- 23	351	359	25
2,000 - 2,999	5	2,319	2	108	658	726	28
3,000 - 3,999	3	3,230	1	223	537	598	17
4,000 - 4,999	4	4,355	2	417	602	502	14
5,000 - 5,999	4	5,756	2	- 221	704	771	12
6,000 - 7,999	3	6,189	1	- 593	921	863	15
8,000 - 9,999	2	8,455	1	- 713	1,158	1,290	14
10,000 - 14,999	1	12,163	1	- 830	830	0	7
25,000 - 49,999	1	35,380	1	- 2,438	2,438	0	7
TOTAL	225		100				

difference between highway and transit times were used by CONSAD to develop a post-distribution, i.e., trip-interchange, modal split model which was not available from PATS. Vehicle occupancy was simply the average occupancy for each originating zone. Traffic assignment was done using trees without capacity restraint.

The results of the study are shown in Table 3-2 which is taken directly from the final report. The outputs of the individual models in the forecasting process were compared against the data from which the models were developed and calibrated in order to determine the "Actual Error" of the forecasts. The "95% Confidence Theoretical Error" is based upon the propagation of errors in the input data through the mathematical formulation of the models and is calculated for each zone, zone pair, etc., calculation performed by the models. All of the errors presented are average errors. For example, the average error in the calculation of the number of trip ends by the production model is 29%. While the average theoretical error is 31%, i.e., with 95% certainty, the output of the production model is accurate within ± 31%. Thus, for the production model, the actual error of the output is within the theoretical error of the model, and it can be assumed that the model is operating properly. Should the actual error exceed the theoretical error, the model probably has what are called "specification errors", e.g. terms are added when they should be multiplied. On this basis, CONSAD rejected its own attraction model.

The averaging of these errors is misleading however. For a model to be correct, the actual error should be within the theoretical error for each zone. For example, although the average actual error for the production model is less than the average theoretical error for the production model, an examination of the detailed data in the report reveals that the model failed the error test in calculating the home-based work productions in about 47% of the zones. It would seem that this would provide sufficient grounds to reject the production model as well.

TABLE 3-2 SUMMARY OF THEORETICAL AND ACTUAL ERRORS* OF THE MODULES OF THE UTP PROCESS

Module	Actual Error**	95% Confidence Theoretical Error
Generation		
Production	0.29	0.31
Attraction	0.51	0.17
Distribution		
Work	0.63	3.49
Non-Work	0.58	6.45
Modal Choice and Auto Occupancy	0.64	4.82
Assignment	N/A	1.21***

* Expressed as proportions of observed values

** The actual error presented here is the absolute deviation weighted by observed values of the output calculated by the model.

*** Obtained by summing the coefficient of variations of the volume grouping, developing and average coefficient of variation and multiplying by the 95% confidence value.

From: Systematic Sensitivity Analysis of the Urban Travel Forecasting Process, CONSAD Research Corporation, December 15, 1968.

In the gravity model, the actual error presented is the error in the number of trip interchanges originating in each zone after the distribution process and <u>not</u> the error in the number of trip interchanges for each zone pair. Since the theoretical error for the distribution process is based on the trip interchange calculation, it is not clear what the relationship is between the theoretical and actual errors presented. One can determine that the gravity model had roughly a 60% error in the number of origins after the distribution was completed. It should be noted that by the time the gravity model has calculated the trip distribution, the assumed error in the raw data has propagated to the point where errors of hundreds of percentage points can be expected.

The explanation for the rest of the figures in the table is less clear. For instance, the report indicates that the actual error of the modal choice/auto occupancy calculation could not be determined because, "... there were available no observed auto or transit trip tables (in machine-processable form) against which could be compared the calculated transit and vehicle interchanges."

Although it is not explicitly stated in the CONSAD report, these models were probably not applied with the skill with which the PATS staff would have been capable. It is common practice in transportation studies to change model inputs and outputs such that the models produce results which appear intuitively correct to the planners.

Finally, one of the conclusions of the CONSAD report is that the greatest variance exists in the Battery approach subsequent to trip distribution but the relative "insensitivity" of the traffic assignment process reduces the variance in the final output of the Battery, viz., volumes on the links.

If the planner is interested in who gets the benefits and disbenefits of a certain link in a transportation network and examines the origins of the travel on a particular link (there is a Battery program called SELINK which can be used for this), the accuracy of such estimates is the same as that achieved by the trip distribution process.

What conclusions can be drawn from these two tests of the Battery approach to reproducing travel patterns? First, the models are capable of doing a reasonable job of estimating travel between zones for those zone pairs in which, all things being equal, the interzonal travel follows a general "minimum effort" or "least distance" relationship. For those pairs of zones which do not exhibit such behavior, other factors, such as physical barriers, economic considerations, or social forces, exert an influence on the travel between these zones which precludes a simple gravity model formulation. The identification and prediction of such interzonal relationships is absolutely essential to the accurate forecast of a trip distribution pattern for a city.

The capability of the traffic assignment process to produce street and highway link loadings with greater accuracy than possessed by the input trip distribution is a phenomenon which works for the street and highway planner. Within reasonable limits, links on a street network with short travel times for their physical length can be expected to attract a large portion of the auto traffic in the area regardless of trip distribution. In fact, other techniques of traffic assignment (e.g., Dial's stochastic assignment[26]) have been developed which take advantage (directly or indirectly) of this phenomenon. The use of capacity restraint in the assignment process will tend to "smear" the traffic and reduce trip distribution errors even more.

Another phenomenon which aids the traffic assignment process is the great crisscrossing of paths at the center of the study area which naturally results from the use of shortest paths between zone pairs in the study area. Various trip distributions will undoubtedly produce the typical build-up of travel volumes at the center of the city.

The best application of the models appears to be in the estimate of parameters describing gross travel behavior such as total vehicle miles of travel, especially in a relative sense as in the comparison of alternative plans. At this level, it is reasonable to assume that the large errors possible in individual zone or zone pair estimates cancel. Using these sub-estimates for planning would be somewhat risky in that large errors are possible.

An application[27] of the HUD Transit Planning Package to the analysis of a bus route structure in the Washington, D.C. area pointed out the limitations of these models in microanalysis. In order to apply the HUD package to the route structure problem, it was necessary to define more than one analysis zone for some of the bus stops in order to properly treat travel to and from these stops by park 'n' ride, kiss 'n' ride, and so forth. None of these zones were compatible with the zones used in the long-range planning process of the urban area of interest. Additional problems were encountered in attempting to use a continuous function for transit service which is valid only in a macroscopic sense. The behavior of the individual transit rider also became more important, and various time penalties and constraints were needed to force the model estimates to become more accurate.

The average model error in reproducing peak load point counts was 11% in the Washington, D.C. study. This accuracy was obtained, however, after the changes identified above and with a 29% net sample of transit trips as opposed to the 4% sample of households in the PATS study.

This discussion naturally leads to a more detailed investigation of the logical consistency of this modeling methodology. It is the rationale behind the models which is the second criterion for determination of the validity of the modeling approach.

3.3.1.2 <u>Logical Consistency</u> - The second criterion which the modeling approach must satisfy before it can be considered valid is simply that the model results are correctly derived from valid premises.

The modeling approach begins with premise that trip generation relationships developed for the base year will be somewhat stable over time. From the limited research on this topic,[28] trip generation relationships do change over time, but the resulting increase in travel has not justified a need to reject this premise. Since relationships for major trip purposes, e.g., home-based work, vary slightly and the major variations which occur in minor trip purposes, such as home-based school, account for a small percentage of the total motorized travel.

The most reliable trip generation relationships are based upon household data as opposed to data aggregated to a zone level. Kassoff and Deutschman[29] concluded after an analysis of Tri-State data:

> The household (disaggregate) equation produced a much lower magnitude of error when compared to the aggregate procedures. It is recommended that household disaggregate equations be utilized in trip-generation analyses, especially when proxy (disaggregate) variables may be derived for areal descriptions.

The authors also show the effects of aggregation in hypothetical, through realistic example presented in Figure 3-5. In the figure one can easily see the very different equations for trips based on household income which can result from aggregate (zone) and disaggregate (household) regressions.

But to proceed with trip distribution, households must be grouped into zones. McCarthy[30] has investigated the results of such grouping and found that zone sampling distributions are skewed indicating that the mean of this distribution is not the central value about which the households are grouped. For this and other reasons he concludes:

> Therefore trip-generation equations developed from individual household data aggregated to zonal averages will be based on invalid trip-generation relationships and, although they provide a reasonably accurate description of existing trip-generation rates, their predictive reliability is questionable because the amount of variation in the dependent variable that they explain is unreliably low.

INCOME AND TRIPS PER HOUSEHOLD PER ZONE
(Hypothetical Case)

Household	Zone 1		Zone 2		Zone 3		Zone 4	
	Income (thousands)	Trips	Income (thousands)	Trips	Income (thousands)	Trips	Income (thousands)	Trips
1	$5.5	4.0	$ 1.0	4.0	$4.0	6.0	$1.0	3.0
2	3.0	2.0	4.0	4.0	8.0	6.0	2.0	0.0
3	2.8	2.0	10.0	7.0			4.0	2.0
4	4.0	3.0	2.0	5.0				
5			8.0	5.0				
Average	$3.8	3.5	$ 5.0	5.0	$6.0	6.0	$2.3	1.7

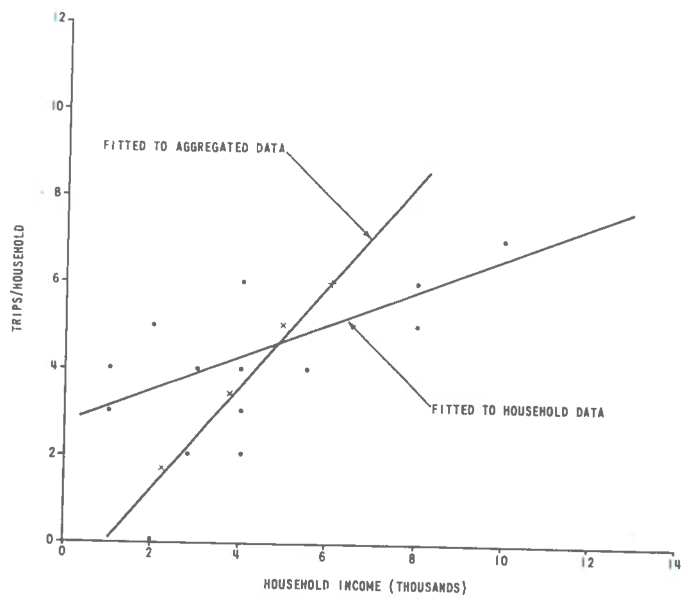

Figure 3-5 Effects of Aggregation in Trip Generation

A further complication results in the use of the same zones for both highway and transit planning. Regardless of the definition of the zones, it can be generally assumed that the auto driver can use his car to go from one zone to any other zone. This assumption cannot be made for the transit traveler; he is generally restricted to those destination zones served by public transportation. Further, the size of the zone does not affect and auto driver's capability to walk to his primary mode of transportation. To make the same assumption about the walking transit traveler's accessibility to his primary mode of transportation, zones must be centered about stations or stops and have radius no larger than a reasonable walking distance. As noted in the discussion of the HUD Package application study,[27] additional zones are perhaps needed to support an analysis involving kiss 'n' ride and other such phenomena.*

Suppose these problems of zone definition are overcome, the next step is trip distribution. A basic input to the trip distribution process is the travel time between zone pairs. The travel time between two zones depends on the mode of travel between the two zones. Commonly, this fact is ignored, and highway times only are used for trip distribution. This of course is inconsistent and would eliminate any effect public transportation might have on the distribution of trips. A few studies have attempted to combine transit and highway times to perform the distribution. One such technique asserts that the travel time can be calculated analogous to the resistance through parallel resistors:

$$\frac{1}{\text{combined time}} = \frac{1}{\text{transit time}} + \frac{1}{\text{auto time}}$$

Such a technique is rather "mechanical", or perhaps "electrical" in this case. It should also be noted that the travel times for

*An alternative to defining different zones for these phenomena is to introduce variables such as the driving time to the nearest transit station into the modeling process.

automobiles would tend to increase as the amount of travel between zones increases, but the travel time on rapid transit might actually decrease with an increase in travel due to an increase in the frequency of service.

The illogical treatment of travel times has ramifications beyond travel forecasting. The link between transportation modeling and land-use modeling is usually travel times. The land use planner gets zone to zone travel times from the transportation planner and uses them to determine accessibilities which in turn are used in activity allocations in the land-use model. Proper specification of travel times is critical to land use forecasting.

An additional point with regard to the adequacy of simple trip distribution in forecasting both highway and transit trips is that in a study by Boyce[31] it was found that a bias in direction exists for transit trips. This invalidates a basic assumption in simple distribution that only the impedance to travel between zones is of importance and that the relative location of the zones need not be considered. Boyce suggests that the choice of mode and of destination zone should be formulated simultaneously in the prediction process.

The interdependency of mode and destination, while not resolved as Boyce suggests, is considered in the Battery approach. The generally accepted model split procedure now used is the trip-interchange method. Under this scheme, the number of transit riders from one zone to another is based upon characteristics of the trip between the zones, the traveler, and the transportation service available. But it should be clear that the number of users of a highway or transit system affect the service provided by that system. Depending on the service, people may choose not to go to the same destination or not to make the trip at all. Indeed, depending on the transportation service available, people make decisions as to where they will live in the urban area so that the modal choice is made before moving into a new residence. One step in this modeling approach cannot be logically isolated from the other steps in the process.

There are some assumptions about traveler behavior which are implicit in the Battery approach using a trip-interchange modal split model. The assumptions are that a trip is generated independent of the transportation available, that the destination of the trip is independent of the transportation available, and that the traveler makes decisions on whether to take his trip or not, his destination, and his mode in that order. The interdependence of these decisions has already been discussed, but it should be further pointed out that there is no reason to assume that these decisions are sequential or that they occur in the order presumed.

To summarize, the current model system lacks the feedback through the various stages of the process which is needed to realistically simulate urban transportation behavior. In addition, a great deal of difficulty arises when one attempts to treat the various modes of transportation consistently.

3.3.2 Ease of Use

3.3.2.1 Documentation - Documentation of computer programs and analytical techniques used in urban transportation planning has historically been inadequate. The first major use of models in urban transportation planning (CATS) set a poor precedent for explicit technical documentation. The models and the information required to use them were not made available for use in other studies; studies in southern Illinois did not have the models used in Chicago. The models were spread to other studies (Penn-Jersey, Pittsburgh, Buffalo, Tri-State) by the transfer of the CATS staff, many of which were originally part of the Detroit Study, to these new study projects. To date, the transfer of planning techniques nationwide has occurred largely through consulting staffs.

The FHWA has recognized this problem and has produced a few special reports on such topics as gravity model use in addition to their documentation related to the Battery. UMTA is also working on such reports. However, the documentation of urban transportation planning techniques is generally lacking. A recent survey[32] of land use models concluded:

> Evaluation of the land-use models developed for public agencies is made extremely difficult by their limited documentation. ... This is true not only of the widely distributed final reports but also of the supposedly more detailed technical papers and memoranda. ... The extraordinary amount of time and effort necessary to interpret, define, and understand current work in land use modeling makes any substantial interchange of ideas between workers in this field very difficult.

The same survey authors point out the bulk of the documentation required to adequately record these software efforts precludes publication or public presentation through the now available media (journals, Highway Research Board meetings, etc.). The authors suggest not only stricter requirements on the software contractors with regard to documentation requirements but also the possible employment of "reporters" to record the necessary detailed technical notes on the software and techniques.

As for specific DOT-distributed computer program documentation, the quality of the program user documentation varies from program to program. The documentation frequently falls short of accepted standards (as outlined by Gray and London[33] for example).

3.3.2.2 <u>Resource Requirements</u> - To run the basic set of programs required to simulate a single transportation network (including transit) costs the Washington, D.C. Council of Governments approximately $1000 in computer time alone using an IBM 370/155 computer. Needless to say, computer costs can become sizeable when a large metropolitan area transportation study investigates several transportation networks under different land-use alternatives. The primary reason for these substantial computer times is the calculations made for zone-to-zone travel in such tasks as trip distribution, traffic assignment, and so forth. The number of zone-to-zone trip possibilities increases approximately in proportion to the square of the number of zones considered. An urban area is typically divided into hundreds of zones which result in tens of thousands zone-to-zone combinations.

But, although computer costs can be large, are they unreasonable? Hillegass[34] has investigated the average costs for eight urban transportation studies as shown in Table 3-3. Model development and application costs are primarily associated with the second, third, and fourth items in Table 3-3 which comprise 16% of the average budget of the studies. Brown, _et al_.[32] show (as reproduced in Table 3-4) that analysis and models in four major transportation studies was 14% to 24% of the study budgets. Since the rule of thumb for systems analysis projects is that 10%-20% of the project cost is devoted to software development and computer time,[35] these costs in urban transportation studies do not appear unreasonable.

TABLE 3-3 AVERAGE COSTS FOR EIGHT URBAN TRANSPORTATION STUDIES

STUDY PHASE	AVERAGE EXPENDITURE	PERCENT OF TOTAL
DATA COLLECTION AND PREPARATION	$250,000	49
DEVELOPING AND TESTING MODELS	31,000	6
FORECASTING	31,000	6
ASSIGNMENTS	20,000	4
ANALYSIS OF ALTERNATIVE SYSTEMS	80,000	15
REPORT PREPARATION	37,000	7
OTHER	68,000	13
TOTAL	$517,000	100

Source: Hillegass[34]

TABLE 3-4 BUDGETS OF FOUR MAJOR URBAN STUDIES

Atlanta Study (1961-68)	
Total budget*	$1.75 million
Data collection and processing	36%
Analysis and models	24%
Planning functions	34%
Miscellaneous projects	6%
Southeastern Wisconsin Study (1963-66)	
Total budget*	$1.99 million
Data collection and processing	62%
Analysis and models	14%
Planning functions	16%
Miscellaneous projects	8%
Bay Area Transportation Study (1968 on)	
Total budget	$5.54 million
Data collection and processing	60%
Analysis and models	18%
Planning functions	14%
Miscellaneous projects	8%
Detroit TALUS (1968 on)	
Total budget	$4.70 million
Data collection and processing	46%
Analysis and models	19%
Planning functions	20%
Miscellaneous projects	15%

NOTE: These budgets and their breakdowns are approximate. Percentages shown, while based on actual budgets, are judgmentally derived because of classification problems.

* This total is an estimate of the entire project which was completed before January 1, 1969.

Source: Brown, et al.

What does appear to be unreasonable in urban transportation studies is the cost of data collection and preparation. Typically one-half of the total budgets of urban transportation studies has been devoted to data development.

In a study of the data requirements for urban transportation planning,[36] the consulting firm Creighton, Hamburg isolated the cost of data collection and preparation for what they called "basic primary data" which is that data collected by surveys conducted by the study itself and is common to most urban transportation studies. As shown in Table 3-5, the cost of collecting this data ranges from 25% to 38% of the total study budget. These figures exclude, however, the cost of data collected initially by the study but not usually gathered in most studies and the cost of collecting and preparing "secondary data" such as transit ridership and fares, parking costs, land use plans, accident and construction costs and other essential information which is provided by other sources. As noted in the report, the "... costs of using secondary data are significant" which explains the lower percentages in Table 3-5 when compared with the previous tables.

3.3.3 Applicability

3.3.3.1 Aid in Analysis - Earlier in this report it was noted that the objectives of urban transportation planning are continually changing. Models are typically built and used for specific analyses related to specific objectives. As a result, one would expect the standard urban transportation planning models to become outdated. However, the flexibility of the analytical approach has limited its potential obsolescence as far as its capability in producing meaningful results. For example, the impedance to travel for trip distribution is essentially a user-defined quantity, and hence trip distribution calculations are not limited within the models to particular modes of travel. However, the burden is on the analyst to properly specify trip impedence relationships in order to correctly apply the models.

TABLE 3-5 COSTS OF COLLECTING PRIMARY DATA IN FIVE TRANSPORTATION STUDIES

STUDY	DATA COLLECTION COSTS ($)[a]	PER CAPITA COST OF DATA COLLECTION ($)	TOTAL STUDY COST FOR DATA COLLECTION (%)
Buffalo	584,000[b]	0.43	36
Chicago	1,160,000[c]	0.22	28
Milwaukee	605,000[d]	0.36	30
Tucson	209,000[e]	0.86	38
Wilmington	236,000	0.73	25
Average (unweighted)		0.52	31

a. These costs, based on data provided by the studies, have been interpreted and adjusted to place costs on a more nearly uniform basis.

b Does not include $25,000 for railroad network and goods movement surveys.

c Does not include cost of statewide motor vehicle use and accident cost studies made late in the study's 6-year planning period.

d Does not include $256,300 for attitudinal, economic, demographic, natural resource, and planning legislation surveys, the large bulk of which were required for the Southeastern Wisconsin Regional Planning Commission's land planning mandate.

e Does not include $13,000 for accident and CBD parking surveys

Source: Creighton, Hamburg[36]

As far as facility inputs to the analysis process is concerned, the problem is one of estimation, by the analyst, of impedance values for personal rapid transit systems, dial-a-ride systems, and the like. It is conceivable that the transit assignment programs in the HUD package and the auto traffic assignment programs in the FHWA Battery could be used for network performance estimates of such systems, but, again, the analyst would be called upon to correctly "fool" the programs to simulate these modes.

The ability of the Battery approach to accept policy variations has received much attention. Certain policy questions such as the effects of parking rates on shopping in the CBD can be addressed with the current models through appropriate specification of the travel impedences. Other policy issues such as the changes to travel behavior due to gasoline rationing are not as straight-forward; the analyst must, _a priori_, have a feel for where the changes might take place. Simply changing travel impedances will change travel patterns and the modal split, but, if gasoline rationing encourages car-pooling, the analyst must develop an auto-occupancy model which is sensitive to this. An investigation of the effects of free public transportation[37] recently pointed out the extensive analysis and modeling required outside the traditional modeling scheme.

This characteristic of the modeling process is even more pronounced when attempting to develop measures of the performance of a given set of policies and facilities. The FHWA Battery and the HUD Package are basically designed to give gross estimates of total travel in the study area. While the HUD Package does provide programs for cost information, generally the economic, social, and environmental impacts of a transportation plan must be developed in analytical activity outside of these modeling packages.

3.3.3.2 _The Production of Alternative Plans_ - Boyce, Day, and McDonald[38] studied the results of seven major land-use/transportation studies conducted during the 1960's. Variations in the transportation system were used in all but one of the studies as a means for preparing alternate plans. The following conclusions resulted from the study of these planning efforts:

a. The methods for preparing alternatives (including urban development models) were substantially more difficult to implement than anticipated.

b. The land use and transportation alternatives were much less different than expected, particularly in light of the number of land use and transportation variations examined. In those programs in which only the transportation policies were varied, no significant differences were apparent in the resulting land use patterns. In those programs in which different land use patterns were used as a basis for developing a transportation system, no significant differences were apparent in the network performance and costs for the different land use alternatives.

c. Evaluation of the alternative plans was not as sucessful as hoped due to the slight differences between alternative plans, the inadequacy of the evaluation methods, and the delays in preparing alternatives left a shortage of time for evaluation.

The authors propose four possible reasons for the lack of difference in the alternatives.

a. The variations in land use and transportation were too conservative and too similar.

b. The models and methods used were not sufficiently sophisticated to respond to policy variations.

c. The period of forecast and the increment of growth were too small for the policy variations to take effect.

d. The size of the districts used for analysis were too large and the travel demand was too great to detect the land-use and transportation interaction.

In discussing the problems of these plan making efforts, the authors note:

> ...the level of detail at which various facilities were described was often inconsistent with the geographic scale of the land use alternatives. Perhaps the most obvious example was the detailed coding of transportation networks as inputs to a forecast of land use at a large geographic scale.

As Table 3-6 indicates, the number of alternative plans evaluated in these studies was only three or four. The primary reason for generating and evaluating so few alternative plans is the effort required to do so. But, it is not clear that an analysis of more alternatives would lead to a better selection of plans. The Doxiadis Associates study[39] of the Detroit area evaluated forty-nine million alternatives using (necessarily) a simpler version of the standard modeling process and yet arrived at plans for Detroit which were remarkably similar in gross performance measures even though the plans had very different arrangements of facilities and land uses. This seems to imply that for large urban areas and planning horizons of a few decades, gross measures developed under current methodologies offer little help in plan selection.

Individual areas within these large urban areas are extremely different in character, however. Planning for these smaller areas seems more important than for the total region since: 1) control of the development for a smaller region is more likely than that of an entire urban region and 2) the performance measures vary more significantly. Thus, there is a need for more accurate planning techniques at the sub-area level than is required at the urban-wide level.

TABLE 3-6 STATUS OF SELECTED METROPOLITAN LAND USE AND TRANSPORTATION PLANNING PROGRAMS IN 1968

METROPOLITAN AREA	NUMBER OF LAND USE AND TRANSPORTATION ALTERNATIVES		PLAN EVALUATION CONCLUDED	ALTERNATIVES UNDER PREPARATION
	PREPARED	EVALUATED		
Baltimore	3	3	yes	
Boston	4	4	yes	
Chicago	5	4	yes	
Detroit				yes
Los Angeles				no
Milwaukee	4	3	yes	
New York				yes
Philadelphia	6	0		
Pittsburgh				yes
San Francisco[1]	4	4	yes	
Twin Cities[2]	4	4	yes	
Upstate New York[3]				no
Washington, D.C.				yes

[1]Two separate but related programs for the San Francisco Bay Area were reviewed, but reference is made to the completed preliminary program only.

[2]Minneapolis and St. Paul.

[3]Programs conducted by the New York State Department of Transportation in cooperation with several upstate metropolitan areas.

Source: Boyce, et al.[38]

4. CONCLUSIONS AND RECOMMENDATIONS

The use of models in urban transportation planning is an extremely large and complex topic. In this study, a great deal of literature was reviewed, and discussions were held with professionals involved in model building, model use, and urban transportation planning. As a result of this review, an attempt has been made to form some objective conclusions and recommendations. It should be understood that objectivity is an ideal quality which can only be approached and that there can always be an important piece of information which was overlooked.

4.1 GENERAL

The fact that transportation problems vary from city to city suggests that alternative approaches to analyzing these problems and planning for their solutions are needed by the individual cities. However, it is critical to planning that the differences between cities may be only apparent and that there may exist many commonalities which are not now identifiable due to a lack of theory. This is critical because a particular city today is as different from other cities as it is from its own future manifestations.

It can be concluded, therefore, that the appropriate role for the Department of Transportation in providing assistance to urban transportation planning methodology should be one of providing flexibility in the planning approach and consistent and serious support in the search for general theories of urban transportation behavior.

Recommendations

a. It is recommended that the Department of Transportation continue to provide technical assistance in such a way as to permit maximum flexibility in the application at the local level.

b. The government should continue to sponsor basic research in urban transportation planning. The importance of this cannot be overemphasized.

4.2 VALIDITY OF THE MODELS AND METHODOLOGY

Travel behavior is not a well-understood phenomenon. For this reason, and for reasons of sampling error and error propagation, the models are unimpressive in their ability to reproduce base year travel patterns. Yet, the models can be reasonably applied in the comparison of gross performance measures of alternative transportation system plans. At this macroscopic level, errors in zonal or interzonal estimates will probably tend to cancel each other.

Apparently, model sub-estimates for anything more specific than gross urban area measures should not be used for system design purposes unless large errors can be tolerated.

It appears that there exist unresolved questions as to the validity of the methodology with regard to internal consistency in the treatment of more than one mode of transportation at a time. Further, the analyst or planner has the resposibility of providing the appropriate feedbacks both within the travel forecasting modeling process and between this process and the land use forecasting process. As in other fields, a great deal of the accuracy of the models depends on the skill of the analyst. (The FHWA is to be commended on its recognition of this problem and its efforts in providing continual training courses and tutorial materials. Intermodal planning, however, currently has no such support.)

The validity of the methodology in accurately forecasting travel patterns has not been conclusively demonstrated. The heavy reliance on descriptive models lacking cause-and-effect relationships raises serious doubts as to the ability of the models to accurately forecast for more than a few years or where significant changes in the city's economy, land use pattern, or transportation system are foreseen.

Recommendations

a. It is recommended that greater emphasis be placed on analytical techniques as opposed to the models themselves. Such an emphasis would include the development of analytical techniques which do not necessarily use computer models. For analysis with the available models, concentration should be placed on the correct procedures for using these models in both old and new applications. One means of implementing such a shift in emphasis is in the development of tutorial guidebooks such as the FHWA's gravity model and traffic assignment documents. Additional instructional books are needed particularly on economic, social, and environmental impact determination, techniques for intermodal planning with the current models, and analysis of low-capital intensive improvements.

b. It is recommended, and readily accepted as being difficult to implement, that analytical approaches used in urban transportation planning be reviewed as part of the plan evaluation activity.

c. A program should be initiated to provide information on the accuracy and limitations of the existing models.

d. It is recommended that research projects be initiated to devise causal models or other techniques to bolster the ability of the methodology to forecast over longer periods of time and under significant changes to the urban system. The first step in such research should be to estimate or determine the accuracy of the current approach under planning horizons of various lengths and under varying conditions.

e. Most of the urban transportation planning efforts of the early 1960's included forecasts for the 1980-2000 time frame. Consideration should be given to a program to extract as much as possible from this upcoming opportunity to compare forecasts with actual developments.

4.3 EASE OF USE

While the effort required to use the existing software is not small, and is hampered by program errors and inadequate documentation, the resources expended in model development and application are not unusual in comparison to other systems analysis tasks. Data collection and preparation efforts for urban transportation studies, typically accounting for 50% of a study budget, do appear unreasonably high.

The documentation of the software could and should be improved. Improvements are needed both in program documentation and application documentation.

Recommendations

a. It is recommended that an attempt be made to reduce the number of programs supported in the current packages. Once this is done, the quality of the documentation and the software of the remaining, supported programs should be improved.

b. The data requirements of the models, particularly detailed network descriptions, should be reduced. This appears possible in the light of the accuracy of the models. Work already going on in integrated urban data banks should be encouraged.

c. A program should be initiated to improve the documentation available on the use and application of the software.

4.4 APPLICABILITY

It is important to realize that travel forecasts are only part of the determination of the impacts of alternative transportation plans involving policy and facility elements. The planner is responsible for the execution of a large amount of analyses outside the standard urban transportation planning process. Improving urban transportation planning, therefore, means improving the general capability of the urban transportation planner to determine the impacts of policy and construction alternatives, and it does not mean, in many instances, improving the standard urban transportation models.

While the existing packages seem most reasonably applied to comparisons of gross measures of transportation system performance, there appears to be at least some doubt as to usefulness of such comparisons under certain circumstances. For whatever reason, clear distinctions between alternative transportation plans have historically been apparently non-existent. What is different in such plans is the character of smaller sub-regions with the total urban area, yet it is for this level of analysis that accurate modeling tools do not exist.

Recommendations

a. Attention should be given to the development of small, easy to use models which address specific problems in planning. Attempting to simulate the activities of an urban area in a single model appears neither practical nor useful.

b. Research into the interaction between land use and transportation should be conducted with the objective of providing insight and information which can be effectively used by urban transportation planners.

c. The Department of Transportation should provide guidance in the evaluation of alternative transportation plans with regard to impacts on the people, economics, and environment of the urban area.

d. A more comprehensive study of the requirements of contemporary urban transportation planning is needed to identify those areas in which model or analytical technique development would be the most fruitful.

e. The flexibility in meeting changing needs and differing applications is possibly the most important quality of urban transportation planning software. Any future software developments should attempt to incorporate as much of this characteristic as possible.

4.5 CLOSING REMARKS

There is much healthy debate in the field on the issues of modeling in urban transportation planning. In this report, an attempt has been made to document these issues and suggest courses of action to resolve them. While much of the report is critical toward the current models used in urban transportation planning, to be honest, the report has to be. Although much worthwhile work has been done over the years in urban transportation modeling by many competent professionals, not many of them would admit that this work is finished. Improving the capability to plan urban transportation begins with recognizing the shortcomings of the current planning techniques and approaches and the still existing lack in our understanding of the functioning of the urban system.

APPENDIX
CONTACTS

The following people were contacted during the course of this study. It should be noted that many of these professionals have worked in several urban transportation studies and in local, state, Federal, private, and university organizations. Their affiliation at the time of contact is indicated. The opinions expressed in this report are the responsibility of the author and should not be attributed to any of the individuals listed. Their help is greatly appreciated.

Mr. John Bates, Metropolitan Atlanta Rapid Transit Authority

Mr. Charles Bell, Texas Transportation Institute, Texas A&M University

Dr. Les Boudrot, Metropolitan Council of the Twin Cities Area

Dr. David E. Boyce, Regional Science Research Institute, University of Pennsylvania

Dr. Dan Brand, Harvard University

Mr. Dwight Briggs, Urban Planning Division, Federal Highway Administration

Mr. Glenn Brokke, Urban Planning Division, Federal Highway Administration

Dr. Al Brown, PRC Systems Sciences Company

Mr. Hurvie Davis, Urban Planning Division, Federal Highway Administration

Dr. Robert Dial, New Systems Division, Urban Mass Transportation Administration

Mr. John Drake, Harvard Business School

Mr. John Fajnor, IBM Federal Systems Division

Mr. Ed Fleischmen, Urban Planning Division, Federal Highway Administration

Mr. Dave Gendell, Urban Planning Division, Federal Highway Administration

Mr. G. T. Giardini, Metropolitan Washington Council of Governments

Ms. Cobe Goligoski, Metropolitan Council of the Twin Cities Area

Dr. Yehuda Gur, Chicago Area Transportation Study and University of Illinois at Chicago Circle

Mr. Ron Hall, Urban Planning Division, Federal Highway Administration

Mr. Bill Hamilton, General Research Corporation

Mr. Walt Hansen, Alan M. Voorhees & Associates

Mr. Kevin Heanue, Urban Planning Division, Federal Highway Administration

Dr. Ron Kirby, PRC Systems Sciences Company

Mr. Walter Kondo, Massachusetts Department of Public Works

Mr. Leon LaCross, Alan M. Voorhees & Associates

Mr. Roy Larson, Metropolitan Council of the Twin Cities Area

Dr. Marvin Manheim, Massachusetts Institute of Technology

Mr. Don Morin, Urban Planning Division, Federal Highway Administration

Mr. Mike Munson, Metropolitan Council of the Twin Cities Area

Mr. Phil Patterson, Environmental Studies Division, Environmental Protection Agency

Dr. Wayne Pecknold, Massachusetts Institute of Technology

Mr. Jack Pierce, Alan M. Voorhees & Associates

Mr. Martin Redding, Environmental Studies Division, Environmental Protection Agency

Mr. Harry Reed, State of Minnesota

Mr. Syd Robertson, Urban Planning Division, Federal Highway Administration

Mr. Martin Ross, IBM Federal Systems Division

Mr. Earl Ruiter, Massachusetts Institute of Technology

Mr. Jim Schmidt, De Leuw, Cather Organization

Mr. Isaac Shafran, Northeast Ohio Areawide Coordinating Agency

Mr. Lee Shrader, PRC Systems Sciences Company

Mr. Jim Skilton, Urban Planning Division, Federal Highway Administration

Mr. Robert Smith, Southeast Michigan Council of Governments

Mr. Ed Weiner, Office of Policy and International Affairs, U.S. Dept. of Transportation

Mr. George Wickstrom, Metropolitan Washington Council of Governments

Mr. Charles Young, Massachusetts Department of Public Works

Mr. Jimmy Yu, Systems Analysis and Technical Support Division, Urban Mass Transportation Administration

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GLOSSARY*

ALGORITHM: A procedure or scheme of calculations for solving a specific problem.

ALL-OR-NOTHING ASSIGNMENT: The process of allocating the total number of trips between two zones to a single path or route between the two zones.

ANALYSIS AREA: Any group of zones that are combined for the purpose of making an analysis.

ANALYTICAL TECHNIQUE: Any methodology incorporated in an analysis.

ANALYTICAL TOOL: Any device, technique, relationship, or model which can be applied to solve a problem.

ARTERIAL: A general term denoting a highway primarily for through traffic, usually on a continuous route.

ASSEMBLER LANGUAGE: A low-level symbolic computer language wherein each instruction is translated on nearly a one-to-one basis to machine language instructions.

ASSIGNMENT: See Traffic Assignment.

BART: Bay Area Rapid Transit

BPR: Bureau of Public Roads. The predecessor to the Federal Highway Administration.

CAPACITY: The maximum number of vehicles that can pass over a given section of a lane or roadway in one direction (or in both directions for a two-lane or three-lane highway) during a given time period under prevailing roadway and traffic conditions. It is the maximum rate of flow that has a reasonable expectation of occurring. The terms "capacity" and "possible" capacity are synonymous. In the absence of a time modifier, capacity is an hourly volume. The capacity would not normally be exceeded without

*Many of the definitions presented here are from Urban Transportation planning - General Information and Introduction to System 360, FHWA, June 1970.

changing one or more of the conditions that prevail. In expressing capacity, it is essential to state the prevailing roadway and traffic conditions under which the capacity is applicable. Refer to the revised edition of the "Highway Capacity Manual" for more detail.

CAPACITY RESTRAINT: The process by which the assigned volume on a link is compared with the practical capacity of that link and the speed of the link adjusted to reflect the relationship between speed, volume, and capacity. The procedure is iterative until a realistic balance is achieved.

CATS: Chicago Area Transportation Study.

CENTROID: An assumed point in a zone that represents the origin of destination of all trips to or from the zone. Generally, it is the center of trip ends rather than a geometrical center of zonal area.

COUNT: The traffic volume counted on a street or highway.

CRT: Cathode Ray Tube. A device similar to a television receiver used to display computer generated graphics and/or alphanumerics.

DEMOGRAPHIC: Used to describe anything related to statistics about a population.

DESIRE LINE: A straight line connecting the origin and destination of a trip. A desire-line map is made up of many such desire lines, the width or density of which represents the volume of trips moving between the origins and destinations.

DESTINATION: The zone in which a trip terminates.

DETERMINISTIC PROCESS: A process in which all factors are known and predictable.

DIGITIZER: A device which is used to convert graphic information, such as a map, into digital data for subsequent data processing.

DISAGGREGATE DATA: Information on the individual as opposed to averages or similar descriptors of a group of individuals.

DISTRIBUTION: The process by which the number of trips between zones is estimated. The distribution may be measured or be estimated by a growth factor process, or by a synthetic model.

DISTRICT: A grouping of contiguous zones that are aggregated to larger areas.

DIVERSION ASSIGNMENT: The process of allocating trips between two possible routes connecting the same zones on the basis of measurable parameters.

DODOTRANS: Decision - Oriented Data Organizer TRansportation ANalysis System. A transportation modeling and analysis system developed at MIT.

EMPIRIC: A well-known land use distribution model originally used in the Eastern Massachusetts Regional Planning Project.

FHWA: Federal Highway Administration.

FORMAT: The predetermined arrangement of characters, fields, lines, punctuation marks, etc.; refers to input and output. To print in an orderly and readable manner.

FRATAR DISTRIBUTION: A method of distributing trip ends based on the growth factor of the origin and destination and on the given trip interchanges. Named for Mr. Thomas J. Fratar.

FREEWAY: An expressway with full control of access.

GRAVITY MODEL: A mathematical model based on the premise that the amount of travel between two zones is proportioned to the amount of travel generated or attracted by the two zones and inversely proportional to the resistance to travel between the two zones.

GROWTH FACTOR: A ratio of future trip ends divided by present trip ends.

HARDWARE: The mechanical, magnetic, electrical, and electronic devices from which a computer is constructed.

HISTORICAL RECORD: A binary tape record used in traffic assignment programs to provide link distance, traveltime, speed, capacity and/or count, and other descriptive information. It may also carry information about previous loadings. The output of program BUILDHR, UPDTHR, LOADVN, CAPRES, etc.

HUD: U.S. Department of Housing and Urban Development.

INPUT: This is information (instructions or data) to be transferred from external storage (usually tape or cards) to the internal storage of the machine.

INTERACTIVE GRAPHICS: Man/computer dialogue through the use of graphics.

INTRAZONAL TRAVELTIME: The total traveltime between zones consisting of the terminal times at each end of the trip plus the driving time.

INTERZONAL TRIP: A trip traveling between two different zones.

INTERZONAL MOVEMENT: The travel between zones.

INTRAZONAL TRAVELTIME: The average traveltime for trips beginning and ending in the same zone, including the terminal time at each end of the trip.

INTRAZONAL TRIP: A trip with both its origin and destination in the same zone.

JCL: Job Control Language. A computer language which provides the operating system of a computer with the information necessary to process a program.

LEVEL OF SERVICE: The term used to indicate the quality and quantity of transportation service provided under a given set of operating conditions.

LINK: A section of a network defined by a node at each end.

LINK LOAD: The assigned volume on a link.

LOADING: The process of determining the link loads by selecting routes of travel and accumulating the trip volumes on each link that is traversed.

MACHINE LANGUAGE CODING: The form of coding in which instructions are executed by the computer; contrasted to relative, symbolic, and other nonmachine language coding.

MAJOR STREET OR HIGHWAY: An arterial highway with intersections at grade and direct access to abutting property, and on which geometric design and traffic control measures are used to expedite the safe movement of through traffic.

MINIMUM PATH: That route of travel between two points which has the least accumulation of time, distance, or other parameter to traverse.

MODAL SPLIT: The term applied to the division of person trips between public and private transportation. The process of separating person trips by the mode of travel.

MODE OF TRAVEL: Means of travel such as auto driver, vehicle passenger, mass transit passenger, or walking.

MODEL: A mathematical formula that expresses the actions and interactions of the elements of a system in such a manner that the system may be evaluated under any given set of conditions.

NBS: National Bureau of Standards.

NODE: A point representing an intersection of links zone centroid.

OFF-LINE: Operation of input/output and other devices not under direct computer control; most commonly used to designate the transfer of information between magnetic tapes and other input/output media.

ON-LINE: Operation of an input/output device as a component of the computer under programmed control.

ORIGIN: The zone in which a trip begins.

OUTPUT: Information transferred from the internal storage of a computer to output devices or external storage.

PARAMETER: An item of information which is usually furnished by the user to make a general routine workable for a particular operation or condition.

PATS: Pittsburgh Area Transportation Study.

PEAK HOUR: That one-hour period during which the maximum amount of travel occurs. Generally, there is a morning peak and an afternoon peak and traffic assignments may be made for each period, if desired.

PERIPHERAL: See Off-line.

PPM: Policy and Procedure Memorandum. Used by the FHWA to set policies and procedures.

PROGRAM: A precise sequence of machine coded instructions for a digital computer to use to solve a problem.

PROGRAM DISCREPANCY: An error in a computer program.

REMOTE-BATCH PROCESSING: A type of computer usage characterized by submitting a computer run at a station remotely located from the computer and receiving the outputs from the run at the same station some time later.

ROUTE: That combination of street and freeway sections connecting an origin and destination. In traffic assignment, a continuous group of links connecting two centroids that normally requires the minimum time to Traverse.

ROUTE STRUCTURE: A network of routes.

SCREENLINE: An imaginary line, usually along physical barriers such as rivers or railroad tracks splitting the study area into two parts. Traffic classification counts - and possibly interviews - are conducted along this line, and the crossings are compared to those calculated from the interview data as a check of the survey accuracy.

SKIMMED TREES: A series of binary records containing the travel-times only between each pair of zones. The data is obtained during the tree building process.

SOFTWARE: A computer program.

SHORTEST PATH: See MINIMUM PATH.

SPIDERWEB (SIMPLIFIED) NETWORK: A simulated highway system for a given area composed only of connections between zone centroids without respect to the physical street layout. This network is usually used for corridor type analysis.

STOCHASTIC PROCESS: A process which involves random variables.

TERMINAL TIME: The traveltime required to unpark or to park and the additional walking time required to begin or complete the trip.

TIME-SHARING: The simultaneous utilization of a computer system from several terminals which are usually remotely located from the computer.

TRACE (TREE): That sequence of nodes which defines the links comprising the minimum path between two centroids. See MINIMUM PATH.

TRAFFIC ASSIGNMENT: The process of determining route or routes of travel and allocating the zone-to-zone trips to these routes.

TRAVELTIME: The time required to travel between two points, including the terminal time at both ends of the trip.

TRAVELTIME RATIO (DIVERSION ASSIGNMENT): Traveltime between points of choice by a freeway route divided by the traveltime between the same points by a nonfreeway route.

TREE: A record showing the shortest routes from a given zone to all nodes in the highway network. See VINE.

TRIP: A one-direction movement which begins at the origin at the start time, ends at the destination at the arrival time, and is conducted for a specific purpose.

TRIP CARDS: Data cards containing survey-derived trip information and related information. The data for each surveyed trip is punched in one trip card. See TRIP.

TRIP INTERCHANGE MODAL SPLIT MODEL: A model used to estimate the allocation of distributed trips to the transportation modes available.

TRIP TABLE: A table of the number of trips from one zone to another.

TRIP DISTRIBUTION: See Distribution.

TRIP END: Either a trip origin or a trip destination.

TRIP FACTOR: The number of trips represented by the trip card in which the trip factor appears. Basically it is the ratio of dwelling units to the interviewed dwelling units or a similar ration of vehicles. It may be modified to offset a poor screenline check.

TRIP GENERATION: The process of estimating the number of trips ends within a zone.

TRIP LENGTH FREQUENCY DISTRIBUTION: The array which relates the trips or the percentage of trips made at various trip time or distance intervals.

TRANS: Transportation Resource Allocation Study. A model developed by FHWA to evaluate investment strategies in the urbanized areas of the U.S.

UMTA: Urban Mass Transportation Administration.

UTCS: Urban Traffic Control System.

A FHWA developed model which simulates traffic flow in street networks.

VETRAS: VEhicle TRAffic Simulator. An IBM developed model for the simulation of traffic in a street network.

VINE: Same as TREE with the additional provision that a node may be traversed more than once from a given zone. This permits realistic paths where turn penalties and/or prohibitors are involved.

ZONE: A portion of the study area, delineated as such for particular land use and traffic analysis purposes.