NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM REPORT 167

TRANSPORTATION PLANNING FOR SMALL URBAN AREAS

TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL

FOREWORD

By Staff
Transportation Research Board

This report is of principal interest to those concerned with the estimation of travel demand in urban areas with populations of 50,000 or less. Transportation planners concerned with growth of small urban areas and/or improving mobility of residents in small urban areas will find this report to be helpful in developing plans for highways, streets, and public transportation.

The report stresses the importance of organizing transportation planning procedures to generate solutions for the specific problems of concern to a small urban area. Examples of several typical problems are given, together with the recommended procedures to follow. The nature of small urban area transportation problems is described in terms of scale, purpose, time frame, and level of detail. These elements are considered within the context of institutional arrangements, personnel, and finances. Land-use input to transportation planning techniques was found to be most appropriately developed by hand methods heavily dependent upon the planner's knowledge of the urban area and the exercising of professional judgment in an ad hoc or opportunistic fashion. Four types of transportation planning techniques were recommended for application in small urban areas: (a) network simulation based on synthetic models and a small-sample household survey, (b) consumer-oriented transit planning, (c) simple techniques for corridor analysis, and (d) hand-computation-oriented procedures for estimating localized impacts of major traffic generators. Under each type, existing techniques were reviewed and tested (to varying levels). Examples are: cross classification and synthetic models under network analysis, corridor growth traffic forecasting model, use of work trip to update continuing transportation studies, development of a consumer-oriented approach to determining local transit needs, and providing activity center traffic estimates to assist in assessing the localized impact of land-use changes on the transportation system.

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ACKNOWLEDGMENTS

The research reported herein was conducted by the Department of Civil Engineering, College of Engineering, and the Graduate School of Planning at the University of Tennessee, Knoxville, with William L. Grecco as principal investigator.

Sincere appreciation is expressed to the Urban Transportation Planning Division, Tennessee Department of Transportation; the Division of Planning, Office of Transportation Planning, Kentucky Department of Transportation; and the Transportation Research Center of the University of Tennessee for generously contributing of their time and data and providing computer assistance during the course of the project. The data and information supplied by the Southeastern Wisconsin Regional Planning Commission and the Thoroughfare Planning Section, North Carolina Department of Transportation, were useful in the analysis related to simplified network simulation models.

Numerous meetings were held with individuals to discuss the nature of transportation—land-use planning in small urban areas The assistance of those who participated in these meetings is gratefully acknowledged The list of participants is included in Appendix A

The principal research staff, all of the University of Tennessee, Knoxville, included: William L Grecco, Professor and Head, Department of Civil Engineering, Arun Chatterjee, Assistant Professor of Civil Engineering, Frederick J Wegmann, Professor of Civil Engineering, and James A Spencer, Professor and Director, Graduate School of Planning. Graduate assistants participating in the project included: Scott Cottrell, Robin McNulty, Donald Parnell, James Sellen, Phillip Sutton, and Rodney Worrell.

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RESEARCH SPONSORED BY THE AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS IN COOPERATION WITH THE FEDERAL HIGHWAY ADMINISTRATION

AREAS OF INTEREST
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TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL
WASHINGTON, D.C. 1976

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

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NCHRP Report 167

Project 8-7A FY '71
ISBN 0-309-02506-0
L C Catalog Card No 76-15790

Price: $4.80

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

are available from:

Transportation Research Board
National Academy of Sciences
2101 Constitution Avenue, N.W.
Washington, D.C. 20418

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Printed in the United States of America.

TRANSPORTATION PLANNING FOR SMALL URBAN AREAS

SUMMARY The initial goal of this research was to develop a simplified transportation planning process for small urban areas of less than 250,000 population that is sufficiently flexible so that travel forecasts can be based on a small-sample home-interview survey or a simulation. To follow through to this objective would have focused the research on the development of new and innovative models of trip generation, distribution, modal split, and assignment; specific improvements to the modeling chain would have been incorporated into a "how to" procedural guide.

Early research was on establishing the nature of transportation planning for small urban areas. Questions investigated were:

1. Who plans and at what level of planning analysis?
2. What role does policy input have? What are data inputs?
3. What are the types and number of alternatives?
4. Are implementation procedures established?
5. Are transportation and land-use plans coordinated?

It was found that the existing standardized procedures were incompatible with the possible variations in the nature of the problems, available resources, and expectations of the participants. A digest of responses from the small urban areas examined typifies the difficulty faced when attempting to adapt the planning problem to the planning process, rather than fitting the process to the specific problem.

A holistic approach was taken that looked into how and under what conditions planning was being accomplished. The findings and recommendations are categorized according to organizational framework, general procedures for achieving land-use and transportation planning, and simplified techniques. These are the four levels of planning activities commensurate with the problem. The elements of the problem were outlined according to scale, purpose, time frame, and level of detail. In addition, it was necessary to identify those elements that affected the capability for carrying out an effective planning process, such as institutional arrangement, personnel, and finances.

ORGANIZATIONAL FRAMEWORK

The research specifically addressed the organizational settings under which planning can be conducted. The level of effort involved in producing a plan can be reduced as much by agency cooperation to avoid duplication of effort in data collection as by use of techniques that require fewer data.

The organizational framework surrounding a particular planning effort is not a neutral feature. It embodies various agencies or groups with different objectives, different capabilities, different roles in the process, and different kinds of personnel.

Both land-use and transportation planning require some organizational responsiveness to variations in local situations. The extension of the customizing notion

to organizational matters is an attempt to identify at the beginning of the planning process the impact of the institutional setting to minimize friction and to ensure that the energies of the participants are directed toward commonly understood objectives. Such a customized approach, cognizant of both the parameters of the problem and the resource capabilities available for response to the problem, is readily adaptable to effective and efficient use in the planning process procedures enough to take into account variations in agency roles and relationships from one planning job to another.

Customization often yields either a reduction in the required volume of technical work over-all or an improvement in the chances that standard technical work would be implemented, or both It is not suggested that the planning process and organizational structure would be completely new in each planning job, but that each planning effort would begin with an explicit effort to identify the best organizational structure for that job The real question then is. "What are the important factors to be considered in examining the organizational structure?"

The local decision makers need to be educated to the maximum extent possible in the implications of the technical work as it proceeds in order to fully support its recommendations. At the same time the close interaction between local public officials and technical personnel during the planning process would make the recommendations more sensitive to political subtleties in the community and thereby enhance their chances of implementation.

Assignment of the various tasks in the planning process to specific agencies is a major decision made on the basis of efficiency and effectiveness. Questions arise as to what organization can produce a given work unit at the least cost and what agency is likely to produce plans with the highest likelihood of effective implementation.

LAND-USE AND TRANSPORTATION PLANNING PROCEDURES

It was found to be appropriate for planners to forego computer procedures in favor of various manual methods that are heavily dependent on the planners' knowledge of the community and the exercise of professional judgment in an ad hoc or opportunistic fashion In communities under 50,000, for example, a planner can make gross estimates of the amount of various land uses needed at some future date on the basis of population and economic studies. The required land-use activities are then spatially distributed more by design principles than projections while taking into account the capability of vacant land and proposed public improvements as well as the planner's knowledge of local development trends, land availability, and similar factors. The research reemphasizes the central importance of land-use planning in transportation planning. Land-use planning influences the procedures to be selected for conducting transportation planning as well as the content of transportation plans. It can provide a substantial resource of data and informed local people that can be utilized by transportation planners as a data source for estimating travel demand and as a process that has the potential for defining key issues in a community

Land-use planning in small communities was found to be highly standardized in format and content, but not in procedures. Customization of land-use planning would tend to foster a transportation planning process more responsive to local needs by identifying those issues most important to the community.

In most cases the transportation alternatives were formulated and evaluated in the context of a given land-use plan However, in recent years a trend exists not to limit the alternatives to transportation system variations only, but also to include the different land-use alternatives in the transportation planning process. This trend confirms the interrelationship of land-use and transportation planning and points out the need for better coordination between these two elements of urban planning. The relationship of land use and travel demand lies at the foundation of present traffic forecasting techniques. This interdependence naturally calls for a high level of coordination between the respective planning responsibilities

Alternatives to land-use growth controls that would significantly affect the transportation/land-use interaction are introduced. The most significant fundamental change proposed by the various alternatives is to require proper consideration of transportation needs (as well as other elements of the infrastructure) prior to the actual land development New concepts which are surely to be tested and eventually evaluated by the courts include impact zoning and demand-based and supply-based methodologies

The findings of this research were not sufficient to answer the question of who has the responsibility for making customization occur The U.S Department of Transportation (USDOT) is in a strong position to foster this effort through guidelines and official memorandums It should act as a catalyst rather than a direct monitor. State departments of transportation (SDOTs) are strong participants in the planning process in almost every state and might be given a charge to see that the flexibility of customization occurs in each transportation planning effort but given broad latitude to vary the responses. It would be pointless to allow a different kind of rigidity to come out of this effort

Research on recommended procedures of the urban transportation planning (UTP) process is presented at four levels of customization. Each level is presented in terms of the community's problem, the time frame, possible simplifications that can be made, and a framework for decision making.

The travel forecasting techniques advanced have been selected to reflect the various scales of transportation needs and resource capabilities typically encountered in smaller urban areas. Recommended procedures also recognize the difference in time horizons (i e , long range versus short range) and the variation in types of impacted areas (i.e., broad geographical areas with network implications, isolated travel corridors, localized impact areas like major streets, or intersections abutting a proposed activity center) The proposed procedure requires that proper attention be given to stratifying the transportation problem and using, where appropriate, simplified procedures such as categorical trip analyses, trip rates, and growth factors. The decision to select a particular analysis technique should be based on the following considerations

1. Sensitivity of the forecasting procedure to the underlying transportation-related issues.
2. Ability to provide results meaningful to the decision maker.
3. Compatibility with the degree of sophistication and time requirement appropriate for a smaller urban area.
4. Availability of data and other informational and computational facilities.
5. Availability of manpower and technical expertise.

INTERPRETATION, APPRAISAL, AND APPLICATION

The research identified four levels of analyses for consideration toward solving small urban area transportation planning problems as (a) network simulation, (b) small-area transit planning, (c) corridor analysis, and (d) localized traffic impact.

Network Simulation

The research attempted to show how a variety of simplified techniques might fit into the network procedure when appropriate for small urban transportation problems. Techniques were applied and evaluated on a limited sample of cities. These findings are more a matter of applying simplification to portions of the conventional process.

Research into the alternative approaches of trip generation are presented and evaluated. Savings in terms of time and cost due to the use of borrowed models are significantly large in the case of the simplified procedures, with a possible disadvantage of a lesser relative accuracy. However, as demonstrated in the case study reported in Appendix F, synthetically developed trip-generation models of various trip purposes, as well as the models based wholly on actual origin-destination (O-D) data for a study area, are all subject to considerable error in duplicating traffic volumes on the transportation network.

Because no significant advantage accrues to any particular technique from the standpoint of accuracy, it is recommended that disaggregate household models be used for trip-production estimates. The advantage of such models in terms of data requirements and adaptability to varying zonal schemes and behavioral modal split analysis makes them ideally suited for the continuing transportation planning process.

Synthetically developed models usually are verified on the basis of the results of traffic assignment and, unless some information on the trip-generation and -distribution pattern is available, the causes of discrepancies are difficult to identify. It is further recommended that a small-sample home-interview O-D survey be conducted with approximately 300 households carefully selected to provide an adequate representation of the household types used in the trip generation and modal split models. In addition a limited external O-D survey covering only the heavily traveled routes and an analysis of special generators should be performed not only to enhance the reliability of the models but also to provide valid data bases for continual surveillance and updates. The new and existing schemes for the periodic reappraisal of an adopted plan were discussed, and a simplified technique based on work trip surveys was presented as an alternative to the regular network simulation procedure. The method is valid and can be extremely cost effective for those areas where car pool surveys are being conducted.

Small Urban Area Transit Planning

Considering the potential changes in small urban areas, the transit planning approach to be used in these areas should be short-range oriented and yet the significance of long-range planning must not be overlooked.

One of the key elements in the development of long-range transit plans is the mode choice analysis and the prediction of future transit use. In the case of small urban areas, the uncertainties associated with mode choice predictions are large and must be recognized explicitly in the long-range planning process.

The short-range transit planning approach in small urban areas must go beyond the traditional emphasis on operational improvements of the existing transit system to utilize a consumer-oriented planning approach The consumer-oriented approach attempts to recognize the variety of demand for public transit The procedure includes the delineation and a preference survey of transit market segments, the identification of potential transit system alternatives for each segment, and a feasibility analysis. Markets can be identified in towns for both discretionary and non-discretionary travel of different population groups to particular activity centers. The stratification and identification of population groups can be based on certain socioeconomic and/or demographic data such as age, income, and occupation. Computer graphic techniques can be useful to display the stratification.

It must not be overlooked that the demand estimates based on questionnaires are approximations and the expressed preferences help frame the size of a potential market. An individual's actual responses when encountering a real situation may not reflect the expressed preferences. The estimates may be adjusted on the basis of previous experience. It must be recognized that the role of transit in a small urban area is a policy issue.

Corridor Growth Techniques

The corridor method provides a convenient way to estimate traffic demands on the major arteries serving each corridor of the urban area. Use of the corridor technique requires that both the capacity of the available thoroughfares and the forecasted future traffic volumes be determined for individual corridors. Comparisons of the street capacities to forecasted volumes then provides an estimate of system deficiencies. This approach may be substituted for the travel simulation procedure using trip generation, trip distribution, and traffic assignment models. The corridor growth factor method has its greatest potential when applied to small communities that have identified bypassable or heavy corridor traffic as an issue.

In the application of the corridor technique, six Tennessee cities were used which ranged in population from approximately 11,000 to 55,000. An over-all evaluation of the procedure indicates that the method provides estimates of external traffic with errors usually within 2,000 vehicles per day.

The results in most corridors, except those which carry an extremely large proportion of through trips (external-externals) and those which serve special generators, were acceptable when the external trips were factored on the basis of growth in county vehicle registrations.

Localized Traffic Impact Estimating Procedure

Specific land-use development decisions, particularly the location of special activity centers on the fringe of a city where the land previously was vacant or in agricultural use, can place special demands on the local street system. Traffic estimations are necessary in such cases to assess the impact of the impending land-use change on the local streets within a 1- to 2-mile area of influence.

After determining the amount of trips generated from different land uses, based on either locally derived or borrowed trip rates, attention must be given to the distribution of trips over the local street system. For this purpose, attenuation factors are applied to represent the decay of trips as a function of distance from the special generator. When the distribution of trips to traffic zones is developed, manual assignments can be made to estimate the additional traffic loadings on existing roads in the area. By incorporating directional splits in the trip distribution, intersection turning movements also can be estimated. Spot traffic improvements can be programmed with these traffic estimates and, in certain situations, an analysis of this nature may lead to the conclusion that the scale of development should be curtailed to better conform to available street capacities.

CHAPTER ONE

INTRODUCTION AND RESEARCH APPROACH

EXISTING URBAN TRANSPORTATION PLANNING PROCESS

The 1962 Federal-Aid Highway Act required that transportation investments in urban areas with a population of 50,000 or more be predicated on a continuing, comprehensive, and coordinated ("3-C") transportation planning process Concern for the need to recognize the mutual impacts of transportation and land use was clearly expressed through the requirements contained in PPM 50-9. (*1*)

Although the guidelines were drawn with awareness of the variations inherent between short- and long-range ("strategic") planning and between transit and highway planning, the urban transportation planning (UTP) process has tended to become both somewhat standardized and complex The attempt by state highway departments to conform with Federal policy has contributed to the uniform treatment Contributing to the complexity has been the inclusion of mathematical models to forecast further travel demand as a function of land use, level of service, and demographic characteristics Federal and state support for modeling research by universities and consultants brought increased sophistication and, in many cases, misplaced emphasis. The data required for the various simulation models (i e., trip generation, trip distribution, modal split, and trip assignment) are substantial Obtaining the necessary data involves as minimum requirements home-interview origin-destination (O-D) studies, commercial, industrial, and other nonresidential surveys; and an economic base study. Although computer software is available to carry out the task of the UTP process, small urban areas in most cases have neither access to adequate computer facilities nor the resident staff capability to effectively utilize the existing mathematical techniques. In addition, the small urban areas are limited in their financial resources The necessary data for the traditional transportation planning process require substantial expenditures, particularly for data collection.

An addtional aspect of the problem is the continued emphasis on the demand-supply-oriented evaluation of alternative transportation systems The standard approach to plan evaluation focuses on provision of transportation facilities to accommodate future travel demand, thereby becoming increasingly less sensitive to other issues confronting transportation planners in both large and small urban areas Included among these issues are environmental, social, and economic concerns in addition to alternative urban development strategies. Given the need to provide relatively rapid responses to the questions raised by local officials and the general public, along with the objective of analyzing all viable alternatives, including their impacts, planners find great difficulty in fully exploring the range of relevant policy issues.

Although the ten elements outlined in PPM 50-9 have been accepted and adhered to by practicing transportation planners, it is reasonable to question the adequacy of simply extrapolating conventional 3-C planning techniques to small urban areas The characteristics of the problems, as well as their solutions, for large and small urban areas differ significantly. This raises doubt whether the planning procedures designed primarily for large areas are equally applicable to smaller areas

Simplification

In establishing a strategy to deal with small area transportation planning, a hypothesis has been advanced by the NCHRP that community size is a key determinant in the level of transportation planning effort and that, for small areas, simplified or short-cut procedures are sufficient.

Simplification as a concept can be interpreted in more than one way To some, simplification has implied a reduction in data requirements, the use of less sophisticated models, and a reduction in the complexity of the analysis and its reliance on large-scale computer-oriented network procedures (*2*) while maintaining a highly structured traffic estimation procedure. Others have viewed simplification as an opportunity to sensitize the highly structured technical process to a range of transportation issues while encouraging more participation of nontechnical professionals Each concept will be discussed.

Simplification in Data Collection and Modeling Procedures

The exploration of a simplified transportation planning process, which retains the basic structure of the conventional long-range and facility-oriented systems planning, has focused on developing traffic-estimating models that minimize the need for current travel data Particular emphasis has been given to calibrating trip-generation and trip-distribution models capable of replicating internal travel patterns, implying less reliance on the costly and time-consuming internal home-interview O-D survey (see Appendix D)

For situations in which conventional models will not work, three strategies have been devised to reduce the time and cost required to estimate internal-internal travel patterns.

1 Eliminate the home-interview O-D survey by borrowing trip-generation and trip-distribution information from other transportation studies for which such data are available (*3, 4, 5*).

2 Reduce the size of the home-interview O-D survey

from the recommended 12.5- to 20-percent sample to a 1- or 2-percent sample (*6, 7, 8*).

3. Develop disaggregated trip-generation models that utilize the household as the level of aggregation rather than the zone (*9, 10, 11*).

An extensive literature has developed which reports on short-cut procedures and tests performed in smaller urban areas to verify the simplification procedures discussed above. Some consensus is being reached. It has been found that alternatives to conducting an extensive home-interview O-D survey provide a reproduction of internal-internal trip patterns suitable for the transportation decisions required in small urban areas. Yet there are drawbacks The use of borrowed information requires that various adjustments be made to calibrate a model for a particular city by reconciling the synthesized trips with observed volume counts and screenline checks (*4*). The testing of synthetic models has not progressed to the point where it is possible to relate consistency in errors to the population size of urban areas or to some other socio-economic or travel characteristics The savings from synthesizing the internal trip pattern are quite substantial although this advantage must be weighed against the fact that synthetically derived models can not match the reliability of studies based on traditional internal home-interview surveys. Yet it is not clear exactly when the benefits of simplification must be sacrificed in favor of capability of responding to system complexities and the unique characteristics of an urban area's traffic problems.

The concept of small-sample surveys has become more popular with the use of disaggregate models for trip generation, which are not dependent on large samples. These cross-classification models relate trip-making to the characteristics of households or land uses, and they show promise for providing trip-production and -attraction rates that could have broader applicability. The generation rates are used to obtain aggregated trip estimates at the zonal level through the use of household or land-use estimates classified by appropriate categories.

Simplification in Structure of Planning Process

Concerns have been voiced regarding the effectiveness of the process in dealing with pertinent issues and time frames in preparing alternatives for evaluation by decision makers (*12*). Reliance on complex networks and computer programs has resulted in a process difficult to manipulate and analyze, particularly so for nontechnical participants. The modeling process itself does not address many of the short-range policy-oriented decisions closely aligned with implementation Considering the lack of technical expertise in transportation planning available to a small urban area, simplification in the structure of the planning process can encourage local input and the ultimate acceptance of the plan. (*13, 14*)

Establishment of a simplified process, which is more design oriented and also permits transportation and land-use plans to be developed and evaluated simultaneously, has been proposed for small areas. (*2*) The emerging process is based on a noncomputer-oriented procedure that relies on synthesized trip generation and trip distribution relationships for conducting variable-scale analyses ranging from preliminary reviews to detailed traffic assignments.

Experience to date indicates that in most cases simplification has been approached by shortcutting existing network-oriented system planning procedures with little devotion to simplifying the structure of the planning process.

PROBLEM STATEMENT

The current research has progressed through several iterations of the project statement. Originally the research problem statement was:

> Urban transportation planning studies in urban areas of less than 250,000 population have evolved as miniature versions of the transportation planning process in large urban areas. These studies are time consuming and costly and have inordinate data requirements The complexity and expense of these procedures are of increasing concern to highway officials because of the need to establish on-going, continuing transportation planning processes in small urban areas

The investigation was to consider both requirements of the planning process and data requirements and to take advantage of recent advances in the understanding of travel behavior, dwelling unit analysis, and increased census data. Six tasks were identified:

1. Based on the current state of the art, determine the explicit minimum output of the planning process
2. Identify significant variables and relationships that, conceptually, should be considered
3. Select and develop methods to describe and predict the desired outputs, utilizing to the fullest extent possible the available data from public and private agencies.
4 To the fullest extent possible, demonstrate the effectiveness of the methodology in the analysis of typical problems and its ability or inability to provide desired outputs.
5. Specify the requirements of a procedural manual and appropriate computer programs.
6. Make recommendations for additional data for verification of the recommended process

A heuristic approach was developed that provides for learning from each reviewer's critique and from each researcher's input The researcher's original interpretation of the stated objective evolved into a six-part work program:

1. Establishment of the nature of required planning process
2 Inventory and evaluation of existing and proposed procedures.
3. Development of land-use and transportation planning models.
4. Model tests
5. Recommendations for further tests.
6 Development of detailed outline for procedural manual of total transportation planning

It was assumed that the pursuit of the first two tasks would give rise to new concepts that might alter the remaining tasks. Where deviations from those tasks are made, a justification for the change is presented.

Social and community value factors were purposefully omitted from consideration in the work program because they are discussed elsewhere.*

RESEARCH PROGRAM

The research team, not unlike others in a similar situation, had preconceived ideas of what was needed and how to proceed Although the research objectives had evolved over several iterations, one research task remained throughout Determination of the nature of the transportation planning process required for small urban areas was the first assignment. The results of this investigation are not reported as part of the findings but rather are included as introductory material to explain their effects in the research approach.

The nature of the process required for small urban areas was studied through extensive literature review, in-depth interviews with planners and engineers, and examination of more than 150 plans. The professionals interviewed held responsible positions in either governmental or consulting agencies (see Appendix A). The discussion focused on the suitability of the present UTP process for small urban areas Of particular interest was the interviewees' responses to possible adaptation of a scaled-down version of the present process for small urban areas

The research was then redirected on the basis of the findings from the literature search, interviews, and examinations and evaluations of plans. An important conclusion that surfaced early was dissatisfaction with the basic premise that a uniform standardized planning process exists which can be applied to all types of urban areas as well as projects of varying scope, and that the process, if strictly adhered to, will result in a uniformly effective planning product. That such an assumption has been made and nurtured can be supported by an examination of the conventional wisdom as expressed in plan documents and associated procedural requirements in both transportation and land-use planning.

An analysis of transportation and land-use programs conducted by the project staff for a cross-section of small urban areas revealed not only that each of the urban areas is confronted with unique problems but also that the available resources to meet the needs vary significantly. All too frequently the plans failed to address critical policy issues within the context of a comprehensive planning process resulting in an ad hoc, or project-by-project, approach to implementation which negates the utility of the planning process. These basic problems are related to the lack of recognition of the variation in the planning environment.

* Manheim, M L, Suhrbier, J H, Bennett, E D, Neumann, L A, Colcord, F C, Jr, Reno, A T, Jr, "Transportation Decision Making—A Guide to Social and Environmental Considerations" *NCHRP Report 156* (1975)

Typical plan documents resulting from the transportation and land-use planning process thus are characterized by standardization in terms of format, elements, and procedures. This uniformity of planning process and its product must somehow be reconciled with the existing multiplicity of planning environments, which can be collectively characterized only in very gross terms such as population size and geographic area. The superficial resemblance among urban areas of a certain population or land area must not obscure their differences. Indeed, the variability of planning environment is probably the most important characteristic that must be recognized by the planning process.

Rather than simplifying the conventional planning process, the research approach was focused on customization as a means to provide a more effective planning process Implicit in this customization is a flexibility not only permitting but encouraging application of planning tools commensurate with the problem Such a customized approach, cognizant of both the parameters of the problem and the resource capabilities available to respond to the problem, should readily lend itself to effective and efficient use by the participants in the planning process in small urban areas of widely varied planning environments

ORGANIZATION OF THE REPORT

This chapter attempts to identify the problem. Although some results are reported herein, they are briefly stated and included only to indicate their effects on the research direction. It is suggested that the most effective UTP process requires customization of both organizational setting and procedural approach based upon the problem definition and resource capabilities.

Chapter Two presents findings on the organizational setting in addition to some amplification of findings presented earlier that affect research direction. Procedural findings are presented in Chapter Three Chapter Four discusses simplification of the customized process on the gross or network level and the more limited or local level. The customized process proposed does not lend itself to evaluation and application except through the use of simplified techniques. Unfortunately the results of the testing reflect more on the total research effort than on the simplified techniques selected for inclusion in the process.

Chapter Five presents conclusions and suggestions for future research. The details of the various applications are presented as Appendices A through G for those inclined toward a more in-depth review.

The report is written to meet the needs of small urban area department personnel, especially those with the various state departments of transportation (SDOTs), who have progressed to positions of responsibility for planning in the small urban areas after baccalaureate training in engineering, planning, or related disciplines.

CHAPTER TWO

FINDINGS: ORGANIZATIONAL FRAMEWORK

INTRODUCTION

Much of the current organizational framework for transportation planning reflects national conditions that existed when the planning process was first being applied broadly. The 1950's and early 60's gave rise to a need to promote the preparation of plans and to overcome the historic tendency to engage in piecemeal project-oriented efforts. The shortage of personnel who were expert in planning techniques made it necessary to promote sound technical practices through the use of guidelines. As experience was gained it was natural for agencies and personnel to fall into routine patterns of behavior. Conditions have now changed to such an extent that the routines are no longer responsive to current needs There are large numbers of technical personnel available, even among fairly small units of government. Most communities now have some track record in their acceptance and use of planning and have now been through the preparation of comprehensive plans one or more times.

Current conditions require that the organizations responsible for delivery of transportation planning services to small communities be more responsive to current circumstances and needs. The ability to tailor technical procedures to local needs will often require the ability to tailor organizational roles and responsibilities as well. Agencies and their personnel should be viewed as resources to be used selectively in responding to local needs. The problems of organization have been identified as (a) recognition of the variety of planning environments and the need to match resources to the nature of the problem, and (b) recognition of the variety of expectations of the many participants in the planning process.

Variety of the Planning Environment

Components of the planning environment generally may be classified into two groups: (a) those elements indicative of the type and magnitude of the planning problem(s), and (b) those elements that influence the resources of an urban area to solve the identified problem(s).

The elements that serve to describe the problem characteristics of an urban area may be categorized as:

1. *Scale.* The areal delineation for which planning is being conducted can range from that for an entire urbanized area to that of a small neighborhood. The usual hierarchy of scale related to urban planning is:

- (a) Regional—a term which can refer to river basins or large multistate areas that have in common some resource, problem, or other feature defined by an agency responsibility. The term can also refer to an area that includes a definable metropolitan/municipal area in addition to outlying areas associated by economics or physical ties. The latter case is usually associated with transportation planning.
- (b) Urban—an area whose boundary is based strictly on demographic and economic characteristics and is not limited by administrative or political jurisdictions; generally includes the central city, its fringe areas, and the outlying suburban areas
- (c) Municipal—an area included within the defined administrative boundary of a municipal government.
- (d) Corridor—the linearly oriented service area of major transportation facilities.
- (e) Sub-areal unit—an area that includes a well-defined local activity center such as a neighborhood or special generator.

2. *Purpose.* The rationale for a particular planning effort can range from developing broad guidelines for long-range developments to finding the solution to a specifically defined problem or need. The purpose of planning is closely related to its scope and can be classified as follows·

- (a) Conceptual overview—the "broad brush" or sketch plan to broadly outline policy alternatives.
- (b) Over-all system plan—the traditional comprehensive plan to guide a city's future development with transportation being recognized as a key factor or a strongly interactive one.
- (c) Implementation of over-all system plan—a specific programming element such as the capital improvement program (CIP) or fiscal plan.
- (d) Solution for specific problems—planning of a specific project, which is only a part of the overall system.

3. *Time frame.* The temporal limits of planning generally range from long-range planning to planning for immediate needs. The common categories of time frame include·

- (a) Long-range planning—generally concerned with a time period 20 to 30 years in the future.
- (b) Short-range planning—focuses on the next 5 to 10 years
- (c) Planning for immediate needs—makes recommendation for projects that would be implemented immediately

4. *Level of detail.* The degree of specificity to be included in the recommendations usually ranges from rather general descriptions to precise specifications for location and capacity The level of detail varies with the scope of planning.

- (a) System planning—includes a general description of the entire system and its components with possible location of facilities being based on network considerations

(b) Corridor planning—recommends the preliminary location and functional details of facilities; includes an evaluation of alternative locations and designs.
(c) Project planning—includes detailed specifications and preliminary geometrics.

Whereas the elements discussed are helpful in depicting the nature of the problem, they describe only a part of the planning environment. The picture of the planning environment is not complete without knowledge of the available resources to meet the challenge of planning. The elements significantly related to the capability of carrying out an effective planning process include:

1. *Institutional arrangements.* The distribution of responsibility for carrying out the planning process may vary from case to case The broad categories of institutional arrangements are
   (a) Single-agency responsibility.
   (b) Multiple-agency responsibility:
      (1) Vertical integration (e.g national, state, regional, and local).
      (2) Horizontal integration (e g. transportation agency, land-use agency, and housing agency).
      (3) Vertical-horizontal mix.
2. *Personnel* The sources of manpower for the execution of planning projects may be different and thus the capability of a planning team may vary significantly. Generally, the planning personnel may be classified as:
   (a) Resident-technical:
      (1) Multiskilled.
      (2) Specialized
   (b) Consultant-technical (includes both private consultants and consultants provided by other levels and agencies of government).
      (1) Multiskilled.
      (2) Specialized
3. *Other resources and constraints.* In addition to the institutional and personnel characteristics, other factors may affect the ability of local government officials to carry out the planning process effectively.
   (a) Technical/political coordination
   (b) Financial resources.
   (c) Other goals and priorities.
   (d) Availability of effective land-use/transportation implementation tools and enabling legislation.
   (e) Facility resources (computers, etc.).

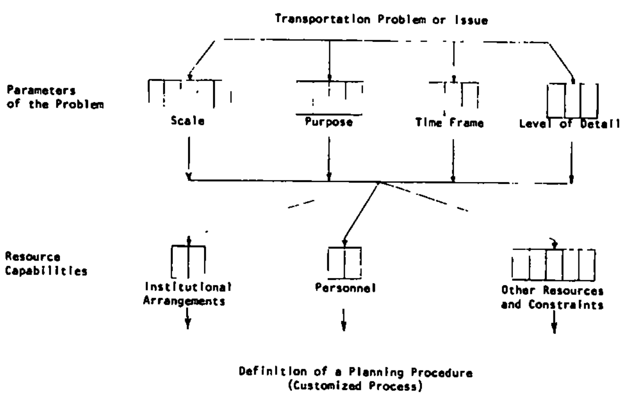


Figure 1. Elements of the planning environment

An understanding of the variety of problem characteristics and available resources for planning facilitates the adaptability of the planning process to the specific needs of the urban area in question. The recommendations, rather than being carved from a standardized package, may be tailored to the unique set of conditions which exist in an urban area at a particular time. As shown in Figure 1, identification of the scope of the planning problem and assessment of available resources must precede definition of the appropriate level of planning.

Variety of Expectations

Another important aspect of the planning environment deals with the expectations of the participants in the planning process. Interviews with selected individuals representing samples of the participants in the planning process have confirmed that expectations vary significantly As the ultimate clients of the planning process, the residents of an urban area typically are interested in the recommendations and actions that are (a) evidenced at the project level rather than the program level, (b) developed with public participation prior to the final decision-making, and (c) directed to problems amenable to quick solution.

On the other hand are professional planners who, by virtue of their education, training, experience, and special expertise, tend to profess expectations of the planning process that often vary from public expectations Professionals typically anticipate (a) plans which would conform with an established pattern and (b) plans which usually provide only a framework for planning and problem solution at the sub-areal level, though rarely including the details at the project level. Finally, the expectations of the public decision-makers tend to be oriented toward (a) plans that facilitate over-all acceptance by citizens and other members of the local governments, and (b) plans that incorporate a policy framework and thus are flexible for adjustments. Thus the planning environment can also be characterized by variations in the expectations of the participants.

BASIC ORGANIZATIONAL ISSUES

Consider, for example, the responses of a SDOT to two requests for planning services. Both requests come from cities of approximately 50,000 people and are made to the same agency at the same time. Both ask for state assistance in the formulation of a transportation plan. Community A is a well-managed city with a small but competent city planning staff. There is a history of commitment to long-range land-use planning. Although the request is a general request for a transportation plan to complement a developing land-use plan, investigation shows that there is widespread concern about (a) identifying the potential demand for major arteries in certain fringe areas that are sensitive because of environmental and historical features and (b) identifying locations for those arteries if they are needed. Community B depends on consultants for technical assistance to its planning commission. The one local planner devotes almost all his time to day-to-day matters of zoning and subdivision control. The motives for the request are to help justify the need for state-financed improvements to the highway network, giving special attention to improving accessibility of existing and proposed industrial sites. There would be a strong tendency for state DOTs to respond to both requests by the preparation of a relatively standardized plan using standard procedures.

In this example, the city planning staff of Community A might be called on to provide the full range of socioeconomic inventories and forecasts for input into the transportation models. In Community B, these tasks might best be carried out by the SDOT or by the consultant who prepared the last over-all community plan. Typically, the same procedures and agency relationships would be imposed in both cases. This is a simple example, but it suggests the point of view that would be brought to the process. The application of that point of view would then lead to other variations. In Community A, for example, special citizen committees might be appointed to assist the staff in identifying the location and political sensitivity of historic areas. In Community B, the planning commission might be asked to clarify the need for an over-all transportation plan. If improving access to an industral area is the only real concern of local officials, the planning effort might be limited to a small corridor study with the SDOT handling all the technical work but reviewing the plan against a previously adopted over-all community plan. Table 1 illustrates how the variations in agency roles might proceed.

The agency preparing the transportation plan would be required to consider the question of what data would be provided and who would best provide it. Interviews among existing agencies have shown a tendency to assume that the answers to such questions would be the same in any community and with respect to any planning problem. It is not to be denied that there would be recurring patterns and that the same answers might occur in a majority of the cases. But in the example described previously the answers would not be the same. Here a particular set of data would be provided by the SDOT itself in one case and by the local community in another case. Such differences occur with sufficient frequency to justify an examination of the question each time the planning process is undertaken. It is not reasonable to depend upon the initiatives of individual personnel to assure that the right questions are asked. Instead a definite agency behavior pattern must be established in

TABLE 1

CUSTOMIZED ORGANIZATION ILLUSTRATED

TRADITIONAL SEQUENCE OF ORGANIZATIONAL CONTACTS	COMMUNITY A ORGANIZATIONAL CONTACTS SEQUENCE	COMMUNITY B ORGANIZATIONAL CONTACTS SEQUENCE
1. Community requests transportation plan of SDOT	1 Community requests transportation plan of SDOT.	1 Community requests transportation plan of SDOT.
2. SDOT reviews request with local public officials and planning commission.	2 SDOT reviews request with local public officials and planning commission.	2. SDOT reviews request with local public officials and planning commission.
3 SDOT prepares plan using socioeconomic data prepared in-house.	3. Citizen committee prepares study of historic sites with staff assistance from state historic committee.	3. State industrial board and local business committee prepares study on potential for industrial growth.
4. SDOT presents standard 20-yr network plan to public officials and local planning commission for adoption.	4. SDOT prepares corridor study with socioeconomic data from local planning staff.	4. City planning consultant prepares report on potential industrial sites
	5. SDOT presents draft plan to planning commission and historic committee for review.	5. SDOT prepares study of access to alternative industrial sites
	6. Local planning commission presents plan to public officials for adoption.	6. SDOT, planning commission, and officials agree on industrial sites to be developed.
		7. SDOT and local officials program work on access to industrial sites.

which the planning process begins with an open-minded design of the procedures and agency relationships to be followed A study design element in the planning process, as suggested in the recommendations, would be very beneficial.

The preceding situations are intended to represent neither the breadth nor the depth of problems which are receiving inadequate response from the traditional planning process. Hundreds of situations would be required to portray the entire range of problems encountered in small urban areas. They are intended, rather, to emphasize the need for the application of the planning process in such a way as to effectively link problem elements with available problem-solving resources.

COMPONENTS OF THE ORGANIZATIONAL FRAMEWORK

Agency Relationships and Roles

One means of developing an overview of the roles of the several agencies involved is to examine the vertical and horizontal relationships between and among these agencies, which are shown in Figure 2 Vertical relationship refers to those contacts, both formal and informal, which occur between an agency at a higher level and an agency concerned with the same functions at a lower level Horizontal relationship refers to contacts between agencies at the same level of government Contacts may also be made diagonally, as between a SDOT and a municipal planning commission.

Vertical relationships tend to be highly structured and long term Horizontal relationships can be structured through contracts or agreements but they tend to be ad hoc and of short duration. Diagonal relationships tend to be less frequent, ad hoc, more specific-task oriented, and of shorter duration.

The formal relationships among the different kinds of agencies vary from state to state State legislation and formal agency agreements give stability to the relationships. But there is a tendency to accept the relationships among agencies as being more fixed than they need to be. This tendency reflects custom and habit, not necessity Some stability in relationships is necessary, but rigidity is unnecessary and sometimes counterproductive

Coordination

One apparent problem within the planning process is the coordination of planning efforts Coordination is made necessary by the variety of planning agencies and actors reacting to various kinds of planning problems The interviews conducted in this research indicate that a reasonable degree of coordination is achieved in vertical relationships among agencies through such things as program guidelines and funding regulations. The major problems are apparent in the horizontal relationships among different agencies involved in the same community or planning process

The deficiencies of the OMB's A-95 review process * provide one example of the difficulties of horizontal coordination. The state agencies assigned the clearinghouse function have tended to view the review process as a federal requirement rather than a method to increase their effectiveness. Thus, the review process often has a perfunctory rather than a substantive effect. Proposals should be reviewed by all affected agencies and cleared through an independent office that has no stake in promoting a particular project. A central state planning office would be a logical place if it has developed a meaningful set of overall state plans and strategies

Horizontal coordination may also falter unless it is actively encouraged by agencies Each agency tends to develop its own way of doing things and rewards employees for their allegiance to the prescribed patterns of agency behavior. In this environment, technical personnel may find their own agency supervisors to be the chief impediments to effective coordination with other agencies. This is especially true when custom requires clearing any nonroutine activity through the vertical chain of command rather than allowing direct horizontal contact among technical personnel in different agencies. It is not the intent to suggest that situations have frequently been found where one agency actively prevents its personnel from interacting in a coordinated fashion with personnel from another agency. What has been found is an absence of the administrative atmosphere, which promotes such coordination in a flexible and innovative fashion.

Coordination is an issue which must be considered in any attempt to make the planning process more responsive to the needs and expectations of the public and the decision-makers What is being recommended is that each effort of an agency to respond to request for planning services be approached with a fresh and open attitude toward coordination and an attempt to explore the possibilities and needs for coordination before the assignment of responsibility and technical tasks is firmed up to the point of inflexibility

Participants in the Process

The diversity evident in the organizational arrangements is compounded by the differences among those who serve and are served by the agencies involved in the transportation planning process. People differ in their views and contributions to the planning process, not because of the organizational setting, but because they bring different skills and objectives to the process Most participants fall into one of three classes—politicians, technicians, or citizens.

Politicians interpret public sentiment, formulate goals, and establish policy As decision-makers they exercise judgment of the broadest kind, balancing technical studies against public opinion or establishing priorities among proposals competing for limited public funds.

Technicians are fact finders, analyzers, and plan formulators. They are influenced by their training and the opinions of their professional peers in developing approaches to problems Technicians have been accused of writing reports to impress other technicians instead of writing reports to inform and influence decision-makers.

Citizens act alone or through organized groups They act alone, usually, to respond to a particular project that

* "What it is—How it works" *Circular A-95 Revised*, Office of Management and Budget, Washington, D C , GPO (1971)

will affect them directly, supporting or opposing a project because they feel it will help or hinder them directly. They act in groups (such as garden clubs, neighborhood associations, the Sierra Club) because of a shared point of view on some issue, topic, or area.

The way in which participants respond to situations is not always consistent with a particular role (i.e , a person may act in two roles). The bureaucrats in upper levels of state transportation departments, for example, often act largely on a political basis even though their language reflects their technical background and agency affiliation. Planning commission members are citizens required to act on behalf of the public interest, but they often mix technical and political elements in their decision-making process.

Expectations of the Decision-Makers

Discussions with local officials uncovered a substantial amount of frustration about the difference between the expectations these decision-makers have and the products they receive from the planning process. This reflects the fact that decision-makers are often allowed to hold highly unrealistic expectations which are not challenged or addressed by technical personnel at a point when they could be altered. It also reflects the fact that the planning process and plan documents produced by various agencies do not address the issues uppermost in the minds of local decision-makers.

Local public officials are inclined to have higher expectations when dealing with an agency, such as a SDOT, having the power to implement its plans as well as the power to develop plans. A SDOT is able to generate support and high levels of expectation in part because of past successes in implementing transportation plans. In addition, the presence of a large body of technical expertise and data resources contributes to a high level of local expectations.

When representatives of planning consultants or agencies, whether oriented to land-use planning or transportation planning, make initial contacts with local decision-makers, a tendency exists to sell the capabilities of the agency rather than candidly explain the limitations of public resources, agency expertise, and the planning process. There is a tendency to allow local public officials to believe that their highest expectations can be met. This places a substantial burden on the entire planning and implementation process. It creates a strong likelihood that the expectations will not be met and that the credibility of the process will be compromised in such a way as to decrease the fruitfulness of future planning efforts

CUSTOMIZATION

Nature of Customization

The discussions in the preceding sections focused on the incompatibility of the existing standardized procedures for transportation and land-use planning with the possible variations in the nature of problems, available resources, and expectations of the participants. The scope of variation and thus the seriousness of the incompatibility of the planning procedure is particularly true for small urban areas. Interviews with the elected public officials in small cities

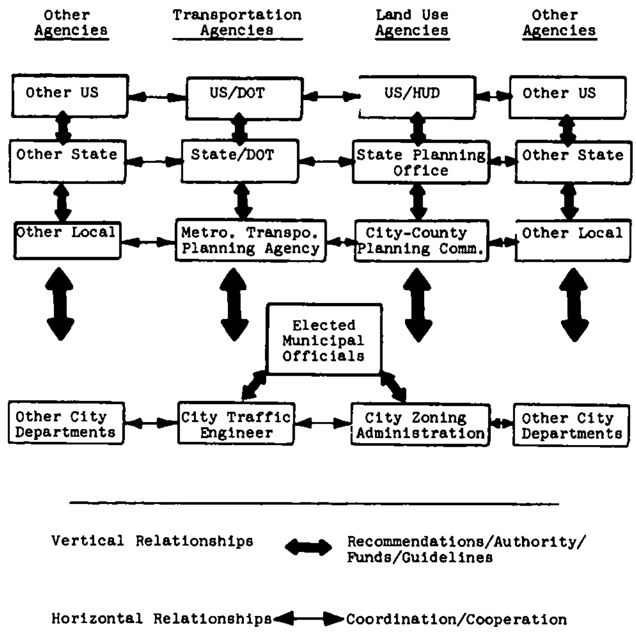


Figure 2 Vertical and horizontal agency relationships

and with local and state planners and a planning consultant as well confirmed their dissatisfaction with the stereotyped procedures and revealed an expressed lack of trust in the "comprehensive plan " Such a response usually is followed by an ad hoc decision-making approach, which defeats the goals of systems planning.

The problems and responses encountered in small urban areas typify the difficulty of attempting to adapt the planning problem to the planning process, rather than fitting the process to the specific problem. For example, the location and timing of the development of bypass facilities is cited frequently by local officials and consultants as an issue in which the local officials have been given little opportunity to provide their input, and for which insufficient information is made available concerning social and economic impact of the proposed facility on the urban area Such a response may not be justified in many cases; however, it confirms the assertion that the needs and expectations of the participants must be given adequate attention in order to carry out a successful planning process.

Effective citizen participation requires public interest, knowledge, and comprehension of the issues at hand. Planning professionals, rather than dismissing citizen input as uninformed and irrelevant, should strive to facilitate the citizens' comprehension of the full range of issues being considered in a particular planning program.

It can be argued that the customization process involves extra work, that it is contrary to the notion of simplification. It is true that a customizing process requires additional work at the beginning of the planning process. However, customization often yields either a reduction in the required volume of technical work over-all or an improvement in the chances that standard technical work is implemented, or both. The planning process and organizational structure would not be completely new in each planning job, but each planning effort would begin with an attempt to identify the best organizational structure for that job. The real question then is. "What are the important questions to be asked in examining the organizational structure?" The basic criteria for assigning tasks to agencies are efficiency and effectiveness.

The concept of efficiency deals with the question of what organization can produce a given unit of work at the least cost. Put more formally, a statement of efficiency might be written in terms of a quality or quantity of output gained as a result of a given input of resources. Costs include expenditures of money but are not limited to that. Costs may include the amount of time required, or the commitment of personnel needed for other tasks, or they may be stated in terms of political costs. Efficiency should always be considered in the assignment of various task responsibilities to particular agencies.

The other major factor to consider in assigning agency responsibility is effectiveness. Effectiveness stresses the quality of the work being done. "What agency or combination of agencies is likely to produce plans with the highest likelihood of effective implementation?" To answer this question there must be some inquiry into the awareness of local needs and the sensitivity and ability of various agencies in addressing those needs. The field interviews of this investigation suggest, for example, that agencies that lack implementation powers, such as regional planning agencies, may be less efficient over-all because they are so far removed from the key political decision-makers.

The concepts of efficiency and effectiveness cannot be entirely divorced from one another. It may be that the assignment of responsibility that is most efficient in terms of the use of technical expertise and rapid production of a planning product is not necessarily the most likely to achieve implementation of a viable plan. It was found that the use of a centralized planning team at a high level of government, such as a SDOT, tends to be most efficient in producing a coherent and technically competent plan in the shortest possible time with the least expenditure of funds. The results of the interviews also suggest, however, that the centralization of these technical tasks tends to remove them from intimate contact with local decision-makers and thereby reduces sensitivity of the technicians to the peculiarities of the locality, which reduces the chances of implementation. In many instances the development of standardized checklists or procedural guidelines has been misconstrued to imply efficiency rather than uniformity. Persons interviewed suggested, indirectly, that the most effective plans in terms of compatibility with political desires and chances of implementation actually may be less efficient in the use of time and money resources and less technically sophisticated.

Guideline Concepts for Customizing Organizational Responsibilities

The notion of customizing the organizational arrangement in which planning is conducted precludes the formulation of set answers to all questions that may be raised. What follows is an attempt to identify certain basic concepts that are applicable to any customizing effort as guidelines toward fruitful use of the customized approach.

Matching the Effort to the Needs

The initial contact between the planning agency, or agencies, and public decision-makers is critical. Planning work is often done in response to a specific request from a public official or legislative body. Planning should result in an examination of precisely what is the local perception of issues and needs as well as the evolution of an agreement between the planning agency and the decision-makers as to the most fruitful planning approach and the kinds of decisions that can be expected to flow from it. This may often mean that the planning agency responds in traditional ways with traditional kinds of long-range comprehensive plans, but such responses occur only when they are appropriate to the problem and the expectations of the decision-makers. In other circumstances, the planning agency might engage in a limited planning effort. The limitation could take the form of a more specific short-range plan, a plan addressed to specific client groups within the community, such as the elderly or the poor, or a plan concentrating on specific areas within the community. In this situation, reduction of the scope of the plan could result in a substantial reduction in the amount of data required and in the dollars spent on the project.

An important concern in this process of establishing initial contact is to maintain a comprehensive or holistic view of the community. In situations where the plan concentrates on a specific area of issue, the approach should not be entirely piecemeal in nature or devoted to one concern to the exclusion of all others. It is not suggested that planning agencies give up the effort at comprehensive long-range planning, which has been developed at such great costs in the past years. But over-all efforts may not have to be repeated with great frequency or they may not need to be done in great detail in order to respond to a specific issue. Such over-all plans can be made in a much more cursory fashion in order to determine whether or not a specific transportation issue or element is compatible with long-range over-all plans

Matching Tasks to the Availability of Resources

Customization of the organizational framework should match the assignment of procedural tasks with agencies having the necessary resources to best carry out those procedures. Assignments will not always be the same, but will vary over time according to the specific resources and workloads of various agencies. The resources that must be considered in this determination include the availability of personnel who have the appropriate technical expertise, the availability of funds to pay for the necessary procedures, and the appropriate time flexibility. There must be flexibility in shifting the work to the then-current best qualified agency.

Keeping the Technical Work Visible to Implementers

One of the persistent complaints among public officials in small communities is that the technical work is so far removed from their observation that it is presented to them in the form of a finished document with which they have little identification and understanding. Planning and design are the culmination of a multitude of decisions made at various points of a continuum. Some of these are so technical as to be far removed from the interest or competence of the local decision-makers, but many are not. The local decision-makers need to be educated to the maximum extent possible in the implications of the technical work as it proceeds in order to evaluate and possibly support the recommendations which come from the technical work. At the same time, the close interaction between local public officials and technical personnel during the planning process can modify the actions of technical personnel in such a way as to make their recommendations more sensitive to political subtleties in the community and thereby enhance the chances of implementation.

Making Customization Occur

The findings of this research are not sufficient to provide a firm designation of responsibility for making customization occur, but some observations can be made. The USDOT is in a strong position to foster this effort through guidelines and official memorandums. It should act as a catalyst rather than as a direct monitor. SDOTs are strong participants in the planning process in almost every state and might be given a charge to see that customization occurs in each transportation planning effort while being given broad latitude to vary the responses. This would not mean that the SDOTs would be responsible for all tasks. On the contrary, the findings of this chapter indicate that all possible work should be assigned to regional or local agencies which are closer to the decision-makers. The responsibility of the state would be to see that careful attention is given to the issues. Figure 3 shows how the assignment of organizational responsibilities might be conducted in each community.

It would be pointless to have a different kind of rigidity come out of this effort. In the long run, the customization process will be dependent on its broad acceptance as an operating premise by personnel at all levels and in many kinds of agencies To be successful, customization must not be limited to state and Federal actions but must filter its way down to the lowest responsible level.

Responsible Agency		Function														
Prime	Support	$	Guidelines	Plan Formulation					Plan Adoption		Plan Maintenance		Design	Construction	Maintenance	Operation
				Organization	Data	Analysis	Forecasts	Plan	Review	Adoption	Evaluation	Update				

Figure 3. Matrix used to assign organizational responsibilities.

CHAPTER THREE

FINDINGS: LAND-USE/TRANSPORTATION PLANNING

INTRODUCTION

The transportation planning process requires forecasts of various socioeconomic and land-use data as input for travel forecasts. Transportation procedures use socioeconomic data that are ultimately dependent on land use because land-use patterns reflect the distribution of population, income levels, employment, and other socioeconomic features. Thus, land-use plans predetermine many of the factors that ultimately affect the content of transportation plans. The mutual dependence of land-use and transportation planning requires the planning strategy harmoniously to accommodate both activities. This chapter presents findings showing that customization is a desirable planning strategy that can simplify land-use and transportation planning activities and focus them more directly toward meeting community needs.

The assessment of current land-use practice, which is discussed, shows that some customization already occurs in land-use planning. The concluding section shows how customization can be carried further and more explicitly applied to the integration of land use and transportation.

REVIEW OF CURRENT PRACTICE IN LAND-USE PLANNING

Planning is now widely accepted as a function of government. Cities, counties, townships, and other units of local government routinely prepare plans for the future development and redevelopment of their jurisdictions. Such plans, typically called comprehensive or general plans, are prepared under the auspices of local or regional planning commissions. Land use has been, and is, a central element in such plans.

One of the most important influences of the past 20 years has been the "701" program (*15*). Section 701 of the Housing Act of 1954 provided matching Federal funds to support city and regional planning efforts. The 701 guidelines tended to standardize community plans. The guidelines did not specify the procedures to be used in preparing plans, but they did specify the scope and content of plans. These guidelines were issued in a variety of forms over a period of years (*16*).

The inquiry into current practice included an inventory and analysis of 155 plan documents drawn from communities of 5,000 to 250,000 people. The communities are located in 30 states with Tennessee, Alabama, Florida, and Kentucky most heavily represented. The plans were prepared by state, regional, and city agencies, by consultants, and by combinations of the above. Over three-fourths of the plans were prepared after 1967. The analysis of the plans was supplemented with in-depth interviews of 15 agency representatives in Kentucky, Tennessee, Ohio, Georgia, Texas, and Pennsylvania. They included representatives of state, regional, and city agencies, and consultants. A special effort was made to interview professionals who would have broad knowledge of practices in their states.

The analysis of plan documents shows that land-use planning in smaller communities tends to be highly standardized in format and content but not in procedures. Where official encouragement existed, plans are openly responsive to land needs.

Plans reflect some investment in goal formulation but the statements have tended to be so general that their utility has been marginal. Goal formulation usually reflects little citizen input other than that through service on planning commissions or other traditional committees. The majority of the plans are long range (20 years or more) and are reasonably consistent in data input and format. Few plans report on procedural methods used but all indications are that most are heavily dependent on manual methods rather than computer methods. The level of sophistication, reflected in such phases as the elaboration of various alternatives, increases with the larger population Plan analysis findings are presented in greater detail in Appendix B.

Coordination of data collection and maintenance is important to transportation and land-use planning. While the benefits to small communities are not so obvious, they are nevertheless real, especially when they can be sustained and refined as between a SDOT and a state land-use planning agency. The interviews provided an opportunity to confirm the observations on current practice and gain additional insight into procedures and agency attitudes.

Positive Aspects of Current Practice

The presence of large numbers of community plans represents a substantial information resource for the preparation of other community plans now and in the future. Although the individual plan documents do not make it apparent, isolated spot checks and the interviews strongly suggest that many of the communities now have documents that represent a second or third comprehensive community plan. In such cases there is not only a current inventory of population, housing, land use, and economic activity, but also a substantial historical record of those key factors. For this reason, the circumstances under which comprehensive land-use and transportation plans are now prepared are substantially different from what they were 15 years or so ago when the current methodologies and practices for preparation of comprehensive community plans were being evolved. We are no longer starting from "scratch."

It is apparent from the review of plan documents and from the interviews that planning is now widely accepted at the local levels of government, even in the smallest population ranges, as a customary practice of local government. The community that has never engaged in systematic planning for development is now clearly the exception rather than the rule. The significant differences in communities are the attitudinal differences that communities bring to the planning process. The substantial increase in planning activities that has occurred over the past 20 years appears to have been spurred significantly by the funding programs of the federal government and the necessity to engage in comprehensive planning in order to acquire various federal funds for local application. The federal funds available for a simulation of planning have had their effect.

Many communities that have engaged in planning have come to appreciate its value as an end in itself and now continue to engage in continuous planning activities because there is a recognition by local public officials that planning enhances the decision-making capability of the community and improves the over-all quality of development. In other cases, however, it is apparent that communities are not fully convinced of the benefits of planning and continue to see it largely as a prerequisite to other objectives. In these instances the planning effort is characterized by a series of spasmodic efforts to produce documents that are technically adequate to satisfy federal agencies but that have little impact on the decision-making of local government.

Because the communities exhibiting these various attitudes are often serviced by the same state-assistance programs or consulting firms, the review of plan documents often provides a very poor clue to the attitudes that individual communities have brought to the planning process. But planners on the scene have usually been quick to detect these attitudes and have often expanded or contracted the advisory activities and educational activities associated with the development of a comprehensive plan in response to the receptiveness of local citizens and public officials. The staff adjustments do not show in the documents themselves.

An increasing number of communities of 25,000 to 50,000 people are establishing resident planning staffs These staffs are usually competent and useful for the day-to-day operations of zoning administration, subdivision review, and the collection and distribution of data. The staffs of the one- and two-person offices serving such communities, however, often lack sufficient technical training, time, or experience to conduct the more sophisticated studies.

The widespread appointment of planning commissions and the provision for some level of technical assistance by means of consultants, resident staffs, or state agencies has also provided a more widespread distribution of the machinery necessary to help implement local community plans. The presence of local planning commissions frequently suggests that there is at least a minimal capability to enforce a zoning ordinance and subdivision regulations. The quality of that enforcement process is substantially affected by the quality and contact hours of technical assistance.

In conclusion, it should be noted that the spread of planning activities has been accompanied by increases in professional staffs and has encouraged some broadening of planning processes and techniques as depicted in the literature. Nevertheless, the planning techniques inventoried in this research provide a broader range of resources than are being used to improve the quality of technical assistance and planning at the local level. Transportation planners will find that they often have a wealth of assembled data that is useful in transportation planning. This research strongly suggests that research and educational efforts may have higher payoff in the near future by concentrating on the improvement of the application of known techniques by technicians at the local level than by trying to improve techniques in ways which require increasingly sophisticated personnel or equipment.

Negative Aspects of Current Practice

One of the obvious areas of difficulty is the problem of coordinating and sharing data between various planning agencies working in the same community. A prime example is the obvious benefit of having land-use and transportation planning agencies share the collection and analysis of data on such current base items as population, land use, and economic activity. There is little overt unwillingness to attempt to coordinate the collection of data and share it between agencies, but there are problems.

Individuals and agencies tend to develop their own operating procedures and study objectives. Once comfortable with a particular data format they are often reluctant to change it to accommodate other agencies. Thus, a land-use inventory may be difficult to coordinate between land-use and transportation planning agencies because the two agencies prefer to have the data collected at different levels of detail. One may prefer a highly generalized classification system with data summarized on a block basis. Another may prefer a rigorous system utilizing a three- or four-digit code with information available for keypunch on a parcel-by-parcel basis.

Another difficulty is that agencies may wish to summarize their data to different subunits. It is not uncommon to find land-use and transportation planning agencies working in the same community but using neighborhoods, planning units, or traffic zones having roughly the same over-all dimensions but different boundaries. In this situation, data must be resummarized in order to be shared from one agency to another at the subunit level. Such difficulties can provide a convenient excuse for personnel within various agencies who prefer to handle their data independently rather than go through the adjustments that are necessary for coordination with another agency.

Some of the differences in the use of data and geographic subunits are historical, but others reflect very different anticipated needs by the agencies. In one state a substantial effort has been made to standardize data collection techniques and classification systems between the SDOT and the state planning office responsible for providing land-use planning technical assistance to small communities. Although progress has been made, very real difficulties exist in this situation. For example, changing the format of data collection in a particular community may gain benefits in coordination with other agencies, but the changed format may no longer be compatible with those of studies done in that same community in previous years and may thus lose the ability to historically compare data for purposes of analysis and forecasts.

Many of the difficulties encountered in preparation of plans for small communities are associated with the difficulties of providing technical assistance on a continuing basis. In those instances where technical personnel are removed from day-to-day contact with the local decision-makers, local planning commissions, and citizens, difficulty exists in providing the kind of educational process and intimate insight into the local issues that enhance the preparation of plan documents and their implementation. In small communities, however, there still is a tendency to emphasize the preparation of planning documents rather than the development of solutions to visible local problems and ongoing advice to local and regional decision-makers. When the technical personnel responsible for preparation of the plan are present in the community for only short intermittent periods, it is very difficult to maintain a sensitivity to the way in which local problems evolve and to maintain the ready access to decision-makers that is necessary to effective plan implementation So long as those agencies responsible for planning assistance are able to document their activity by the production of planning documents per se, there is no way to assure that the planning documents are a means to effective decision-making rather than an end in themselves. The most apparent assurance seen in the interviews is the increased sense of professional responsibility in some agencies.

One of the most persistent deficiencies encountered in planning documents and mentioned in the interviews was the inadequate documentation and recording procedures of agencies responsible for technical planning efforts. The absence of documentation occurs in two general areas. First, there is an absence of documentation in the methods used in preparation of plans. The documents examined show a clear tendency to provide elaborate documentation of actual data and reasonably good documentation and description of plan proposals What is often missing is the provision of documents illustrating or describing the assumptions and methods used in collecting data, making forecasts, developing plans, and making recommendations. The other area in which documentation tends to be absent is in descriptions of local situations that influence the development of various strategies on the part of the technical staff.

The difficulties of documentation are probably caused by the practice of having single planning documents serve several purposes. The same plan report often serves (a) as the vehicle for presentation of recommendations to local officials and (b) as the repository of information, data, and techniques used in the preparation of the recommendations. It would appear that substantial improvement could be made in plan documentation if funding agencies encouraged more flexibility by allowing planning agencies to prepare shorter and more popularized presentations of their recommendations for local consumption and limited numbers of mimeographed technical documents for technical review and record.

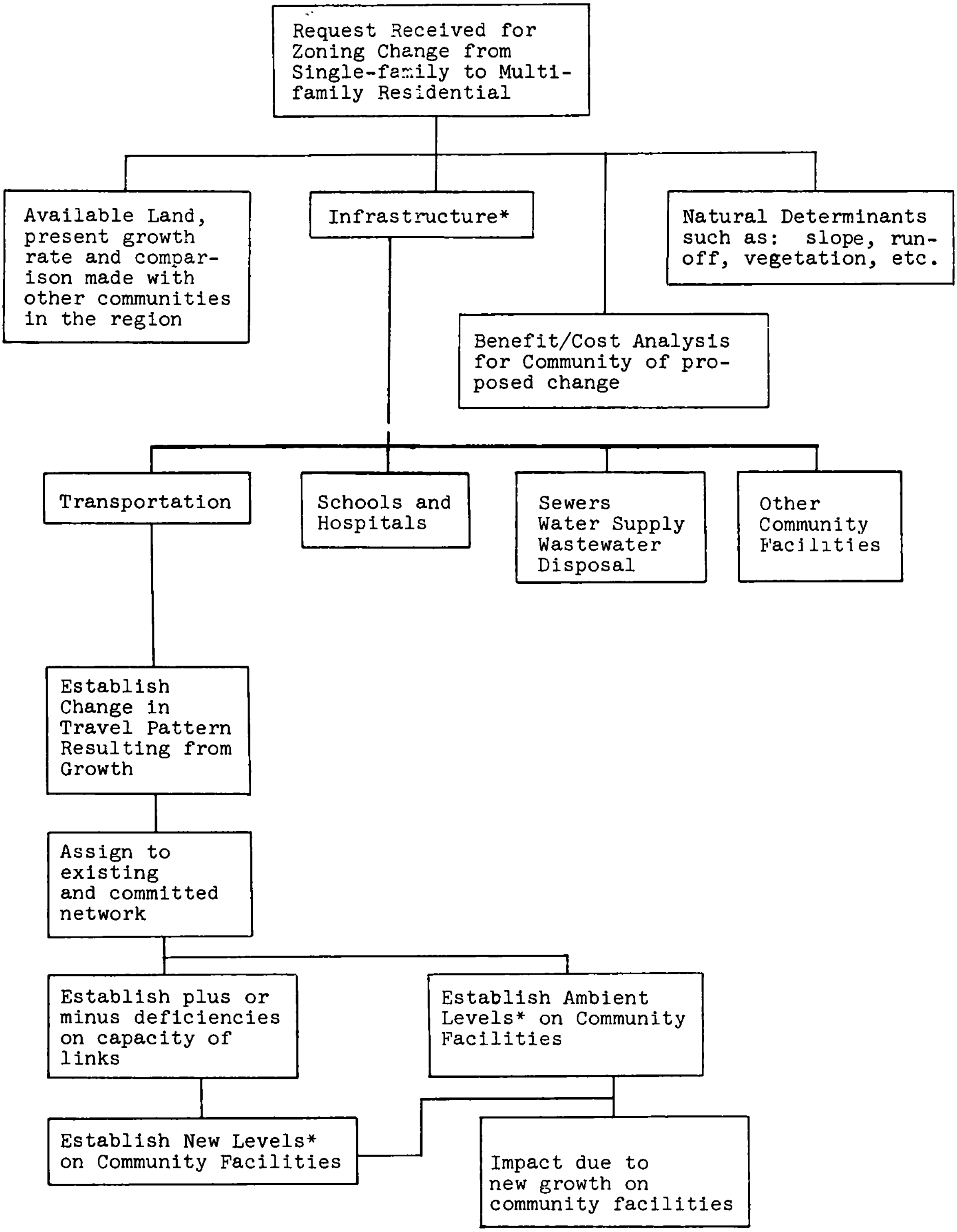
One of the problems associated with poor plan documentation is that the process of upgrading plans is made substantially more difficult for a technical staff. There is a strong tendency observed in the plan documents examined, and exposed in the interviews, for plan preparation efforts to start over from "scratch" rather than to update information collected within recent years by the same agency in the same community. This not only represents an unnecessary expenditure of funds for the collection of information but also tends to preclude the accumulation of some rationale and history of the decision-making process in the communities Thus, each technical staff person who has not worked in a community previously is required to discover personally on a trial-and-error basis a great deal about local value systems, personalities, and physical or economic pecularities of the community that influenced previous plan proposals. It is little wonder that highly capable technicians find that they do not have as much credibility with local people as they might reasonably expect to have.

FUTURE PRACTICE: LAND USE/TRANSPORTATION

This section puts forth the thesis that changes in the process of determining land-use controls could eliminate many of the shortcomings under which the UTP process must function. Improvement could come through advance considerations of land-use development and its impact on the community's transportation needs. Traditionally land-use decisions have been made from data collected on the need for the new land use. The argument put forth is that because there is a market-place demand, the proposed land-use change will be of service to the public. When the change has taken place, it almost always is a land use at higher intensity and a use that will generate more traffic. For this reason, very few zoning changes or subdivision permits will assist the transportation planner in his quest for producing higher levels of service on the congested arteries. Land-use changes are then followed by demands by users for improvements to the transportation system. In recent years proposed transportation improvements have been stopped or at least stalled because of environmental impacts. The increase in traffic facilities due to the land development can now be equated to its demand for land, its destruction of schools or homes, its contribution to air pollution, and so forth. In one sense, the insurmountable problems created by land development are thrust upon the transportation planner. But, if what is proposed in terms of new land-use growth controls comes about, transportation system evaluations will be performed in advance or at least at the time of the planned development.

The customized procedures proposed are oriented to the existing state of land-use controls, but the future will bring alternatives to land-use growth controls that will significantly affect the land use/transportation interaction. The most significant fundamental change will be to require proper consideration of transportation needs (as well as other elements of the infrastructure) prior to the actual land development. The steps in one possible urban growth control process are shown in Figure 4.

To varying degrees, land-use control can be achieved through proper use of the comprehensive plan or performance standards. New concepts, which are surely to be tested and eventually evaluated by the courts, include impact zoning and demand-based and supply-based methodologies. Further, within the next decade there will be a



* Levels for transportation are:
- a. accidents
- b. congestion
- c. noise at schools, hospitals, residences, etc.
- d. air pollution measured in carbon monoxide, hydrocarbons, particulate matter, sulphur dioxides and oxides of nitrogen at the locations of (c) above
- e. aesthetic effects

Figure 4. Steps in the urban growth control process.

shift in control of land uses to the federal and state governments. This will not completely void local governmental power or responsibilities, but those land development issues which have multistate and/or regional implications will be addressed by the appropriate governmental level.

In anticipation of improved land-use controls, transportation planners must concentrate on:

1. Establishing simplified relationships between land-use types and traffic generated for both peak and nonpeak periods. Average trip rates do exist, but with large variances. Little has been researched relative to trip rates by time period.
2. Assisting in the establishment of relationships between land-use type and demands on other elements of the infrastructure.
3. Establishing relationships that could assist in predicting what levels of service are tolerable for each element of the infrastructure and particularly acceptable levels of service for travel by peak and nonpeak periods
4. Assisting in the establishment of measures of economy of scale for each element of the infrastructure and to identify what variables influence these values.
5. Assisting in the establishment of how sensitive is the functional performance of each element of the infrastructure to variations in demands near the capacity value.
6. Assisting in the establishment of community goals and objectives, which can provide insights into proper land-use development.
7. Assisting in the establishment of a community data bank to serve the data needs for land-use control decision-making and other planning activities in the community or region

CUSTOMIZATION: A ROUTE TO SIMPLIFIED PLANNING

An important strategy towards simplification of transportation planning in small urban areas is to recognize the inherent variability of transportation problems in different urban areas and devise traffic forecasting and planning procedures commensurate with the nature of the problem. Although customization is being implemented in some situations, all too frequently planning procedures remain as standardized or scaled-down, lower-budget modifications of large-area studies. From the field interviews, it was found that variations in the characteristics influencing the over-all nature of the transportation problem include:

1. The nature and extent of the transportation problem.
2. Sensitivity of the forecasting procedure to the underlying transportation-related issues.
3. Ability to provide results meaningful to the decision-maker
4. Compatibility with the degree of sophistication and time requirement appropriate for a smaller urban area.
5. Availability of data and other informational and computational facilities
6. Availability of manpower and technical expertise.

Land-use planning is partially responsive to such variability, and customization is already occurring to a considerable extent in the procedures used to forecast land use in small communities. Many planners are foregoing elaborate computer procedures in favor of various manual arrangements that are heavily dependent on the planner's knowledge of the community and the exercise of professional judgment in an ad hoc or single-minded fashion. In communities under 50,000, for example, the planner often makes gross estimates of various land-use needs at some future date on the basis of population and economic studies. The planner then spatially distributes the required land-use activities, more by design principles than projections, while taking into account the capability of vacant land, proposed public improvements, and his knowledge of local development trends, land availability, and similar factors. In communities over 50,000, somewhat more structured short-cut procedures may be used, such as the one developed in Cumberland County, New Jersey (*17*).

The major needs for customization in land-use planning are in defining the scope of work and in organization. Circumstances do not require that all land-use plans be cast in the format of 20-year area-wide schemes. There is a need for some short-range planning and small-area planning. There is a need for land-use planners to focus more specifically on the transportation impact of major land-use decisions. All these efforts are now conducted to some extent, but the allegiance to long-range comprehensive plans appears to be diluting the extent and effectiveness of these more issue-oriented efforts.

Customization needs to be oriented to organization and land-use and traffic forecasting procedures that can utilize simplified techniques. The scope of planning in small urban areas is not the same as that in large metropolitan areas, and the role of the standardized, unified systems-oriented transportation plan also is somewhat different. Long-range transportation plans establish a framework for providing transportation facilities to satisfy future growth of the community as contemplated by the long-range land-use plan. Yet in small areas, development is often not in conformance with the long-range plan. Thus the validity of long-range planning is more questionable in small areas than anywhere else (*2*). The 20-year plan serves as a guide for making short-range decisions and identifying relative priorities, but dangers are inherent in pursuing short-range objectives at the exclusion of long-range developments A piecemeal approach can lead to irretrievable commitment of resources, which can handicap the expansion of transportation facilities later. Without the guidance of a long-range plan, decisions become day-to-day, this effect overlooks future requirements and results in inefficient allocations of resources. Transportation decisions should be made within the context of a planning framework scaled down to intermediate years. It is likely that this plan would not require the detailed level of traffic forecasting capability conventionally provided by trip-generation, trip-distribution, and traffic assignment models Little can be accomplished by postponing immediate or short-range transportation needs while awaiting the completion of a long-range plan relying on detailed traffic estimates.

Small area transportation plans have not pursued short-range planning to any practical extent The role of public transit and the effective utilization of traffic operational improvements such as channelization, street extension, restricted curb parking, intersection redesign, and signalization or the assessment of the impact of an imminent land-use change on the localized area transportation system are typical small-area issues demanding immediate attention but not adequately treated in long-range planning Short-range planning is characteristically concerned with stopgap measures which are highly visible and use relatively low-cost improvements (*13*)

The recent energy crisis has emphasized the need for contingency planning and the ability to consider service-oriented plans in order to obtain maximum benefit from existing facilities With only limited transportation expertise available to the smaller urban areas, the development of a transportation plan provides a unique opportunity to investigate transportation issues and should not be restricted to systems-oriented facility plans at the exclusion of short-range planning.

Reflecting on the structure of a small urban area consisting of a limited street system, a few well-defined residential areas, and special generators, it is conceivable that the major long-range capacity deficiencies, if any, can be identified without utilizing network traffic forecasting models. A simple comparison of traffic patterns with traffic volumes might explain major street deficiencies attributed either to severe congestion along the most direct route or the absence of a direct route. Also in the case of smaller study areas, traffic external to the community can assume a dominant role in establishing the level of service on the major street system

In the event a street planning policy is adopted that first satisfies capacity deficiencies by improving major thoroughfares by means of widening and subsequently seeks a new alignment (only after the other measures have been exhausted), such as a bypass or loop road, then traffic forecasts might be developed on the basis of corridors Future traffic forecasts suitable for preparing a thoroughfare plan in a small urban area may be derived without resorting to

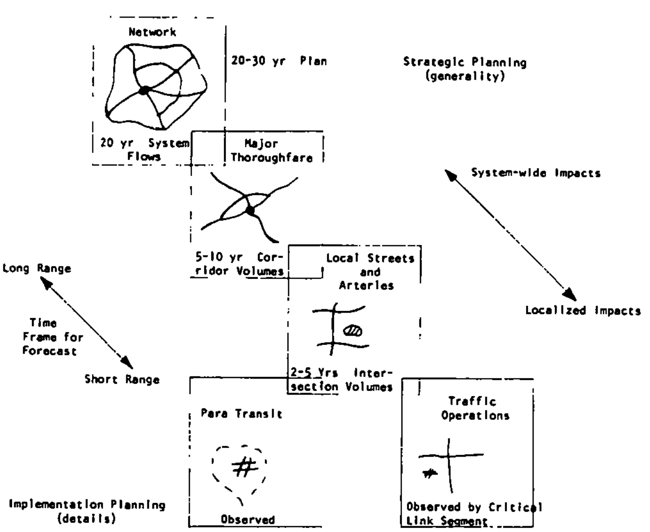


Figure 5 Transportation forecasts for a range of planning environments

sophisticated and time-consuming network models (*18*) Because external trips as a percent of total trips generally increase as the population size decreases and the number of corridors in a smaller area is generally less than that in a larger area, the net result is that the small-area traffic corridors are more intensely utilized and play a more dominant role in determining travel patterns (*19*). Where growth rates are expected to be irregular or difficult to anticipate, a system-oriented transportation plan might well be postulated on basic principles and general community characteristics such as population, land-use, and land development data without formally preparing future traffic estimates Prior to any commitments of resources for facility construction, however, the design requirements can be defined more precisely and the need formally justified (*18*).

It is the finding of this research that transportation planning in small urban areas must be tailored to the nature of the problem, the characteristics of the community, and the resources available in order to conduct a transportation study An important element of the plan is to explore a range of topic areas, as shown in Figure 5, extending from "strategic" long-range facility-oriented plans to implementation planning stressing shorter-range service-oriented improvements. The basic strategy devised by this research is to first identify the magnitude of the planning problem and resources available and then define the appropriate level of planning. The following subject areas related to planning techniques and different levels of planning have been investigated.

1 Development and testing of simplified models using the conventional structure of trip generation, trip distribution, and traffic assignment directed to the development of a long-range systems plan and also alternative strategies for updating travel patterns.

2 Development and testing of corridor models appropriate for small urban area thoroughfare planning where the number of alternatives is limited.

3. Development of a short-range consumer-oriented transit system planning procedure

4 Development of a localized traffic impact analysis technique for assessing the impact of new land developments on the traffic-carrying capacity of the local street system.

These simplified travel forecasting techniques, discussed at length in Chapter Four, have been selected to reflect the various scales of transportation needs and resource capabilities typically encountered in smaller urban areas. These simplified procedures also recognize the difference in time horizons (i.e , long-range versus short-range) and the variation in impact areas such as broad geographical coverage with network implications, isolated travel corridors and localized impact areas like major streets, or intersections abutting a proposed activity center. This approach is particularly significant because emphasis is shifting away from long-range plans to shorter-range improvements and the need to update and refine the initial plans periodically is recognized Rather than relying on a complex and computer-oriented travel-simulation package for application in all planning environments, more attention must be given to stratifying the transportation problem and using, where appropriate, such simplified procedures as categorical trip analyses, trip rates, and growth factors, and in general drawing on the wealth of travel data already collected for other small urban areas. The concept that planning tools should be commensurate with the problem also requires that consideration be given to organizational changes as previously discussed.

Although not intended to represent an exhaustive array of potential procedures, the following analysis techniques, also summarized in Table 2, were investigated to illustrate simplified procedures that could be used in a customized process:

1. Network simulation.
2. Corridor analysis.
3. Small-area transit planning.
4. Localized traffic impacts.

TABLE 2

SUMMARY OF TRAFFIC FORECASTING PROCEDURES

ANALYSIS LEVEL	TIME FRAME	LEVEL OF ANALYSIS	DECISION FRAMEWORK
Network analysis	5 to 20 years	Areawide transportation system	Physical roadway deficiencies with network implications—thoroughfare planning
Traffic corridor analysis	5 to 10 years	Travel corridor	Physical roadway deficiencies within a corridor with view of construction of a bypass or improving corridor capacities
Transit planning	Existing traffic	1. Neighborhood 2 Activity centers (identification of common trip end clusters and time clusters)	Define the role of mass transit and paratransit
Localized traffic impacts	Existing traffic generated in response to proposed land-use development	Street intersections and access points	Localized roadway deficiencies requiring traffic operational improvements

CHAPTER FOUR

INTERPRETATION, APPRAISAL, AND APPLICATION

SIMPLIFIED NETWORK PROCEDURES

To fully test the customization recommended for organization and procedures, a large number of cities of varying characteristics and problems would be required. Testing would be further complicated if one identified a large number of simplifying techniques for possible application. As an alternative, the researchers selected a limited number of simplified techniques to illustrate the procedures rather than to endorse simplification itself. Readers interested in the application of simplified techniques at the network level and at the corridor or local level will find the appendices valuable.

Network travel simulation procedures based on the modeling of generation, distribution, modal split, and assignment have had the greatest use in large urban areas. Simplification has been attempted in each of the modeling phases in an effort to reduce the costs in time and money. The use of synthetic models has been proposed in an effort to reduce these costs.

Borrowing the travel models from a community or cross-section of communities of similar characteristics in terms of population size, economic base, and geographic form reduces the need for costly internal home-interview O-D survey. The relationships that are to be transferred or fabricated in the absence of an internal O-D survey are zonal trip-production and -attraction values, in the form of either rates or equations, and the travel time (or friction) factors for a gravity trip-distribution model. It should be pointed out that although the lack of O-D data precludes any rigorous verification of the adopted models, some adjustments usually can be made based on the results of traffic assignments. A comparison of the assigned link volumes with actual ground counts is a valid check of accuracy of the fabricated models.

The experience of using borrowed or fabricated models for transportation planning in small urban areas is still limited. However, the use of this simplified approach is increasing, and the following discussion of the various phases of the procedure is presented as a general guideline for conducting a simplified network analysis for small urban areas.

INTERNAL TRIP GENERATION

The trip-generation phase of the travel simulation is the most critical phase because it sets the scope of the entire procedure Subsequent models are affected by the variables and model form used for trip generation.

Alternative Approaches for Trip-Generation Analysis

There are two basic alternative approaches for developing models for estimating internal trip productions and attractions. The first approach, aggregate trip analysis, develops relationships of trip production and attractions with appropriate independent variables at the traffic zone level, in most cases using multiple regression analysis. The principal advantage of the approach lies in its zonal orientation. Generally, the task of forecasting independent variables is simplified because of the aggregate nature. One of the primary disadvantages of this approach is that the models are not behavioral in nature and may be valid only for the zonal scheme on which they were developed and not readily adaptable to alternative zonal schemes or smaller-area analysis.

The disaggregate approach is based on the development of equations or rates describing the effect of independent variables on the trip-making of a basic unit. For trip-production analysis, households usually are considered the basic source of travel. Two alternative techniques can be used for developing disaggregated household trip-generation models The first, similar to the aggregate approach, uses the regression analysis method to develop equations describing the relationship between the number of trips per household and appropriate household characteristics (*20*). The second technique is the cross-classification method, which categorizes household trip-making rates according to such household characteristics as automobile ownership, family size, and income (*21*). The disaggregated approach in trip-production analysis has the advantage of being able to reflect a trip-maker's behavior and can also be useful for modal choice analysis. This approach is equally applicable to trip-attraction analysis, but land use or employment becomes the basic trip-generating unit rather than the household. The adaptability of disaggregated models to any traffic analysis zonal scheme is an important advantage in small urban areas for synthetic models and updates.

An approach becoming increasingly popular in recent years utilizes both aggregate and disaggregate techniques. A disaggregate cross-classification model is used for trip productions, and aggregate zonal equations are used to estimate trip attractions. In this manner, the basic trip-producing units (households) will be directly related to trip productions; and the trip attractiveness of each traffic analysis zone will be related to such independent variables as zonal employment, commercial and residential land, and population.

Disaggregate Household Models

In the selection of either zonal regression equations or household category models for trip production analysis, the criteria for evaluation are varied, and results of comparison often are inconclusive. One of the limitations commonly attributed to cross-classification analysis is the inability to perform statistical significance tests for the variables in the model; however, this criticism is probably unjustified considering the statistical techniques available in the area of experimental design including factorial analysis (*22*). On the other hand, a strong case used to be made for the time stability of the trip rates, but recent studies do not confirm this (*23*). Similarly, the transferability of trip rates among all types of urban areas has to be questioned; and, as reported in the application test of Appendix E, significant differences may be expected. These problems are, however, common to most forecasting procedures.

The accuracy of different techniques is an important criterion for model selection, and the ability to duplicate the existing travel pattern generally is accepted as the standard test for this purpose. (As reported in Appendix F, the application of synthetic trip-generation models of different types, both aggregate and disaggregate, for a test city indicated that no definite conclusions can be drawn as to the superiority of one technique over another.) None of the techniques was able to duplicate the link volumes and the screenline crossings very accurately at the first attempt. However, all of them could be made acceptable by making certain adjustments in the models and the network. In general, the inaccuracies were not large enough to result in a difference in the number of highway lanes to be recommended.

Because both modeling approaches have problems with temporal stability, transferability between areas, and accuracy, the criteria of flexibility and simplicity become the deciding factors in the selection of the approach for trip-generation models. Here, a disaggregate household model clearly is preferable to aggregate or zonal equations estimating internal trip productions. Included in its advantages are (a) the ability to verify or update the trip rates with a small sample and also (b) the development of behavioral models which are particularly important for reflecting future changes in travel behavior.

An important consideration in network traffic analysis is the coordination of data requirements of transportation and land-use planning. Guidelines are presented to achieve this coordination by means of the study design. Data items on which the local planning agency should concentrate are presented.

COORDINATION OF LAND-USE AND TRANSPORTATION PLANNING DATA

Coordination of Areal Analysis Units

The areal analysis units used for transportation planning (traffic zones) usually are much smaller than the census tracts used by the Bureau of Census to report population and housing information. Analysis units generally preferred by land-use planners are larger than traffic zones but not necessarily the same as the census tracts. This inconsistency has caused much difficulty in transportation studies. Previously, the traffic zones were delineated without any reference to census tracts, but presently there is a growing concensus on the need to establish a certain level of compatibility between the two units. Care is being taken to ensure that each group of traffic zones coincides with the boundaries of an official census reporting unit. This approach has done much to improve the coordination of data sources The land-use planner also must ensure that his analysis units are compatible at some level with traffic zones If, for valid reasons, the land-use planner is forced to use analysis units that are not compatible with census tracts, then the transportation planner must be made aware of the situation before the traffic zones are delineated and expensive data gathering efforts are in motion

Land-Use/Socioeconomic Data for Demand Estimation

Data requirements for travel simulation models have undergone many significant changes in recent years. The gradual substitution of land-use data by socioeconomic data has been one of these Data such as acres of residential land and retail floor area are of less value than such data as the number of households having the various characteristics of automobile registration and employment, for example This trend in the use of socioeconomic data reflects the increasing popularity of disaggregate and behavioral models

Accompanying the increased use of disaggregate models, a renewed emphasis on household data is occurring which is particularly significant for a transportation study of a small area The investigations on simplified travel simulation techniques for small urban areas suggested the possible elimination of costly home-interview O-D surveys and the use of synthetic models. However, traditionally home-interview surveys have been one of the main sources of data for household characteristics. Thus, the need for developing and maintaining household data on a zonal basis without resorting to home-interview surveys is critical if the new and simplified techniques of transportation planning are to be successful Whereas household data are used primarily for trip-production and modal split analysis, an increasing reliance also is placed on employment variables for trip-attraction models. The need exists for developing and maintaining employment data on a zonal basis

Household Characteristics

The household characteristics generally used in trip-generation analysis are family size, car ownership, family income, and dwelling unit structure type. The relative importance of these characteristics depends on the model utilized. From the standpoint of trip generation alone, family size (generally the number of persons over 5 years old) has been found to be very significant (*24, 20, 22*). Car ownership and family income have also been found very significant for travel simulation, especially for modal choice. The use of both these characteristics in the same model, however, has been questioned because of their high correlation with each other. The projection of income at the household level has been troublesome, and its use is complicated further by inflation, price changes, or state laws preventing its collection. As a result of these problems, the need for car ownership data has increased Car ownership data are almost essential for transit planning, especially if income data are not available.

The classification of dwelling units by structure type multifamily apartment, duplex, and single-family home) is desirable if such data are available. However, in spite of the significance of this characteristic, its use as a variable in either trip-generation or mode choice analysis has been limited. It can be concluded reasonably that if the other characteristics—family size and car ownership (or income)—are available, the classification by structure is not a critical requirement.

Employment Data

The use of employment data in travel simulation models is limited to the derivation of trip-attraction and nonhome-based trip-production equations. Employment data, expressed as the number of employees working in each traffic zone, usually is classified into various categories according to the type of business Several different categories of employment have been used in the various transportation studies, some of which are listed·

1 Total employment.
2 Retail employment.
3 Convenience retail employment.
4. General merchandise, apparel, and furnishings retail employment
5. Highway-oriented retail employment.
6. Wholesale employment.
7 Industrial or manufacturing employment
8. Service employment.
9. Government and institutional employment.

The preceding list represents a fairly detailed breakdown of employment categories and reflects a similarity with the standard industrial classification system. In the case of small urban areas the base-year data for these categories may be estimated by a windshield survey and/or from the records of the state agencies involved with labor and employment, but the task of forecasting these on a zonal basis may be formidable. However, there is a growing consensus that it is not necessary to develop employment data with a large number of categories Generally, in the case of small-area studies using a simplified procedure for travel simulation, the categories of total, retail, wholesale–industrial, and "other" are sufficient. It should be pointed out that in addition to the employment categories that generate traffic during the morning and afternoon peak hours, particular emphasis should be given to retail employment and the identification of large shopping centers.

Land Area and Land-Use Density Measurements

As mentioned previously, the use of land area measurements (residential land area in acres and office floor area in square feet) for particular land uses in travel simulation models gradually is decreasing because of the increasing use of household and employment data and because of the difficulties associated with their forecasts. However, the significance of land-use measurements must not be overlooked entirely. Although for trip-production and modal split models the overwhelming trend is to use household-related data, which tends to make the models behavioral in nature, the land-use measurements can still be used for trip-attraction models and for special impact analyses. Trip-generation rates for special traffic generators, such as shopping centers, airports and hospitals, are often derived in terms of land area measurements The impact of new or proposed developments cannot be made unless travel data on the various land uses are available.

Land-use density measurements are of particular significance in transportation planning, and the use of socio-economic variables does not necessarily preempt their incorporation in the same models. Indices of residential densities may be included in modal split models in addition to the behavioral characteristics of car ownership and income. The density of commercial development is also useful in traffic studies (as, for example, in parking analyses).

Land area forecasts are useful in aspects of transportation planning other than forecasts of future travel patterns. If, for example, land-use forecasts indicate a rapid rate of intense development where new right-of-way areas need to be acquired, then early attention should be given to right-of-way acquisition or to adoption of regulations to protect areas needed for right-of-way from encroachment. The possibilities of land area and land-use density measurements basically imply that they must not be ignored. However, it is difficult to specify exactly to what extent the information on land area measurements must be updated because it depends largely on the available manpower and the nature of the study area.

Forecasting Land-Use/Socioeconomic Data

The ability to forecast and continually update an item of data should be an important criterion for its selection as a variable in a predictive model In the early stages of the evolution of travel-forecasting models, this factor was often overlooked and models based on very detailed data were not uncommon Naturally difficulties were encountered in the continuing use of these models because of the lack of subsequent data availability for many of the variables. It is now clear that transportation and land-use planners must address the question of data availability at the very beginning of the planning process when the study design is prepared. The increasing use of disaggregate household data in travel simulation models requires that land-use planners forecast at a stratified household level. Generally forecasts are made for such aggregate information as average or median income, total number of automobiles, population, and households in each zone. The disaggregate approach, on the other hand, creates discrete classes for each characteristic, which are needed for the multidimensional matrix of household types The task, therefore, is to allocate each of the total households in a zone to the appropriate cell of the household stratification matrix. The development of forecasting models, however, requires "factored" data as available from regular internal O-D surveys. This requirement constrains the use of disaggregate household models for which a small sample generally is adequate. Appendix C contains a detailed treatment of simplified procedures for developing household stratification models.

TRAFFIC FORECASTING PROCEDURES

Internal Household Trip-Generation Analysis

The procedure of using synthetic or borrowed household category models for trip productions and zonal equations for trip attractions is recommended for use in synthesizing the internal household travel pattern in small urban areas. It should be pointed out that any limitation in the transferability of zonal-attraction models due to a difference in the zonal scheme generally is overcome by balancing the total attractions of a trip purpose to the corresponding total trip productions Comments follow on some of the details of the analysis.

A Small-Sample Survey

The criteria for selecting a parent city from which travel models can be borrowed for a particular study area are not clearly known at this time. Although the typical characteristics of population size and nature of economic base are useful indicators, they do not guarantee similarity in travel characteristics. It is recommended that, if feasible, a small-sample home-interview survey be conducted to derive trip rates. The sample may be chosen to obtain approximately 30 households in each category For example, for a very simple classification of households based on two characteristics and each stratified into three classes, a sample size of only 270 households could yield 30 observations in each of the nine cells of the matrix. As tested and reported in Appendix E, given evenly distributed observations in each category, a small-sample survey can yield trip rates that are not significantly different from those obtained from a much larger sample obtained in the usual manner In order to obtain such a uniform distribution of observations among the various cells, the sample must be carefully selected The trip rates obtained from the small sample also can be compared with those of other areas for verification.

A detailed breakdown of trip purposes is not necessary for small urban areas and usually the three purpose categories of home-based work, home-based other, and non-home-based have been found to be satisfactory for household trips (*4, 5*).

Independent Variables

Although the choice of independent variables may be limited in the case of synthetic or borrowed models, it is preferable to avoid those variables which may be difficult to forecast. For the category models, household size and auto ownership are recommended for trip production. Household size is very significant from the standpoint of the number of trips, whereas car ownership is important for modal split analysis. For trip-attraction models, total employment, retail employment, industrial–wholesale empoyment, "other" employment, and population in each zone would provide a reasonably sufficient choice for independent variables.

Special Generator Analysis

In every city, there are usually a few activity centers not incorporated in the generalized trip-generation models that have unique characteristics and are major traffic generators. Examples are large shopping centers, airports, universities, and hospitals. An effort should be made to obtain traffic count information at these locations for verifying the results of the regular travel simulation models. In most cases the trip ends in the zones containing these generators are estimated with separate trip rates or equations. Trips can be estimated as a function of employment or household size, as discussed in the latter part of this chapter. It should be pointed out that sometimes the trip distribution for these generators also may require special treatment, such as a judgmental or manual process

Internal Trip Distribution

The development of trip-distribution models requires substantial effort and resources, traditionally in the form of an O-D survey and subsequent data processing. Unlike the case of category models for trip production, a very small sample is not adequate for generating the zone-to-zone trip movements for all zones. Thus, in the absence of the standard O-D survey, a trip-distribution model initially must be completely fabricated or adopted in its entirety from another area; and only after the results of traffic assignment are available can any adjustments be made.

Although a few different types of trip-distribution models have been used in the urban transportation studies, extensive experience with the gravity model makes it a natural choice for use in a simplified planning procedure. The key element in synthesizing a gravity model is related to the friction (or travel time) factors, which can either be derived synthetically or adopted from another urban area. The Georgia Highway Department (*25*) developed synthetic friction factors based on measures reflecting the size of an urban area, maximum trip length, and average trip length Ashford and Covault (*26*) analyzed the friction factor curves from nine cities and related them to the socioeconomic and travel characteristics. The North Carolina Highway Commission (*27, 28*) gained considerable experience in the use of the friction factors of one area for another area, and their experience indicates that transferability is acceptable. Many planners often use the trip length frequencies as the first approximation of friction factors and adjust them repeatedly until the frequencies obtained from gravity models match the desired trip length frequencies adopted from another city and based on the maximum trip length expected in the study area (*9*). Hajj (*4*) also reported the derivation of friction factors for an area based on a comparison of those from several other areas. Based on the present state of knowledge, it appears that the adoption of the initial friction factors for different trip purposes from another area of similar size is valid and simplifies the modeling tasks considerably. It may be noted that the so-called "K_{ij}" factors are not used very frequently and, if needed, they also have to be developed from the results of traffic assignment.

Modal Split Analysis

Because of the low level of transit use, modal split analysis has been neglected in transportation studies for small urban areas. Increasing emphasis on the development of public transportation has generated a new interest in transit planning for small urban areas, for which the conventional approach for modal split analysis has been found inappropriate (*29*) A discussion of these aspects of transportation planning is presented later in this chapter.

Internal Truck Trips

Traditionally, urban transportation studies focused on the movement of persons and freight movements were relatively neglected In larger urban areas, a special survey usually was conducted to obtain data on truck and taxi trips. In some cases zonal trip-production and -attraction models in the form of regression equations were developed, followed by a gravity model for trip distribution. In other cases the zone-to-zone trip matrix for the base year was projected by growth factor techniques. For small urban areas the internal truck trips were ignored completely in many cases.

The experience in synthesizing internal truck trips for small areas is not adequate at this time for recommending any specific procedure. However, the equations available from larger urban areas may be used for estimating zonal production and attractions, and the friction factors derived in these studies may be used for trip distribution. In using this procedure, care must be taken about possible errors in the over-all magnitude of truck trips, and the total trips estimated by the equations should be compared with control totals obtained by some other methods. For example, the proportion of truck trips with respect to the total household trips or total population in one area may be used to estimate the total internal truck trips in another area. In addition to verifying the total trips, one must identify the special generators such as a large truck terminal or a warehouse complex and obtain information on truck trips by contacting its management. The zonal values for these generators as estimated by the equations should be compared with the information obtained from other sources.

The importance of goods movement in urban transportation cannot be overemphasized. Although truck trips may constitute a small proportion of the over-all travel, their localized impact may be significant. The location of truck terminals and the routing of trucks through the urban street system must be planned appropriately, to contribute to the over-all quality of transportation planning.

External Trips

External travel, in the form of external-internal trips and through trips, constitutes a small proportion of total travel in an urban area. However, its magnitude varies widely between areas, usually within the range of 5 to 20 percent of total trips, and the proportion generally is higher for smaller areas. The impact of external travel on smaller communities may be significant and cannot be ignored in the development of the over-all transportation system.

The travel simulation procedure for external trips is not as advanced as that for internal trips, and the transportation planners usually rely on a roadside-interview O-D survey to obtain information on the existing travel pattern. The future external-internal trips are predicted either by projecting the base-year trip distribution with appropriate growth factors for each internal traffic zone and external station, or by the gravity model trip-distribution technique. In the latter case, the modeling is simplified by assuming that all external-internal trips are produced at the external stations and attracted to the internal zones. The productions then are forecast with growth factors, while a linear regression model is derived to forecast the zonal attractions. The through trips, on the other hand, in almost all cases are projected with a growth factor technique. Attempts to synthesize external travel have been limited and none of the present techniques tested adequately in a variety of environments (*30*).

Considering the present state of the art and the significance of external travel, it appears that a complete reliance on synthetic techniques to estimate the external travel pattern is not advisable in the case of small urban areas. However, an appropriate combination of a limited external O-D survey and synthetic techniques would not only reduce the cost and time required but also increase the reliability of the analysis.

Nonresidents and Taxi Trips

Internal trips by nonresidents of an area traditionally have been ignored in urban transportation studies. Recently, some attention has been given to this category of travel, but the emphasis has been on the additional traffic volumes rather than the population serviced. This type of trip may be particularly important in resort communities. If an external survey is conducted, a question related to these trips should be included so that an average trip rate with respect to the external-internal trips can be developed for future projections. A very simplified procedure of developing the zone-to-zone distribution of these trips is to combine them with the nonhome-based trips by the residents. This task can be accomplished simply by factoring up either the nonhome-based productions and attractions before distribution or the zone-to-zone trips after distribution.

Although the impact on facility planning is negligible, the role of taxi service in a community as a demand-responsive transportation system must not be overlooked. Several urban transportation studies included taxi trips in their analysis of the over-all travel demand. However, it is becoming increasingly clear that the traditional network simulation approach is not very suitable for analyzing the needs and scope of taxi service.

Traffic Assignment and Model Adjustments

In the case of synthesized travel models, the results of traffic assignments are of special importance because they verify not only the traffic assignment technique but also the models used at the preceding phases of trip generation and distribution. A travel-time study should be conducted to obtain realistic travel times for each link on the network, and the "trees" also should be checked thoroughly to verify logical routing of zone-to-zone trips.

The discrepancy between the assigned volumes on various links and actual traffic counts should be evaluated by examining parallel routes and conducting screenline checks in addition to a link-by-link comparison. A comparison of the vehicle-miles of travel generated by the simulation models with those estimated with actual traffic counts should also be made.

Simulated screenline crossings can be expected to be lower in the central business district (CBD) areas. The localized discrepancies can sometimes be attributed to special generators like shopping centers, airports, hospitals, and universities, for which additional analysis is generally necessary. However, if the discrepancies are beyond any explanation related to traffic assignment or special generators and the assigned volumes are uniformly higher or lower than the actual counts, the error may be attributed to either the trip-generation or the trip-distribution models.

No adjustments of the trip-production models should be made until all other means are exhausted or some obvious reasons become evident. Therefore, the next step after adjusting the assignment and special generators is to examine the friction factors of the gravity models, which affect the trip lengths and thus the link volumes. The friction factors can be adjusted by changing the slope of the trip-length decay curves. A steeper curve would result in shorter trips and reduce the link volumes, and vice versa. Adjustments of the trip-distribution model may not have a significant effect in some cases, and trip-generation models may have to be modified as the last resort.

A small-sample home-interview O-D survey, traffic counts at special generators, and the limited external O-D survey recommended earlier can be very helpful in decisions related to model adjustments. Without such data for the specific study area, it is very difficult for an analyst to pinpoint the exact sources of discrepancy.

UPDATING TRAVEL PATTERNS FOR CONTINUING PLANNING PROCESS

The continuing phase of transportation planning involves periodic monitoring and updating of study results and traffic estimates. Only through periodic reviews and updates can a plan respond to the dynamic and ever-changing planning environment. When present traffic volume trends show evidence of deviating from interim study forecasts (as interpolated between base year and future year volumes), the cause of change requires investigation. Deviations might be caused by unexpected changes in (a) trip-making activity, (b) land use, or (c) the provided level of transportation service. An investigation of underlying trends helps assess the need for a revision of traffic forecasts. Considering the time and cost of preparing traffic estimates, it is not unexpected that little attention has been devoted in the past to the periodic updating of small urban area transportation plans, but without periodic monitoring and adjustments these plans soon become obsolete. A need thus exists to devise a simplified approach to permit periodic reviews and updates of small-area transportation studies

Some Basic Strategies for Updating Traffic Estimates

Discrepancies that might be noted between observed ground counts and interpolations of forecasts can be attributed to many factors, including.

1. Short-range fluctuations in travel pattern due to partial construction of the recommended transportation system
2. Changes in the anticipated intensity of trip-making activity, such as trips generated per household
3. Changes in a zone's anticipated land-use and demographic characteristics, such as zonal population, employment, and density.

The seriousness of a discrepancy depends on uses of the traffic assignment data. The predicted traffic volumes are utilized not only to develop a network of facilities but also to evaluate their capacity and levels of service or to determine the need for additional lanes Usually an increment of one lane serves as the level of accuracy for investment decisions. Various illustrations of forecasting accuracy are shown in Figure 6, several of which may lead to a conclusion that the traffic estimates need to be updated and be brought into closer concert with current observations.

Surveillance and Reappraisal Procedures

In recognizing the importance of the continuing nature of planning, the Federal Highway Administration has established an elaborate procedure for the continuous monitoring and periodic review of the adopted transportation plans in urbanized areas with 50,000 or more population (*31*). In addition to current estimates of growth annually, the procedure requires reappraisal of the transportation plan at three levels of intensity—routine annual review, major review every 5 years, and plan reevaluation at least every

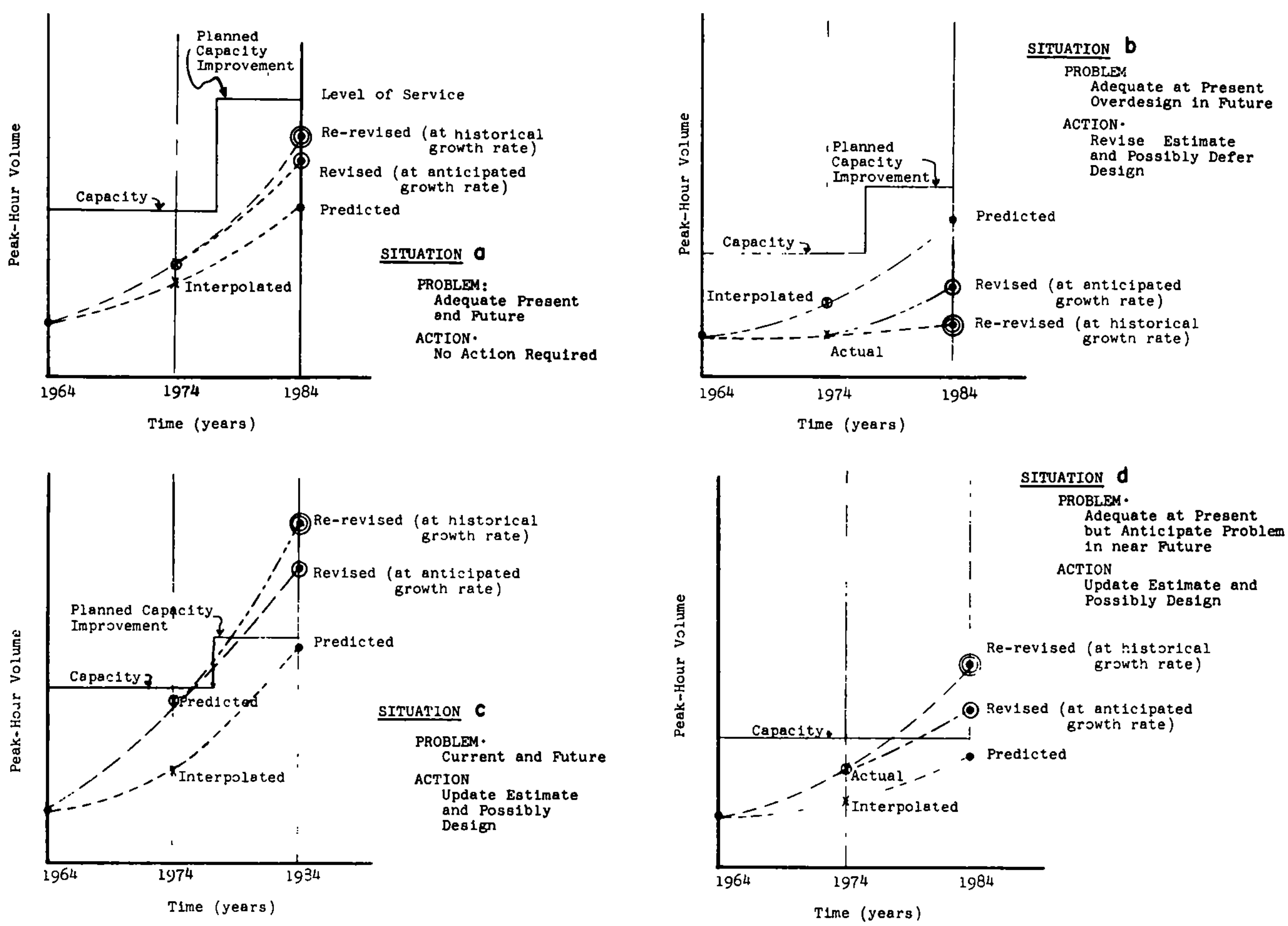


Figure 6. Comparisons of revised trip estimates with forecast trips.

10 years. The routine review is based primarily on local traffic counts and a growth analysis of urban development Any adjustments in forecasts that are made as a result of the routine annual review are of a localized nature and based on simple techniques. Similarly, the major review does not require any major data collection or adjustments in models unless the travel characteristics are found to have altered significantly. However, the major review in some cases and the plan reevaluation in all cases require a large investment in new data collection and model adjustments and could be beyond the resource capabilities of small urban areas, particularly those below 50,000 population unless there was special federal funding for this purpose. A simplified network simulation technique would be helpful not only for the smaller areas but also for others in reducing the time and cost of plan reevaluation. A procedure based on the simulation of work trips is presented here as a simplified alternative to the regular full-scale travel simulation procedure usually necessary for plan reevaluation

Reappraisal Based on Work Trips

Past investigations have revealed the importance of work trips in urban transportation planning, and a hypothesis has been advanced that work trips alone can be expanded to replicate a small area's traffic pattern and utilized for travel forecasting without resorting to models for all types of trips based on a complete O-D survey (*32, 33*). Work, the predominant trip purpose, represents 30 to 45 percent of the daily home-based trips More significantly, work trips comprise 80 to 90 percent of all trips undertaken in the morning peak and 70 to 80 percent of all trips undertaken in the afternoon peak The afternoon peak usually represents the critical period for highway design consideration, and the ability to replicate peak-hour travel patterns could provide planners with useful data for sizing future transportation systems as well as aiding in the verification of previous traffic estimates

The method proposed here represents an approximate technique relying on many simplifying assumptions. Where available and appropriate, the census journey-to-work data should supersede the simplified approach presented (*34, 35, 36*). Through use of models based on census relationships, peak-hour or total daily volumes can be developed and assigned to a small-area road network. In some situations, however, the census work-trip data may be slow in becoming available or may be coded to a geographic level not appropriate for traffic estimation purposes In these cases the census journey-to-work travel data could be replaced by an independent work-trip survey as presented here.

For the survey, information can be obtained on the employee's place of residence, place of work, time of work trip and route followed in traveling to and from home. Such information may be acquired easily by either using an employer's records or contacting workers at the major employment sites in the community.

Many of these data are currently being acquired as part of the car pool surveys (*37*). With cooperation from employers, these optical scan questionnaires can be processed at a cost of 5 to 10 cents per sample with a light-sensitive optical scanning machine (*38*). With little cost constraint a larger sample of the working population can be contacted, the only limitation being the cooperation of the participant. With subsequent processing by magnetic tape, although manual tallys are also feasible, a density matrix can be obtained that lists the number of persons leaving for a common destination (usually a work site) from a precise geographical area (traffic zone or grid) by incremental time units of 15 to 30 minutes. The resulting analysis then can provide extensive information on work-trip patterns at relatively little cost and with the potential for conducting periodic updates as the dynamics of travel change

Based on the proportion of work trips with respect to total trips, a relationship or model can be developed to estimate total trips using the results of work-trip simulation. Thus, when justified, a network analysis can be performed with average daily traffic (ADT) models based primarily on work trips Although the accuracy of such models can be questioned, they do present a viable alternative considering especially the substantial savings in cost and time in comparison to the conventional updating procedure The decision about when the work-trip procedure should be used is dependent on particular needs and constraints of a situation. An over-all approach to plan review is shown in the flow chart of Figure 7.

Alcoa-Maryville Example. A supplemental work-trip survey in the Alcoa-Maryville area focused on the two major community employers Employees who were questioned concerning their work trips represented a 4-percent sample of the total employment. A 46-percent response was received, or 370 usable questionnaires. Respondents traced the route path for their work-trip journey The work-trip samples were expanded to represent total area work trips.

Comparison of the factored work trips with observed average daily traffic for fifteen major links resulted in a R^2 (coefficient of determination) of 0.945, which means that 94 5 percent of the variations in total daily traffic can be explained through the use of work trips alone A similar comparison for the estimation of peak-hour traffic resulted in a R^2 of 0.826. The work-trip survey for the Alcoa-Maryville study area would have provided designers with sufficient accuracy to avoid over- or underdesigning the highway sections Only three of the fifteen sections would require further analysis.

SIMPLIFIED TECHNIQUES

The transportation planning techniques discussed previously are directed primarily towards the development of the overall transportation system in a small urban area. Although the importance of such a systems approach cannot be overemphasized, the need for additional techniques for the analysis of specialized transportation services or more localized problems must not be overlooked. Without such additional techniques, the capability of transportation planners to respond expeditiously to a variety of problems would be seriously impaired. This section discusses the techniques applicable using the customized process for three special purposes—public transit planning, corridor analysis, and

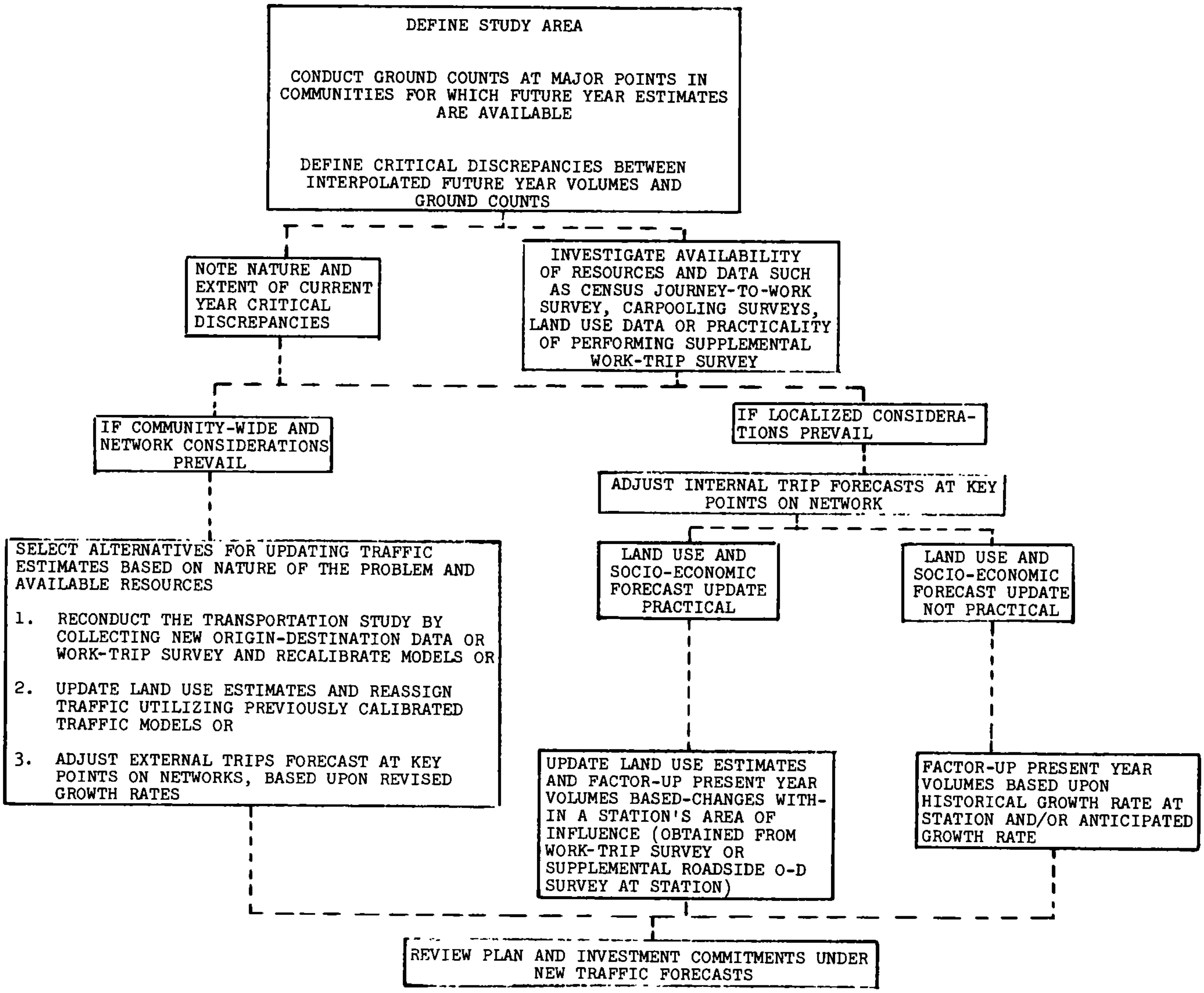


***Figure 7.** Flow diagram of the general plan update procedure.*

localized traffic impact estimation (see Table 2). Although the analysis in each of these areas can be carried out independently, every effort should be made towards their coordination with the over-all planning process.

SMALL URBAN AREA TRANSIT PLANNING

Statistics indicate that at least 90 percent of all trips in small areas are made by automobile, with 90 percent of all families having access to at least one automobile. It is not surprising, given the over-all dominance of the automobile, that most public transit systems in small areas are either nonexistent or inadequate in terms of service or equipment. Small-area transit systems cannot hope to duplicate the high levels of services provided in the larger cities (*13*). Without sufficient ridership, it is not always economical to support conventional fixed-route, fixed-schedule systems. Fixed-route systems are most effective in urban areas where population or employment is concentrated along fixed travel corridors and the movement of large numbers of people is required. However, in small urban areas where development patterns are less concentrated and per capita auto ownership is high, fixed-route systems may lack the flexibility necessary to serve the dispersed travel demand (*13*). In developing alternative transit systems for small urban areas, the unique characteristics of demand and the tremendous competition with automobiles must be considered fully and the planning approach designed accordingly.

While some small urban areas can function without an effective public transportation system, there is a growing awareness of the need for an alternative to the private automobile. The demand for an acceptable level of public transportation is no longer confined to the segment of population without access to automobiles, the so-called captive riders, but also includes the growing number of people who prefer an alternative to the problems associated with urban driving. A redefinition of public transportation to include all alternatives for moving people within urban areas, therefore, is essential to effective planning in small areas.

Transit planning in small urban areas actually is a relatively new area for which the techniques are evolving and several alternative approaches are available. These techniques can be grouped into the two broad categories of (1) long-range planning techniques primarily involving network analysis and demand modeling and (2) short-range planning techiques, which are oriented to operational improvements of the existing system and a consumer market analysis for new types of service. There is a growing concensus that because of changing characteristics of the small urban areas, transit planning has to be short range, although the role of long-range planning must not be overlooked Some of the small urban areas have performed long-range transit planning studies, and such efforts should not be preempted by short-range planning. The scope and alternative approaches for long-range planning in small urban areas are discussed first, followed by the presentation of a consumer-oriented short-range planning approach

Long-Range Transit Planning Approach

Current techniques for long-range transit planning are oriented toward network analysis and travel simulation models. The computer software developed by the Urban Mass Transportation Administration, UMTA Transportation Planning System (UTPS), includes powerful analytical tools for evaluating alternative networks of fixed-route and fixed-schedule transit systems. These techniques reflect the approach used for highway planning which is being extended to transit planning. They are basically facility oriented as opopsed to being service oriented. Although it may be difficult to envision rail rapid-transit systems for smaller urban areas, the use of exclusive right-of-way for car pools and bus service and even busways is not unrealistic for urban areas of 200,000 or more population. Thus, there is a definite need for advance planning of future transit facilities in small urban areas. The long-range planning tools, such as the UTPS, evaluate different levels of service in terms of convenience, frequency, and speed of service and can generate information useful for management purposes.

In comparison with the highway-oriented UTP process, the long-range transit planning procedures are less standardized Key elements in the development of long-range transit plans are mode choice analysis and the prediction of future transit use. Whereas some of the elements of the long-range planning process are relatively routine and do not vary in their basic approach between large and small urban areas, the mode choice analysis is particularly sensitive to the size and nature of a study area. Chatterjee and Sinha (*29*) analyzed alternative approaches to mode choice analysis in small and medium-size urban areas and found that most of the recent studies use a compromise approach which attempts to recognize the past trend as well as the possibility of significant behavioral and technological changes. One of the most difficult tasks of long-range planning in small urban areas is the estimation of the potential changes in transit use characteristics. The use of attitude surveys to accomplish this task has been quite widespread in recent years (*39*), and the use of a theoretical model also holds considerable promise (*40*).

Long-range transit planning techniques do not necessarily have to be time-consuming and expensive. Simplified procedures being developed by UMTA include both manual and computerized sketch planning techniques (*41, 42*). Although these simplified techniques are not designed particularly for small urban areas, they would be useful there, especially where resources and time are limited

Consumer Orientation in Plan Development

Traditional long-range planning based on network analysis and travel simulation has been criticized on the grounds that the travel demand forecasts are aggregated and a single system is proposed which is supposedly sufficient for the variety of users. Such a criticism, however, is not entirely valid from the standpoint of the planning techniques The disaggregated trip-generation models, which were discussed previously, recognize the unique characteristics of tripmakers and should incorporate variables that are significant for transit planning purposes, such as car ownership and income The stratifications by trip purpose should also recognize the difference in transit service requirements. The current techniques of mode choice analysis can provide for the incorporation of behavioral attributes of users (*43, 44*). It is highly desirable that the capability of these models is fully utilized. The disaggregated approach should be carried on beyond the modal split analysis and utilized in the actual development of consumer-oriented plans and also in their evaluation (*45*).

Uncertainty of Demand Forecasts

The basic difference in the approach and strategy for long-range transit planning in small versus large urban areas is not so much in the details to be included in the procedure as in the treatment of uncertainties. Whereas travel behavior in large metropolitan areas may be assumed to be relatively stable, the uncertainties associated with the transit demand forecasts in small urban areas must be recognized and a continuing process of monitoring and adjustments of forecasts must be established (*29*).

Consumer-Oriented Short-Range Transit Planning Approach

Short-range transportation planning deals with immediate needs and improvements; and in the case of transit planning, short-range studies usually focus on operational improvements. The scope of such studies includes primarily analyses of existing demand, user characteristics, routes and schedules, equipment needs, fare structure, and management. The techniques for carrying out these tasks are straightforward and well documented (*46, 47, 48*).

The conventional short-range transit studies will continue to play a significant role in urban areas that have existing transit systems, as they basically focus on the improvements of existing service. However, it must be pointed out that the conventional approach does not apply to a small urban area where a transit system does not exist and also that even in an area with a transit system the scope of short-range transit planning must not be limited to the analysis of the existing system only. An aggressive and imaginative approach must be taken to develop a transit system that not only is capable of responding to the varied needs of the existing users but also can attract new customers by satisfying their needs and preferences The consumer-oriented approach presented in the following sections explicitly recognizes the diversity of demand characteristics and preferences for transit service in a study area by identifying different market segments and subsequently determining the need for and feasibility of appropriate transit alternatives for each segment. This approach also views transit services from a broader perspective and such systems as demand-responsive operations, taxi service, express buses, and car and van pools are included among the alternatives in addition to the traditional fixed-route and fixed-schedule bus system.

The key steps of the transit planning procedure based on the consumer-oriented approach, as shown in Figure 8, include the delineation and survey of transit market segments, the matching of preferences with alternative systems, and the feasibility analysis and implementation of potential alternatives for each segment These steps are discussed further.

Market Segmentation

A transit market segment may be defined as a group of potential users with common preference for modal and service characteristics. However, there is a need to go beyond such a definition to examine the travel patterns of each group because different travel characteristics, such as travel with dispersed origins and destinations as compared with travel with common origins and destination, would imply different types of transit service In a market-analysis-oriented transit study of a large urban area, it was found (*49*) that persons who have common work or commercial trip destinations also often have common trip origins. The approach was to establish a trip origin-destination relationship for each selected group within the area, with a transit market assumed to exist only in the cases where such a relationship was discovered. This approach tends to overemphasize the significance of a concentration of travel, which is particularly favorable for fixed-route transit systems or car/van pools It must be pointed out again that the concentration of travel should not be a limiting criterion because other types of transit services can satisfy the dispersed group of travel desires. Thus a transit market segment may be defined in a variety of ways—in terms of user groups or common destinations, or a combination of both. The definition of markets and techniques would vary from case to case; some of these techniques are further discussed

The demand for transit service is basically derived demand because it is used primarily to fulfill other needs. The transit rider is hardly interested in the ride itself, but needs the service to go to work or to shop or to satisfy another purpose. This nature of transit demand and the importance of the destination of a trip must be recognized For this reason, the segmentation procedure of a transit market should focus initially on the activity centers at which the travel in a small urban area is concentrated The majority of these activity centers, such as shopping centers, major employers, or other large traffic generators, are self-evident These may be grouped according to the predominant nature of the generated trips—discretionary and nondiscretionary. An example of typical activity centers is given in Table 3, which gives the results of a study performed by the University of Tennessee for the cities of Maryville and Alcoa (population 13,803 and 7,739, respectively)

In some cases, the major concentrations of travel and related activity centers may not be self-evident. The centers of discretionary and nondiscretionary travel in such cases can be identified by tracing the travel of different population groups to particular activity centers for which a preliminary survey may have been performed The stratification of population groups may be based on certain socioeconomic and/or demographic data such as age, income, and occupation Essentially this approach would require

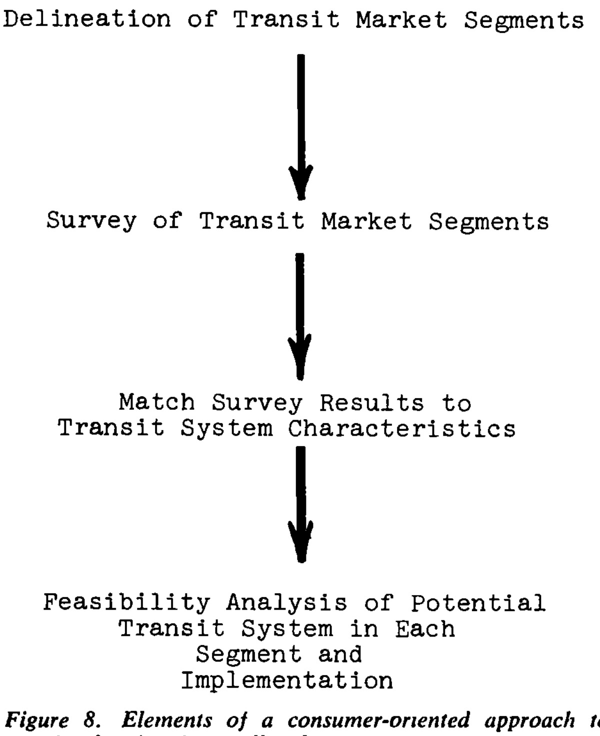


Figure 8. Elements of a consumer-oriented approach to transit planning in small urban areas.

TABLE 3

ACTIVITY CENTERS IN MARYVILLE-ALCOA, TENNESSEE, THAT GENERATE A LARGE NUMBER OF TRIPS

DISCRETIONARY TRIPS	NONDISCRETIONARY TRIPS
Maryville CBD [a]	Aluminum Co of America plants
Midland Shopping Center [a]	Levi Strauss
Springbrook Park Center [a]	Blount County Courthouse
Harper Library	Blount Hospital
Hall Community Park	Maryville College
	Maryville High School
	McGhee-Tyson Airport
	Alcoa Industrial Park
	Alcoa High School

[a] For purposes other than work

the location of population groups of given socioeconomic and/or demographic characteristics and then a survey of these groups to determine the destinations of their travel. In most cases, the location of population groups critical to segmentation would require the plotting of census or other planning data on a map, which may be performed manually However, in those larger areas having access to a computer, computer graphic techniques can be used to draw the study area outline and zones and to assign preselected characteristics such as age, income, and occupation to those zones. An example of the result of a computer mapping of senior citizens for Knox County, Tennessee, is shown in Figure 9. In this figure, each of the small areas on the map is a census tract. The computer symbol shown within each tract identifies the range that the absolute number of senior citizens for that tract falls within. For example, a tract designated with 0's indicates that the actual number of senior citizens residing there is between 350 and 550 With a transparent overlay of the street network at the scale of this computer map, existing and potential segments of senior citizen transit demand could be identified (*50*)

Synagraphic computer mapping program (SYMAP) is a quick and reliable technique, but its use is restricted by cost, availability of data, and data processing equipment. Therefore, in small urban areas manual tabulation of data for the purpose of market segmentation can be just as effective and may be preferred because it allows the transit planner to become better acquainted with the study area

It should be pointed out that it is possible to delineate a great many activity centers or segments of the transit market, although it may not be feasible to serve all markets. Thus, it is necessary to assign priorities to each segment on the basis of the transit planning goals formulated for the particular study area. For example, if the goals are directed at reducing congestion and highway expenditures, segments of choice riders should receive a high priority However, if the goal is to increase accessibility to low-income groups as well as to reduce highway expenditures, the selected segments of both captive and choice riders should be given priority.

Survey of Market Segments

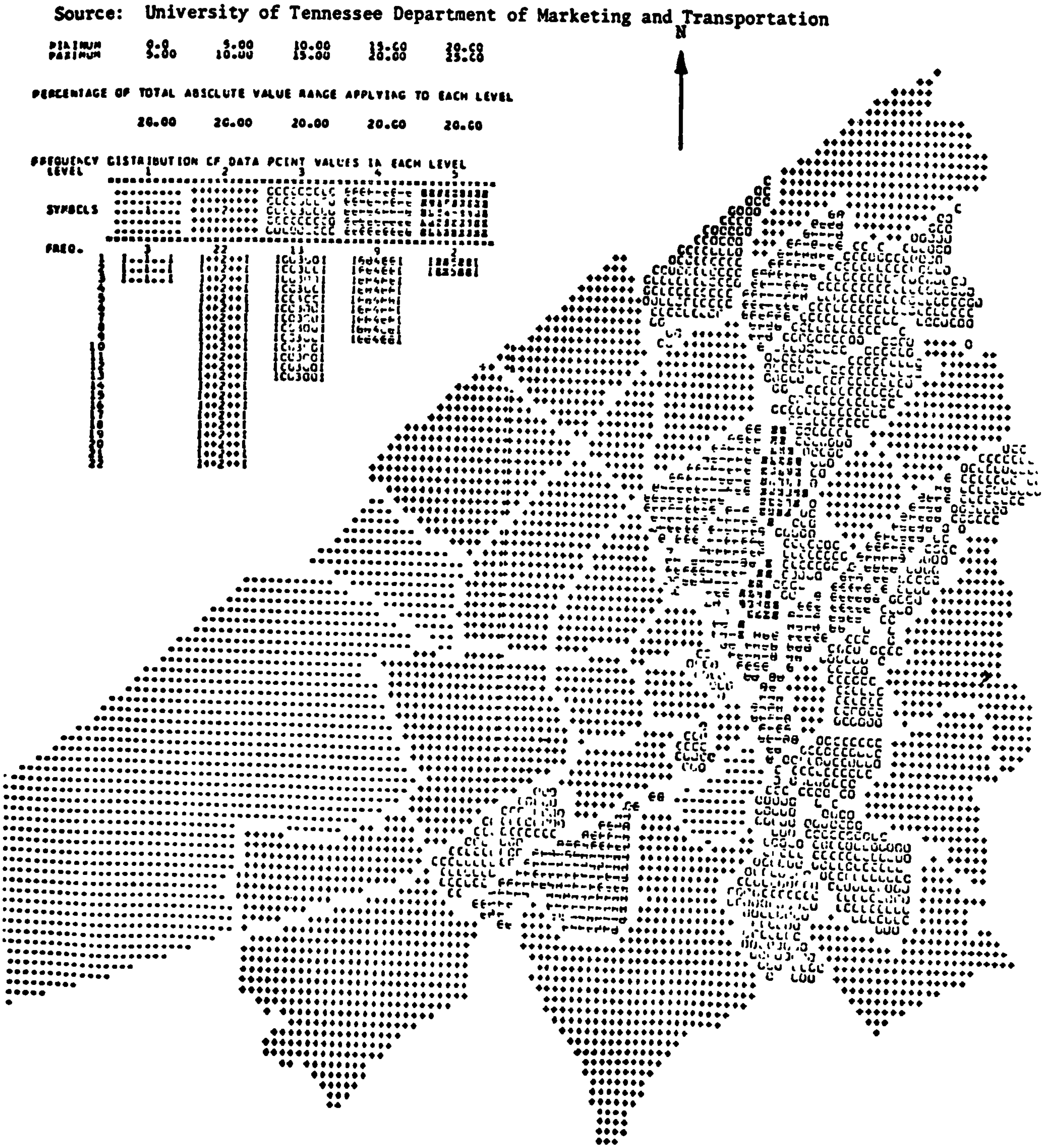
Once the segments of the public transit travel market are delineated and priorities assigned, the next step is to survey each segment to determine its demand for the various transit alternatives. As noted previously, a preliminary survey of population groups may be required for identification of segments of discretionary and nondiscretionary travel pertinent to certain activity centers used in market segmentation However, the survey following the segmentation is more detailed, and a formal questionnaire can be used for this purpose The questions in the survey are according to three categories of information—personal characteristics, actual or desired travel, and transit system preferences. Questions in the first category are necessary to determine such information as the characteristics of the rider (captive or noncaptive), the availability of an auto, and the existence of other family members besides the household head who may need some type of transit service Questions in the category of actual or perceived travel demands concern such items as the trip origin and/or destination and the time a trip is made as well as the present mode of travel (car, bus, taxi, etc) used to make that trip. The information on both the personal characteristics and the actual or desired trips is necessary for a feasibility analysis in the subsequent steps of this procedure.

Questions regarding the system preferences depend on the public transportation alternatives and their service variations available for use in small urban areas. An appropriate sampling technique, of course, must be used for the survey of the transit market segments

Matching Preference with Transit System Alternatives. After the transit survey has been administered to each market segment, the results must be interpreted so that the preference for transit service can be "matched" with the appropriate system alternative. Each questionnaire returned from a particular market segment is examined to determine how individuals have responded to questions on transit system preferences, such as fare, willingness to adhere to schedule, and maximum walking distance The answers to these questions then are matched with the operating characteristics of various transit systems, and the alternative most capable of fulfilling the system preferences is assigned For example, the operating characteristics for an express bus service may require (a) a fare of $0 50 to $0 75, (b) the individual to walk or find transportation to the point of pick-up and (c) adherence to a schedule If the answers to questions related to these characteristics in the questionnaire are in the affirmative, the express bus alternative would be assigned to fulfill the respondent's travel demand. All questionnaires should be similarly interpreted using the responses to questions on operational characteristics to screen the alternatives until the most appropriate alternative is found. This screening process can be accomplished through the use of a series of matching guides such as the one shown in Figure 10. In examining this figure, it should be noted that the model is composed of questions to determine transit preferences so that a particular series of responses to the questionnaire follows a path through the branches of this model until a hierarchical transit system alternative is arrived at. It should be pointed out that the automobile is always considered an alternative and whenever a particular question is answered in such a way that none of the possible transit alternatives can meet the respondent's preference, he is assigned to the block for private automobile use. Also, it should be noted that because some individuals might not have experienced some new types of transit, preferences should be analyzed in terms of service characteristics. The results of the matching process applied to the survey performed at the central business district (CBD) of Maryville, Tenn , and the south plant of the Aluminum Company of America at Alcoa, Tenn , are given in Tables 4 and 5.

Feasibility Analysis and Implementation Once alternative transportation modes have been assigned to each questionnaire returned and the preference analysis is completed, considerations of both demand and supply must be examined. The estimated level of demand must be assessed against considerations of supply to determine whether a particular type of service is in fact feasible for a market segment.

The estimation of demand can be performed by grouping the questionnaires returned from each segment by the transit system alternative assigned and comparing the individual responses to questions on such travel characteristics as time of travel and place. To obtain the over-all demand estimates for each segment, appropriate factors based on the sample size will have to be used. These estimates are necessary for feasibility analyses. For example, the operation of an express bus without subsidization requires that the time and place of travel be similar and that individuals



Percent Elderly (65 Years or Older) of the Census Tract Population

Figure 9 Example of computer graphics to locate senior citizens in a census tract population

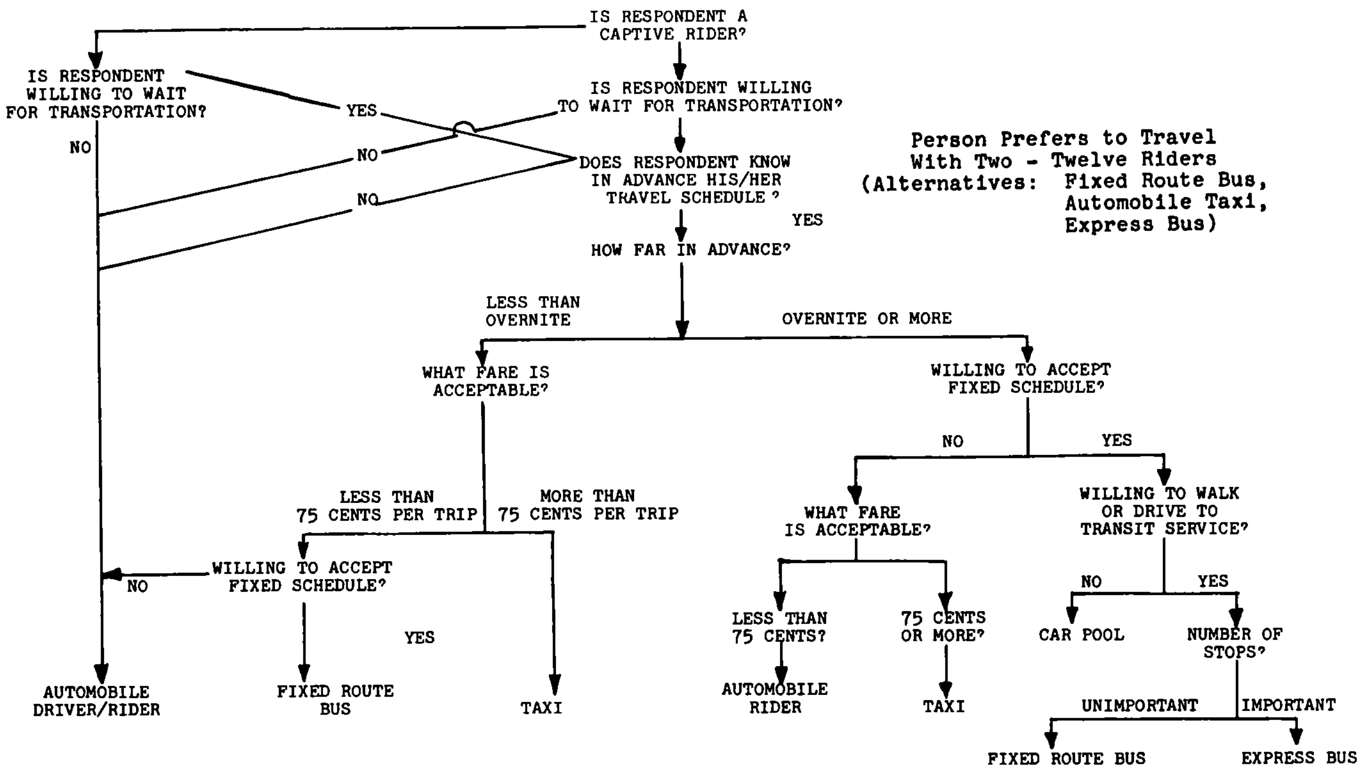


Figure 10. Mode preference matching guides

demanding this service be concentrated in numbers large enough for at least a break-even operation. In the test application, it was determined that express bus service should be investigated between the Alcoa plant and an area seven miles to the southwest.

It must not be overlooked that the demand estimates based on questionnaires are approximations and that the preferences help frame the size of a potential market. An individual's actual responses when encountering a real situation may not reflect the expressed preferences. As Hartgen (*51*) reports, the noncommitment response reported in a survey can be expected to be higher than the actual response and it may be adjusted on the basis of previous experience. These demand estimates, however, provide a transit operator an indication of the extent and size of various markets which he might explore with various service and marketing innovations The estimates also may be adjusted based on previous experience. The fact that an attempt has been made to frame various market segments should encourage innovative approaches to delivering transit services in small urban areas. The transit operator then also must decide which service types and levels might be supported under the prevailing physical, financial, and institutional constraints. As a guide, the characteristics of various public transportation forms are given in Table 6 (*52*).

Implementation Planning. The success of a consumer-oriented transit planning effort depends to a large extent on the ability to institute trial services and undertake demonstration projects. As service experimentations are attempted and actual responses recorded, greater experience can be gained in determining the extent to which definable market segments can be penetrated with various transit alternatives. It must be recognized that the role of transit in a small urban area is a policy issue. Reliance on present use trends can grossly underestimate the potential role which public transportation can play in a small urban area when it is operated under new service concepts and financial requirements.

TRANSPORTATION CORRIDOR ANALYSIS

In larger urban areas the sheer magnitude of the transportation system and interactions of various traffic generators make the transportation problems almost impossible for planners to conceptualize. The analysis of such large and complex systems, therefore, necessitates the development of a detailed planning process that includes assimilation of extensive amounts of data with the aid of computers. However, this time-consuming and costly procedure may not be appropriate for small urban areas.

In many small urban areas with populations under 250,000, the critical transportation problem can be identified as demand exceeding capacity on a few important arterials or congestion of a major central business district (CBD)-oriented facility. In some cases the problem is a combination of both. The scaling-down of the conventional network-oriented urban transportation planning process developed for larger urban areas would not specifically address these issues. To minimize the planning costs and

TABLE 4

RESULTS OF A SURVEY SHOWING DISTRIBUTION OF TRANSIT SYSTEM PREFERENCES

CONDITIONS AGREEABLE TO USER	NO OF RESPONSES: MARYVILLE CBD	NO OF RESPONSES: ALCOA PLANT
Fare		
$0 35–0 50	33	50
$0 50–0.75	20	10
$0.75–1 00	3	5
$1.00 or more	2	2
Advance time requirement known		
½ hour	13	3
1 hour or more	12	7
Overnight	14	38
One day	14	19
Do not know	5	0
Wait for service		
5 minutes	3	15
5-15 minutes	36	48
15-30 minutes	15	4
One hour or more	1	0
Would not wait	2	0
Share vehicle:		
2 to 6 persons	8	0
2 to 12 persons	12	15
20 to 40 persons	35	51
Ride alone	0	0
Accept a fixed schedule		
Yes	48	63
No	10	4
Acceptable walking distance		
One block	22	17
Three blocks	28	41
Six blocks	6	7
Would not walk	2	2

attack the specific problem of corridor analysis, a more customized planning process as provided by one of the many corridor growth models might be used. The corridor method provides a convenient way to estimate the traffic demands on the major arteries serving each corridor of an urban area. The Jones-Grecco-French model was selected for presentation (*53, 54, 55*). Appendix G describes this model and its application to six Tennessee cities.

Conceptualization and Assumptions

Small urban areas in this country have typically developed in conformance with the concentric circle and modified sector growth patterns. Major shopping centers, if they exist, are usually located on existing arterial streets. Although fairly large in general, the centers do not compare with the size of the CBD area and they play a subsidiary role in traffic generation. The CBD represents the major traffic generator in the community, and traffic corridors radiate outward from this center. Thus the problem locations in small urban areas can be examined in the context of linear, or wedge-shaped, corridors that usually are oriented towards the central area. The traffic corridor concept of thoroughfare planning is not new. In fact, many transportation planners have felt that this approach can provide an adequate transportation system for small urban areas and is superior to a zone-by-zone analysis even with the advent of third-generation computers (*56*).

The entire procedure, like many others in use, is predicated on the assumption that the existing travel patterns in the community remain stable over time. Even in very large cities the basic travel patterns remain somewhat stable except for the circuitous travel on controlled-access facilities that tend to encourage such travel. In small cities the growth in most cases is an extension of present patterns. A disruption or change in the basic travel patterns in a small city usually occurs only with the elimination of a large portion of the existing street network, which is unlikely

The corridor planning procedure analyzes the external traffic separately from the internal trips. The external traffic is further stratified into external-external and external-internal trips. The conceptual basis of the method and the

TABLE 5

RESULTS OF A TRANSIT SYSTEM PREFERENCE SURVEY OF TWO AREAS

MODE	MARYVILLE CBD: NO RESPONSES [a]	MARYVILLE CBD: PERCENT (%) OF TOTAL RESPONSES	ALCOA PLANT: NO. RESPONSES [a]	ALCOA PLANT: PERCENT (%) OF TOTAL RESPONSES
Fixed-route bus	35	42	—	—
Express bus	11	13	39	20
Car pool	5	06	28	15
Demand response (Many-to-few)	4	05	—	—
Taxi	4	05	—	—
Auto	24	29	126	65
TOTAL	83	100	193	100

[a] Number of responses is the actual number of completed questionnaires and not the "factored" data

TABLE 6

OPERATIONAL CHARACTERISTICS OF ALTERNATIVE TRANSIT SYSTEMS (*52*)

CHARACTERISTICS	DEMAND-RESPONSIVE SYSTEMS	TAXI SYSTEMS	FIXED-ROUTE AND SCHEDULE BUS SYSTEM	ROUTE DEVIATION SYSTEM	EXPRESS BUS TRANSIT SERVICE	CAR POOLING
Service area (square miles)	1.0 (min)	1.0 (min)	No minimum	No minimum	No minimum	No minimum
Population density (persons per square mile)	1,000 (min)	1,000 (min)	Medium to high	Medium to high	Low to medium	Low to medium
Average wait time (minutes)	10 to 15	10 to 15	15 or less	Less than 30	Little or none	Less than 15
Vehicle size (number of passengers)	5 to 12 (avg.)	2 to 5	20 to 40	20 to 40	20 to 40	2 to 5
Average fare	$0 50 to $1 25	$0 75 to $1.25	$0 35 to $0.50	$0.50 to $0.75	$0.35 to $0.50	None specified
Time. Must know in advance if service is required (minutes)	30	30	None	30 or less	Little or none	Overnight
Schedule required	No	No	Yes	Yes	Yes	Yes
Distance to vehicle pick-up point (blocks)	None	None	3	Flexible	3	None

assumptions were tested by Jones (*53*). Briefly, these assumptions state that:

1. Changes in external corridor traffic are related to changes in vehicle registration of the county.
2. The amount of external-internal traffic destined to the CBD is related to the percentage of total employment in the CBD.
3. The percentage of total external traffic that is external-external or external-internal is stable over time.
4. Total external trips and external-external trips can be estimated by an equation developed for other cities having the same population range, and that the relationship developed remains stable over time.

The corridor planning procedure attempts to update past cordon station volumes through the growth in vehicle registration. If this check is successful, future volumes (total externals) are projected for each external cordon station. If this check fails, another procedure, such as cordon survey, statewide model, or multiple regression model from the cited reference (*53*), is used Corridor midpoint and inner point volumes are stratified by type to establish internal-internal trips at each of the points. The external-internal trips to the CBD are correlated with the ratio of CBD employment to total employment. The internal-internals are factored separately. The procedures are described as flow charts shown in Figures 11, 12, and 13. The details are discussed in Appendix G.

Corridor Identification

A corridor area generates trips that are served by one or more basically parallel major streets within the corridor, and the orientation of a corridor in small urban areas is basically towards the central area. With knowledge of the local travel habits supplemented by aerial photographs, street classifications, land-use maps, and traffic volume maps, the corridor limits can be determined. The corridor boundary should be equidistant between the arterials of adjacent corridors unless physical constraints dictate otherwise. Radial corridors may overlap with other corridors identified along circumferential or cross routes.

The identification of corridors begins with the delineation of the central area This central area includes the CBD, or core, and generally includes the "frame" of the CBD. Specifically, the central area begins at the point where radial corridors and the arterial streets serving the corridors merge and lose their individual identity. Usually the merging movement would be served by cross routes bordering the CBD, providing for the disbursement of traffic to scattered destinations.

Methodology

The Jones-Grecco procedure attempts to estimate future corridor volumes on the basis of a factoring of previous or present traffic volumes. Corridor traffic is stratified into external and internal trips. A portion of the external traffic originates from outside the cordon area and continues through the area. This external-external traffic is most likely to bypass the city center in the event a new Interstate or bypass route is constructed to serve that directional flow. The other segment of external traffic can be divided into two parts (a) external-internal to the CBD and (b) external-internal to non-CBD areas The external-internal traffic to non-CBD areas usually is so dispersed that it can be ignored for the radial corridors

The total external trips can be factored through a growth ratio based on the change in the county's vehicle registration. Jones' methodology also proposes a multiple regression model to predict total external trips in those cases where the vehicle growth factor does not prove satisfactory. External trips should be obtained from statewide forecasts or by performing an external cordon study. The internal

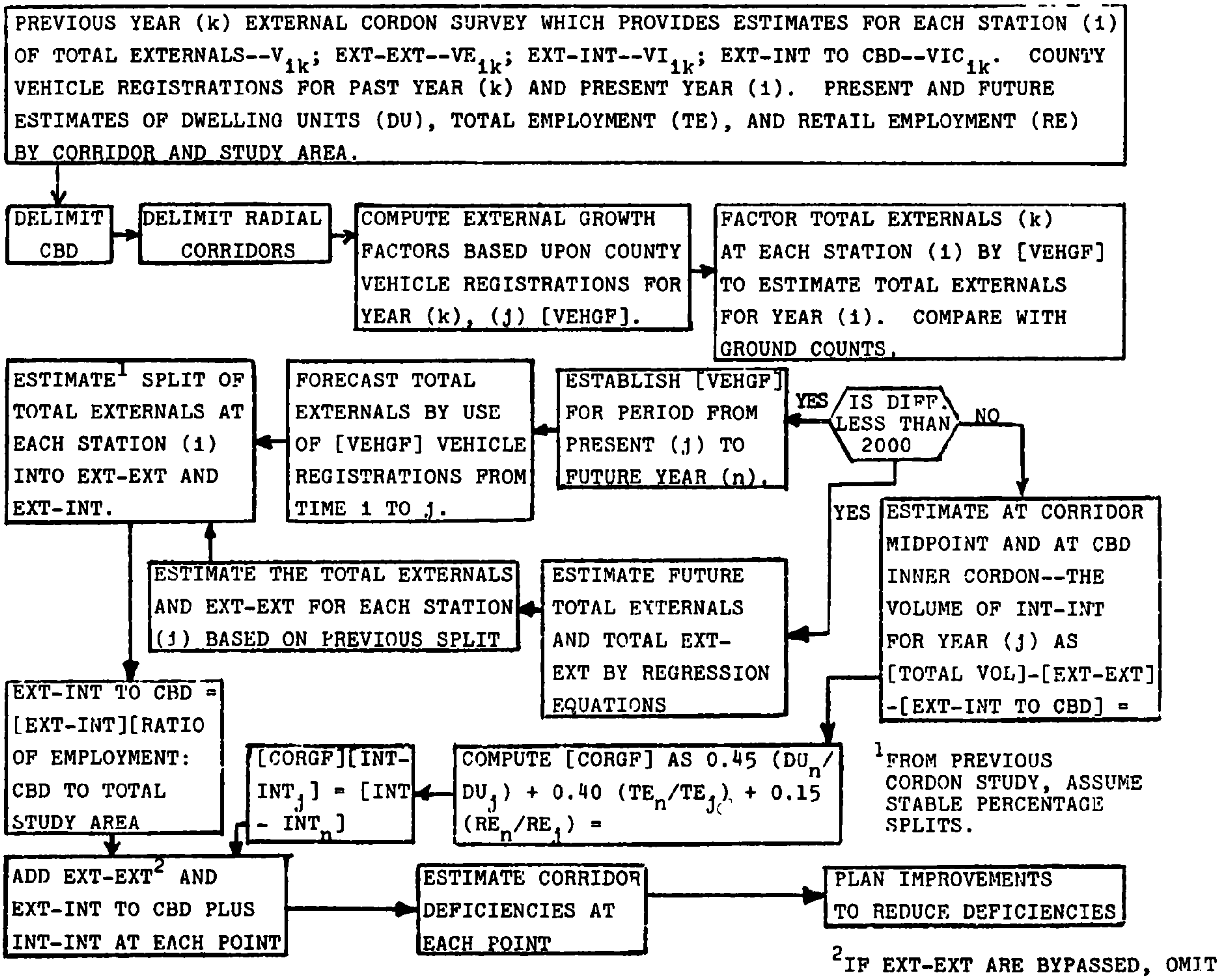


Figure 11. Corridor growth factor model—Procedures 1 and 2

trips in the corridor can be factored based on the changes in parameters most related to trip production such as population, employment, or automobiles.

External Trips

Different procedures are developed for determining the various elements of the external traffic depending on (a) the availability of a previous external cordon survey and (b) knowledge of past traffic volumes at the external cordon stations. When both an external survey and historical volume data are available, the procedure basically examines how well the historical data, after factoring, agree with present-day ground counts. If substantial agreement is achieved, then the historical relationship is assumed to be valid for the future. In the case of disagreement, it is necessary to rely on new cordon surveys or statewide modeling. The five procedures for forecasting external trips (see Figs. 11, 12, and 13) are developed for the following situations:

Procedure 1. An external cordon survey study is available. When previous ground counts are factored proportional to the change in the county's vehicle registration, the volume is within acceptable agreement with the actual external traffic counts. The next step is to utilize the forecast change in vehicle registration to forecast total external trips for each cordon station.

Procedure 2. An external cordon survey study is available, but the present-year ground counts do not check within acceptable limits. It is necessary to use other techniques to forecast future external trips.

Procedure 3. Only traffic volumes for a past year (preferably more than five years back) are available for the external cordon stations. When updated through a growth factor, the actual ground traffic counts check within acceptable limits with estimated traffic volumes for the present year. The next step is to utilize the forecast change in vehicle registration to forecast total external trips for each cordon station.

Procedure 4. Traffic volumes for a past year are available, but the actual ground traffic counts do not check, after being updated through a growth factor, with the estimated traffic volumes for the present year. It then becomes necessary to use other techniques to forecast future external trips.

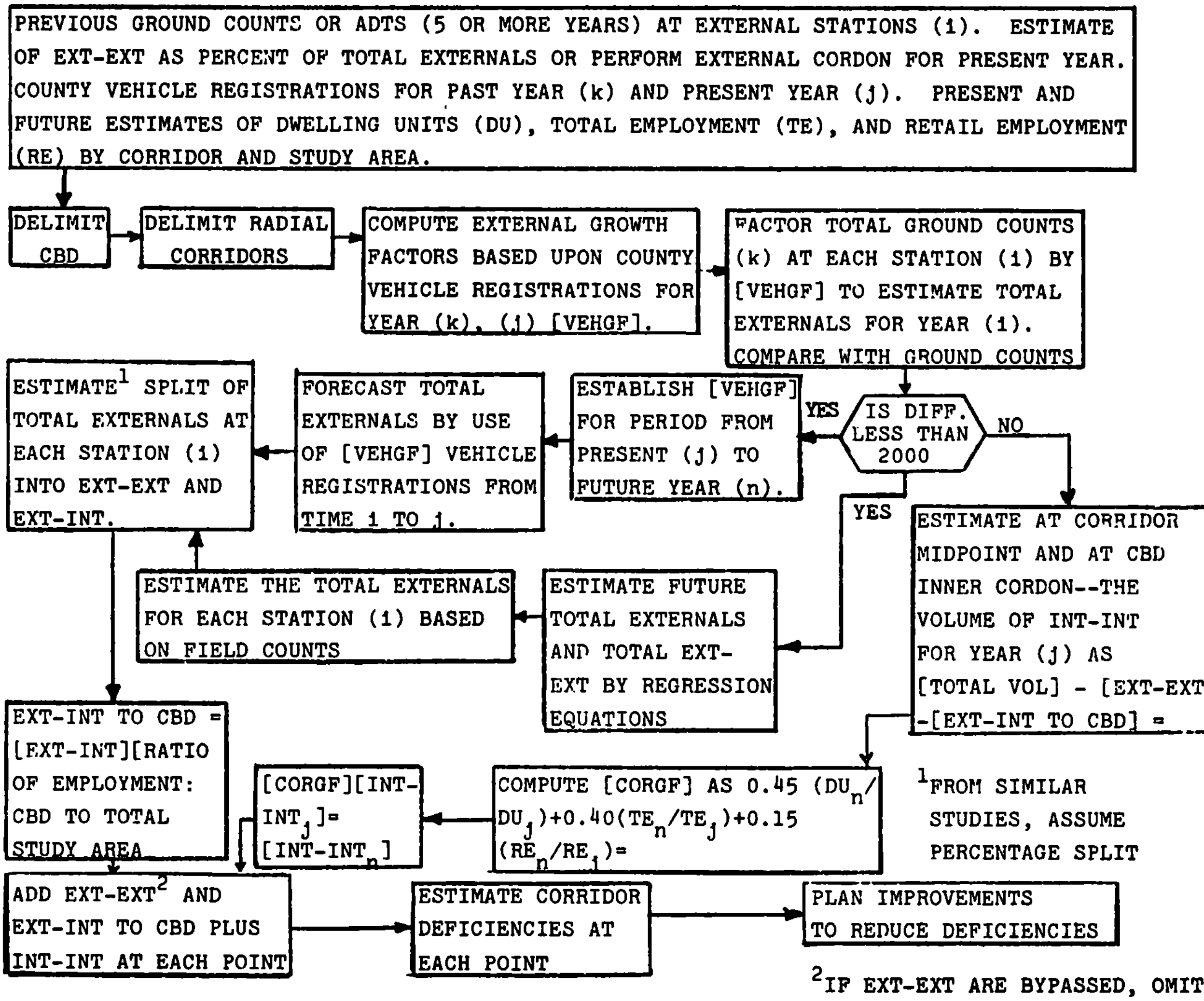


Figure 12. Corridor growth factor model—Procedures 3 and 4.

Procedure 5. No previous traffic counts or cordon survey results (greater than 4 years back) are available for the cordon stations.

Internal Trips

The methodology for estimating future internal traffic in a corridor involves simply the use of a growth factor, which would adequately represent the growth of all "activities" in the corridor. Corridors commonly contain an agglomeration of land uses, each having a different trip generation necessitating a method of weighting.

The attractiveness of various land uses from the standpoint of traffic generation is reflected by their trip generation rates, which can be used as the weights in developing the growth factors. However, in the absence of reliable trip generation rates, the areawide proportions of trips for different trip purposes can be used because the trip purposes can be related to specific land uses or selected parameters. It may be pointed out that the proportions of trip purposes for auto driver trips have been found similar for various sizes of cities (*53*).

The land-use parameters to be related to various trip purposes must be suitable for quantification and forecasting. Land area measurements, such as acres of land, have been used in many studies for this purpose but they present difficulties due to varying densities of development. Socioeconomic parameters, therefore, have been used frequently to represent land uses.

The greatest number of internal trips result from work, home, and shopping purposes. The total number of employees within a corridor is a good indicator for work and business trips. This information is available from several sources and is usually listed by business establishments. It can be forecast satisfactorily. Shopping trips may be determined by using the total number of retail employees by corridor, which can be obtained concurrently with the collection for work trips of the number of employees. Home trips can be determined based on the number of dwelling units within a corridor.

Social-recreation trips to clubs, theaters, residential areas, and the like are difficult to represent with any single parameter because of their diversity. The three parameters used for work and business, home, and shopping trips can

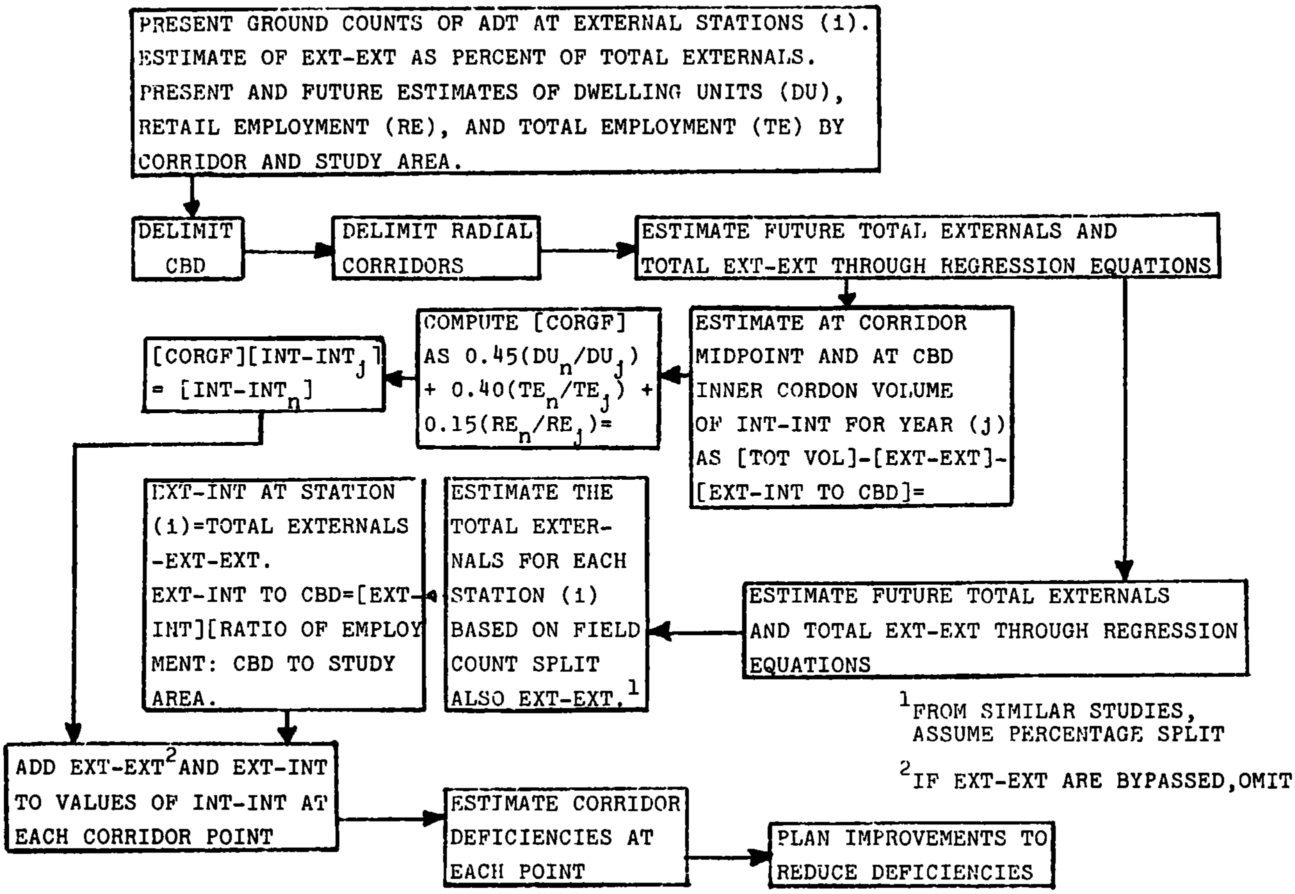


Figure 13. Corridor growth factor model—Procedure 5

be assumed to represent these trips without the addition of a separate parameter. The average trip production rates per employee are established by dividing the proportion of total trips of respective trip purposes by the number of employees in the corresponding categories in the study area The same procedure is followed for the remaining parameters such as households. These rates are assumed to remain constant over time and are used in both the base and the target year. For the demonstration analysis, the percentage of the total internal trips to be represented by each of the three parameters of dwelling units, total employment, and retail employment were taken as 45, 40, and 15, respectively. In Columbus, Indiana, Jones used 50, 35, and 15 as the percentages. The proper values to be used are a subject for further research.

The procedure for developing a growth ratio for the internal trips in a corridor is summarized

1. The relative trip rates for each parameter are multiplied by the quantity of the parameter in the corridor for the base year, and the products are totaled.
2. The procedure is repeated for the target year using forecast quantities of the parameters.
3. The ratio of the target year sum to the base year sum is the corridor growth factor.
4. The corridor growth factor multiplied by the base-year internal traffic volume in the corridor gives the forecast or design volume for the corridor

The five procedures for different situations are described in the flow charts shown in Figures 11, 12, and 13 The details of the procedures are discussed in Appendix G.

Demonstration

In the development of the corridor growth procedure, French (*55*) tested his methodology in Lafayette, Indiana. Further development and refinement were added by Jones (*53*), using Lafayette and Columbus as demonstration cities In the recent demonstration, six Tennessee cities were used whose population ranged from approximately 11,000 to 55,000.

An over-all evaluation of the procedure indicates that the corridor growth method provides estimates of external traffic that are within the accuracy of 2,000 vehicles per day. For most corridors except those which carry an extremely large portion of through trips (external-externals) and those which serve special generators, acceptable results are obtained when the externals are factored according to the growth in county vehicle registrations

It should be noted that it was not necessary to resort to the use of the multiple regression models as used in external procedures 2, 4, and 5; but the researchers decided to provide the computations for test purposes. Model results of total externals for 1973 by model and actual ground counts were judged as unsatisfactory. This would indicate the need to place less reliance on cross-sectional models and use other techniques or to require a cordon survey. Results of the corridor check stations (near the CBD inner cordon and at midpoint) were found to be reasonable in most corridors.

Although input data were available for future years, forecasts were not made. The only comparison that could be made is with the state DOT forecast. To know that these estimates were the same or different would not provide a basis for comparison or evaluation of the corridor method. It should be pointed out that the Jones-Grecco corridor technique represents a simplified approach for transportation planning, for which other suitable techniques also can be used. The technique presented was selected because it provided quick estimates of future corridor volumes with a minimum requirement for data collection

LOCALIZED TRAFFIC IMPACT ESTIMATING PROCEDURE

In addition to planning and designing major thoroughfares, urban transportation planners must be sensitive to the needs of local streets. The corridor or network models are usually oriented to arterial streets and thus are not suitable for assessing the impact of increased traffic loads on local streets. Specific land development decisions, particularly the location of special activity centers on the fringe of a city where the land was previously vacant or in agricultural use, can place a large demand on the local street system. Traffic estimations are necessary in such cases to assess the impact of the impending land-use change on the local streets within a 1- to 2-mile area of influence. Such estimation procedures should be designed to provide insights into the following types of questions (*57*):

1. How much traffic will the new development generate during various periods of a day?
2. Will the additional traffic loadings exceed the peak-hour capacity of the streets? If so, can traffic operational changes relieve the problem or will major improvements, such as widening of the existing facility or provision of a new facility on a different alignment, be required to meet the traffic demand?
3. If it is undesirable to program additional road improvements, can the increased traffic load be met by other transportation means such as carpooling or public transit, or should the size of the development be restricted to conform to street or corridor capacity?

The traffic impact analysis for special activity centers enables local officials to structure policy decisions to limit land development or program the needed transportation improvements. Typical activity centers generally ranked as having high, medium, and low traffic impacts are (*57*).

1. High impact—shopping centers (all sizes), free-standing department stores, grocery stores, large office buildings, industrial developments, large apartments, colleges, high schools, hospitals, drive-in banks, drive-in restaurants, drive-in theatres, car washes.
2. Medium impact—smaller apartments, medical clinics, smaller office buildings, sit-down restaurants, motels, service stations, libraries, mobile home parks, airports (commercial), civic centers, truck terminals, bowling alleys, elementary schools, recreational facilities.
3. Low impact—subdivisions, retirement communities, airports (general aviation).

Over the past several years extensive data have been collected regarding the amount of vehicular trips originating or terminating at a particular type of land use (*57-66*). Data can be obtained on daily generation rates, peak-hour rates, and directional distributions. In lieu of precise estimates available for a particular community, reliance can be placed on secondary sources. Available rates are based on cross-sectional data; they must be viewed in terms of average values and should be used only as guides (see Table 8) A range of values, however, can help frame the size and scope of a problem and encourage the exploration of alternative development policies.

Traffic Estimation Strategy

Figure 14 outlines a potential procedure for estimating the traffic volumes generated by a special activity center during its peak hour of operation and the peak street hour. The peak-hour operational volume represents the highest combined in-and-out traffic movement observed at the site of an activity center. The peak street hour represents the hour during the day when the highest traffic movement occurs on streets in the vicinity of the development. The distinction between the two types of peak hours may not be critical because peak flows produced by a generator, as noted in Table 7, do not necessarily overlap with the peak flows on the local street system For design purposes, however, both values must be considered (*65*).

After determining the number of trips generated from different land uses, attention must be given to the distribution of trips over the local street system For this purpose, attenuation factors are applied to represent the decay of trips as a function of distance from the special generator (*64, 67*). When the distribution of trips to traffic zones is completed, manual assignments can be made to estimate the additional traffic loadings on existing roads in the area. By incorporating directional splits in the trip distribution, intersection turning movements also can be estimated. Information on the trip distribution pattern and decay curves for special generators is not as adequate as the trip generation characteristics previously discussed. Yet, if necessary, some information can be acquired through limited field surveys conducted at a similar site in the local community, and car pool surveys conducted in numerous cities provide a wealth of data for work trips.

Example of Application

Given the anticipated development of a large motel, office, and commercial complex on the outlying fringe of a small urban area, as shown in Figure 15, it is desired to determine the ability of the arterial roads in the vicinity of the generator to accommodate future traffic loads.

TABLE 7

TRIP-GENERATION RATES FOR VARIOUS ACTIVITY UNITS

SITE NO.[a]	ACTIVITY UNIT	TRIP-GENERATION RATES [b] BASED ON EXISTING VOLUME COUNTS	PUBLISHED TRIP-GENERATION RATES [b] USED FOR FUTURE PROJECTION
1.	Hospital	3.02 trips/bed, 2.0 trips/employee	9.0 trips/bed, 2.0 trips/employee
2.	Restaurant (sit-down)	7.0 trips/1000 sq. ft., 2 0 trips/employee	237 trips/1000 sq. ft., 2.0 trips/employee
3.	Motel #1	3 14 trips/room, 2.5 trips/employee	9.0 trips/occupied room, 2.5 trips/employee
4.	Office building #1	19.25 trips/1000 sq. ft.	17 trips/1000 sq. ft.
5.	Motel #2	3 14 trips/room, 2 5 trips/employee	9.0 trips/occupied room, 2.5 trips/employee
6.	Restaurant with motel #2	33.0 trips/1000 sq. ft., 2.5 trips/employee	237 trips/1000 sq. ft., 2.5 trips/employee
7.	Motel #3	3 2 trips/room, 2.25 trips/employee	9.0 trips/occupied room, 2.5 trips/employee
8	Restaurant with motel #3	33 trips/1000 sq. ft., 2.25 trips/employee	237 trips/1000 sq. ft., 2.5 trips/employee
9.	Office building #2	13 87 trips/1000 sq. ft.	17 trips/1000 sq. ft.
10.	Shopping center (including an office building)	20 trips/1000 sq. ft.	20 trips/1000 sq. ft
11.	Office park	14.3 trips/1000 sq. ft	17 trips/1000 sq ft.
12.	Apartments (adults only)	2.1 trips/unit	8.1 trips/unit

[a] Correspond to those of Fig. 15.
[b] Rates are for vehicle trips and includes trips coming into and leaving a facility

The trip generation analysis for this site progressed in two distinct phases because part of the complex was already completed, and the remaining portion would be completed within the next two years. For the first phase, the existing traffic estimate was based on the present development; for the second phase, traffic generated when the project reaches completion was estimated. The basic objective was to conduct a capacity analysis for which traffic loadings and turning movements had to be estimated for the critical road sections between points A and E as

TABLE 8

TYPICAL PEAKING CHARACTERISTICS OF SPECIAL GENERATORS [a]

TYPE	PEAK HOURS	PEAK VOLUME AS PERCENT (%) OF TOTAL DAILY TRAFFIC GENERATED
High Impact:		
Shopping centers	4-6 pm, 7-8 pm 2-5 pm Saturday	9 to 16
Discount stores	7-8 pm	10
Industry	7-8 am, 2-5 pm	13 to 33
Apartments	4-7 pm	10 to 15
Colleges	7-8 am, 4-6 pm	10 to 25
High schools	7-9 pm	17 to 32
Hospitals	7-8 am, 2-5, 7-8 pm	9 to 25
Fast food restaurants	12-1 pm	13
Medium Impact:		
Sit-down restaurant	8-9 am 12-1 pm, 5-7 pm	13
Medical offices	9-10 am, 2-5 pm	11 to 17
Airport	7-8 am 3-6 pm, 8-9 pm	10 to 50
Mobile homes	7-9 am, 4-6 pm	10 to 15
Civic centers	Vary	11 to 16
Low Impact		
Park facilities	3-5 pm	10 to 20
Residential subdivision	7-8 am, 4-7 pm	10 to 14
Retirement community	Vary	11 to 27

[a] Sources vary

shown in Figure 15. Trip productions can be estimated as a function of such variables as floor area, employment, number of residential units, and so forth, which reflect the relative intensity of development, and typical trip rates are available in the literature. For the completed developments, 8-hr turning-movement counts were collected and expanded to annual average daily traffic (AADT) estimates, as shown in Figure 16. Based on the volume counts, it was possible to estimate the trip production rates for each activity unit, as given in Table 8. Comparisons indicated that these trip rates were generally lower than the published rates for comparable land uses in other communities (*65*). The variations can be explained in terms of the unique characteristics of the community or the type of development, or may be attributed to the fact that the development had been completed just recently and its traffic productions had not yet matured. Acceptance of the latter argument suggests designing for higher traffic volumes. Supplemental traffic counts obtained for similar land uses in the community could help establish the adequacy of the published trip rates for application in the smaller urban area.

In the second phase of this analysis, published rates were accepted as reasonable and the traffic generated was recomputed for the ultimate planned development and assigned to the critical road sections based on the observed

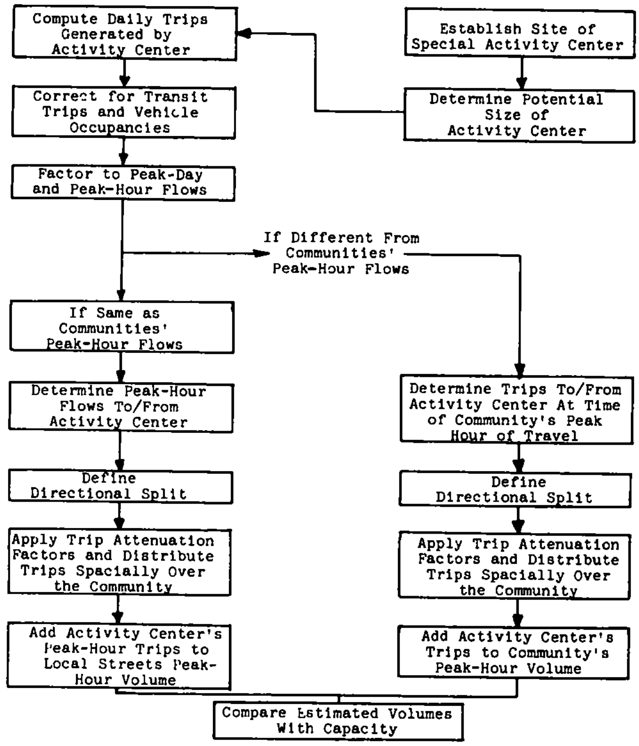


Figure 14 Flow diagram for localized impact analysis.

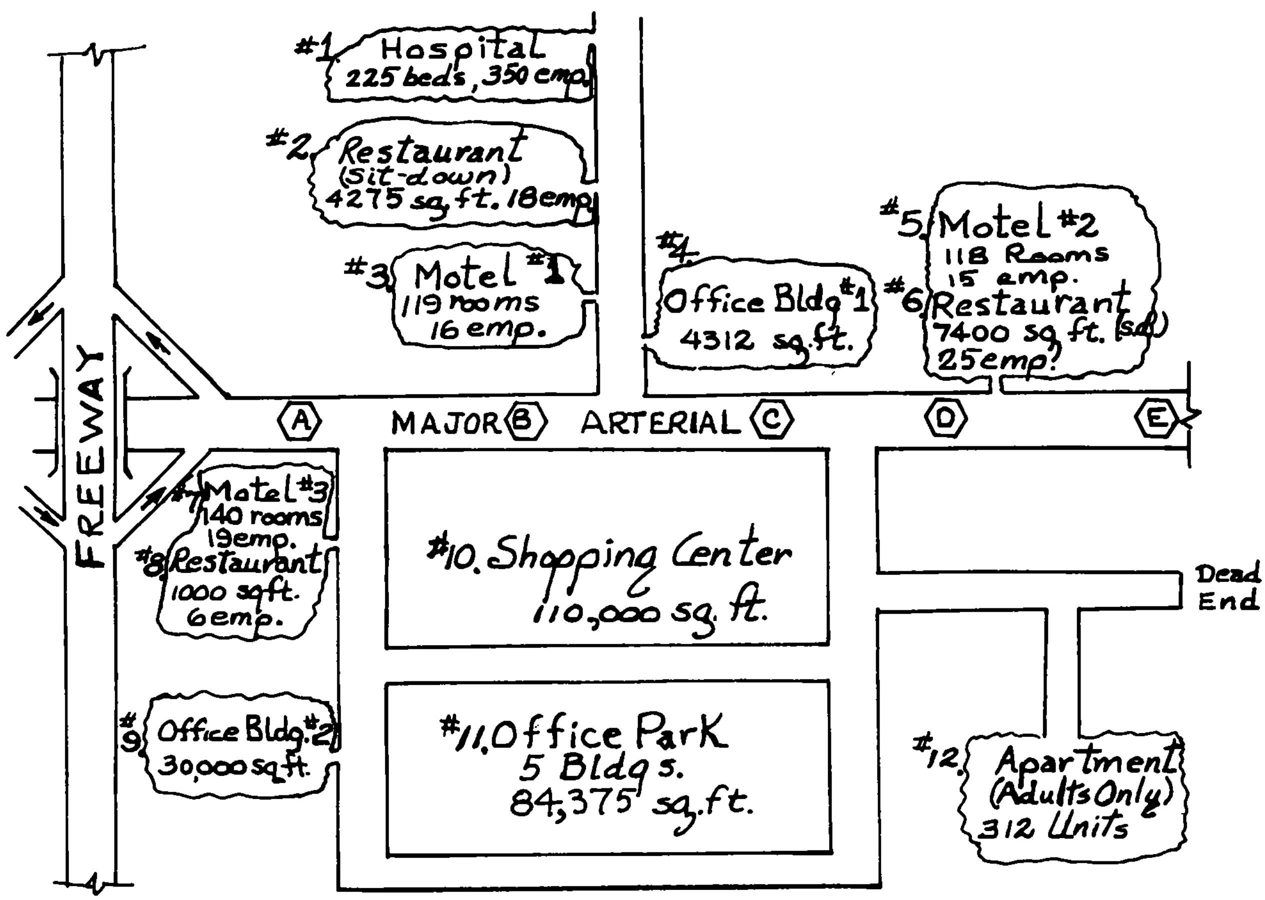


Figure 15. Land-use development for case study.

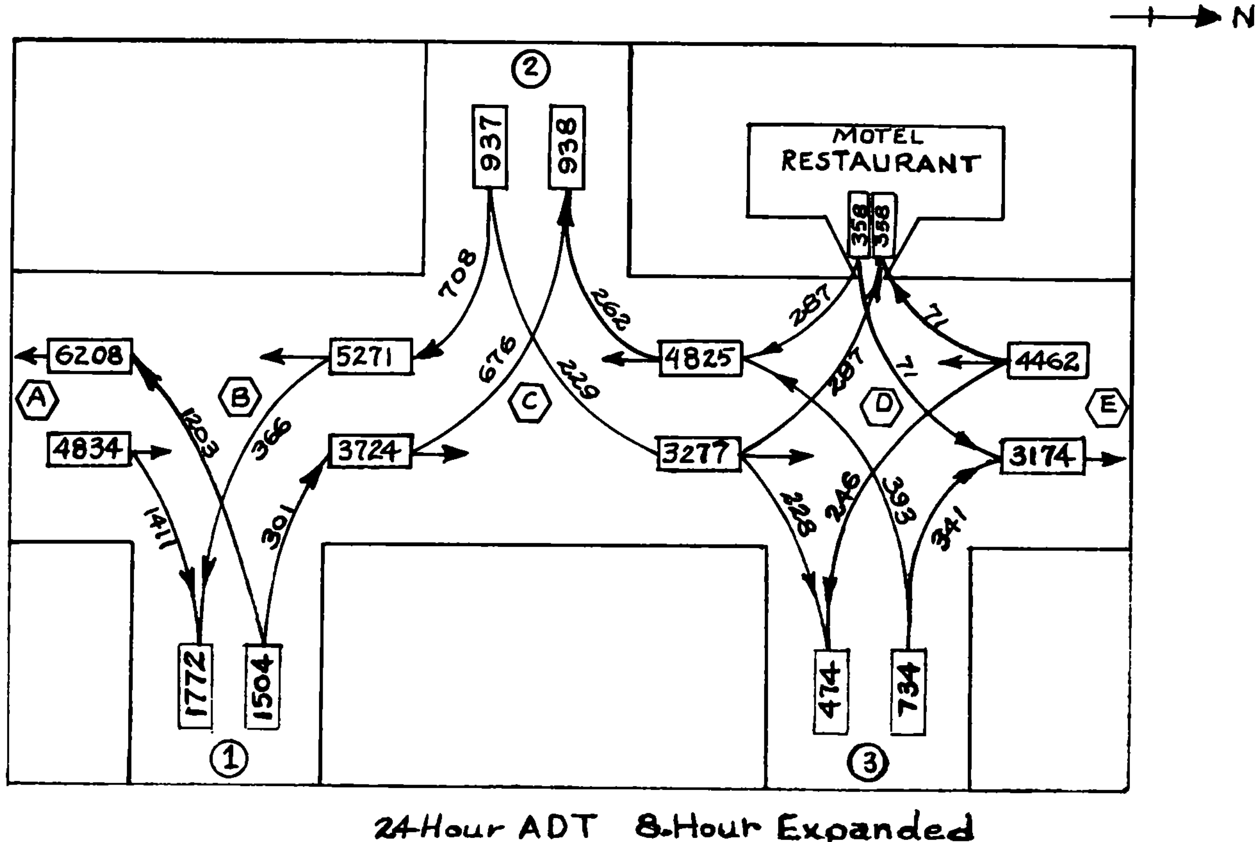


Figure 16 Existing turning movements at case study site.

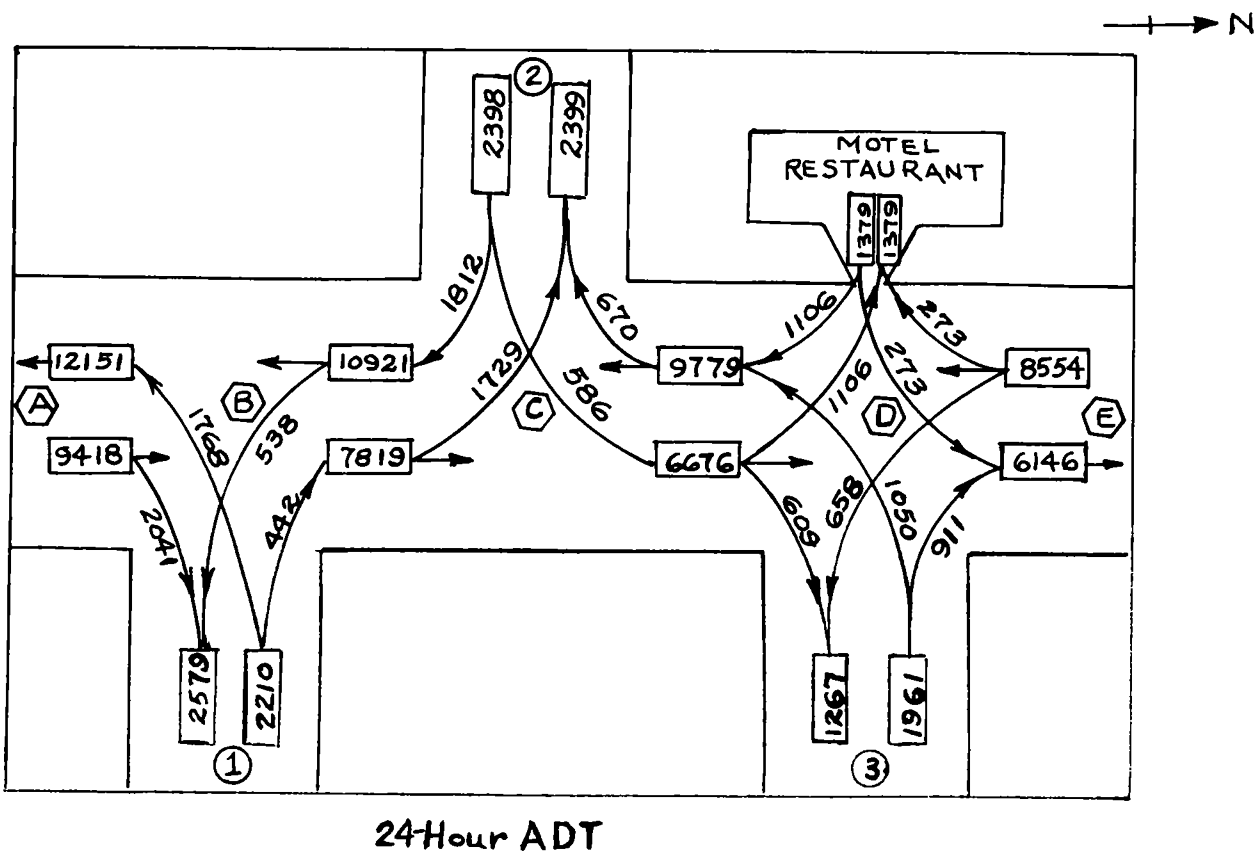


Figure 17 Estimated turning movements at case study site

trends in turning movements. The results are shown in Figure 17. With these traffic estimates available, the final step involves comparison of the projected traffic volumes with roadway capacities, leading to the identification of potential difficulties that will need to be addressed in the immediate future. It should be noted that, through the use of attenuation factors representing vehicle trip lengths, the trips can be assigned to links beyond the immediate area of concern. Trip distribution estimates based on the spatial distribution of activities in the community can aid in estimating turning movements at key intersections. Traffic estimates such as those provided by the foregoing example can become an integral part of a city street priority-needs analysis (*68*).

CHAPTER FIVE

CONCLUSIONS AND SUGGESTIONS FOR FUTURE RESEARCH

CONCLUSIONS

The initial task of this research was to establish the nature of the UTP process required for small urban areas. As a result, extensive investigation needs were established at three levels—organizational, procedural, and technical. The nature of findings ranges from general or policy-type at the organizational level to more specific at the technical level From the research the following conclusions can be stated:

1 Past attempts at urban transportation planning have been largely process-oriented instead of issue-dependent.

2 Previous organizational and procedural approaches have failed to recognize explicitly that planning must be performed in a variety of environments under various institutional, personnel, and other resource constraints Technical procedures must be selected on the basis of resources available and issues to be resolved. A recommendation was made to alter the present organizational framework to overcome these shortcomings.

3. Customization of the procedures for land-use planning would tend to foster a transportation planning process that is more responsive to local needs by identifying those issues most important to the community. Wide-spread concern for the environment causes a change in the sequencing of considerations for future land-use developments. Impacts of new land-use proposals on transportation facilities need to be evaluated prior to an approval for a change in zoning. Such approval places transportation planning into a lead position rather than one of having to catch up with demands.

4. Traffic forecasting procedures should be customized for varying levels of analysis and differing time frames to best respond to the decisions required. Past studies in large urban areas concentrated on developing area-wide transportation systems for 20 years and, hence, utilized complex computer-oriented network analysis and travel simulation techniques.

5. It is possible to reduce the time and cost requirements of network simulation procedures through the use of synthetic travel models. However, there is a need to complement this approach with a selectively chosen small-sample home-interview survey as well as an external cordon roadside survey Savings in planning also can accrue as a result of better coordination of data needs for transportation and land-use planning.

6. Disaggregate behavioral models have added considerable flexibility and reduced the magnitude of data requirements They can be extremely valuable in the updating phase of the continuing planning proecss.

7 Short-range transit planning for small urban areas can be more effective by using a consumer-oriented approach that differentiates between transit demand characteristics in the study area Demand analysis is performed in terms of potential market segments and, subsequently, a broad range of transit alternatives is evaluated from the standpoint of meeting the needs and preference of each market. Demand concentrations by time of day and/or spatial distribution of trip ends should be evaluated for feasibility analyses, but at the same time the need for experimentation and demonstration must be fully recognized.

8 Many small-area transportation problems are primarily congestion on certain major arterial streets. This level of analysis is best handled with the corridor approach. For those small urban areas which meet the criteria, a corridor growth factor based on dwelling units and employment densities can yield acceptable traffic estimates for present and future conditions.

9. In many instances the siting of a new specific traffic generator in a small urban area has monumental traffic impact. Simplified techniques using locally derived or borrowed trip rates for various land uses can provide data required for assessing localized traffic impacts.

10. Each effort of an agency to respond to requests for planning services should be approached with a fresh and open attitude toward coordination and an explicit effort to explore the possibilities and needs for coordination before the assignment of responsibilities and technical tasks is firmed-up to the point of inflexibility

SUGGESTIONS FOR FUTURE RESEARCH

One of the findings of this research is that the existing transportation planning process does not always meet the varied needs and resources of small urban areas and that customized procedures must be developed for different situations. However, further investigations must be performed to answer the following questions:

1. Who should make customization in transportation planning a reality?
2. How can one achieve customized procedures and at the same time require minimum levels of performance and coordination with an over-all process?
3. How can one ensure that long-range planning will not be sacrificed for short-range programs for which there is also a great need?

Further research is necessary on improved planning techniques. Traffic estimation procedures based on the disaggregated approach cannot be successful unless techniques for forecasting household characteristics at the disaggregate level are improved and simplified. Research is needed to examine the various trip-generation techniques for time stability and the transferability of cross-sectional data from area to area. More tests need to be performed to compare results of alternative corridor growth techniques. Transit planning using the market-oriented approach has great potential but requires further investigations in varied environments. Research is needed into the options of transit service that might be accepted in small urban areas.

Lastly, there is a need for research into the ways in which citizens participate in the planning of small urban areas. Is the leadership group similar to or different from those in larger urban areas? How can citizen participation be better utilized?

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APPENDIX A

OFFICIALS SELECTED FOR PERSONAL INTERVIEWS

Name	Title	Agency Name	Geographic Location
Bob Bowling	Planner	Georgia Department of Transportation	Atlanta, Georgia
Gene Burr	Assistant Director	Knoxville Metropolitan Planning Commission	Knoxville, Tennessee
Bob Caldwell Charles Caldwell	Director Planner	Caldwell and Associates	Bryan, Texas
Dick Courtney	Chief of Planning	Atlanta Regional Commission	Atlanta, Georgia
John Edwards	President	Traffic Planning Association	Atlanta, Georgia
Leon Eplan	Director of Planning	Eric Hill and Associates	Atlanta, Georgia
Lucian Faust	Director of Planning	City of Oak Ridge Planning Department	Oak Ridge, Tennessee
Gary Head	City Manager	City of Alcoa	Alcoa, Tennessee
Jack Housworth	Planner	State of Texas Highway Department	Austin, Texas
Hubert Nelson	Director	Bryan City Planning Department	Bryan, Texas
Roy Newsome	Local Planning Coordinator	State Department of Community Development	Harrisburg, Pennsylvania
George Olson	Director of State 701 Planning Program	State of Kentucky 701 Planning	Frankfort, Kentucky
Don Peterson	City Manager	City of Maryville	Maryville, Tennessee

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Name	Title	Agency Name	Geographic Location
Bill Pickering	Planner	Pennsylvania Department of Transportation	Harrisburg, Pennsylvania
William Pollard	Director of Planning	Pollard and Associates	Memphis, Tennessee
Ray Pruitt	Director	State Department of Community Development	Austin, Texas
George Reed	Planner	Pollard and Associates	Memphis, Tennessee
Clifton Rogers	President	Rogers and Associates	Harrisburg, Pennsylvania
Ron Schimed	Planner	Pollard and Associates	Memphis, Tennessee
Bob Seago	Planner	Georgia Department of Transportation	Atlanta, Georgia
Ladilas Segoe (retired)	Director	Ladilas Segoe and Associates	Cincinnati, Ohio
Charles Selvers	City Administrator	City of Clinton	Clinton, Tennessee
Joel Stone	Chief of Transportation	Atlanta Regional Commission	Atlanta, Georgia
Dave Switzer	Public Works Director	City of Alcoa	Alcoa, Tennessee
Don Waller	Director of Local Planning	Tennessee State Planning Office	Nashville, Tennessee
D D Williamson	District Engineer	State of Texas Highway Department	Bryan, Texas
Darrell Wright	Transportation Planner	Vogt, Sage and Pflume and Associates	Cincinnati, Ohio

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APPENDIX B

SURVEY OF PLAN DOCUMENTS

The survey of plan documents described in Chapter III included an analysis of each plan in terms of the following issues

a Definition of needs and goal formulation
b Citizen participation
c Planning time frame
d Data requirements
e. Documentation and recording procedures
f. Preparation of plan alternatives
g. Updating procedures
h. Coordination

The scope of each issue and major findings are reviewed below Full documentation of the findings and examination of procedural variation are found in the McNulty Report (69).

Definition of Needs and Goal Formulation

Community plans require some definitions of community needs, but the process of defining and recording such needs has not been reduced to a standard practice In some instances the statement of needs may be set forth in the form of community goals addressed to a broad range of topics In other instances the statement of needs may be in the form of a specific problem statement related to a single issue

Goals are generated in a variety of ways In a minority of cases a broad series of statements may be generated by a

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citizen committee created specifically for that purpose More frequently the goal formulation process is carried out by a local planning commission or city council.

The degree to which goal statements accurately reflect the views of the public is open to serious question. Off the record remarks by planners indicate that the process and the resulting statements are sometimes formalities to which neither the planners nor the decision-makers pay much attention. The role of the citizen planning committee or legislative body is not infrequently a ratification of rather superficial statements drafted by staff In such a context, the goals may reflect the intent and bias of the staff on the kind of planning process to be undertaken more accurately than they represent public desires Goal statements in the plan documents are often very general, perhaps superficial.

The assumption that goals statements will address the problems and issues that are on the mind of local public officials should be questioned. Submerging problems within general language of broad goals statements may in fact reduce their prominence and impact on technicians preparing plans. Broad goals statements are useful and have a place in the planning process, but should not be allowed to substitute for responsiveness to specific needs of communities. When general goals are allowed to substitute for issue identification, they legitimatize the production of plans on a broad scale that may provide little or no information on the problems as seen by local decision-makers. It is little wonder that such decision-makers have little sympathy for implementing such general plans. Field

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interviews strongly suggest that plans oriented to specific issues or problems are more likely to be supported for implementation than general plans.

Citizen Participation

The use of citizen committees has been a standard practice in urban planning for many years. The planning commission was originally conceived as a mechanism that would involve "blue ribbon" citizens directly in the planning process. It was thought that such involvement would moderate the technical recommendations of professionals by filtering them through a group knowledgeable of community values and desires. Various federal laws and programs further institutionalized citizen participation by requiring citizen committees, as in the Workable Program for Community Improvement, and by requiring public hearings before proceeding with specific projects such as highways

Planners today work within the accumulated collection of commissions and committees produced by past legislation and programs. The attitudes of professionals expressed in interviews range from the modest despair of those who worry about the time and effort required to deal with these mechanisms for inputs of dubious quality, to the cynicism of those who view committees and public hearings as obstacles to be overcome on the way to plan implementation. It is not surprising that there is some skepticism on the part of citizens about the good faith with which planning agencies solicit public views

Citizen participation has been a popular subject in planning

literature in recent years (70). The visibility of the topic in the literature could lead to the assumption that planners in small communities would routinely foster vigorous citizen participation activities. But an examination in the field, through interviews and examination of plans, does not support the assumption.

Published plan documents are virtually devoid of information about the methods or content of citizen input The interviews produced no clear consensus of views. The experience of increased citizen involvement over the last fifteen years does seem to have produced a greater awareness among planners of the need to anticipate public reaction to plan proposals. But there is no unity of thought on the proper role of citizens in relation to the professionals and elected officials. One persistent view is that the time required to progress from the beginning of the planning process to plan adoption or implementation is lengthened in direct proportion to the amount of citizen involvement.

Planning Time Frame

The use of a stated time frame is a well-accepted technique in urban planning. The time frame serves as a common dimension for forecasts of population, employment, land use, and other data Without the unity of a common time frame or some other common dimension, these elements could easily be inconsistent.

The investigation shows that the overwhelming majority of those plans that report a time frame use a twenty-year period A few cities are working on five- or ten-year time frames. It

is clear that the willingness of agencies to use shorter time frames is found more frequently in the larger agencies. This indicates that agencies responsible for planning in small communities are committed to the accepted practice of long-range planning.

Data Requirements

The community planning process requires many different kinds of information, including such things as population and economic data, physiographic data, sociological data, etc For purposes of this research, the most critical data is that required as an input into the process of forecasting the amount and distribution of future land use. Eighteen potential inputs were investigated. The frequency of their use is shown in Table B-1. In this table, "transportation" means that existing and proposed transportation facilities and flows are taken into account in land use forecasts. The application of data to transportation studies has been discussed in the report.

The ten most commonly used inputs were population, existing development, master plan considerations, land utilization rates, economic projections, physiographic influences on development, quantity of vacant land, past trends, transportation factors, and social and community value factors The least-used inputs were areas in transition, redevelopment policies, and zoning policies. The number of data inputs increases with the size of the community.

Table B-1

CLASSIFICATION OF PLANS BY AUTHOR TYPE AND INPUTS TO THE PLANNING PROCESS

Inputs	Author Type									
	State		Regional		City		Consultant		Combination	
	No.	%	No.	%	No.	%	No.	%	No	%
Population	29	100	18	100	13	100	76	98	18	100
Economy	29	100	13	72.1	13	100	69	89	18	100
Employment	4	13.8	8	44.4	10	76.8	39	50.3	9	50
Existing Development	29	100	17	94.4	12	92.2	74	95.5	18	100
Physiography	26	89.7	17	94.4	13	100	66	85.2	16	88.8
Quantity Vacant Land	25	86.2	15	83.3	13	100	69	89	17	94.4
Suitability Vacant	7	24.1	8	44.4	10	76.8	31	40	8	44.4
Utilities	11	37.9	10	55.5	11	84.5	36	46.4	8	44.4
Transportation	27	93.1	17	94.4	12	92.2	62	80	15	83.3
Zoning	4	13.8	5	27.8	1	7.7	12	15.5	1	5.6
Master Plan	29	100	13	72.1	13	100	77	100	18	100
Redevelopment	1	3.5	4	22.2	5	38.4	13	16.8	0	0
Other Policies	5	17.3	2	11.1	1	7.7	20	25.8	2	11.1

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Table B-1 (Continued)

Inputs	Author Type									
	State		Regional		City		Consultant		Combination	
	No	%	No.	%	No.	%	No.	%	No.	%
Social and Community Values	22	75.9	10	55.5	10	76.8	59	76.1	12	66.6
Past Trends	26	89.7	18	100	12	92.2	65	88.9	15	83.3
Land Utilization	27	93.1	17	94.4	12	92.2	70	90.3	17	94.4
Areas in Transition	1	3.5	1	5.6	3	23	9	11.6	0	0
"Other"	2	6.9	2	11.1	0	0	14	18	0	0
Totals	304	58	195	59.1	164	70	861	61.1	192	58.2

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Documentation

Careful documentation of procedures used to forecast and distribute future land use is seldom practiced Only a few of the documents that were examined contained extensive descriptions of assumptions, methods, data sources, etc Most had little or no documentation of procedures. The frequency of documentation does increase with population size of the community.

Presentation of Plan Alternatives

The development and presentation of alternative plans for consideration by decision makers is one indicator of the complexity and amount of effort expended on a plan. When compared to population size a clear trend emerges in the preparation of alternative plans. Only three plans in the population range of 5,000 to 25,000 formally presented alternatives. All were elaborated manually and received only limited evaluation. Two plans presented alternatives in the 25,000 to 50,000 range with both plans elaborating the alternatives manually and one of the plans being evaluated in depth.

The frequency with which alternative plans were presented increased significantly with the population of the community.

Plan Updating

Published plan documents show little effort to build on past efforts or to create mechanisms for easy plan updating. Approximately three-fourths of the plans examined made little or no mention of plan updating. The highest percentage of

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those plans containing more than superficial comments in this area were in cities above 100,000 people. Plans authored by municipal agencies were the only ones where authorship could be associated with a positive effort to build updating procedures. The investigation produced few examples of small communities publishing annual summaries of amended plans, or periodic updates of a previously prepared plan. The typical plan document had the appearance of having been prepared from scratch. Annual reports tend to recite data on the number of subdivision plots reviewed and the number of zoning changes made with the same perfunctory qualities found in the plans themselves.

The interviews suggest that plan updating may be more efficient than the documents reveal. Several agency people indicated that they seek to program new community plans on a cycle of about every five years and to reuse previously collected information that remains constant, i.e., climate and natural features. The presence of a resident professional staff appears to be a key to continuous updating of information of features subject to constant change. In most instances, collection of data on land use is a fresh effort each time the plan is updated rather than drawing on information continuously updated It can be argued that it is easier to do a new inventory in a small community than to try to keep it up to date with little or no professional staff. Nevertheless, well maintained regional information systems or data files could minimize this problem.

B-9

APPENDIX C

HOUSEHOLD STRATIFICATION MODELS

Simplified Models for Forecasting Household Characteristics

There is no generally recognized or standardized procedure available for forecasting household characteristics on a zonal basis This inadequacy of the state of the art may be attributed to the fact that such detailed data have not been used much for the land use planning process and as such have been ignored However, in recent years a few attempts have been made primarily by transportation planners to develop simplified techniques for predicting the distribution of household characteristics within a zone (85) The procedure proposed by Wilbur Smith and Associates in connection with the Charlotte-Mecklenburg Transportation Study for developing household stratification by household size, income and car ownership is depicted by the flow chart in Figure C-1 (71) The individual models for household size, income distribution and car ownership based on 1970 data are shown in Figures C-2, C-3 and C-4, respectively It should be noted that this procedure did not address the question of forecasting the population, number of households and average income in each zone The procedure assumed that those forecasts would be developed through standard techniques

The procedure used in the Charlotte-Mecklenburg Transportation Study was designed specifically for a three way classification of households including income as one of the characteristics However, as noted earlier, the use of income

C-1

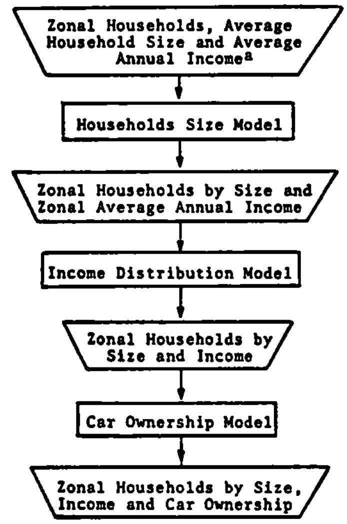


Figure C-1 Relationship of Household Stratification Models Used for Charlotte-Mecklenburg Urban Area Transportation Study Source (71)

[a]Income is not a necessary input to the household size model, but is necessary for the subsequent stratifications.

C-2

Figure C-2. Household Size Model for Charlotte-Mecklenburg Transportation Study (1970) Source: (71)

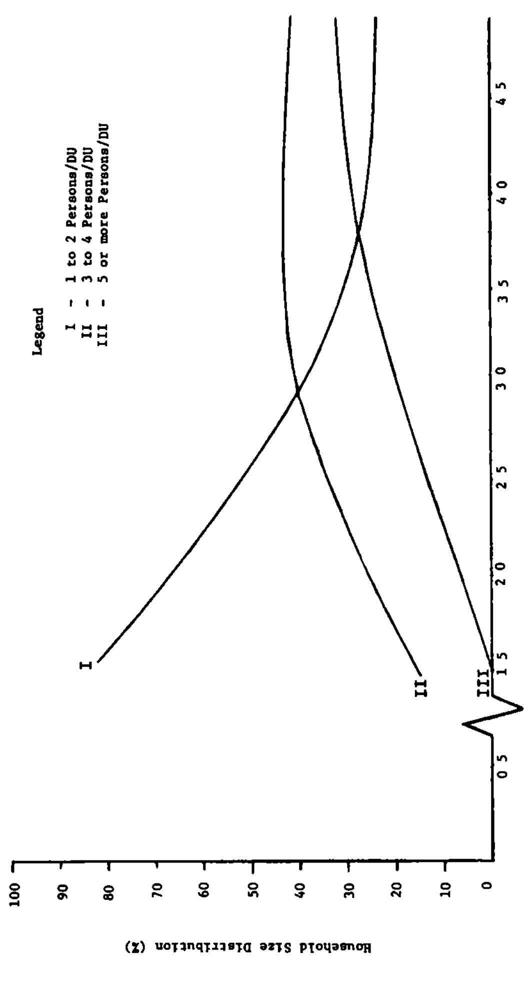
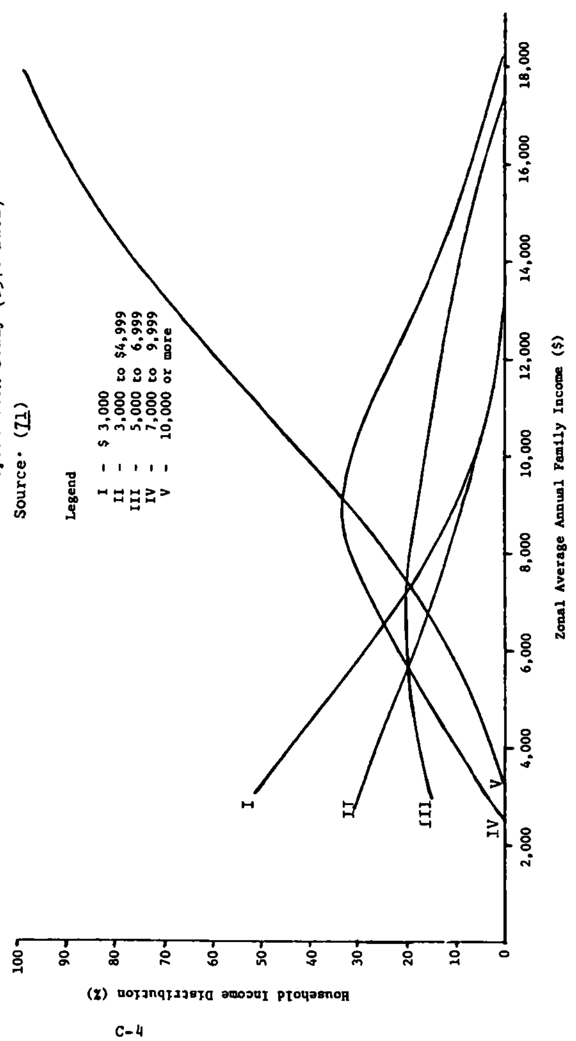
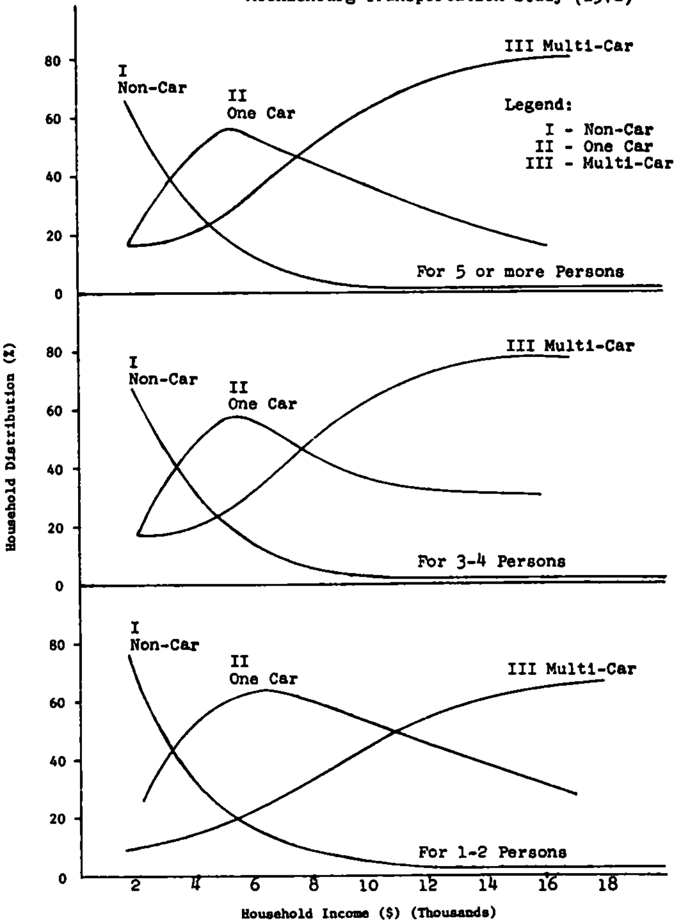


Figure C-3. Income Distribution Model (All Household Sizes Combined) for Charlotte-Mecklenburg Transportation Study (1970 Data) Source· (71)



C-4

Figure C-4. Car Ownership Model for Charlotte-Mecklenburg Transportation Study (1972)



as a variable may be avoided in travel simulation models due to the difficulties of forecasting, the prohibition of collection by some states, and the uncertainties regarding inflation. In such cases, a similar procedure can be developed to stratify the households in each zone by household size and auto ownership only. The household size model can be of the same type, but the auto ownership model must be changed to reflect the elimination of the income variable. New auto ownership models can be developed using the same approach as used for the household size — income distribution models, i.e., based on the relationship of the zonal distribution among the various categories with the average zonal value. However, it is questionable whether the auto ownership probabilities are independent of household size and a technique to incorporate their relationship must be developed. The actual development of two sets of household stratification models and the procedure used are discussed below.

Developing Household Stratification Models

This study developed two sets of household stratification models for two small cities — Racine, Wisconsin (population approximately 110,000) and Elizabethton, Tennessee (population approximately 20,000). The household characteristics used were household size (based on the number of persons 5 years or older) and auto ownership. The same categories were used in both cases so that the models from two different cities can be compared for similarity. It should be pointed out that the development of these models require 'factored' data

with a wide coverage of the study area The actual procedure used to develop the models is outlined below.

Procedure for Developing Household Size and Auto-Ownership Models — The following is a step-by-step procedure for developing household stratification models based on the distribution of household size and auto ownership distributions with the respective zonal average values

1. For each zone, using the zonal factor reflecting sample size, compute the number of households in each household-size category. (The categories should correspond to those used in cross-classification, preferably '1-Person,' '2-Persons,' '3 or 4-Persons' and '5 or more Persons' per household based on persons 5 years or older.)
2 Repeat step 1 for auto ownership categories. (Use categories '0-Auto,' '1-Auto' and '2 or more Auto' per household.)
3. For each zone estimate the total population and total number of autos using data from steps 1 and 2. (Note that for a household-size or auto-ownership category using a range of values, an average value has to be assumed For example, for the category of '5 or more Persons per household,' an average of '5.4 Persons per household' may be appropriate.)
4. Compute the average household-size and auto-ownership for each zone by dividing zonal population and number of autos computed by number of households.

5. For the Household Size Model·
   (a) Group the zones into 17 classes based on their zonal average household-size — begin with '1.00 to 1.25 persons per household,' then '1.26 to 1.50,' . . . ., and end with 'more than 5.00 persons per household.'
   (b) For each class, add the number of households in each household-size category for all zones belonging to the class and compute the proportion (or percentage) in each category.
   (c) Perform (b) for all 17 classes and plot the proportions of each household-size category against the midpoint of the respective classes.
   (d) Draw a smooth curve through the points of the respective categories. (There will be four curves, one for each household-size category)
6. For the Auto-Ownership Model
   (a) Group the zones into 12 classes based on their average auto-ownership — begin with '0 to 0.25 autos per household,' then 0.26 to 0.5, ..., and end with '3.00 or more autos per household '
   (b) For each class, add the number of households in each auto-ownership category for all zones belonging to the class and compute the proportion (or percentage) in each category
   (c) Perform (b) for all 12 classes and plot the proportions of each auto-ownership category against the midpoint of the respective classes.

(d) Draw a smooth curve through the points of the respective categories (There will be three curves, one for each auto-ownership category)

Application and Calibration of Models

The household size and auto-ownership models developed with 1972 data for Racine, Wisconsin are shown in Figures C-5 and C-6, respectively It may be noted that although each model is independent of the other, the results have to be combined to develop the desired cross-classifications. Two alternative ways of obtaining the joint probabilities are described below

Alternative 1 Assuming independence of auto ownership and household size, the joint probability of a particular household size category m, HS_m, and an auto ownership category n, AO_n in a traffic zone (i) is given by

$$P\ (HS_m \cap AO_n)_i = P\ (HS_m)_i \times P\ (AO_n)_i \ \cdots\cdots \quad [1]$$

The probability values $P(HS_m)_i$ and $P(AO_n)_i$ are to be obtained from the respective models corresponding to the average values for zone (i)

Alternative 2 Assuming dependence of auto ownership on household size,

$$P\ (HS_m \cap AO_n)_i = P\ (HS_m)_i \times P\ (AO_n \mid HS_m)_i \ \cdots \quad [2]$$

where, $P\ (AO_n \mid HS_m)_i$ is the probability of auto ownership category n when the household size category is m in zone (i).

Figure C-5. Household Size Model for Racine, Wisconsin (1972)

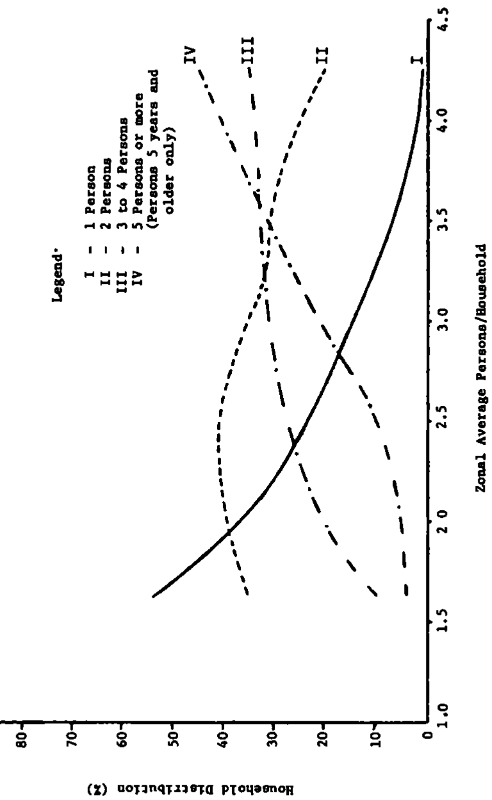
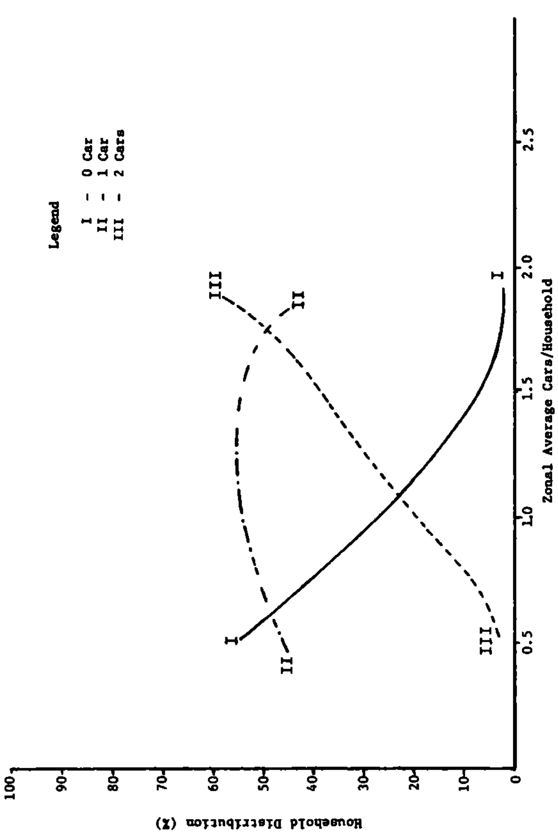


Figure C-6. Auto Ownership Model for Racine, Wisconsin (1972)



Although the approach of Alternative 1 is very simple and straightforward, an examination of the areawide distribution of households in Racine, shown in Table C-1, indicates clearly that there is a relationship of auto ownership with household size. Therefore, it is recommended that the dependence of auto ownership on household size be reflected in the application of the models. It is suggested that the areawide relationship of auto ownership with household size be utilized to obtain the value of $P(AO_n \mid HS_m)_i$ as follows

$$P\ (AO_n \mid HS_m)_i = C_1\ P(AO_n)_i + C_2\ P(AO_n \mid HS_m)\ \text{areawide} \ .. \quad [3]$$

where, C_1 and C_2 are the weights assigned to the respective values, and $C_1 + C_2 = 1$. The actual values of the weights C_1 and C_2 have to be derived by trial and error, that is, by assuming certain values and comparing the results with actual household distributions in each zone. This approach was used by Chatterjee and Martinson in developing household stratification models with the 1972 O-D data for the Southeastern Wisconsin region. They found that equal weighting, i.e., using $C_1 = 0.5$ and $C_2 = 0.5$ yielded satisfactory results.[1]

[1]The investigation referred to is an unpublished in-house analysis performed for the Southeastern Wisconsin Regional Planning Commission in 1974

TABLE C-1

AREAWIDE DISTRIBUTION OF HOUSEHOLD CHARACTERISTICS IN RACINE, WISCONSIN (1972 DATA), (71).

Auto Ownership (Cars Per Household)	Household Size (Number of Persons 5 Yrs. or Older) 1	2	3	4	5 or More
0	3281 (0.50)	1058 (0.08)	206 (0.03)	436 (0.09)	555 (0.09)
1	3113 (0.48)	9469 (0.71)	2676 (0.46)	2348 (0.46)	1924 (0.30)
2	118 (0.02)	2857 (0.21)	2978 (0.51)	2263 (0.45)	3968 (0.61)
TOTALS	6512	13384	5860	5047	6447

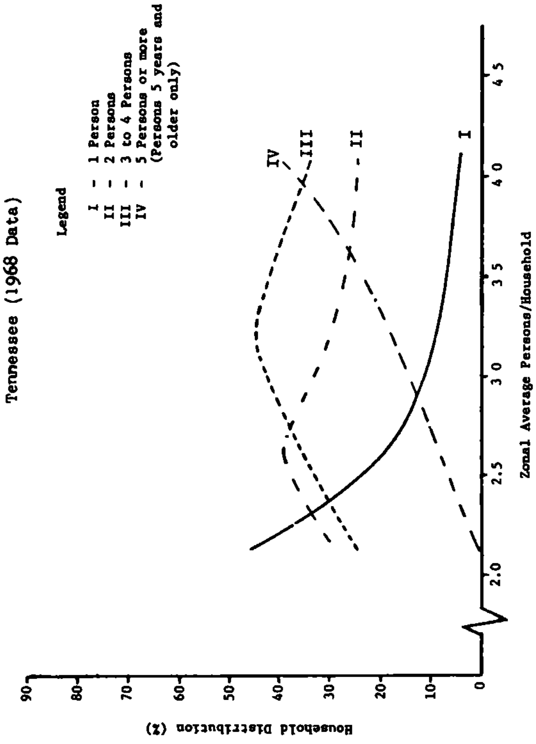
Explanation of Cell Values: Upper Value is Number of Households
Lower Value is Proportion of Households

COMMENTS ON THE USE AND ACCURACY OF MODELS. The procedures presented in this section for developing household stratification models implicity assume that the values for certain parameters related to household characteristics in a traffic zone, average household size, average car ownership, average or median income, would be developed by other techniques. These procedures are not completely self sufficient and their results should be examined carefully . For example, if the average household size in a zone was estimated based on past characteristics and judgement, the same information should be used to verify the results of the stratification models Although these models yield satisfactory results on an area-wide basis, the zonal results should be examined carefully and adjusted, if necessary

Comparison of Models for Different Urban Areas

The use of household stratification models of the type described in the preceding sections has not been as frequent as the use of cross-classification models for which they are used, because in many cases the future household stratifications in each zone were developed based on the existing characteristics and judgement. In addition, the stratifications have not been consistent in each study so that a comparison of the models used is difficult. This study developed a second set of household stratification models based on data for Elizabethton, Tennessee for the purpose of comparison with the Racine models using the same stratification in both cases. Household size and auto ownership models for Elizabethton are shown in Figures C-7

Figure C-7. Household Size Model for Elizabethton, Tennessee (1968 Data)



and C-8, respectively. A visual comparison of the two sets of curves reveals similarity in the general shapes of the curves, although a uniqueness can be observed in a few curves. A similarity of auto-ownership curves developed with data from Great Falls, Montana and Providence, Rhode Island, also are reported by Hillegass, Fleet and Heanue (21) Thus, the concept of using household stratification models 'borrowed' from another area appears to be feasible although more research must be performed before conclusions are drawn. Unless a procedure to synthesize these models is developed, their data requirements would act as a constraint to the use of household category type models. Also the temporal stability of these models is subject to further investigation.

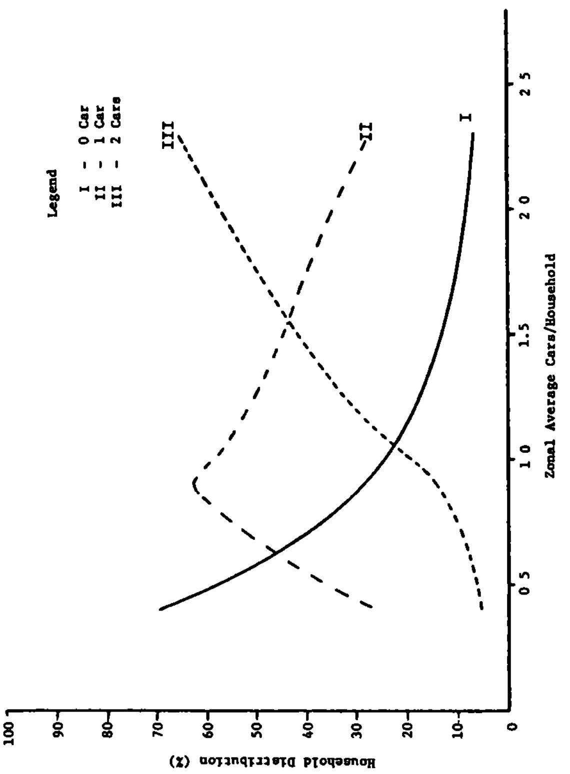


Figure C-8. Auto Ownership Model for Elizabethton, Tennessee (1968)

APPENDIX D

CURRENT PRACTICE FOR TRANSPORTATION PLANNING IN SMALL URBAN AREAS

A questionnaire was distributed to seven selected Departments of Transportation[1] requesting information on the nature and extent of transportation planning effort for urbanized areas of less than 50,000 population The responses are tabulated below

1 Do you have a formal program to conduct urban transportation plans for communities less than 50,000 population?

yes 5 no 2

2 If so, could you indicate the number of studies completed and in progress over the past five years?

Pop Size		
5-10,000	Completed Studies 4	Studies in Progress 2
10-20,000	Completed Studies 9	Studies in Progress 0
20-50,000	Completed Studies 9	Studies in Progress 2

3 In general, for the less than 50,000 population-size community who provides the

a Data on Existing Land Use — local planning agencies with some assistance from State Department of Transportation

b Forecasts of Future Land Use — local planning agencies

4 Please describe briefly the procedures typically used in preparing the land use forecast

Judgement is utilized to locate future employment and population in zones based on knowledge of existing development, near term developer expectations and the local communities' concept plan

[1]Responses were received from California, Illinois, Indiana, Kentucky, New York, Pennsylvania, and Texas

5 Have you applied any simplified traffic modeling procedures in forecasting internal traffic movements for these small area studies?

2 no (rely on FHWA guidelines)
0 no (do not analyze future travel patterns)
3 yes

6 For the prediction of internal traffic movement, what internal origin-destination data do you use?

2 small sample , home interview (4 percent, 10 percent)
1 FHWA sample size recommendations for home interviews
1 O-D data collected at other than home
4 none - rely on synthetic trip generation or distribution relationships
___ other (please describe)

(multiple responses were obtained for combinations of procedures)

7 If synthetic trip generation distribution equations are used, how are these equations derived?

	Trip Generation	Trip Distribution
Borrowed from Another City	1	1
Pooled Relationships from Other Cities	3	2
Pooled or Borrowed Data with a Small Sample O-D Study	2	1

8 Are the above procedures generally standard or do they vary with factors such as population of city, etc ?

2 - Standardized for all sized cities between 5,000 and 50,000 population

2 - Techniques must vary with unique problems of the area, but generally the studies are treated as scaled down, lower budget, modified large area studies

9 Have any of the above procedures been tried and discarded?

1 - Ratio procedure to factor existing traffic by a ratio of existing population and employment to future population and employment has been discarded due to amount of work and problems of conducting by pass analyses

2 - Currently re-evaluating results

10 In your judgment, what is the general level of professional transportation expertise in areas of less than 50,000 population?

	Good	Fair	Poor	None
Land Use Planners	2	2	2	0
Transportation Planners	1	2	1	2
Traffic Engineers	3	2	0	1

11. Have you had good success with the implementation of small area transportation plans?

3 - No experience
1 - Not successful with system plan or networks
2 - Yes

12 If not, what have you found to be the basic problems of implementation encountered in small urban areas?

1 - System models did not fit the local problem
2 - Need active citizen participation with local interest

13 Where implementation has been particularly successful, what were the critical ingredients?

2 - Community participation
1 - Approach planning based on corridor analysis and not abstract network models

14 Do you have a formal continuing transportation program for updating of a small area transportation study once it is prepared?

1 - Yes
4 - No

APPENDIX E

HOUSEHOLD CATEGORY MODELS FOR TRIP PRODUCTION

There are several reasons for the increasing popularity of household category models for estimating trip productions in traffic zones. Some of the advantages, such as the adaptability to varying zonal schemes and the possession of behavioral attributes, are inherent characteristics of disaggregated household models and are beyond any question. Some of the other acclaimed advantages of such models are not so obvious and have not been established conclusively. For instance, the household trip rates generally are expected to remain stable over a long period of time, however, a recent study has cast doubts on such temporal stability (72) Two other characteristics -- the transferability of trip rates between different urban areas and the adequacy of a small sample in developing a household category model--need further investigations and are discussed in the following sections

Transferability of Trip Rates

Many recent studies for small urban areas have reported the use of trip production models borrowed from another 'similar' area. The criteria that have been used to evaluate 'similarity' between two areas, in most cases, have been limited to population size and very gross indicators of the economic base. In order to evaluate whether such assumptions and gross criteria for 'similarity' are valid, com -

parisons of trip rates from different areas were made as reported below.

Comparison of Trip Rates. Martinson compared the trip rates of Milwaukee, which has a population of approximately one million, with two small cities in the same region, Racine with a population of approximately 110,000 and Kenosha with a population of less than 100,000. He also compared Milwaukee's trip rates with those for the rural area in the same region. The household categories and typical data used in the analysis are shown in Table E-1, which actually represents the home based work trip rates for Racine. The results of comparison are presented in Table E-2 (73). The comparisons were based on trip rates treated in groups and utilized a statistic 'Q', which was developed specifically for this purpose and is described below:

$$Q = \sum_i \sum_j [(X_{ij}-Y_{ij})^2 + (SX_{ij}^2/n_{ij} + SY_{ij}^2/m_{ij})]$$

where, X_{ij} is the cell mean of the i th row and the j th column of the trip rate matrix for Area 1.

Y_{ij} is the cell mean of the i th row and the j th column of the trip rate matrix for Area 2.

SX_{ij}^2 is the cell variance of the i th row and the j th column for Area 1.

SY_{ij}^2 is the cell variance of the i th row and the j th column for Area 2.

n_{ij} is the number of observations (samples) in the i th row and the j th column for Area 1.

TABLE E-1

CROSS-CLASSIFICATION ANALYSIS OF HBW TRIPS FOR RACINE, WISCONSIN (1972 DATA)

Auto Ownership (No. of Cars)	Household Size (Number of Persons 5 Yrs. or Older) 1	2	3	4	5 Yrs. or More
0	0.26 (57) (0.64)	0.48 (31) (0.98)	1.00 (6) (1.15)	0.29 (7) (0.70)	1.20 (15) (2.17)
1	1.13 (60) (1.09)	1.53 (210) (1.40)	2.15 (61) (1.35)	2.11 (45) (1.64)	2.08 (49) (1.72)
2 or More	0.00 (2) (0.00)	2.14 (72) (1.59)	2.63 (65) (1.74)	2.31 (49) (1.47)	3.42 (91) (2.25)

Explanation of Cell Values : X.XX = Average Trip Rate
(XX)= Number of Observations
(X.XX)= Standard Deviation of Trip Rates

TABLE E-2

STATISTICAL COMPARISON OF TRIP RATES BY GEOGRAPHIC AREA WITH A REGION (1972 Data)

Areas Compared	Trip[a] Purpose	1 and 2 Person Households With 0 and 1 Autos: Q Statistic	$X^2_{.05}$ (df=4)	Are Rates Significantly Different?	2 and More Person Households With 1 or More Autos: Q Statistic	$X^2_{.05}$ (df=8)	Are Rates Significantly Different?
Milwaukee Vs. Kenosha	HBW	Insufficient Number of Samples In Cells			9.04	15.51	No
	HBS				9.98	15.51	No
	HBO				6.86	15.51	No
	NHB				17.57	15.51	Yes
Milwaukee Vs. Racine	HBW	6.29	9.49	No	9.30	15.51	No
	HBS	48.20	9.49	Yes	9.21	15.51	No
	HBO	2.36	9.49	No	13.96	15.51	No
	NHB	5.78	9.49	No	10.50	15.51	No
Milwaukee Vs. Rural	HBW	60.46	9.49	Yes	33.15	15.51	Yes
	HBS	17.95	9.49	Yes	35.18	15.51	Yes
	HBO	20.82	9.49	Yes	32.23	15.51	Yes
	NHB	43.84	9.49	Yes	55.72	15.51	Yes

[a] Trip purpose abbreviations are: HBW - Home-Based Work; HBS - Home-Based Shopping, HBO - Home-Based Other; and NHB - Nonhome-Based

m_{ij} is the number of observations (samples) in the i th row and the j th column for Area 2

The null hypothesis formulated was that the cell means of the two matrices being compared were not significantly different. The 'Q' value was compared with the value of Chi Square (χ^2) for i x j degrees of freedom at the level of signifiance of 0.05 If 'Q' is larger than χ^2 0 05, the hypothesis can be rejected which signifies that the trip rates for the two areas are different. It may be pointed out that the number of observations in each cell may vary widely and it is desirable to exclude the values based on only a few samples, say less than 30, from the comparison, i.e , the calculation of the 'Q' statistic.

The results of Martinson's investigation indicate that there was a significant difference between urban and rural trip rates for all trip purposes. However, the difference in trip rates between large and small urban areas was not significant except for the nonhome-based trip rates of Milwaukee and Kenosha, and home-based shop trip rates of Milwaukee and Racine, which were found to be significantly different. Because the cities involved in the analysis are in the same region, it was considered necessary to extend the analysis to cities from different areas. Therefore, person trip rates from three small cities -- Elizabethton, Tennessee, with a population of approximately 20,000, Murray, Kentucky, with a population of approximately 27,000,

and Paducah, Kentucky, with a population of approximately 45,000--were developed for the three trip purposes, home-based work, home-based other, and nonhome-based, using the same household categories as previously shown in Table E-1. The results of a comparison based on the data for the four cities of Racine, Elizabethton, Murray, and Paducah are presented in Table E-3, which indicates that in most cases the trip rates from different cities were significantly different. It must be pointed out that no universal conclusion can be drawn based on the limited number of comparisons and that the results merely imply that the transferability of trip rates between urban areas should not be taken for granted.

Sample Size for Household Category Models

The sample size for regular home interview O-D surveys are based on criteria that are primarily concerned with the reliability of aggregated values such as the zonal trip ends or the interzonal trips (74, 75). Thus in the case of regular surveys, samples must be taken from every zone and when the number of zones is substantial, even small numbers from each zone add up to a large overall sample. However, one of the advantages of disaggregate household models is the ability to 'pool' data from various zones to common categories based on household characteristics, and thus, the sample size requirements are much less. In case households of similar socio-economic characteristics are expected

TABLE E-3

STATISTICAL COMPARISON OF TRIP RATES OF SMALL URBAN AREAS

Cities Compared	Trip Purpose	No. of Cell Pairs Included In Comparison[1]	'Q' Statistic	$\chi^2_{.05}$ (df= No. of Cell Pairs)	Are Rates Significantly Different
Elizabethton (1968) Vs. Racine (1972)	HBW	12	24.30	21.03	Yes
	NHB	12	18.67	21.03	No
Elizabethton (1968) Vs Murray (1967)	HBW	9	33.39	16.92	Yes
	HBO	9	79.50	16.92	Yes
	NHB	9	24.78	16.92	Yes
Elizabethton (1968) Vs. Paducah (1971)	HBW	11	46 61	19 68	Yes
	HBO	11	30 70	19 68	Yes
	NHB	11	142 46	19 68	Yes

1 The cells with less than 15 observations were not included in the test.

to have different travel behavior at different locations, the household category models should be developed separately for each unique location, or alternatively a variable characterizing the locational difference, such as an accessibility measure, may be introduced in the category model. Such an approach would be necessary for a large region with a mixture of different types of urban areas and rural areas. For small urban areas such locational differences are negligible. Nevertheless, in all cases the samples should be distributed throughout the study area as uniformly as possible. The use of 'factored' data for developing disaggregated models is sometimes advocated to properly 'weigh' any unique locational biases. Such a procedure would imply that samples be taken from every zone and this tends to increase the sample size. However, 'factoring' should not be necessary if the households are stratified approximately and, as mentioned earlier, if there are valid reasons to expect strong locational biases within a study area, the models for such locations should be developed separately rather than combining them by 'weighing'. The primary criteria for determining the sample size from the standpoint of the reliability of household category models alone, should be based on the expected or observed variance of trip rates in each cell of the cross-classification matrix.

Effect of Reducing Sample Size. A hypothesis related to the sample size for household category models which was examined in this study, was that 30 samples for each cell would be adequate for estimating the average trip rate for each type of household. To test this hypothesis, the original 17 percent sample of 1020 households from Elizabethton, Tennessee, was used The distribution of the original samples among the various cells as well as the average rates for home based work trips and the respective standard deviation is shown in Table E-4. The number of observations varied from cell to cell. And it was decided to reduce the sample size of cells that had observations larger than 30 by random sampling from the households of the respective cells. The new samples had observations close to 30 and the samples in cells that originally had observations either close to 30 or less were not reduced at all The resulting distribution of 443 observations and the new trip rates along with their standard deviation are shown in Table E-5.

A comparison of the original trip rates and the new rates was performed by computing the statistic 'Q', which was described earlier. The results of the subsequent chi square test for the three trip purposes home based work, home based other and nonhome based, are presented in Table E-6. It can be concluded from the results that from the standpoint of the household category models, the sample size can be much smaller than what usually is used in urban

TABLE E-4

CROSS-CLASSIFICATION OF ORIGINAL HOUSEHOLD SAMPLES AND HBW TRIP RATES FOR ELIZABETHTON, TENNESSEE (1968 DATA)

Auto Ownership (No. of Cars)	Household Size (Number of Persons 5 Yrs. or Older) 1	2	3	4	5 Yrs. or More
0	0.05 (58) (0.34)	0.44 (48) (0.87)	0.31 (16) (0.70)	0.40 (10) (0.84)	0.50 (16) (0.82)
1	0.56 (34) (0.89)	1.27 (175) (1.41)	1.79 (117) (1.48)	2.17 (76) (2.13)	2.51 (76) (1.81)
2 or More	- (0) -	2.08 (86) (1.63)	2.65 (100) (1.89)	2.85 (104) (1.80)	2.95 (94) (2.23)

Total Number of Observations = 1020

Explanation of Cell Values: X.XX = Average Trip Rate
(XX) = Number of Observations
(X.XX) = Standard Deviation of Trip Rates

TABLE E-5

CROSS-CLASSIFICATION OF REDUCED SAMPLES AND NEW HBW TRIP RATES FOR ELIZABETHTON, TENNESSEE (1968 DATA)

Auto Ownership (No. of Cars)	Household Size (Number of Persons Yrs. or Older) 1	2	3	4	5 Yrs. or More
0	0.06 (32) (0.34)	0.44 (48) (0.87)	0.31 (16) (0.70)	0.40 (10) (0.84)	0.50 (16) (0.82)
1	0.56 (34) (0.89)	1.44 (39) (1.43)	2.00 (38) (1.36)	2.42 (36) (2.74)	2.61 (36) (2.08)
2 or More	- (0) -	2.21 (34) (1.55)	2.57 (35) (2.15)	2.69 (35) (1.99)	2.41 (34) (1.86)

Total Number of Observations = 443

Explanation of Cell Values: X.XX = Average Trip Rate
(XX) = Number of Observations
(X.XX) = Standard Deviation of Trip Rates

TABLE E-6

STATISTICAL COMPARISON OF TRIP RATES OF ORIGINAL AND REDUCED SAMPLES FROM ELIZABETHTON, TENNESSEE

Trip Purpose	No. of Cells Included in Comparison	Q Statistic	$x^2_{.05}$ (df=14)	Are Rates Significantly Different
HBW	14	3.69	23.69	No
HBO	14	7.73	23.69	No
NHB	14	7.35	23.69	No

transportation studies.

Summary.

This section presented the results of statistical analysis related to acclaimed similarity of trip rates between urban areas of similar size. The effect of a reduction in sample size on the household trip rates also was examined. One of the noteworthy features of the data presented in the analysis is the large 'variance' in the cells of the household category models which implies a wide variation in the intensity of trip making, even among the households of similar socio-economic characteristics. The variability within each cell was included explicitly in the statistical tests and served an important role in the final results.

It should be pointed out that the analysis was limited to only a few cities and the results may not be valid universally Nevertheless, the results were significant, as they basically indicated that the concept of transferability of trip rates between urban areas should not be taken for granted. It is recommended that a small home-interview survey be conducted to develop the household category models. It was demonstrated that a small sample that would provide approximately 30 observations in each cell would be adequate for this purpose.

APPENDIX F

COMPARISON OF SYNTHETIC TRIP-PRODUCTION AND-ATTRACTION RELATIONSHIPS

Current literature has advocated the transferability of travel relationships calibrated for one community or a cross-section of communities to simulate internal-internal trips for a community of similar socio-economic characteristics. In addition, the technique is being utilized in current practice (Appendix D). Reported here are some limited tests conducted to:

1. Compare small area synthetic trip-production and-attraction relationships with relationships derived from internal O-D survey data.
2. Compare assigned link volumes with ground counts when the synthetic trip productions and attractions for a test city derived with different models are assigned to the network after being distributed with a gravity model using the same set of friction factors in all cases.

The tests were concerned primarily with the consequences resulting from extending synthetic travel relationships between smaller urban areas. A related analysis was conducted for cross-classification trip-production rates and reported in Appendix E. It must be noted that the tests are limited

in scope and do not permit the development of broad generalizations. Only the internal-internal trips were simulated, as the external-external and external-internal trips were obtained directly from the results of an external cordon survey. A three-trip purpose classification was performed using home-based work, home-based non-work (or other) and nonhome-based auto driver trips. The test cities included:

1. Maryville - Alcoa, Tenn. (pop. 41,232)
2. Lawrenceburg, Tenn. (pop. 10,302)
3. Elizabethton, Tenn. (pop. 19,518)

The characteristics of these communities and their geographic locations are described in more detail in Appendix G, and Table F-1. Maryville-Alcoa had a 20-percent internal home-interview survey conducted in 1964. Elizabethton had a 20-percent survey in 1968 and Lawrenceburg had a 20-percent survey performed in 1967. The internal travel simulation phase of the comprehensive transportation study prepared by the Tennessee Department of Transportation for Elizabethton relied on the application of trip-generation relationships and friction factors developed in the Lawrenceburg study. This fact eliminated Elizabethton from the production and attraction comparisons, although it was utilized in assigned volume comparisons.

Small Area Trip-Production and-Attraction Relationship

This analysis was concerned with testing the ability of

TABLE F-1

TRAVEL COMPARISONS FOR TEST CITIES

	Alcoa-Maryville	Lawrenceburg	Elizabethton
Population	41,200	10,300	19,500
Internal Vehicle Trips Per Capita	1 84	2 17	1 47
Types of Internal Vehicle Trips			
1. Home-Based Vehicle Trip	21%	22%	Internal Travel was Synthesized
2. Home-Based Non-Work Trip	57%	58%	
3. Nonhome-Based Vehicle Trip	22%	20%	
Types of Trips			
1. Internal-Internal	70	60	51
2. Internal-External	24	34	40
3. External-External	6	6	9
Autos Per Capita	37	33	42

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various zoned trip-generation relationships reported in the literature to replicate zonal trip productions and attractions for Lawrenceburg and Maryville-alcoa. The models considered are discussed below.

Fabricated Equations Based on Pooled Data. Three sets of models were explored in this category. The first set was developed by Georgia State Department of Highways using data pooled from a number of small-area transportation studies (25). After testing in several cities in Georgia, the following set of estimating equations was adopted for urban areas in the population range of 5,000 to 50,000 with the implicit conclusion that the resulting trip productions and attractions would be sufficiently reliable to be used in lieu of an internal origin-designation (O-D) survey.

a. Production Equations

1) Homebased Work = 8 + 1.2 Motor Vehicles
2) Homebased Other = 18 + 2 7 Motor Vehicles
3) Nonhomebased = 67 + 0 1 Dwelling Units + 0.1 Motor Vehicles + 0.6 Employment + 0.1 School Enrollment

b. Attractions Equations

1) Homebased Work = 54 + 0 9 Employment
2) Homebased Other = 206 + 0 8 Dwelling Units + 0 6 Employment + 0.3 School Enrollment
3) Nonhomebased = 67 + 0.5 Dwelling Units + 0.4 Employment

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The second and third sets of models in this category which were fabricated by Harland Bartholomew and Associate, were based on models developed for several other small urban areas. The applicability of various trip-generation models was assessed by determining the reasonability of internal vehicle trips per capita and the percentage distribution of trips by trip purpose. Two sets of relationships were tested. One was for Ponca City, Oklahoma (pop.10,435) and the other for Madisonville, Kentucky (pop. 18,224) (76), (77). The Ponca City equations are

a. Productions Equations

1) Homebased Work = -2.90486 + 0.75377 (Autos)
2) Homebased Non-Work = -23.82007 + 3.74414 (Autos)
3) NHB = 20 8651 + 0.5241 (Autos) + 5.5973 (R-Emp.) + 0.2986 (NR-Emp) + 0.1441 (Sch Enr)

b. Attractions Equations

1) Homebased Work = 34 51357 + 1.47557 (R-Emp.) + 0.48970 (NR-Emp.)
2) Homebased Non-Work = 88.7802 + 1.0354 (Autos) + 11 4978 (R-Emp) + 0.3718 (NR-Emp) + 0.3924 (Sch.Enr.)
3) NHB = 26.2343 + 0.5987 (Autos) + 5 3545 (R-Emp.) + 0.2326 (NR-Emp.) + 0.0935 (Sch.Enr.)

The Madisonville equations relies on only three socio-economic factors which can be forecasted easily - population, total employment and industrial employment. The equations are:

a. Production Equations

1) Homebased Work = 0.42 (population)
2) Homebased Non-Work = 1.02 (population)

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Nonhomebased Work = 0.34 (population + 1.57 (employment)

b. Attraction Equations

1) Homebased Work = 1.268 (employment)
2) Homebased Non-Work = 0.40 (population) + 2.22 (total employment - industrial employment)
3) Nonhomebased = 0.34 (population) + 1.57 (employment)

Equations Based on Per Capita Trip Rates The Kentucky Highway Department developed zonal trip-generation estimates based on area-wide trips per capita, percentage of trip by purpose, and a ratio of a zone socio-economic characteristics with respect to the area-wide total (78).

The equations are as follows.

a. Production Equations

1) Homebased Work = 0.40 (zonal population)
2) Homebased Other = 0.96 (zonal population)
3) Nonhomebased = 0.64 (total population) (zonal employment/total employment)

b. Attraction Equations

1) Homebased Work = 0.4 (total population) (zonal employment/total employment)
2) Homebased Other = 0 96 (total population) (zonal non industrial employment/total non industrial employment)
3) Nonhome based = 0.64 (total population) (zonal employment/ total employment)

Equations Using Detailed Trip Stratifications Included in the comparisons were two sets of trip-generation models

F-6

using six-trip purpose stratifications. These regression equations developed for the transportation studies in Maryville-Alcoa and Lawrenceburg, Tennessee are summarized in Tables F-2, and F-3, respectively (79, 80). The detailed zonal estimates obtained from these equations were combined into the three-trip purposes of home-based work, home-based other and nonhome-based to permit comparisons with the other equations As noted by Table F-4, the detailed trip purpose models require forecasting up to eight independent variables while the other models rely on a maximum of four variables.

Productions and Attractions Comparisons

The synthetic models were tested by applying Lawrenceburg and Maryville-Alcoa socio-economic data to develop zonal trip estimates. These synthetically derived estimates were then compared with the values obtained from the trip-generation equations calibrated with the O-D survey data for the respective study areas. Results of the comparisons are summarized in Table F-5 for Maryville-Alcoa and Table F-6 for Lawrenceburg. The evaluation of each equation was based on the following factors.

1. "The multiple correlation coeficient ('R') indicates the strength of linear relationship between the dependent and independent variables. The value R^2 measures the proportion of the variation of the dependent variable that is explained by the

TABLE F-3

LAWRENCEBURG TRANSPORTATION STUDY
INTERNAL TRIP-GENERATION EQUATIONS[1]

Work Productions = 1.14 x Labor Force + 17.04
Work Attractions = .87 x Total Employment + .0008 x Mfg Floor Area + 32.94
Business Productions = 1.05 x Cars Owned
Business Attractions = 2.57 x Retail Employment + 75.78
Social - Rec Productions = 90 x Cars Owned + 22 13
Social Attractions = .76 x Cars Owned + 30.12
Shopping Productions = .86 x Cars Owned
Shopping Attractions = 3.07 x Retail Employment + 33 61
Misc. Productions =- 63 x Retail Employment + .0004 x Trade Floor Area + 39.64
Misc. Attractions = .172 x Retail Employment + .0003 x Services Floor Area + 38.55
Nonhome Base Productions = 3 66 x Retail Employment + 80 74
Nonhome-Base Attractions = 3.62 x Retail Employment + 82.31

[1]Truck and Taxi Trip Equations Not Shown

TABLE F-4

INDEPENDENT VARIABLES UTILIZED IN SYNTHETIC GENERATION EQUATIONS

	Home-Based Work						Home-Based Other						Nonhome-Based					
Variable	Ga.	Mdson	Ponca	Ky.	M-A	Lwbg	Ga.	Mdson	Ponca	Ky.	M-A	Lwbg	Ga.	Mdson	Ponca	Ky.	M-A	Lwbg
Population		P		P/A				P/A		P/A	P			P/A		P/A	P/A	
Dwelling Unit							A				P/A		P/A					
Vehicles/Cars	P		P				P		P/A		A	P/A	P		P/A			
Labor Force					P	P					P/A							
Sch.Enrol.							A		A		A		P		P/A			
Employment																		
Total	A	A	A	A	A	A	A	A	A	A	A		P/A	P/A	P/A	P/A	P/A	
Industrial								A		A								
Retail			A						A		A	P/A			P/A		P/A	P/A
Floor Area																		
Trade/ Commercial											A	P						
Service												A						
Manuf					A	A												
Public					A													
Number of Variables Used	2	2	3	2	4	3	4	3	4	3	8	4	4	2	4	2	3	1

TABLE F-2

MARYVILLE-ALCOA TRANSPORTATION STUDY
INTERNAL TRIP-GENERATION EQUATIONS[1]

Work Productions = 1.12 (Labor Force)
Work Attractions = 1.04 (Total Employment) - 20 (Manufacturing Floor Area)+ .40 (Public and Quasi-Public Floor Area)

Business Productions = 1.57 (Dwelling Units)
Business Attractions = 52 (Dwelling Units) = 4.24 (Retail Employment)
Miscellaneous Productions = .81 (Dwelling Units)
[2]Miscellaneous Attractions = .26 (Dwelling Units + .45 (School Enrollment)
[3]Miscellaneous Attractions = 20 (Dwelling Units + 06 (Total Employment) + .62 (Retail Employment)
Social Productions = 09 (Population)
Social Attractions = .12 (Cars Owned) + 19 25 (Labor Force Per Dwelling Unit)
Recreation Productions = .03 (Population)
Recreation Attractions = 05 (Dwelling Units + .22 (Retail Employment) + .02 (School Enrollment)
Shopping Productions = .52 (Labor Force)
Shopping Attractions = 2.99 (Retail Employment - 1.55 (Local Retail Comm. Floor Area)
Nonhome-Base Productions = .11 (Population) + .08 (Total Employment) + 3.99 (Retail Employment)
Nonhome-Base Attractions = 12 (Population) + 06 (Total Employment) + 3.46 (Retail Employment)

[1]Truck and Taxi Trip Equations Not Shown
[2]School Zones Only.
[3]School Zones Deleted.

TABLE F-5

CORRELATION ANALYSIS FOR TRIP GENERATION

MARYVILLE-ALCOA - 1964

Maryville-Alcoa	Base Equations Maryville-Alcoa	Fabricated Models Based On Pooled Data			Unit Rate Model Ky.	Detailed Trip Purpose Model Lawrenceburg
		Georgia	Madison-ville	Ponca Fla.		
Home-Based Work Productions (R)	14,677	18,690 (0 95)	17,316 (0.86)	11,457 (0.88)	16,493 (0.86)	16,169 (0.90)
Attractions (R)	14,315	16,778 (0 94)	28,708 (0.78)	12,563 (0 82)	16,500 (0.91)	21,587 (0.84)
Difference (P-A)	362	1,912	-11,392	1,106	-7	-5,418
Home-Based Other Productions (R)	39,058	42,009 (0.94)	42,031 (0.88)	56,309 (0 85)	39,587 (0.88)	45,772 (0 93)
Attractions (R)	37,411	37,119 (0.17)	22,887 (0.49)	62,923 (0.01)	39,581 (0.72)	39,790 (0.03)
Difference (P-A)	1,647	4,890	19,144	-6,614	6	5,982
Nonhome-Based Productions (R)	14,777	17,629 (0.16)	36,736 (0.12)	28,173 (0.80)	26,388 (0.15)	26,427 (0.78)
Attractions (R)	15,156	16,807 (0.09)	36,736 (0.09)	30,269 (0 56)	26,388 (0.19)	15,203 (0.79)
Difference	379	822	0	-2,096	0	11,224
Total Productions (R)	68,512	81,991 (0.83)	95,486 (0.54)	114,705 (0.45)	82,465 (0.39)	76,953 (0.49)
Attractions (R)	66,887	85,074 (0.43)	88,329 (0.45)	123,188 (0.79)	82,470 (0 74)	77,081 (0.72)
Difference (P-A)	1,625	-3,083	7,157	-8,483	-5	-128

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TABLE F-6

CORRELATION ANALYSIS FOR TRIP GENERATION

LAWRENCEBURG - 1967

Lawrenceburg	Base Equa Lawrenceburg	Fabricated Models Based On Pooled Data			Unit Rate Model Ky.	Detailed Trip Purpose Model Maryville-Alcoa
		Georgia	Madison-ville	Ponca Fla.		
Home-Based Work Productions (R)	4,466	3,671 (0 84)	4,326 (0.99)	2,133 (0.84)	4,119 (0.99)	4,018 (0 99)
Attractions (R)	7,026	6,311 (0.99)	7,343 (0.99)	4,291 (0.94)	4,126 (0.99)	5,718 (0.99)
Difference (P-A)	-2,560	-2,640	-3,017	-2,158	-7	-1.700
Home-Based Other Productions (R)	11,598	7,858 (0.65)	10,507 (0 50)	10,382 (0.64)	9,890 (0.50)	10,681 (0.52)
Attractions (R)	10,306	11,291 (0.43)	5,426 (0.73)	16,207 (0 96)	9,888 (0.97)	6,523 (0.49)
Difference (P-A)	1,292	-3,433	5,081	-5,825	2	4,158
Nonhome-Based Productions (R)	3,955	5,771 (0 44)	12,596 (0.43)	7,907 (0.94)	6,601 (0.43)	3,990 (0 97)
Attractions (R)	3,955	5,285 (0 43)	12,596 (0.44)	7,578 0.95	6,601 (0.43)	7,502 (0.78)
Difference (P-A)	0	486	0	329	0	-3,512
Total Productions (R)	20,023	18,160 (0.71)	27,433 (0.62)	23,679 0.93	20,609 (0.99)	18,693 (0.77)
Attractions (R)	21,286	22,883 (0.88)	25,630 (0.91)	31,772 0 95	20,615 (0.99)	16,658 (0.70)
Difference (P-A)	-1,263	-4,723	1,803	-8,093	-6	2,035

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independent variables."

2 The area-wide total number of estimated trip productions and attractions for each trip purpose. A comparison of the estimated totals with those obtained for O-D survey revealed the reasonableness of the equations in estimating the trip rates per capita and percentage distribution by trip purpose.

3. The difference between total trip productions and attractions for each trip purpose reflects the degree of association between the production and attraction equations.

The results indicated that no single synthetic equation was consistantly superior to the others for all trip purposes. Also, some variations in results were detected in the tests for the two cities For Lawrenceburg, the simplified equations relying on a few socio-economic variables generally provided reasonable results but when applied to the larger urban area of Maryville-Alcoa, the same equations yielded poorer results in estimating nonhome-based productions and attractions for home-based other and nonhome based trips

In all cases, however, some simplified synthetic equations performed compariable to a detailed trip stratification model. This would suggest that small area studies can take advantage of using only a few independent variables, thereby reducing inventory, forecasting, and updating costs.

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In an overall basis, the Georgia equations based upon pooled data, yielded the greatest consistancy in results Best results were obtained in synthesizing the home-based work and home-based other trip productions, whereas the correlation was poorest for the nonhome-based trips. The difference between total productions and attractions was significantly large in some cases implying that the planners must remain sesitive to establishing reliable regional totals for productions and attractions not the balancing of attractions to productions It also was revealed by the results that without independent verification checks, it can not always be assumed that attractions should be balanced to productions. It is important that the reasonableness of internal trips per capita be established, perhaps through a small sample O-D survey as well as by checking results against experiences gained in other small area studies. The standards related to regional totals such as vehicle miles of travel also are useful for applying synthetic regression equations

As suggested by Harland Bartholomew and Associates (76), special consideration must be given to zones which have a unique characteristic, such as a large employment retail center. Relationships derived from other communities may not necessarily reflect the unique travel characteristics of these special generators Supplemental special generator trip rates can be developed from data sources described in the body of the report.

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Traffic Assignment Comparisons

The second series of tests for the synthetic trip-generation models were used to link volumes to natural ground counts. Elizabethton, Tenn., was the test city for this purpose. The internal zonal productions and attractions computed with the previously discussioned equations were used as inputs into a three-purpose gravity model which used the friction factors derived for Lawrenceburg (81). The zone-to-zone trip volumes then were assigned to the network using the all-or-nothing assignment technique and without capacity restraints. External-external and external-internal trips obtained from an external O-D survey were also assigned to the network to permit the comparison of assigned link volumes with the base year ground counts.

In the traffic assignment tests a set of cross-classification models for trip production was included. These models were developed from O-D survey data for Elizabethton and are shown in Table F-7.

Results of Comparisons. Screenline comparisons traditionally are utilized as tests in evaluating and calibrating traffic models. Six screenlines were established for Elizabethton and screenlines 1, 2, and 3 divided the urban area in a north-south direction while 4, 5, and 6 run east-west. Screenlines 2 and 5 bisected the CBD. As reported in Table F-8, no particular synthetic model could be judged

TABLE F-7

HOUSEHOLD CROSS-CLASSIFICATION MODEL FOR INTERNAL TRIP PRODUCTION
ELIZABETHTON, TENNESSEE

Auto Ownership (Number of Cars)	Household Size (Number of Persons 5 Years or Older) 1	2	3	4	5 or More
	0.06 (HBW)	0.44	0.31	0.40	0.50
0	0.59 (HBO)	0.75	0.86	2.00	2.94
	0.06 (NHB)	0.00	0.06	0.20	0.07
	0.56	1.27	1.79	2.17	2.51
1	2.47	3.98	5.19	6.57	9.84
	0.58	1.11	1.07	0.96	2.36
		2 08	2.65	2.85	2.95
2 or More	(No Observa- tions)	4.86	5.77	9.53	12.19
		0.99	1.33	1.92	2.14

Explanation of Cell Values
First Number in a Cell = Home-Based Work Trips per Household
Second " " " " = Home-Based Other Trips per Household
Third " " " " = Nonhome-Based Trips per Household

TABLE F-8

SCREENLINE CHECKS.
ELIZABETHTON STUDY AREA

Screenline	Ground Count	Fabricated Models Based on Pooled Data: Georgia	Madison-ville	Ponca	Unit Rate Model Ky.	Detailed Trip Purpose Model Maryville-Alcoa	Lawrenceburg	Cross-Classif-ication Model
1-1	23,200	26,248* +.13**	30,386 +.31	24,271 +.04	31,100 +.34	20,709 -.10	22,688 -.02	19,351 +.17
2-2	31,580	28,943* -.08**	34,893 +.10	37,500 +.18	43,144 +.37	33,361 +.06	31,144 -.01	30,158 +.05
3-3	5,800	6,981* +.20**	7,004 +.20	6,990 +.21	7,081 +.22	6,391 +.10	6,963 +.20	1,177 -.79
4-4	12,800	11,667*	11,748 -.08	12,238 -.04	12,015 -.06	10,760 -.16	11,685 -.09	7,397 -.42
5-5	40,440	27,904* -.31**	35,540 -.12	30,045 -.26	41,681 -.03	26,600 -.34	27,742 -.31	31,921 +.21
6-6	6,000	6,248* +.04**	6,548 +.09	6,973 +.16	5,959 -.01	5,866 -.02	5,737 -.04	5,473 -.08
Total	119,820	107,991* -.10** .17***	126,119 +.05 .15	118,017 -.02 .17	140,980 +.18 .19	103,687 -.13 .17	105,959 -.12 .13	95,477 -.20 .20

*Screenline Count ** Percent Error *** Weighted Average

to be superior. On an overall basis, five of the seven methods closed within 15 percent of the actual total number of trips with a weighted average error of between 13 and 17 percent. The fabricated Georgia models, and detailed trip purpose Maryville-Alcoa and Lawrenceburg equations provided the closest agreement, if less reliance is placed on screenlines 2 and 5. Both screenlines run through the commercial district, and because street volumes in their area could be inflated due to circulation traffic, the models can be expected to under report trips. Some reasonable judgement can be applied to the results considering that the Lawrenceburg equations were actually utilized in the preparation of the Elizabethton study. Cross-classification provided the highest error with a large under-prediction of trips. However, the two screenlines - 3 and 4 for which the comparisons were very poor for the cross-classification models, were low-volume screenlines where a small deviation in absolute terms would result in large percentage error.

Root mean square errors were computed for link volume comparisons to evaluate how well the different synthetic methods duplicated traffic on 104 traffic links in the Elizabethton study area as noted in Table F-9. The weighted average error ranged from 67.3 to 107.6 percent. The fabricated Georgia and detailed stratification. Maryville-Alcoa and Lawrenceburg equations displayed the best results. Cross-classification models yielded the best results.

TABLE F-9

ROOT MEAN SQUARE COMPARISONS OF LINK VOLUMES
ELIZABETHTON STUDY AREA

Volume Group	No. of Links	Average Ground Count	Fabricated Models Based on Pooled Data: Georgia	Fabricated Models Based on Pooled Data: Madison-ville	Fabricated Models Based on Pooled Data: Ponca	Unit Rate Model Ky.	Detailed Trip Purpose Model Maryville	Lawrence-burg	Cross-Classif-ication Model
0-499	12	221	293* 2.06**	284 2.10	290 2.11	277 2.04	280 2.06	279 2.03	539 4.67
500-999	16	681	1,114 4.58	1,186 5.07	1,180 5.36	1,121 4.73	1,078 4.74	1,124 4.49	2,021 8.47
1000-1999	11	1,455	1,378 2.14	1,478 2.66	1,453 2.77	1,367 2.35	1,216 2.00	1,354 2.20	1,905 3.08
2000-2999	13	2,446	3,877 9.30	3,936 9.50	3,786 7.96	3,923 8.17	3,440 7 36	3,635 7.66	5,648 13.58
3000-4999	23	3,933	5,120 18.90	5,464 20.36	6,214 26.70	5,882 24.98	5,113 19.85	5,541 21.86	6,632 32.15
5000-9999	23	7,122	6,718 26.80	7,350 26.97	7,725 29 62	7,615 29.03	7,019 23.84	7,008 26.08	7,906 34.14
10,000-14,999	6	12,067	7,745 6.96	9,617 5.61	7,479 7.35	10,780 5.07	7,240 7 44	7,144 7.24	7,386 11.54
Total Average	104	3,731	3,900 70.74	4,252 72.27	4,356 81.87	4,446 76.37	3,858 67.29	3,990 71.56	4,992 107.63

*Average Assigned ** Percent weighted Average Error

TABLE F-10

COMPARISON OF ASSIGNMENT NETWORK ACCURACY
FOR OTHER STUDY AREAS

Transportation Study Central City	Weighted Average Error (Percent)*
Madison, Wisconsin	26.9
LaCrosse, Wisconsin	32.8
Minneapolis-St.Paul, Minnesota	33.3
Wisconsin Rapids, Wisconsin	34.1
Salt Lake City, Utah	34.2
Janesville, Wisconsin	37.0
Sheboygan, Wisconsin	37.4
New Orleans, Louisiana	40.0
Green Bay, Wisconsin	42.9

*All values are after four iterations of restraint except for Sheboygan,Janesville, and Wisconsin Rapids which are unrestrained assignments.

highest error. Compared to results experienced in other studies, the weighted average error of the link assignments with synthetic techniques were much higher (Table F-10). This can be attributed partly to the fact that the results of the synthetic models represented the first iteration and subsequent adjustments could be made to improve the results All assignments were unconstrained in capacity and some deviations of link volumes could be attributed to the all-or-nothing assignment technique. Also, since the trips in a small network can only be loaded at a few points, variations can develop depending on retrival configurations and this was found to be a problem in the Elizabethton case study

It should be noted that verification checks based on assigned volumes play a significant role in model adjustments in the absence of O-D trip data The study design must give careful consideration to collecting ground counts and screenline data Also, serious consideration should be given to conducting a small sample home-interview survey to develop trip rates as discussed in the text. Traffic counts for special generators also should not be overlooked.

A final evaluation examined the synthetic assignments from the standpoint of the utilization of the data. As described in the text sufficient accuracy should be provided by a traffic assignment so that a difference of one lane does not result due to the traffic forecasting procedure

This criterion implies that the tolerable limit of error is approximately 4,000 vehicles per day for volumes under 19,000 vehicles per day. An error less than 4,000 vehicles per day do not change the basic street design, and the number of links exceeding this limit is shown in Table F-11. The results indicate that in the case of equations based on the first assignment results, 17 to 19 links could be over- or under-designed. For cross-classification about 30 percent of the links did not meet the criterion.

<u>Summary</u>

It can be conducted from this limited testing of synthetic trip-generation models that these relationships yield a large variation in results when forecasting internal-internal trips for different small urban areas. To develop adequate results with such models in the absence of an O-D survey, concern must be given to conducting elaborate verification checks. It is recommended that small sample O-D surveys be conducted to better establish some confidence on the trip rates per capita and percentage distribution of trips by purpose. Such data is important in establishing area-wide totals in trip attraction and trip production. A large number of ground counts properly distributed in the study area can be used to estimate vehicle-miles of travel. This is also an important parameter to check. Also, in verification checks, it is feasible to utilize synthetic

TABLE F-11
NUMBER OF LINKS WITH GREATER THAN 4000 VPD
DIFFERENCE BETWEEN ASSIGNED VOLUME AND GROUND COUNT
ELIZABETHTON STUDY AREA

Range	Fabricated Model Based on Pooled Data: Georgia	Madinsonville	Ponca	Unit Rate Model Kentucky	Detailed Trip Purpose Model Maryville-Alcoa	Lawrenceburg	Cross Class-ification Model
0-499 (12 Links)	0	0	0	0	0	0	1
500-999 (16 Links)	0	0	0	0	0	0	4
1000-1999 (11 Links)	0	0	0	0	0	0	0
2000-2999 (13 Links)	0	2	2	2	1	1	4
3000-4999 (23 Links)	6	6	6	7	6	6	8
5000-9999 (23 Links)	10	9	9	8	9	9	10
10,000-14,999 (6 Links)	3	2	3	1	3	3	4
Total	19	19	20	18	19	19	31

techniques for reproducing travel patterns in a small urban area Given the cost and time constraints, the selection of an appropriate model should consider the types of planning data available. Fabricated models based upon 'pooled' data over a range of population sizes, such as the Georgia equations provided estimates of zonal productions and attractions consistent with the more stratified and detailed models The Georgia equation utilizes such simple variables as population, employment, dwelling units and school enrollment These socio-economic factors are easy to collect and can be easily updated for use in the continuing transportation study In the absence of cross-sectional models designed to be applicable over a broad range of community sizes and characteristics, great care should be given to selecting a community which has similar travel characteristics. In lieu of precise parameters to define community similarity, emphasis must be placed on performing detailed validity checks

The limited test with cross-classification models is not sufficient to develop definite conclusions, but as indicated by other studies the regression models provide better results than the category models (82). There are advantages to these models such as flexibility to varying zone sizes and the adaptability to independent variables of a discrete non-linear correlation with the dependent variables A number of studies have been conducted for transit analysis using the disaggregate technique (83, 84)

APPENDIX G

CORRIDOR TECHNIQUE

Procedure-External

As described in the text, the procedure for determining the various elements of external traffic depends on the availability of a previous external survey or traffic count Depending on the availability of data, any of five procedures are utilized to estimate external trips The procedures are as follows

Procedure One This procedure is based upon an external cordon survey for some past year being available Before the procedure is presented, terms are identified and assumptions are made

From the previous year cordon study, the following are available

a V_{ik} is volume (ADT) of total externals at cordon station (i) for past year (study year) (k)

b VE_{ik} is volume (ADT) of external-external traffic at station (i) for past year (k)

c VI_{ik} is volume (ADT) of external-internal traffic at station (i) for past year (k)

d VIC_{ik} is volume (ADT) of the external-internal traffic that is destined to the CBD at stations (i) for past year (k)

For computing an external growth factor, the county's total vehicle registration for the past cordon study year (R_k) is needed and a similar value (R_j) for the present year is required The growth factor (GFE) is a ratio of the above county vehicle registrations or $GFE_j = R_j/R_k$

In addition the procedure will require present statistics on existing volumes at each cordon station, V_{ij} as total externals, and total employment in the central area, EC_j, and total employment in the study area, ES_j

Assumptions The procedure utilizes the following assumptions

a $V_{ik}/\sum_{i=1}^{m} V_{ik} = V_{ij}/\sum_{i=1}^{m} V_{ij}$

Proof for this assumption can be found in Reference (53), as Table 9 and Figure 9

b $VI_{ik}/V_{ik} = VI_{ij}/V_{ij}$

Proof for this assumption is found in Reference (53), as Table 10 and Figure 10

c $\hat{V}_{ij}/V_{ik} = R_j/R_k$

Proof for this assumption is found in Reference (53), as Table 11, and Figure 11

d $VIC_{ij}/VI_{ij} = EC_j/ES_j$

Proof for this assumption is found in Reference (53), as Table 12 and Figure 12

Procedural Steps Using the information provided as given and the above assumptions, the corridor volume for future year N, destined to the central area from each cordon station (VIC_{in}) is computed through the following steps

I Compute $\hat{V}_{ij}$ as V_{ik} R_j/R_k

II Test if $|\hat{V}_{ij} - V_{ij}| > 2000$

a Yes Go to Step III of Procedure Two

b No Continue with Step III

III Estimate forecast year county vehicle registrations, R_n

IV Compute GFE_n as R_n/R_j

V Compute V_{in} as GFE_n V_{ij}

VI Compute VI_{in} as $V_{in} \cdot VI_{ik}/V_{ik}$

VII Compute VE_{in} as $V_{in} - VI_{in}$

VIII Estimate EC_n and ES_n from employment forecasts

IX Compute VIC_{in} as $VI_{in} \cdot EC_n/ES_n$

<u>Procedure Two</u> This procedure is utilized when the ground counts from Step II of procedure one do not check within the accuracy stated

Assumptions This procedure utilizes the assumptions previously stated plus the following

a The total external crossings for all cordon stations can be forecasted as a result of the regression analysis, (see Reference <u>53</u> on Model Development) A model for predicting total external cordon vehicle crossings (for an inference space of 10,000 to 100,000 population) is given below as equation (1)

$$Y_1 = 28\ 55 + 0\ 068\ (X_1) + 0\ 00009\ (X_2) - 369\ 8\ (X_3) + 78\ 3\ (X_4) \quad (1)$$

where

Y_1 = Total external cordon crossing (thousands)

X_1 = County population density (population/square mile)

X_2 = County Area multiplied by population of the cities larger than subject city within a 25 mile radius of the city center (population/1000)(square miles)

X_3 = Reciprocal of the total study area population in thousands

X_4 = Reciprocal of the total study area employment in thousands

Procedural Steps Using the assumptions and definitions from procedure one, the corridor volume for future year $_n$, destined to the central area from each cordon station (VIC_{in}) is computed through the following steps

I Compute $\hat{V}_{ij}$ as V_{ik} R_j/R_k

II Tests shows $|\hat{V}_{ij} - V_{ij}| > 2000$

III Use $Y_1 = 28\ 55 + 0\ 068\ (X_1) + 0\ 00009\ (X_2) - 369\ 8\ (X_3) + 78\ 3\ (X_4)$ to compute total external crossings for all cordon stations for

future year (terms previously defined)

$$Y_1 = \sum_{i=1}^{m} V_{in}$$

IV $V_{in} = \left[V_{ik}/\sum_{i=1}^{m} V_{ik}\right] Y_1$

V Compute VI_{in} as V_{in} VI_{ik}/V_{ik}

VI Compute VE_{in} as $V_{in} - VI_{in}$

VII Estimate EC_n and ES_n from employment forecasts

VIII Compute VIC_{in} as VI_{in} EC_n/ES_n

<u>Procedure Three</u> This procedure is utilized when traffic volumes from some past year, at the cordon stations are available These counts are greater than four years old In addition, a check of ground traffic counts is within the level of precision stated

Assumptions In addition to the assumptions proposed in procedures one and two, this procedure includes an equation for estimating the total external-external cordon vehicle crossings A detailed discussion of this equation is found in Reference (<u>53</u>)

The total external-external cordon vehicle crossings are forecast using regression modeling and Equation 2

$$Y_2 = 4\ 28 + 0\ 035\ (X_1) + 0\ 066\ (X_2) - 0\ 064\ (X_3)$$

where

Y_2 = total external-external cordon crossings (in thousands),

X_1 = population of the cities larger than subject city within a 25-mile radius of the city center (in thousands),

X_2 = county population density (in population/square mile) and

X_3 = population of the cities smaller than subject city within a 25-mile radius of the city center (in thousands)

Procedural Steps Using the assumptions and definitions previously stated, the corridor volume for future year $_n$, destined to the central area from each cordon station (VIC_{in}) is computed through the following steps

I Compute $\hat{V}_{ij}$ as V_{ik} R_j/R_k

II Test Shows $|\hat{V}_{ij} - V_{ij}| \leq 2000$

III Estimate forecast year county vehicle registration R_n

IV Compute GFE_n as R_n/R_j

V Compute V_{in} as GFE_n V_{ij}

VI Compute $Y_2 = 4\ 28 + 0\ 035\ (X_1) + 0\ 066\ (X_2) - 0\ 064\ (X_3)$ which is total external-external cordon crossings for all stations (terms previously defined)

VII Compute VE_{in} as Y_2 $V_{ik}/\sum_{i=1}^{m} V_{ik}$

VIII Compute VI_{in} as $V_{in} - VE_{in}$

IX Estimate EC_n and ES_n from employment forecasts

X Compute VIC_{in} as VI_{in} EC_n/ES_n

<u>Procedure Four</u> This procedure is utilized when traffic volumes from some past year $_k$, (greater than four years old) at each cordon station are available. In addition, the check of ground traffic counts is not within the prescribed level of precision

Assumptions The assumptions previously stated are appropriate for this procedure

Procedural Steps. Using the previously stated assumptions and parameter definitions, one can compute the corridor volume destined to the central area from each cordon station for the forecast year, $_n$ VIC_{in} is computed through the following steps

I Compute $\hat{V}_{ij}$ as V_{ik} R_j/R_k

II Tests shows $|\hat{V}_{ij} - V_{ij}| > 2000$

III Use $Y_1 = 28\ 55 + 0\ 068\ (X_1) + 0\ 00009\ (X_2) - 369\ 8\ (X_3) + 78\ 3\ (X_4)$ to compute total external crossings for all cordon stations for future year (terms previously defined)

$$Y_1 = \sum_{i=1}^{m} V_{in}$$

IV $V_{in} = \left[V_{ik}/\sum_{i=1}^{m} V_{ik}\right] Y_1$

V Compute $Y_2 = 4\ 28 + 0\ 035\ (X_1) + 0\ 066\ (X_2) - 0\ 064\ (X_3)$ which is total external-external cordon crossings for all stations (terms previously defined)

VI Compute VE_{in} as Y_2 $V_{ik}/\sum_{i=1}^{m} V_{ik}$

VII Compute VI_{in} as $V_{in} - VE_{in}$

VIII Estimate EC_n and ES_n from employment forecasts

IX Compute VIC_{in} as VI_{in} EC_n/ES_n

<u>Procedure Five</u> This procedure is utilized when there are no previous traffic counts (or cordon study) that are at least four-years old In this case the cordon stations will be established and traffic volume counts will be made V_{ij} is total volume (total externals) at station $_i$, for the present year $_j$ Traffic counts at these stations less than four-years old are used only to split total traffic between stations

Assumptions No additional assumptions are required

Procedural Steps This procedure is similar to that used in procedure four except that vehicle registration for the county are not utilized VIC_{in}, the portion of external volume that will be assigned to the radial corridors will be computed through the following steps

I Using $Y_1 = 28.55 + 0\ 068\ (X_1) + 0\ 00009\ (X_2) - 369\ 8\ (X_3) + 78\ 3\ (X_4)$ the total external crossings for all cordon stations for future year (n) is computed as Y_1 which is equivalent to $\sum_{i=1}^{m} V_{in}$ (terms previously defined)

II $V_{in} = \left[V_{ij}/\sum_{i=1}^{m} V_{ij}\right] Y_1$

III Compute $Y_2 = 4\ 28 + 0\ 035\ (X_1) + 0\ 066\ (X_2) - 0\ 064\ (X_3)$ which is total external-external cordon crossings for all stations (terms previously defined)

IV Compute VE_{in} as $Y_2 \quad V_{ij}/\sum_{i=1}^{m} V_{ij}$

V Compute VI_{in} as $V_{in} - VE_{in}$

VI Estimate EC_n and ES_n from employment forecasts

VII. Compute VIC_{in} as $VI_{in} \quad EC_n/ES_n$

From the use of one of the procedures noted above, the contribution of external traffic to the corridor traffic can be estimated

Procedure-Internal

This element of the methodology requires that the amount of traffic that is internal-internal be separated from the total, and a growth factor is established which would best represent the change anticipated Corridors are established which are radial and CBD oriented These corridors serve as analysis units

An essential part of the corridor method of forecasting internal travel patterns is the development of an appropriate growth factor for each corridor This factor must be representative of all the activities in the corridor Many corridors contain dwelling units, employment centers and shopping areas as well as recreational facilities, etc All of these types of land uses have different trip-generating characteristics Therefore, it was necessary to weigh the relative trip attractiveness of the various land uses

A measurable parameter was required to indicate each trip purpose A criterion of selection was that these parameters be obtained easily for the present year by corridor and be easily projected to some future year The corridor growth method requires land use forecasts that can provide future estimates of these parameters

Previous research results indicate that three parameters were sufficient Total employees were used for work trips, business trips and any other trips to places of employment Retail employees were used for shopping trips and social-recreational trips to restaurants and taverns Dwelling units were used for trips to home and other trips to residential areas The percentage of total trips that was considered to be measured by each parameter is given as total employees - 40 percent, retail employees - 15 percent, and dwelling units - 45 percent The exact percentages are, of course, not known The above values are believed to be reasonable A study of O and D study data from similar size cities should help determine what percentages should be used in any specific city

The above percentages would be used to establish relative trip production rates for the three parameters for this method This can be accomplished by determining the total quantity of each parameter in the study area and

then dividing the percentage by this total. The trip rate if the study area contained 20,000 employees would be 0 40/20,000 or $2\ 0 \times 10^{-5}$ The 10^{-5} could be dropped for all parameters

The procedure proposed for developing a growth rate for each corridor using the relative trip rates would be as follows

1 Multiply the relative trip rates by the quantity of each appropriate parameter in the base year and add the three products

2 Repeat step 1 using the future quantities of the three parameters

3. The ratio of the two sums is the growth factor for that corridor.

Demonstration

The corridor analysis was demonstrated for application to six Tennessee cities and the cordon check results are in Table G-1

The smallest city is Lawrenceburg, the county seat of Lawrence County It is located 78 miles southwest of Nashville at the junction of U S Route 43 (also State Route 6) and U S Route 64 (State Route 15) The larger of the economic land uses are manufacturing and commercial In 1967, a twenty-percent home-interview survey was made as well as an external cordon survey

The City of Cookeville is the county seat of Putnam County and is approximately 70 miles east of Nashville and 110 miles west of Knoxville The Cookeville study area, which also includes the City of Algood is served in the east-west direction by Interstate 40 and State Route 24 (U S Route 70) and in the north-south direction by State Routes 135, 136 and 42 The study area population during the study year (1966) was 15,400 The study area contains Tennessee Technological University which is considered as a major employer Only an external cordon study was performed in Cookeville

The City of Greeneville serves the agricultural market area of Greene

TABLE G-1

External Cordon Station Check for 1973 ADT

Study Area and Station Number		Forecast Volume	Actual Volume	Error ADT
Lawrenceburg	24	5250	7770	-2520
	25	250	----	250
	26	750	2370	-1620
	27	250	380	-130
	28	3190	4410	-1220
	29	125	--	125
	30	125	1690	-1565
	31	936	--	936
	32	125	--	125
	33	5380	6870	-1490
	34	500	--	500
	35	--	--	--
	36	125	--	125
	37	1440	2030	-590
	38	310	410	-100
	39	2630	2920	-290
	40	1625	2600	-975
Cookeville	59	1495	1360	135
	60	339	--	339
	61	4262	3880	382
	62	340	300	40
	63	530	--	530
	64	1228	1190	38
	65	448	1030	-582
	66	6527	5210	1317
	67	1036	1910	-874
	68	1643	550	1093
	69	4484	4610	-126
	70	992	1630	-638
	71	3478	2860	618
(Interstate)	72	5550	13610	8060
(Interstate)	73	7918	18220	10302
Greeneville	39	11200	13700	-2500
	40	1730	1860	-130
	41	2860	3010	-150
	42	3080	3200	-120
	43	760	6320	-5560
	44	9530	10490	-960
	45	4050	4580	-530
	46	865	2170	-1305
	47	565	--	565
	48	530	--	530

TABLE G-1 (Continued)

Study Area and Station Number		Forecast Volume	Actual Volume	Error ADT
Greeneville (Continued)	49	4000	3640	360
	50	555	--	555
	51	2670	2700	-30
	52	1580	1480	100
Elizabethton	37	12043	13740	-1697
	38	--	--	--
	39	--	110	-110
	40	1785	1330	455
	41	--	--	--
	42	3380	5100	-1720
	43	--	--	--
	44	--	--	--
	45	--	--	--
	46	3772	3100	672
	47	1404	790	614
	48	571	--	571
	49	--	--	--
	50	8651	9380	-729
	51	--	--	--
	52	1404	930	474
	53	524	--	524
	54	5605	5810	-205
Clarksville (Interstate)	43	25830	28360	-2530
	44	882	--	882
	45	5292	3470	1822
	46	882	480	402
(Interstate)	47	8820	6820	2000
	48	3528	2520	1008
	49	4284	6820	-2536
	50	8316	7910	406
	51	--	--	--
	52	1890	1300	590
	53	1386	2690	-1304
Maryville-Alcoa (Airport Road)	79	23035	30550	-7515
	80	6312	4510	1802
	81	1120	490	630
	82	2198	2930	-732
	83	1717	880	837
	84	955	280	675
	85	6274	6960	-686
	86	777	930	-153
	87	690	250	440

TABLE G-1 (Continued)

Study Area and Station Number		Forecast Volume	Actual Volume	Error ADT
Maryville-Alcoa (Continued)	88	1173	--	1173
	89	906	820	+86
	90	952	1980	-1028
	91	13036	9340	3696
	92	2557	1740	817
	93	2655	1640	1015
	94	1825	950	875
	95	1804	2850	-1046

County The largest land use other than for residential is for manufacturing The study area population in 1968 was approximately 18,500 Greeneville, the county seat of Greene County, is located approximately 60 miles northeast of Knoxville and 36 miles southwest of Johnson City North-south traffic is serviced by State Routes 70 and 34 The east-west traffic uses portions of State Routes 93, 107 and 35 In addition to the external cordon study, a twenty-percent home-interview survey was made

Elizabethton, the county seat of Carter County, is located 108 miles east of Knoxville In 1968, the study area population was 19,518 The study area is served by State Route 37 in a north-south direction and State Routes 91 and 67 in the east-west direction In addition to an external cordon study of over 14,000 roadside interviews, a twenty-percent home-interview was conducted The greatest amount of non-residential land use was devoted to commercial and manufacturing uses

The Clarksville study area is located near the center of Montgomery County and nine miles south of the Kentucky State line and 42 miles northwest of Nashville The area is serviced by State Route 12, 48 and 13 in the north-south direction and by State Route 76 in the east-west direction The City serves as county seat and in the study year, 1965, the population was 37,900. Although the City served as an agricultural center for tobacco and livestock, there has been increased industrial development since the study year. In addition, Clarksville serves as home to Austin Peay State University and to Fort Campbell Air Force Base The survey consisted of an external cordon and a home interview of 5 5 percent of the dwelling units

In 1964 the Maryville-Alcoa Study was performed and at that time the population was approximately 41,000 Both communities are located in Blount County. The larger land area users include Alcoa Corporation, the Knoxville

Airport and Maryville College In this area there is no single central business district for the entire area Maryville which serves as county seat has a typical CBD but Alcoa does not An external cordon survey was made in addition to a twenty-percent home interview to develop internal-internal travel patterns In contrast to the other Tennessee cities studies, this study area is more likely to be considered as part of a larger metropolitan survey area

<u>Application of Methodology</u> In each of the above noted cities there were external cordon studies for a previous study year which would be covered by either procedure one or two noted earlier In each of the study cities, a test of the growth factor on external trips was made In general, the number of trips forecasted for the present year (1973) agreed within 2000 vehicles per day at the external cordon stations For Lawrenceburg only station number 24 of the seventeen external cordon stations had a 1973 volume difference greater than 2000 (2520) The growth factor based upon the change in vehicle registrations in Lawrence County from 1967 to 1973 was 1.25 When the ADTs for 1967 were taken from the State Traffic Volume Map the greatest variation occurred at Station 24, but the difference was less than 2000 vehicles per day

The Cookeville Study area had thirteen external cordon stations plus two more that existed on the Interstate 40 The growth factor of 1 48 was based upon the vehicle registration change from 1966 to 1973 for Putnam County. All thirteen stations were within the stated check value and the highest difference was approximately 1300 ADT The two cordon stations on Interstate 40 were underestimated by 8,000 to 10,000 vehicles, but it should be noted that the corridor method was not intended for this specific use

Of Greeneville's fourteen cordon stations used in the 1968 study, only two did not check within 2000 daily vehicles when compared with the 1973 ADT. Stations 39 and 43 were underforecasted and both of these stations are extremeties of a downtown bypass Station 39 which serves the east-north corridor is assisted by station 40, but together the forecast is off by only approximately 2600 vehicles

Elizabethton's cordon study performed in 1968 utilized 18 stations All stations met the criterion when traffic was updated from 1968 to 1973

The Clarksville Study area was bounded by eleven cordon stations The 1973 traffic was forecasted by applying a growth factor based upon an increase in county vehicle registrations Three of the eleven stations were not within the 2000 limit of daily vehicles Station 43 in the north and station 47 in the south are off by 2530 and 2000 respectively, but some of this movement is due to the special generator (Fort Campbell, Kentucky) and that corridor will be supplemented by Interstate 24

The Maryville-Alcoa Study utilized seventeen external cordon stations A forecast of externals at each station was made to update ADTs from the 1964 study year Two stations exceeded the check by a daily volume of 2000 Station 91 was forecasted to be at a higher estimate and station 79 has actual volumes in excess of the amount forecasted by 7500+ for 1973 This station is on U S 129 which is the access route from the Knoxville Metropolitan Area to Knoxville Municipal Airport A more logical growth factor for this station might be the change in enplaned passengers at the airport

In summary, the approach based on vehicle registration growth, when tested on six Tennessee cities, provided reasonable estimates of external traffic for the present or test year (1973) These cities used 92 cordon

stations and only ten failed the criterion of 2000 daily vehicles Of the ten stations, two stations serve traffic to special generators and two stations would be significantly affected by Interstate openings

Although the corridor method proved adequate for a new cordon study, a test was made of the models presented for use by the Jones report Even though the criterion check was satisfied in all but a few cases, the regression models were computed with data from each of the six Tennessee cities The total externals for each study area and the total external-externals were calculated and the results are shown in Table G-2

As can be noted from the Table, the regression model for predicting total externals for all external cordon stations in the study area was erratic The model estimates for the study year was poor for Lawrenceburg when compared with the actual study year ADT (3,290 vs 18,300) But for other areas, the estimates were judged reasonable by the researchers The comparisons are Cookeville, (20,520 vs 18,110), Greeneville, (28,630 vs 34,100), Elizabethton, (32,910 vs 32,890), Clarksville, (33,075 vs 34,715) and Maryville-Alcoa, (41,890 vs 34,619)

Based upon forecasts of the independent variables, the total externals were computed for 1973 and compared with the actual Tennessee DOT reported ADTs The study area comparisons of equated versus actual are Lawrenceburg, (6320-31,450), Cookeville, (24,100-24,530), Greeneville, (29,440-53,150), Elizabethton, (35,110-40,290), Clarksville, (35,030-41,741), and Maryville-Alcoa, (45,080-58,577) It should be noted the population of Lawrenceburg was outside the range of cities used by Jones to evolve the models

The regression model which was tested for computing the total of all external-externals proved inadequate Outside of Greeneville and Elizabethon

TABLE G-2

COMPARISON OF JONES REGRESSION MODEL (53) RESULTS WITH ACTUAL GROUND COUNTS

Study Area	No. of Stas.	Estimated Total External	Actual Total External	Estimated Total External-Externals	Actual Total External-Externals
Lawrenceburg	17				
1967		3,290	18,300	5,730	
1973		6,320	31,450	5,850	
Cookeville	13				
1966		20,520	18,110 27,210*	7,610	
1973		24,100	24,530 56,360*	8,700	
Greeneville	14				
1968		28,630	34,100	8,120	10,058
1973		29,440	53,150	8,240	12,975
Elizabethton	18				
1968		32,910	32,890	14,760	9,297
1973		35,110	40,290	14,830	11,063
Clarksville	11				
1965		33,070	34,715 48,500*	9,040	
1973		35,030	41,741 60,370*	9,530	
Maryville-Alcoa	17				
1964		41,890	34,619 38,849*	15,900	
1973		45,080	58,577 61,700*	17,410	

* Includes Interstate or Special Generator Traffic

studies, the actual traffic which was external-external for 1973 was difficult to determine Only Greeneville and Elizabethton values are reported

In accordance with the previously identified methodology, corridor volumes were computed at the intersection of each radial corridor at the inner or CBD cordon line In addition a second check was made at the mid-point or midway between the previous point and the external cordon station These values with the specific corridor error expressed as the difference between the estimated 1973 traffic and the actual ADT The comparisons are noted in Tables G-3 and G-4

In Lawrenceburg the check at the CBD was acceptable at three of the four corridor points and at the midpoint it was acceptable at five of the six corridor points Results for Cookeville indicate that three of the five corridors are acceptable near the CBD points and four of the seven checks at the midpoints

The check at the CBD points was satisfactory for five of the six corridors and seven of the nine for the midpoints for the Greeneville area Elizabethton only had two of the four as acceptable at CBD and at the mid-points

Clarksville's results were the poorest of the six test cities Only one out of four check points for CBD and two out of five for midpoints were acceptable Maryville-Alcoa had three out of seven at the CBD and seven out of nine at the midpoints as acceptable levels

No effort was expended on forecasting 1985 or other year levels at these check points It should be noted that these test cities do not specifically meet all the conditions specified by Jones For example, Jones suggested that corridors or transportation facilities that serve major generators (Knoxville Airport) be treated separately

TABLE G-3

MIDPOINT CORRIDOR VOLUMES

Study Area	Corridor No	1973 Volumes Estimated	Actual	Corridor Error
Lawrenceburg	1	5322	7770	-2448
	2	4642	4410	231
	3,4	5422	6870	-1448
	5	5378	6820	-1442
	6	1958	2600	-642
	7	1567	2370	-803
Cookeville	1	1635	2290	-665
	2	8473	16110	-7637
	3	4802	8870	-4068
	4	11401	12830	-1439
	5	2446	6260	-3814
	6	7501	7100	401
	7	3355	2860	950
Greeneville	1	7060	7090	-30
	2	5113	6140	-1027
	3	11695	15560	-3865
	4	2336	3010	-674
	5	3232	3200	32
	6	7761	6320	1441
	7	11804	14330	-2526
	8	1562	2370	-808
	9	1123	1330	-207
Elizabethton	1	18132	18730	-598
	2	5995	7820	-1825
	3	3675	7550	-3875
	4	10086	13360	-3274
Clarksville	1	24764	29450	-4686
	2	11776	13130	-1354
	3	17574	20500	-2926
	4	8824	14720	5896
	5	9811	7910	1901
Maryville-Alcoa	1	2935	3360	-426
	2	14530	15270	-740
	3	6299	5440	859
	4	5731	3990	1741
	5	20365	23790	-3425
	6	12266	12950	-684
	7	2995	5300	-2305
	8	8738	7950	788
	9	2727	2300	427

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TABLE G-4

INNER POINT CORRIDOR VOLUMES

Study Area	Corridor No	1973 Volumes Estimated	Actual	Corridor Error
Lawrenceburg	1,7	7082	10470	-3388
	2	5762	5440	322
	3,4	5422	6870	-1448
	5,6	5623	7520	-1897
Cookeville	1,2	15659	16580	-921
	3	6374	7030	-656
	4	11921	23420	-12167
	5,6	13646	8810	4836
	7	7002	6500	502
Greeneville	1	--	--	--
	2	13552	11950	1602
	3	10230	7000	3230
	4	1736	--	--
	5	6496	6530	134
	6,7	15163	15300	-37
	8	5834	4800	1034
	9	5119	4800	-319
Elizabethton	1	20561	21300(E)	-739
	2	7295	10000	-3444
	3	19897	16150	3747
	4	11124	12300(E)	-1176
Clarksville	1,5	19314	16850	2464
	2	8549	9460	-3399
	3	14590	13320	1270
	4	6845	4600	2245
Maryville-Alcoa	1	4140	4730	-590
	2,3	20536	15860	4676
	4	19912	17520	2392
	5	19980	20250	-270
	6	12266	11130	1136
	7,8	14001	19930	-5929
	9	8221	2340	5881

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A more severe check was used to check the corridor technique traffic forecasts against ground counts than for other portions of this research Simplistic techniques are generally suspect when the professionals have been conditioned to expect very elaborate and lengthy modeling chains The advent of computers with very extensive memory cores have further accented these expectations In spite of the above, the demonstration showed that the corridor growth model satisfactorily addresses the issues of either a corridor arterial congestion or bypass need Other similar type models may also be just as appropriate Each state may wish to generate a statewide forecasting model or its own regression (or other type of simplistic model) equations Data requirements for the specific model tested are readily available to state DOT planning agencies

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The National Academy of Sciences was established by a congressional act of incorporation signed by President Abraham Lincoln on March 3, 1863, to further science and its use for the general welfare by bringing together the most qualified individuals to deal with scientific and technological problems of broad significance. It is a private, honorary organization of more than 1,000 scientists elected on the basis of outstanding contributions to knowledge and is supported by private and public funds. Under the terms of its congressional charter, the Academy is called upon to act as an official—yet independent—advisor to the federal government in any matter of science and technology, although it is not a government agency and its activities are not limited to those on behalf of the government.

To share in the tasks of furthering science and engineering and of advising the federal government, the National Academy of Engineering was established on December 5, 1964, under the authority of the act of incorporation of the National Academy of Sciences. Its advisory activities are closely coordinated with those of the National Academy of Sciences, but it is independent and autonomous in its organization and election of members.

TRANSPORTATION RESEARCH BOARD
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ADDRESS CORRECTION REQUESTED