NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

NCHRP Report 423A

Land Use Impacts of Transportation: A Guidebook

Transportation Research Board
National Research Council

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Land Use Impacts of Transportation: A Guidebook

PARSONS BRINCKERHOFF QUADE & DOUGLAS, INC.
Portland, OR

Subject Areas

Planning, Administration, and Environment
Aviation
Public Transit
Rail
Freight Transportation
Marine Transportation

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

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Each report is reviewed and accepted for publication by the technical committee according to procedures established and monitored by the Transportation Research Board Executive Committee and the Governing Board of the National Research Council.

To save time and money in disseminating the research findings, the report is essentially the original text as submitted by the research agency. This report has not been edited by TRB.

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FOREWORD

By Staff
Transportation Research Board

This report contains the results of research into the land use implications of transportation investments and decisions. Presented as a guidebook, it provides reference information on land use planning and its integration into the multimodal transportation planning process. The guidebook is intended to improve the practice of land use forecasting and to provide perspectives on the tools and procedures available to practitioners in evaluating the land use impacts of transportation services and improvements. The guidebook should be especially valuable to state departments of transportation (DOTs), metropolitan planning organizations (MPOs), and local transportation planners as well as other practitioners concerned with assessing transportation impacts on land use. The guidebook will also be a useful educational resource into the concepts, tools, and procedures currently employed to integrate transportation planning and land use planning.

During the 1990s, federal transportation policy, as embodied in the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) and the Transportation Equity Act for the 21st Century (TEA-21), placed a high priority on integrating and coordinating transportation decision making with land use objectives, especially within metropolitan areas. There has been a growing expectation that transportation system services and improvements should contribute to the achievement of local, regional, and statewide growth and land use plans and objectives. As a result, transportation planning at both the statewide and MPO levels requires that the impacts of investment decisions on land use patterns be considered. Transportation policies and their relationship to land use planning have significantly changed and continue to evolve in the post-Interstate era. Thus, there is a need to provide land use impact information and analysis tools to enable transportation decision makers to fully consider land use impacts in their plans and programs.

From a transportation management perspective, the effectiveness of capacity improvements, travel demand management initiatives, the use of alternative modes, and mobility-enhancing investment strategies depends, in part, on land use development patterns. Better coordination of regional transportation planning with local land use planning can help to optimize the timing of investments, identify transportation facilities and services needed to support land uses, and coordinate the nature and pattern of land development with available transportation services. As a result, it is essential that these intergovernmental coordination activities be supported by accurate, timely, consistent, and cost-effective analytical processes and procedures.

Under Project 8-32(3), "Integration of Land Use Planning with Multimodal Transportation Planning," Parsons Brinckerhoff Quade & Douglas, Inc., of Portland, Oregon, developed guidance for use by planning practitioners and other transportation decision makers based on the relationship between transportation facilities and services

and land use on a regional and project-level basis. This guidebook discusses the following issues of importance to practitioners: (1) what is currently known about transportation and its relationship with land use; (2) what analytical tools are available to MPOs and state DOTs to describe how transportation investments and strategies influence land use; (3) a framework to better understand urban development and growth; and (4) some possible processes for base case forecasts and land use impact or policy impact assessments.

In addition to this guidebook, the project will produce UrbanSim, an integrated land use model for metropolitan areas, and companion user documentation for the model, which will be published as *NCHRP Report 423B*. Panel review of the UrbanSim software and the user documentation and final publication is to be completed by mid-1999.

CONTENTS

AUTHOR ACKNOWLEDGMENTS

Judy S. Davis of Parsons Brinckerhoff is the principal author of this report. Genevieve Giuliano of the University of Southern California wrote the initial version of the literature review which is excerpted and summarized in Chapter 1. Paul Waddell of Urban Analytics wrote the material on formal land use models in Chapter 2. Robert Cervero from the University of California at Berkeley and Paul Waddell provided helpful reviews of earlier drafts of this report. Samuel Seskin of Parsons Brinckerhoff is the Principal Investigator for the project.

EXECUTIVE SUMMARY

This Guidebook has two basic objectives:

1. To improve the practice of land use forecasts.
2. To identify tools and procedures for realistically evaluating the land use impacts of transportation investments and policies.

These improvements in best practices are needed because of the transportation planning requirements of ISTEA, the need to evaluate the land use impacts of transportation investments in MIS/EIS processes, and the many policy questions about the interrelationships of transportation and land use that MPOs and DOTs have been asked.

The Guidebook meets these objectives in a series of steps. In Chapter 1, we reviewed what is known about the relationship between land use and transportation. In Chapter 2, we evaluated the analytical tools that are currently available for these tasks. In Chapter 3, we outlined a behavioral framework for understanding the process of urban growth and development. In Chapter 4, we described processes for doing base case forecasts and land use impact assessments using familiar tools but drawing upon the behavioral framework. This chapter summarizes each of these steps and identifies the key lessons learned.

The Guidebook is not the last word on how to evaluate transportation-land use interactions. Because every region and every transportation project has its unique characteristics, the guidebook cannot provide a definitive set of steps that will answer all questions. Rather the guidebook is a "guide" to a variety of strategies that can be used. The particular choice of approaches will depend upon the scope and scale of the required analysis, the available data, the budget, and the skills of the personnel doing the analysis. We hope that the guidebook will provide MPOs and DOTs with improved ways to think through land use analysis and this will produce better results.

In addition to producing this Guidebook, this NCHRP project is documenting and making available UrbanSim, an integrated land use model for metropolitan areas. This will add another tool to those described in the Guidebook. This model is based on the same behavioral framework presented in this guidebook. There are components reflecting the behavior of households, businesses, developers, and government. This model draws on random utility theory for its theoretical foundation and builds on the well-developed basis of disaggregate choice modeling now widely employed in models of mode choice. In extending the discrete choice modeling framework to households and businesses, we have developed a model framework that is intuitive and transparent to the user, as well as theoretically sound and computationally tractable.

WHAT DO WE KNOW ABOUT TRANSPORTATION AND LAND USE?

The review of the literature in Chapter 1 pointed out that accessibility is the key to understanding the link between transportation and land use. When a transportation project or policy makes it easier to access certain locations, these places can become attractive to

more or different types of development. However, improving accessibility does not guarantee that land use changes will follow. The type, amount, and timing of land use changes will also depend upon the state of the regional economy, the current levels of accessibility, the types of development permitted by land use regulations, the availability of services such as sewer and water, the desirability of the area for development, and other factors. Land use changes can also vary because travelers have many options about the ways they can change their behavior in response to a change in the transportation network or the cost of travel. They can adjust the timing, route, or mode of trips as well as change the locations where they live, work, or shop.

We do know that the type and scope of the transportation project or policy change can affect the range of potential outcomes. Larger scale transportation projects, like adding capacity to freeways, are more likely to produce measurable land use changes than small scale projects, like changing signalization on arterials. Similarly, policies that make large changes in the cost or ease of travel are likely to have greater land use impacts than policies that make minor adjustments. Highway improvements tend to produce more spatially diffuse impacts than transit improvements because more types of travelers are affected and the benefits are dispersed by the street systems connected to the highway.

WHAT ANALYTICAL TOOLS DO MPOS AND DOTS CURRENTLY USE?

MPOs and DOTs currently use a variety of tools for land use forecasts and land use impact assessment depending upon their size, the questions they have been asked to answer, and their interests in advancing the practice. In Chapter 2, we identified eight basic types of analytical procedures or tools currently available and in use. These are described below along with their strengths and weaknesses.

Use Of Comprehensive Plans and Other Land Use Regulations

It is important to understand the land use regulations that influence where and what type of development can occur. However, current practice tends to rely too heavily on public policy as the primary shaper of urban form. For political reasons, many regions produce "plancasts" that assume that development will occur where land use policies and regulations direct that growth. When using comprehensive plans in forecasting and impact assessment, it is important to evaluate realistically the effectiveness of these tools at shaping growth and to consider how the land market might produce different outcomes from those described in policy.

Qualitative Methods that Tap Expert Knowledge

MPOs and DOTs use a variety of qualitative methods to understand the complexity of urban development. These tools can be used as the primary method of analysis or in conjunction with other tools. Panels of experts, Delphi's, interviews, surveys, and case studies are qualitative techniques that rely on the knowledge and skills of one or more experts to determine where growth is likely to occur. These methods can combine understanding of the theory of urban development, empirical knowledge of transportation-land use interactions, and understanding of local situations.

Qualitative methods are not substitutes for data collection. They should be based on a sound understanding of existing conditions and trends, but this information is analyzed by experts without statistical techniques or models to estimate what the future will hold. The results of qualitative approaches depend upon the breadth and depth of knowledge of the experts involved in the process.

Allocation Rules for Assigning Population and Jobs to Zones

Allocation rules use simple trend extrapolations (e.g. fast growing areas will continue to grow rapidly) or simple measures of accessibility and other attractiveness factors to allocate expected growth to different zones. They are easy to use and do not require extensive data. They work best in typical situations and for widespread activities like retailing and residential development. They must be supplemented with other methods, such as qualitative analysis, to decide how to handle issues such as the location of large employers, changes in household and business locational preferences, and other factors that might cause future development to differ from past patterns. All assumptions must be made explicit.

Decision Rules

Many land use forecasting or impact assessments require some simple decision rules that quantify certain relationships between transportation and land use. These rules are based on empirical evidence from the region or from other locations with similar projects. Decision rules are often needed because the process of urban development is too complex to analyze in its full detail. They are typically used in conjunction with other process such as GIS analysis of developable land. Especially when using decision rules from another location, the context in where they were developed must be carefully compared with the study area to determine whether there are any critical differences in these places that might invalidate the use of the rule.

Statistical Methods

Multiple linear regression and discrete choice models are two statistical methods for evaluating the relative roles of multiple factors in shaping land use patterns. Because they consider the effects of multiple variables, they can represent more of the complexity of urban systems than simple allocation or decision rules, provided the appropriate variables are included in the analysis. These methods require considerable technical skills and large data sets to provide accurate results. Like other methods that rely on recent local data, they assume that past trends will continue into the future. These models provide information about what happens "on average."

Geographic Information Systems

Increasingly MPOs and DOTs are using GIS to manage, analyze, and map geographic relationships. GIS can be used in conjunction with any of the other tools to help understand trends and development opportunities and to sort out the complex behavior and interactions in the land market. While the cost and difficulties of using GIS have been

declining as new PC-based systems have been developed, it still requires considerable staff time to set up and maintain the databases for an effective GIS.

Regional Economic Models

Regional economic models simulate an area's economy and are useful for estimating regional population and employment growth totals that are needed as an input to other forecasting processes. They can also be used in intermetropolitan impact assessments to assign growth to individual counties for large geographic scale projects. Some models predict only job growth; others include both job and population growth. A number of models are commercially available and others have been developed for particular regions by MPOs, DOTs, and other state agencies. It is important to understand the assumptions of the regional economic model when interpreting the output.

Formal Land Use Models

Chapter 2 reviewed the theory, requirements for use, outputs, and characteristics of the following models (listed with their developers):

DRAM/EMPAL	Stephen H. Putman
MEPLAN	Marcial Echenique
TRANUS	Tomas de la Barra
METROSIM	Alex Anas
HLFM II+	Alan J. Horowitz
LUTRIM	William Mann
CUF	John Landis

Experience with these models varies. Some have been developed recently, such as the CUF model. Others have been used by MPOs and DOTs with DRAM/EMPAL having the most widespread use among large MPOs. TRANUS and MEPLAN have been applied in South America and Europe, but the first United States applications of TRANUS are currently being developed in Sacramento, California, Baltimore, Maryland and in Oregon.

Users of formal land use models are concerned about how difficult they are to use; their high costs in time, data, and consulting needs; the accuracy of the results; the lack of integration with transportation models; and insufficient documentation. The most widely used of these models were developed to answer different questions than those that MPOs and DOTs must now answer. DRAM/EMPAL and HLFM II+ are based on Lowry gravity models that assume that accessibility is the key concept in locational choice. They do not adequately represent other factors that influence the locational choices of households and firms.

Some of the models such as CUF and TRANUS have been designed for ease of policy analysis. The experience with these models is, however, limited with the first full-scale applications of these models in the United States currently underway.

In addition, to these models, a number of MPOs and DOTs have developed sketch planning models that are simpler than some of the commercially available models, but also

incorporate specific regional characteristics. Unfortunately, these efforts are not well documented, preventing regions from easily learning from each other's experiences.

A FRAMEWORK FOR UNDERSTANDING THE LAND MARKET

Chapter 3 outlined a behavioral framework for understanding urban development and growth. This chapter focused on the four main types of actors in the development process, the choices they make, and the factors that influence their choices. These actors include households, firms, developers, and governments.

Households seek housing that satisfies their needs and preferences and fits within their budgets. Accessibility is only one of many factors that households consider in making these choices. Since the majority of trips are made for non-work reasons, households consider access to stores, services, friends, and other destinations besides work when choosing housing. Many households are more concerned about affordability than with access to jobs, provided they are not too distant from the current jobs of household members. For the households who have a large set of affordable choices, other factors such as school quality, neighborhood amenities, and the type of people living in the community can play a decisive role in their final choices.

Firms seek locations where they can make a profit. Different types of firms place different emphases on access to workers, customers, suppliers, and others. Like households, firms must consider multiple factors including accessibility and affordability in making location decisions. The final site selection may hinge on factors such as differences in local tax rates, the cost and availability of services, and the prestige of the location.

Developers balance the needs and preferences of potential customers with the costs of developing in different locations when deciding where and what to build. They consider both the factors that influence household and locational choices, such as preferred locations and site characteristics, and the costs and land supply limitations, if any, due to governmental policies.

Government policies influence the supply of land available for development and affect the cost of development. The supply of land available for different types of development is constrained by zoning, environmental regulations, and the provision of water, sewer, and other infrastructure. The cost of development can be lowered with economic development incentives. The cost of development can increase with the cost or uncertainty of obtaining permits, of infrastructure extensions, or of meeting requirements for parking or design standards.

These players interact in a market where the price for land acts as a sorting mechanism to determine the type and location of development. Households, businesses, and developers are willing to pay for land up to the amount they anticipate they will receive in future benefits. Some stand to benefit from certain locations more than others and will outbid all others for these desirable sites.

DOING LAND USE ANALYSIS

Chapter 4 describes similar processes for doing base case forecasts and land use impact or policy impact assessments. The steps are outlined in Table E-1. Both processes require understanding the existing transportation and land development patterns, making assumptions about the policy framework that will guide the process, estimating the amount of growth expected during the planning period in the study area, inventorying land that might be developed and any physical and regulatory constraints on that development, and assigning the expected growth in households and jobs to specific locations. The key difference between the processes is that an impact or policy assessment requires estimates of the ways that accessibility and travel behavior will change because of the investments or policy changes. In addition, an impact or policy assessment requires a comparison not only with existing conditions, but with the quantity, type, and location of future growth that would occur without the projects or policies.

Table E-1
Comparison of Steps in Base Case Forecasts and Impact or Policy Assessments

Base Case Forecast	Impact or Policy Assessment
1. Understand existing conditions and trends	1. Understand existing conditions and trends
2. Establish policy assumptions	2. Establish policy assumptions
	3. Measure the transportation outcomes with and without the projects or policy changes
3. Estimate regional population and employment growth	4. Estimate total study area population and employment growth with and without project
4. Inventory land with development potential	5. Inventory land with development potential
5. Assign population and employment to specific locations	6. Estimate how the project will change the location and type development within the study area from what would occur anyway.

The behavioral framework can be incorporated into these steps using a variety of land use analysis tools as summarized in Table E-2. Impact or policy assessments also require the use of travel demand models in Step 3 to provide estimates of the changes in transportation demand that transportation investments or policies will produce.

Table E-2
Summary of Analytical Tools and Their Relationship to the Behavioral Framework

Analytical Tool	Relationship To The Behavioral Framework	Use In Forecasting Or Impact Assessment
Qualitative methods	Means of gathering and analyzing information on local actors, their choices, and their motivations. Way to estimate future locational choices based on understanding of development processes in the region.	Understand existing conditions. Establish policy assumptions. Estimate total population and employment growth. Inventory of developable land. Assign households and jobs to zones.
Allocation rules	When based on local data, they reveal typical outcomes of the land market for widespread activities like residential development and retailing.	Assign households and jobs to zones
Decision rules	When based on local data or empirical evidence from similar regions, they reveal relationships that are outcomes of the land market.	Inventory of developable land. Assign households and jobs to zones.
Statistical models	By estimating the relative effects of multiple factors on locational choices, they clarify the role of these factors in locational decision-making.	Understand existing conditions. Estimate total population and employment growth. Assign households and jobs to zones
Geographic Information System	Analyze and map the relationships between land supply, constraints and opportunities for development, and choices of households and firms.	Understand existing conditions. Inventory of developable land. Assign households and jobs to zones.
Regional Economic Models	Simulate the economy to estimate county or regional population and employment growth.	Estimate total population and employment growth.
Formal land use models	Only models that incorporate the supply and demand for land and the choices of the key actors in the market fit within the behavioral framework.	Assign households and jobs to zones.

MAJOR LESSONS FROM THE GUIDEBOOK

The following summarizes the key lessons of this Guidebook about how to do land use forecasts and impact assessments.

Think through the process of development. How do developers decide what and where to build? Where do households of various types want to live? Where do firms want to locate? How do public policies restrict or expand the choices available?

Improve understanding of both the general process of development and the particular players in your region. General patterns can tell a lot. Households base their locational choices on the same factors in most parts of the country. Developers of national franchises consider a standard set of criteria. But regions do differ in the types of developers who work there, in the nature of households and firms, and in the role of public policies. It is equally important to improve understanding of these differences from general patterns.

Incrementally improve the land use forecasting and impact assessment process. Develop a plan to acquire over time the data and skills needed to better understand and analyze the process of development.

Develop measures of accessibility that reflect the complex decision-making of households and firms. Households may be considering both the current and future job locations of household members, access to services such as daycare facilities, the convenience of shopping, the location of cultural and recreational opportunities, and the homes of their friends and relatives when deciding where to locate. Likewise, consider the different accessibility needs of retailing, offices, and industry.

Recognize that affordability and other factors may be just as important as, or even more important, than accessibility. Most households and firms have budgets that limit their choices. If there are a wide variety of choices within their budgets, households and firms consider a wide variety of factors before making final locational choices.

Understand the potential and limitations of public policies for shaping the pattern of development. Zoning land for a particular type of development does not guarantee that that type of development will occur; neither do economic development incentives. However, when these policies work in concert with market forces, they can shape development.

Realistically evaluate local governments' approaches to public policies. Does development follow the designations in zoning or are changes readily made? Do local governments make it easy or difficult for development to occur through their permitting process, costs charged for fees and permits, and incentives offered?

Recognize that infill and redevelopment can accommodate a significant share of growth. Forecasts that assume all development occurs on vacant land will overestimate the demand for vacant land.

Involve both technical and policy people in the process. Every land use forecast and impact assessment includes making assumptions about the policies that will affect land uses. Every process uses analytical tools with inherent assumptions. Both policy makers and technical people should be involved in making these assumptions explicit. Agreeing on the assumptions should produce forecasts that are more credible.

Choose analytic techniques and tools that suit the data, the complexity of the problem, and the resources available. For example formal land use models require the most data and time, and generally suit analyses of a larger number of decisions, at a larger geographic scale. Qualitative methods suit smaller sites and projects, though they also may be applied to larger areas.

Document the process and use quality control procedures. Because the outcome of every analysis is unique and uncertain, it is important that participants choose and apply analytic techniques carefully. The credibility and accuracy of results will depend on such diligence.

1.0 INTRODUCTION

This guidebook provides practical suggestions to State Departments of Transportation (DOTs) and Metropolitan Planning Organizations (MPOs) on how to carry out the main types of land use analyses used in conjunction with transportation planning. The major types of analyses covered are:

1. Base case land use forecasts for use as inputs into travel demand modeling

2. Impact assessments of transportation projects such as the following:

   - Highway expansions and additions
   - Transit expansions and additions
   - Airport expansions
   - Intermodal freight facility expansions and additions

3. Impact assessments of the land use consequences of regional or statewide transportation plans containing multiple transportation projects.

4. Land use impact assessments of transportation policies, such as the following:

   - Transportation demand management
   - Intelligent transportation systems
   - Congestion pricing
   - Parking pricing and management

This guidebook is one of the two major products of NCHRP Project 8-32(3), "Integration of Land Use Planning with Multi-Modal Transportation Planning." The second product, under development, is a metropolitan land use forecasting model, described in Section 2.8.7 of this report. Completion of model development for NCHRP will occur in 1998.

1.1 ISTEA MANDATES GREATER ATTENTION TO TRANSPORTATION AND LAND USE RELATIONSHIPS

The most recent and significant mandate which has led to the need for this research project is contained in Section 134(f) and Section 135(c) of the Intermodal Surface Transportation Efficiency Act (ISTEA) legislation. Section 134 states,

> "In developing transportation planning plans and programs pursuant to this section, each metropolitan planning organization shall, at a minimum consider the following...
>
> 4. "The likely effect of transportation policy decisions on land use and development and the consistency of transportation plans and programs with the provision of all applicable short- and long-term land use and development plans."

Similarly, among the factors required for consideration in State Transportation Planning, Section 135(c) requires States to undertake a transportation planning process which considers...

> 14. "The effect of transportation decisions on land use and land development, including the need for consistency between transportation decision making and the provision of all applicable short-range and long-range land use and development plans."

1.2 OVERVIEW OF THE RELATIONSHIP BETWEEN TRANSPORTATION AND LAND USE

The concept of accessibility is the key to understanding how transportation and land use relate to one another. Transportation promotes spatial interaction between activities or land uses. This interaction is measured by accessibility, which reflects both the attractiveness of potential destinations and ease of reaching them (Handy, 1993). Accessibility includes the attractiveness of a place as an origin (what opportunities there are to reach other destinations) and as a destination (how easy it is to get there from all other origins). The pattern of land uses is important because it determines the opportunities or activities that are within range of a given place. The potential for interaction between any two places increases as the cost of movement between them--either in terms of money or time--decreases. Consequently, the structure and capacity of the transportation network affect the level of accessibility. Figure 1 illustrates this relationship between transportation and land use.

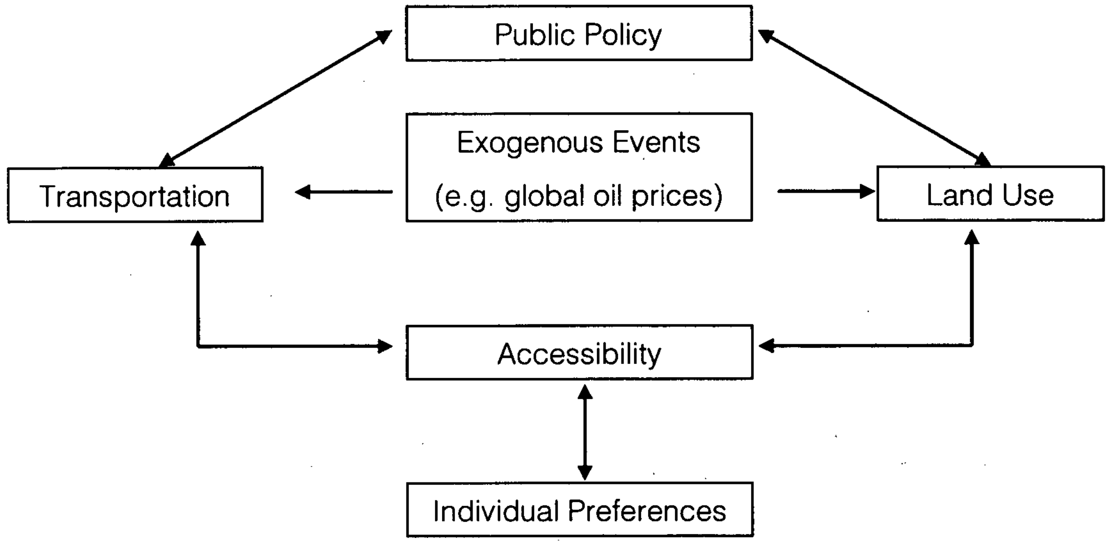
Figure 1: Accessibility Links Transportation and Land Use

Transportation ⟷ Accessibility ⟷ Land Use

The simple diagram in Figure 1 assumes that transportation and land use adjust to each other without the influence of other factors. However, in the real world, that is seldom the case. In the case of freeway construction, for example, land use policies must allow new development within the freeway corridor if the benefits of increased accessibility are to be realized. In addition, public policy makers must approve the project and allocate public funds for it to be built. Furthermore, the supply of both land uses and transportation can be affected by exogenous factors, such as the world price of oil or the cost of construction. A more detailed diagram adding these factors is shown in Figure 2.

The relationship between transportation and land use can thus be conceptualized as an interaction of the supply of and demand for accessibility that is further affected by public policies. The supply side considers the physical aspects of land use and transportation, while the demand side considers the preferences of individuals and firms. It should be noted from Figure 2 that preferences are not independent of public policies. In the given context of transportation-land use interaction, however, preferences are affected by public policies only through the effect of policies on accessibility.

Figure 2: Supply and Demand for Accessibility



A Critical Consideration: Travel Behavior

In order for a change in transportation to generate a significant shift in land use, the transportation change must affect accessibility enough to generate a change in land use. Consider the construction of a new freeway interchange. Locations in the vicinity of the interchange are made more accessible, and some shift in travel patterns occurs. As travelers make more trips to this location, development pressures intensify which leads to increased land values as competition for the sites rises, provided land use policies allow changes in land uses near the interchange. As new development occurs, this will cause additional shift in travel patterns. The magnitude of changes in land use depend upon a) how much accessibility is improved, b) the relative attractiveness of the locations near the transportation improvement, and c) the real estate market in the region.

Likewise, a land use change must also change accessibility significantly in order for there to be changes in travel behavior. For example, the opening of a new shopping center will shift shopping trip patterns. Customers who had previously shopped at other locations now frequent the new center. The degree to which customers shift (and therefore travel choices shift) depends upon a) the shopping center's location (how accessible it is to the shopping population) and b) its attractiveness relative to the other centers in the area. Will the opening of the center generate more travel? It is possible that some people will make more shopping trips, because the new center makes shopping more convenient, but it is also possible that some people will make fewer shopping trips, because the new center provides a larger number of shopping opportunities.

Note that the same principle can be applied to land use or transportation policies that do not deal with changes in capital structures. Raising parking prices can induce shifts from driving alone to ridesharing and transit use and, thereby, reduce the demand for parking. As parking demand declines, more intensive development can be accommodated. Given sufficient demand, higher density development will follow. On the other hand, if there are competing locations where the price of parking is lower, some development may shift to those locations, since travelers will prefer them.

The changes in these examples will be mediated by the marketplace for housing and commercial expansion. In a robust fast-growing economy, demand for new housing and commercial activities will be high. Under these conditions, the effects of accessibility changes will be much stronger than they are in a weak market.

Factors that Affect Transportation — Land Use Relationships

Relationships between transportation and land use exist within the larger context of metropolitan growth and urban structure. It is, therefore, useful to review the major historical trends in urban development patterns and regional growth.

Urban Development Trends

It is well known that metropolitan areas within the U.S. have been decentralizing throughout this century, in concert with transportation technology improvements. The streetcar systems and commuter rail lines of the turn of the century made it possible for population to spread out from the central city core and to live at increasing distances from the workplace (Warner, 1962; Fogelson, 1993; Mohl, 1985; Goldfield and Brownell, 1990). Decentralization accelerated with the adoption of the automobile and truck in the 1920's and 1930's, and has continued to this day (Muller, 1981, 1995; Lowry, 1988). With population and employment decentralizing, metropolitan development densities have declined.

A comprehensive discussion of the causes of decentralization is beyond the scope of this review, but it is useful to identify the major factors involved. Decentralization is not simply the result of the adoption of the automobile and truck, but rather of a convergence of economic trends and policy decisions. Rising incomes have allowed more households to own automobiles and to move to the suburbs. In addition, widespread use of the automobile was promoted by a massive public highway building program and regulatory policies that kept auto ownership and fuel prices low. Decentralization was promoted by federal tax and mortgage policies that made suburban residential development more economically attractive. Decentralization was further promoted by changing industrial technology that favored horizontal manufacturing structures and shifts to service-sector activities less reliant on central location. Political and cultural factors also played a role: political fragmentation of local government that enabled escape from urban social and fiscal problems; ethnic and racial segmentation; historical preferences for single family home ownership; and the tradition of private property rights.[1] Decentralization is also not unique to the U.S.. Metropolitan areas throughout the developed world are decentralizing as a result of rising household incomes, rising auto ownership rates, and structural economic shifts. These trends are expected to continue and perhaps even intensify as the shift to an information-based economy and globalization continue.

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[1]For a review, see Jackson, 1985; Muller, 1981.

Dominance of Private Auto

The decentralization process has been accompanied by growing reliance on personal modes of transportation. The 1990 census data show that throughout the U.S., people own more private vehicles, use them more frequently, drive more miles, and are more likely to drive alone than ever before. By 1990 there was a automobile for every 1.7 persons. If we include privately owned light trucks (minivans and compact trucks are in this category) in the figures, in 1990 there were 179.8 million private vehicles, 191.4 million persons of driving age, and 167 million licensed drivers.

The recent growth in vehicle travel has been far in excess of population or employment growth. Between 1983 and 1990, private vehicle miles traveled (VMT) increased 37 percent, while population increased by just four percent. Growth in VMT reflects increases in the number of trips, longer trips, more trips by private vehicle, and more driving alone (Vincent, Keyes and Reed, 1994). In contrast, public transit use has continued to lose market share, and now accounts for just two percent of all person trips and 5.5 percent of all journey-to-work trips, although there is great deal of variation from place to place (Hu and Young, 1993).

Context of Land Use and Transportation Decision-Making

Understanding the relationships between transportation and land use also requires an understanding of the context in which decisions are made. It is difficult to measure, predict, and coordinate transportation and land use because of differences in the parties making decisions, the types of organizations involved, and the time that it takes for effects to be seen. The public sector is a major provider of transportation infrastructure, but most land use investments are made by the private sector. Land policies are largely a responsibility of local governments while federal, state, and local governments determine transportation policies. Travel responses to land use and transportation system changes are seen much more quickly than land use responses.

Public vs. private decision-making. In the United States most land use investment decisions are made by individuals and firms within a local regulatory context. In contrast, most major transportation investments are made by governments, often involving multiple levels of government. Land owners in the U.S. traditionally have had the opportunity to develop their property to its "highest and best use." Intervention in the land market is justified only when significant externalities exist, such as in the case of incompatible land uses, or when damage to protected species is demonstrated. In contrast to Canada and most European countries, government controls over land use are quite limited in the U.S.

The public sector regulates land use through its zoning powers and building regulations. Regulatory powers are typically exercised to achieve local objectives that have broad support from resident voters, like exclusionary zoning practices and local growth controls. Because of the power of private property rights, however, there is some question regarding the effectiveness of zoning and other forms of land use controls (Fischel, 1989). Public sector influence on land use also occurs indirectly through investments in public infrastructure, such as water and sewer systems.

On the transportation side, demand is clearly expressed by private individuals and firms, but the supply of transportation services is determined in the public sector. Hence transportation investments are often viewed as appropriate policy instruments for achieving regional or statewide goals.

Federal, state and local governments spend significant sums of money on transportation infrastructure, with the exact amount changing in response to available funds and new initiatives at the federal level. While local government funds are largely spent maintaining the local road network, new local roads often are paid for by developer contributions, exactions or impact fees. At the state and federal level, funds are spent on a combination of maintenance, rehabilitation and new construction, with the majority of dollars spent in urban areas. While the federal and state highway networks are designed to support intercity and interstate travel, the majority of the growth in travel demand is local in nature.

A small number of highly prominent, privately financed capacity expansions have occurred in the last decade. In some states, such as California, where significant financial constraints reduce the prospects for publicly funded capacity improvements, privately financed projects may make a more significant contribution.

Different organizations make public decisions. Land use regulation has been largely a local government responsibility with only a few states setting statewide frameworks for planning. Regional land use planning is rarely done in the United States. On the other hand, transportation planning has been the responsibility of state Departments of Transportation, transit agencies, and city and county traffic engineering, planning and economic development offices with significant funding and accompanying regulation from the federal government. Federal law requires coordination of transportation planning in metropolitan areas through a designated Metropolitan Planning Organization. Indeed, transportation is one of the few areas in which regional planning and decision-making takes place.

Even within a single jurisdiction, such as a city government, land use and transportation planning are often assigned to separate departments, with engineers making transportation decisions and planners being responsible for land use planning and regulation. As a result, transportation and land use planning and policy-making can have different, even conflicting, goals and objectives.

Different time contexts. Travel responses to land use or transportation system changes are seen more quickly than land use responses. People and firms adjust their trip scheduling and routes much more quickly than they change locations because travel decisions involve less capital investment. This has political consequences. Political leaders can be fairly confident that transportation outcomes will be seen during their term of office, but advocating land use changes can be risky. Consequently, transportation planning and transportation projects often gain more political legitimacy than land use planning and policy-making.

Conclusions

While there is a basic understanding of transportation and land use relationships, the outcomes of specific plans or policies are difficult to predict. The main reason for this

uncertainty is the complex, dynamic nature of the urban development process. More specifically, our ability to predict outcomes from a transportation or land use policy change is affected by the following:

- Local Conditions: Metropolitan areas differ greatly in historical development patterns, geography, population mix, political traditions, and economic vitality. All of these factors play a role in the specific outcomes of policy initiatives. For example, development impacts of the Bay Area Rapid Transit system (BART) differ from those of the Washington Metropolitan Area Transit Authority (WMATA) or the Metropolitan Atlanta Regional Transit Authority (MARTA). Even within the BART system, observed impacts have varied greatly from one station area to another.

- Incremental, Long-term Process of Land Use Change: Land use patterns change very slowly due to the durability of capital stock and the high cost of redevelopment.

- Random Events: Changes that are likely to have significant impact on land use or transportation patterns may be unpredictable, such as the location of the Saturn plant or the timing of an oil price increase.

- Flexibility of Travel Demand: Travelers have many different ways of responding to changes in transportation or land use systems. Travelers can shift travel schedules, routes, destinations, trip sequences, modes, and their home or firm location.

Despite these difficulties, long-range planning must take place, and transportation/land use impacts must be evaluated within the planning process to the extent that it is possible to do so. Tables 1 to 3 summarize the state of knowledge about the impacts of transportation investments and policy on land use and vice-versa. These tables oversimplify things, since all transportation initiatives that change accessibility, to whatever degree, have an effect on the location, intensity of uses, land prices, and possibly the mix of uses over the long term. The impacts will vary considerably depending upon the mitigating circumstances, such as the regional economic conditions, the "market" for accessibility, and local land use policies.

Tables 1 and 2 indicate the relative elasticity of land use impacts from various types of highway and transit investments and policies, respectively. In other words, the tables provide a measure of the degree to which land use impacts will occur. When an action is labeled as having "high" land use elasticity this means that the results are high in relation to the other options, not that the changes are necessarily large. Similarly Table 3 indicates the relative elasticity of transportation impacts from land use changes.

Table 1 shows that major infrastructure investments such as new freeway segments or interchanges have high potential for changing land use. The extent of land use impacts depends on the extent to which capacity is increased and on the overall demand for additional capacity. Impact magnitude also depends on the characteristics of the investment. For example, the largest magnitude impacts are expected from new facilities in fast growing areas. At the metropolitan scale, highways have been associated with decentralization of both population and jobs as well as decreased development density. Locally, highways can affect land values and development patterns.

Automated highways have the same potential to decentralize development and concentrate growth at nodes as other highway improvements. If automated highways would vastly

improve travel speeds, it could support even more exurban development including the development of new towns.

In contrast, traffic system management improvements are not likely to have significant land use impacts, although they can support other policies that potentially would affect land uses. Such improvements have a limited effect on capacity and, therefore, little effect on overall accessibility.

Large impacts are also expected for policies that significantly affect the user price of automobile travel. The greater the price change, the greater the impact will be. Congestion pricing and parking management and pricing would have significant effects on travel demand, and should therefore also have measurable long-run effects on land use patterns. Other transportation demand management policies, such as rideshare matching or preferential parking for carpools are not expected to have significant land use impacts.

Table 1
Summary of Land Use Impacts of Highway Investments and Policies

Action	Land Use Elasticity	Land Use Impact	Mitigating Factors
New Facilities	high	Redistribution of metropolitan growth to highway corridors Decentralization of population and employment Increased land values and concentration of development around interchanges	Local and regional economic conditions Degree of impact on regional accessibility Congestion levels Local land use policies NIMBYism
Added lanes, intersections	high	Same as above, but to a lesser degree	Same as above
Automated highway systems (AHS)	high	Decentralization of population and employment Increased land values and concentration of development at nodes and terminals Possibly new towns	Magnitude of change in travel speeds Extensiveness of system Cost of use Local land use policies NIMBYism
System management	low	None likely	Levels of congestion and latent demand
Congestion pricing	high	Unknown Possible shift of population and jobs toward more accessible locations. Possible shift of population and employment to exurban areas	Local and regional economic conditions Magnitude and spatial extent of pricing policy Degree of congestion Availability of alternative modes, routes
Parking pricing, management	high	Unknown Possible increased development of major employment centers Likely increased development density	Local and regional economic conditions Magnitude and spatial extent of pricing policy Long-run incidence of parking fees Availability of alternative modes
Vehicle, fuel tax	moderate	More compact development if cost of driving high enough to encourage use of other modes	Magnitude of tax Availability of alternative modes
Transportation demand management	low	None likely	N/A
Safety Improvements	low	None likely	The extent to which the improvement changes capacity or accessibility

Table 2
Summary of Land Use Impacts of Transit Investments and Policies

Action	Land Use Elasticity	Land Use Impact	Mitigating Factors
New rail facilities	moderate	Increased land values and development density Redistribution of development to downtown, station areas Decentralization of population	Local land use policies Degree of impact on accessibility Local economic conditions Station access and local circulation patterns Corridor congestion levels
Rail extensions, stations	moderate	Same as above, to a lesser degree	Same as above
New high capacity arterial bus lines, stations	moderate	Possible redistribution of development to major bus transit corridors	Local economic conditions
Changes in local service	low	Possibly some redistribution of development to transit corridors	N/A
Fare policy changes	low	None expected	N/A
Safety Improvements	low	None expected	Whether the improvement changes perceptions about passenger safety

Table 2 shows that major transit infrastructure investments are less likely to have significant land use impacts than highway investments. The accessibility benefits of added transit capacity accrue to a far smaller share of the travel market, and so cannot be expected to have the same range of impact as added highway capacity, although localized changes can be significant. As with highways, anything less than major infrastructure investments are not likely to have significant, measurable land use impacts. Potential land use impacts include increases in both land value and development density.

In reading Tables 1 and 2 it is important to remember that highway and transit improvements may have different spatial impacts. Highway impacts tend to be more diffused, and thus may be harder to measure than transit impacts. Highways are often multimodal; they serve individual travelers, public transit, and goods movement. Changes in highway accessibility therefore directly affect all aspects of economic activity. Under favorable conditions, then, highways may have major impacts on the distribution of development in metropolitan areas. Because transit only serves passengers, its land use effects are likely to more localized and thus more definable than highway impacts.

Table 3 shows that land use policies can have significant impacts on travel demand, although none of these impacts are likely to be high in an absolute sense and can take a long time to achieve. High density development is associated with less automobile use per

traveler, more transit use, shorter trips, more non-motorized travel relative to low density development, as well as with potentially more automobile congestion. The design of transit oriented development and its location near convenient transit service may promote transit use and non-motorized travel. Jobs-housing balance can reduce vehicle miles of travel.

Table 3
Summary of Impacts of Land Use Policies on Travel Demand

Action	Travel Demand Elasticity	Travel Demand Impacts	Mitigating Factors
Compact development	high	Reduced motorized travel Increased transit use Increased non-motorized travel Shorter trips	Relative distribution of population and employment Level of density Metropolitan development patterns Transit availability and level of service
Dispersed development	high	Increased vehicle miles of travel Decreased use of transit and non-automotive modes Higher speed travel Trip chaining	Metropolitan development patterns Transit availability and level of service Parking pricing and management Taxes on automobile use
Transit oriented development (TOD)	moderate	Reduced motorized travel Increased transit use Increased non-motorized travel Shorter trips	Relative location of TOD within metropolitan area Density and other characteristics of the TOD
Jobs-housing balance	low to moderate	Reduced vehicle miles of travel	Zoning restrictions Importance of non-employment factors on location Degree of match between income levels of workers and housing costs

1.3 OTHER NCHRP 8-32(3) PRODUCTS

In addition to this guidebook, this project is documenting and making available UrbanSim, an integrated land use model for metropolitan areas. This model is based on the same behavioral framework presented in this guidebook. There are components reflecting the behavior of households, businesses, developers, and government. These stakeholders interact through the land market, policy interface, and transportation system characteristics.

This model draws on random utility theory for its theoretical foundation and builds on the well-developed basis of disaggregate choice modeling now widely employed in models of mode choice. In extending the discrete choice modeling framework to households and businesses, we have developed a model framework that is both intuitive and transparent to the user, as well as theoretically sound and computationally tractable. It simulates the complex set of behaviors which we have summarized here, which we will explore more fully in Chapter 3.

1.4 ORGANIZATION OF REMAINDER OF THE REPORT

Chapter 2 describes the analytical tools that are currently used by MPOs and DOTs to analyze transportation-land use interactions. These include policy tools such as comprehensive plans and technical tools such as statistical models and formal land use models.

Chapter 3 presents the behavioral framework that provides the basis for the doing land use analysis in conjunction with transportation. This framework focuses on four key actors--households, businesses, developers, and government--who make the decisions that determine land use outcomes. The framework identifies factors that shape these decisions.

Chapter 4 describes the ways to use the behavioral framework in the types of transportation and land use analysis most often conducted by MPOs and DOTs. We describe the steps in base case forecasts, impact assessments, and policy assessments and recommend specific tools to use for each step.

2.0 ANALYTICAL TOOLS

The purpose of this chapter is to identify and evaluate the types of tools currently used or available for use by Metropolitan Planning Organizations (MPOs) and state Departments of Transportation (DOTs) in the analysis of transportation-land use interactions. The concept of "analytical tool" is defined quite broadly, ranging from qualitative assessment to integrated land use-transportation models.

The chapter is divided into sections based on the major categories of tools. The types of tools available today include:

1. Comprehensive plans and other land use regulations
2. Qualitative methods that tap expert knowledge
3. Allocation rules for assigning population and jobs to zones
4. Decisions rules based on local, historic data or data from other locations
5. Statistical methods
6. Geographic Information Systems
7. Regional economic models
8. Formal land use models

The description of each of the formal land use models in Section 2.8 is more detailed than the descriptions of other tools. We provide this greater detail for the following reasons:

- Many practitioners would like a comprehensive tool that can be used for a variety of analyses.
- These tools are less familiar to many practitioners than the simpler tools.
- Many of these models require extensive data and considerable time and skill to calibrate and operate. We want to make it clear what sort of commitment of resources each model requires and what types of output it can produce given that commitment.
- Some of the models can be integrated with travel demand models to simulate the feedback between transportation and land use.

This section considers the strengths and weaknesses of each analytical tool, but does not make specific recommendations about their use. These recommendations are covered in Chapter 4 after considering the behavioral framework in Chapter 3 that we think should shape the analysis. At that point we can discuss the suitability of tools for the types of land use forecasting and impact assessments that MPOs and DOTs must carry out.

2.1 USING COMPREHENSIVE PLANS AND OTHER LAND USE REGULATIONS

Comprehensive plans, zoning codes, and other land use regulations provide information on the types, densities, and locations of land uses that communities want and the transportation system needed to support these uses. They also identify the goals of jurisdictions and the policies they are using to achieve their goals.

Land Use Forecasting Applications

Land use plans may have the force of law, or may be only advisory in nature, depending upon state and local law and precedent. Hence, they may be a measures of land supply "as-of-right" or may merely be one of several indicators of land supply. MPOs and DOTs rely extensively on land use plans to inform their judgments about the supply of land available for various types of development when preparing land use forecasts for travel demand models. This information can be adjusted to take into account development already in the planning stages and constraints on development such as slopes and fragmented ownership. Analysis of comprehensive plans can play different roles ranging from a source of information on the types of uses allowed to a set of policies used to turn the forecasts into politically acceptable numbers, as the following examples illustrate.

A Supply Side Forecast Based on Comprehensive Plans

The Lane Council of Governments in Eugene-Springfield, Oregon, is an example of a small MPO that uses city and county comprehensive plans as the principal tool in forecasting. In Oregon, comprehensive plans have the force of law. The MPOs forecasts are mainly based on the supply of vacant and underdeveloped land. MPO staff have entered the local comprehensive plans and existing land uses into a Geographic Information System (GIS). This information is then combined with planners knowledge of development in the pipeline to identify the parcels where development can occur and the number of jobs and households that can be accommodated. Except for some large industrial sites, households and jobs are allocated to traffic analysis zones in proportion to the share of the region's developable land within each zone.

This method accurately reflects the constraints that land use policies place on development patterns in a state like Oregon where zoning and development permits must be consistent with comprehensive plans. It is limited by the assumption that all zones with vacant land are equally attractive to development. In reality, parts of the region are likely to grow faster than others due to different costs of development, proximity to desirable neighborhoods, and other factors that influence development decisions.

This policy-based forecast can be modified to identify how changes in policies would affect the forecasts. In essence this requires developing a "new" comprehensive plan to reflect the policy changes. The Lane Council of Governments is evaluating an alternate scenario that focuses growth in nodes. A task force has identified the location, type, and density of nodes and this information has been put into another layer in the GIS system. The data is then used to develop a new forecast of employment and households that can be input into the transportation demand model to determine if the more concentrated pattern of development changes transportation outcomes.

The Lane Council of Governments can be reached at:

Lane Council of Governments
North Plaza Level, PBS
125 East 8th Avenue
Eugene, OR 97401
(503) 687-4283

Tempering Forecasts with Local Growth Goals

The Capital District MPO in Albany, New York, uses shift-share techniques and expert judgment to allocate population and employment to small areas. They adjust forecasts based on community comprehensive planning goals when doing the forecasts. Some central cities in the metropolitan area have been steadily losing population in recent decades but have policies in their comprehensive plans that they hope will stabilize their populations. In order to obtain local government acceptance of the forecasts, the MPO must assume the effectiveness of these policies and adjust the population assignments accordingly. This problem is exacerbated by the low level of growth expected in the region providing little population and job change to allocate among jurisdictions. Planners are left wondering if their numbers are really "forecasts" of likely future events or "plancasts" of the way communities would like to grow, illustrating the tensions between technical and policy viewpoints of forecasting.

The Capital District MPO can be reached at:

Capital District MPO
5 Computer Drive,
West Albany, NY 12205
(518) 458-2161

Impact Assessment/Policy Analysis Applications

MPOs and DOTs also utilize comprehensive plans and other land use plans and policies as one of the tools in impact assessments. Major investment studies, for example, consider how transportation system changes would support current land use designations and policies or would lead to pressure to alter them.

The following two examples illustrate that statewide land use policies, where they exist, should be considered in assessing the impacts of transportation system changes. In both cases, a statewide policy underlies the development of alternatives to current comprehensive plans.

Using Comprehensive Plans in Developing Metropolitan Transportation Plans

The Tallahassee-Leon County MPO does regional transportation planning for an area with around 200,000 residents. The MPO responded to Florida's growth management requirement that transportation facilities be provided concurrently with development by developing and analyzing three land use scenarios as part of developing their 20 year regional transportation plan. The Comprehensive Plan Scenario, or base case, distributed growth based on historic growth patterns and vacant land inventories assuming the current comprehensive plan land use designations and policies would hold in the future. Under this scenario, much of the growth would occur in the east and northeast sections of the urbanized areas where vacant subdivision lots are plentiful. The Urban Infill Scenario assumed more redevelopment in the low density urban core and limits or disincentives to growth outside the urban infill area. This scenario provides the greatest opportunities for

alternative transportation modes but also requires the most dramatic changes from current trends. The Southeast Strategy put growth in the southeastern part of the county where many facilities are underutilized and assumed that growth would be discouraged elsewhere. More mixed use development was also included in this scenario.

The transportation outcomes of these land use scenarios were evaluated by loading the trips generated by each scenario with several highway network configurations into the regional transportation demand model. This process generated a clearer picture of transportation needs than considering only the base case scenario. It also resulted in a regional transportation plan that recognizes that transportation investments by themselves cannot solve transportation problems (Post, Buckley, Schuh & Jernigan, Inc., 1995).

The Tallahassee-Leon County MPO can be reached at:

Tallahassee-Leon County MPO
City Hall
300 South Adams Street, 4th Floor
Tallahassee, FL 32301
(904) 559-8641

Using Comprehensive Plans in Major Investment Studies

The Western Bypass Major Investment Study in the Portland, Oregon metropolitan area was unusual for its consideration of a land use alternative for solving transportation problems. This study illustrates two roles for comprehensive plans in developing and evaluating alternatives. One is to assume that land use plans will be followed. Then the analysis determines whether proposed transportation investments support or conflict with them. The second is to use selected parts of comprehensive plans (such as the amount of multi-family development) while changing other parts (such as the location of that multi-family housing).

The Western Bypass Study considered five alternatives for solving the transportation problems within suburban Washington County on the westside of the region. Four of the alternatives--No Build, Transportation System Management, Arterial Expansion/HOV Express Service, and Bypass--assumed that future land uses would follow the designations in current comprehensive plans. The impact assessment identified how the transportation changes might lead to pressure to change comprehensive plan designations, speed up planned growth, or direct growth to rural communities that would have improved access to the metropolitan area.

The fifth alternative, known as the LUTRAQ (Making the Land Use Transportation Air Quality Connection) alternative, was developed by a non-profit advocacy group, 1000 Friends of Oregon. This alternative rearranged land uses to put most new growth in jobs and households in areas where it could be served by planned transit. One of the reasons for developing this alternative was an Oregon land use requirement to reduce reliance on the automobile. In particular, metropolitan areas like Portland are required to reduce per capita vehicle miles traveled by 20 percent over the next 30 years.

The LUTRAQ alternative was developed by first evaluating existing comprehensive plans. The alternative kept the overall density of Washington County the same as in the plans, but

moved medium to high density residential and commercial development from the edges of the urban area to developable land along light rail lines. Market analysis was conducted to determine what types of transit-oriented development would be feasible in Washington County, and the proposal only included housing and commercial developments for which there would be a market. This alternative also included additional transit service and strategic highway improvements.

The study evaluated all of the alternatives on a full range of environmental and social impacts including mode choice, congestion, vehicle miles traveled, and consistency with comprehensive plans and statewide planning goals. The region ultimately selected parts of several alternatives as the preferred alternative (ODOT, 1995).

1000 Friends of Oregon can be reached at:

1000 Friends of Oregon
534 SW Third Ave., Suite 300
Portland, OR 97204
(503)497-1000

Strengths and Weaknesses

Comprehensive plans and other land use regulations provide policy information and planned future uses of developable land that are useful for developing a land use forecast or evaluating the land use impacts of changes in the transportation system. The danger lies in putting too much faith in the ability to achieve policy goals. The supply side information of land use plans needs to be balanced with an understanding and analysis of the market forces that also shape development patterns. The demand side analysis can be done by a variety of methods described in the following sections.

The consistency between plans and development varies from state to state and jurisdiction to jurisdiction, creating greater uncertainty in locations where plans serve merely as guides to development. Over the long term it is unlikely that comprehensive plans will remain static, especially in growing areas; yet, land use forecasts often assume that plans will not change.

2.2 QUALITATIVE METHODS

Qualitative or intuitive, knowledge-based methods are frequently used alone or in conjunction with quantitative methods or models to predict and evaluate transportation-land use interactions. These methods rely on the knowledge and skills of one or more experts to analyze the situation. Intuitive methods are needed to understand complex events when models do not exist or can only partly represent the dynamics at work. They are also useful for evaluating situations where conflicting societal values are present and can help identify and clarify these underlying issues.

Types of Qualitative Methods

Qualitative methods can involve groups or be individual efforts. Groups of experts are often utilized in the belief that several people will generate better ideas and a more accurate assessment of impacts and future conditions than one. The Delphi is a highly structured way to utilize the skills of a number of experts while avoiding the dysfunctional aspects of group meetings. More commonly panels or committees of experts meet face-to-face to accomplish their task. In many cases, transportation-land use interactions are evaluated by an individual or team of experts who may conduct interviews, collect and analyze data, and make field visits.

Delphi

Delphi is a systematic way to utilize expert opinion that was developed by the Rand Corporation in the 1950s for use in defense applications. Since the method was made public in the 1960s, it has been widely used in forecasting and policy formation applications. Experts provide their judgments about likely future events or the impacts of potential transportation investments and programs by responding to several rounds of questionnaires. The Delphi moderator summarizes the results of each round and submits these summaries to the experts for reconsideration of their analysis. In this way the thinking of the experts are shared with each other to either arrive at consensus or clarify differences of opinion.

The Delphi process differs from a panel meeting face-to-face in that participants are anonymous, the process is done iteratively with controlled feedback, and a statistical group response is reported. Anonymity allows participants to focus on the issues, not the personalities of the participants. The repeated rounds with feedback from the moderator allow participants to reconsider their responses in light of new information but prevents lobbying for any point of view. The statistical group response gives the range of opinion as well as the most common response. This helps clarify how strongly people agree or disagree (Linstone and Turoff, 1975, Cavalli-Sforza, 1982).

Delphi's begin with the selection of a panel. A panel includes people with a broad range of viewpoints about transportation-land use interactions. Expertise in both land use policy and market conditions should be included. Bajpai (1990, p. 17) recommended that a land use forecasting Delphi include local government officials, land use and transportation planners, utility company representatives, school district officials, neighborhood and citizen group members, private consultants, academics, and business representatives. A successful Delphi requires at least 8 to 12 participants. Panel members are sometimes compensated as the process can require considerable time and effort.

Many Delphi processes begin with a questionnaire with open-ended questions. The responses are then used to develop more structured questions for succeeding rounds. The unstructured approach takes full advantage of the expertise of the participants, but adds another round to the process. Other Delphi processes begin with a structured questionnaire. In a structured questionnaire panelists may be asked to forecast the number of households expected in a zone by a specified year, estimate the attractiveness of each zone for job growth during a specified time period, or rate the likelihood of certain external events taking place.

The moderator also provides each panelist with background information so that all are working with the same information. If panelists are being asked to forecast future job numbers in zones, they should be provided with numbers and types of current employment, trends in employment, amount of vacant or developable land zoned for commercial or industrial activities, characteristics of planned changes in transportation systems, and other pertinent information.

The Delphi moderator summarizes the responses using graphical displays of the frequency of responses. Comments are also included in the summary. To maintain objectivity, the moderator avoids identifying the panelists or interjecting his or her views into the summaries. After the second or later round, the moderator also assesses the stability of responses. If respondents have made few changes in responses from the previous rounds, this indicates that results are stable and further rounds are unlikely to reveal new information. The Delphi is then complete.

Committee or Panel

Another way to utilize a group of experts is to hold face-to-face meetings. In these meetings, panelists address the same issues as in a Delphi but are able to discuss and clarify their opinions. This can lead to better understanding of each other's position, but the group can also take on a life of its own focusing on certain issues to the detriment of others. People also tend to have different roles in the group process, while in a Delphi all have the same role of responding to questionnaires. Panels should be selected to represent the same breadth and depth of knowledge as in a Delphi.

Panels may use aspects of the Delphi process such as completing questionnaires between meetings. Webler et al (1991) used a structured meeting process using small group discussions to replace questionnaires and plenary sessions as summary times. They found this to be an expeditious and satisfactory means of evaluating controversial issues. This process sacrificed anonymity to reach consensus on many issues and clarify the values behind the fundamental disagreements on others. The entire process was completed in a one-day meeting while a standard Delphi can take months. Another alternative is to use a face-to-face meeting to discuss general issues since discussion and group brainstorming can sometimes generate additional ideas. Then future rounds can either be completed with questionnaires summarized by a moderator or in face-to-face meetings.

Interviews, Surveys, and Expert Analysis

An expert may also be called upon to undertake qualitative analysis using a combination of interviews, surveys, field visits, and secondary data. A real estate consultant might investigate how businesses would react to changes in the transportation system by interviewing building and businesses owners and analyzing this information in light of his or her understanding of how the real estate market works. An economist or planner might determine the economic and land use impacts of various corridor projects by analyzing data on the local economy and land uses, interviewing business people and planners, comparing the situation with that in previous studies, and using knowledge about how the urban development takes place.

Case Studies

Another qualitative approach is to conduct several case studies of places that have built the type of transportation project or adopted the sort of policies being evaluated. Case study research can utilize a variety of methods for collecting data including interviews, site visits, and compilation of primary and secondary data. Case study researchers look for patterns among the cases and for reasons why some cases deviate from these patterns. This method can help identify the types of land use changes that have occurred and the local conditions that have supported or detracted from land use changes (Yin, 1989).

Land Use Forecasting Applications

MPOs often use qualitative methods in developing the land use forecasts needed for modeling travel demand for their regional transportation plan. One method is for planners from local jurisdictions to meet and determine allocations based on comprehensive plans and their knowledge about where growth is occurring or likely to occur. Smaller MPOs rely heavily on this method. Techniques involving a wider range of experts include interviews with knowledgeable people in both the public and private sectors. This is often needed for forecasting industrial development which MPOs report is more difficult to forecast than households or retail. The following example illustrate using a third method--using a staff committee to develop zonal attractiveness measures for several land use scenarios.

Developing Attractiveness Measures for Alternate Scenarios

The Denver Regional Council of Governments, an MPO for a region with about 2 million residents, created an attractiveness index methodology to use in their base case and three alternative scenario forecasts. The process used data like that employed in land use models, but it relied on a committee of staff planners and economists to determine the relative importance of each variable.

The MPO identified measurable factors that influenced development. Both land use and transportation factors were included. The factors included :

- proportion of each zone in residential (or employment) use
- proportion of land planned for residential (or employment) use
- amount of vacant land
- recent growth rates (residential and employment)
- roadway accessibility
- presence of a transit station
- availability of water and sewer service
- per capita income (a proxy for quality of life)
- change in per capita income, 1980-1990
- proportion developed before 1950 (a proxy for pedestrian orientation).

The MPO considered two aspects of each factor in developing the attractiveness index. First, they measured the factor for each traffic analysis zone providing factual data on current conditions. These measurements were standardized by converting each to a scale ranging from 1 to 10. Second, a committee of staff members decided the relative importance of each factor, considering residential and employment development

separately. Based on their understanding of the development process, the committee assigned a total of 100 points to the fifteen factors (negative assignments were allowed). Then the standardized measures were multiplied times the importance scores and summed across all the factors for each analysis zone. Zonal attractiveness indices ranged from the low 200s to the high 600s.

The MPO used a quasi-Delphi process for deciding the relative importance of each factor. Multiple rounds of questionnaires were used, but the participants met in face-to-face meetings where they could debate their differences of opinion.

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Impact Assessment/Policy Analysis Applications

MPOs and DOTs also rely on qualitative methods when assessing the land use impacts of specific transportation improvements or policies. Qualitative methods can include the full range of options from a Delphi to interviews and surveys as the following examples illustrate.

Base Case Forecasting Using the Delphi Process

An excellent example of the application of a formal Delphi process was completed in 1993 in Texas, where the Texas Transportation Institute (TTI) worked with the Longview, Texas MPO staff to develop a 2015 base case forecast for travel demand modeling purposes. Longview is the central city of a small metropolitan area whose current population is approximately 100,000.

TTI staff were interested in developing a reliable, efficient and politically acceptable means for developing allocations of population and employment for travel forecasting. In cooperation with the Longview MPO, they prepared an application of the Delphi process (Gamble, et al., 1993).

Longview staff assembled a panel of 28 members from an initial list of approximately 50 individuals representing a cross-section of occupations in the public and private sectors. They prepared a packet of technical information for panel members which included historical information on population and employment, current (base year) employment and population data, population and employment forecasts for the year 2015, and current land use and zoning information.

Staff convened an orientation meeting to acquaint the panel with the process and to distribute information packets. After this meeting, panel members were asked to consider the growth potential of each of six large districts within the metropolitan area. Panelists replied to a written questionnaire. They were asked to rate the importance of 13 factors

which might influence growth in one or all of the districts, and to rate their familiarity with each of these factors. Then they were asked to rate the potential for population and employment growth for each of the six districts, using broad ranges of growth potential ("Stable", "No Change", "10% Increase", "25% Increase", etc.) They were also asked to make a judgment regarding what level of growth would occur during each of three intermediate time periods, leading up to the 2015 forecast year. The questionnaire accommodated additional comments from panel members.

In the second round of questionnaire, staff asked panel members to reply to a similar set of questions as were asked in the previous round, with the exception of the removal of questions dealing with factors that influence growth. In addition, panelists had the benefit of seeing the results of the previous round's questions, including high and low responses, median and mode for each of the key questions. They were given the opportunity to change their replies in light of the summarized results from the previous round, as well as written comments by other panel members and verbal comments made at the second panel meeting itself.

After two rounds of questionnaires the panel reached a consensus on a growth allocation at the district level. Two additional rounds of questionnaires were completed in order to further disaggregate growth from the six districts to 35 smaller areas. Once again, panel members were allowed to review the results of the initial survey and modify their conclusions. The panel reached a consensus on the area level allocations in two rounds of questionnaires.

The final level of disaggregation, the traffic analysis zone level, was conducted by Longview staff. Staff took into consideration the availability of land in each of the areas zones, as well as future land use plans and other information. In a final round of questionnaires, the panel was allowed to evaluate the overall process, including the staff allocation figures for individual traffic analysis zones.

At all meetings, an informal atmosphere enabled open and free discussion among members. The process required approximately eight weeks to complete. Following the final meeting of the panel, the results were presented to the MPO Technical Committee, Steering Committee and local Planning and Zoning Commissions. All three groups responded positively both to the process and its outcomes. The MPO Steering Committee voted unanimously to adopt the growth allocations that resulted from the panel's work.

In their evaluation of the process, Texas Transportation Institute researchers identified several benefits from applying a Delphi process to a base case future forecast. They identified a significant savings in time and money due to the speed and simplicity of the process, the ability to integrate data with the perceptions, intuitions and judgment of people familiar with the region, the defensibility of the results, and the advantage of involvement by key public and private stakeholders in the process. Panel members themselves who took the time to give feedback in writing on the process expressed a high level of satisfaction with their own participation.

In the Spring of 1998, MPO staff have begun an update of the base case forecast, once again to the use of a Delphi panel. The results of the 1998 efforts will also be available as the result of Longview's selection as one of several case studies for metropolitan land use

forecasting techniques, by the US Department of Transportation, Federal Highway Administration. A complete account of the 1993 allocation process, including all supporting materials, is available through the National Technical Information Service by referencing report no. FHWA/TX-92/1235-12.

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Using a Delphi to Assess the Land Use Impacts of Alternate Transportation Scenarios

The Program in Infrastructure Planning and Management at Stanford University researched and developed methods of predicting the inter-relationships between infrastructure and land use in the 1980s. They used the Delphi method in San Jose, California to predict the land use impacts of three transportation alternatives that emphasized highways, bus and HOV lanes, and light rail. The study recruited twelve panelists with expertise in transportation and land use who worked as economists, engineers, planners, or public administrators or were community activists involved in transportation and land use issues. Panelists were asked to forecast population, housing, employment, commuting patterns, and mode choice for four zones for two dates.

The process produced forecasts that varied among the alternatives and seemed reasonable. The process was, however, lengthy due to the complexity and number of questions being asked of panelists (120 different combinations of variables) which created difficulty securing results (Cavalli-Sforza et al. 1982).

Using a Panel to Develop Market-Based Forecasts for a Corridor Study

The Maryland DOT used an expert panel to evaluate the land use impacts of various transportation options for their Highway 301 Corridor Study. They recruited six people with expertise in land economics, transportation, land use, and real estate lending to serve on the panel. They provided panel members with maps, the MPO's base case forecast, descriptions of the alternatives, and other pertinent information prior to a panel meeting.

At the meeting, some panelists questioned the base case forecasts. They argued that too many jobs had been assigned to the District of Columbia for political reasons, and some of these jobs should be the corridor. In the end the panel produced three forecasts--revised base case numbers, an estimate that the highway option would attract about 80,000 additional employees, and an estimate that light rail would attract a lesser number of employees, about 40,000. They forecast no change in household numbers for either alternative because the new jobs would be filled by people who already lived in the area and currently commuted to the District.

The Task Force for the corridor project has accepted the panel's estimates as the market-based forecasts for the highway and light rail options. The panel has provided the Task

Force with reassurance that the numbers are realistic. In hindsight, project consultants think it would have been more effective to involve the panel earlier in the process and to hold more meetings. This would have given the panel more time for reflection and would have provided the MPO with an opportunity to discuss its base case forecasts with the panel members.

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Interviews and Expert Analysis of Economic Impacts of the Boston Artery/Third Harbor Tunnel Project

The economic impacts of the Boston Artery project were estimated by using a detailed site by site analysis to estimate the capacity for growth within the study area. Data was gathered from a survey of downtown businesses, interviews with real estate brokers, inventories of existing land uses, and a list of all development projects in the pipeline. Economic development staff met with consultants to estimate the likelihood of each development taking place, its size, and its completion date. The result was a forecast of employment growth rates with and without the project.

Most employment growth was forecast in the office sector. The survey and interviews revealed a sharply segmented office market with banking, law, and finance firms in downtown Boston and all other types of offices in the suburbs. This indicated that there was little competition between the suburbs and city for office growth, and the primary impact of the project would be on whether office growth occurred downtown or went to some other city because of congestion. The validity of the project-by-project forecast was checked by comparing the rate of office space and employment growth with historic trends (Cambridge Systematics, Inc., 1990).

Using Case Studies to Understand the Land Use Impacts of Interstate Highways

Case studies have been used in two different studies of the impacts of the interstate highway system. In the 1970s, The Federal Highway Administration and U.S. Department of Housing and Urban Development jointly sponsored a study of beltways to test the widely-held assumption that beltway construction was undermining other federal efforts to support central cities. The beltway study used detailed case studies of eight beltway regions, along with statistical analysis of the differences in land use between 27 cities with beltways and 27 without them. The criteria for selecting case studies included the size of the region, its growth rate, its geographic location, and the age, length, capacity, and other characteristics of the beltways. The case studies helped identify the local conditions, such as zoning, downtown revitalization programs, and the location of interchanges, which influenced the location of activities in the region (Payne-Maxie and Blayney-Dyett, 1980).

A current Transportation Cooperative Research Program project (TCRP H-13A) is taking another look at the effects of interstates using a series of case studies. This study uses case studies in nations with different national policies regarding interstate highways and in cities with different levels of interstate development. Case study regions were selected in the United States, Germany (which has the second largest interstate system but generally keeps them out of cities), and Canada (which has no federal transportation programs). In the United States, case studies were selected based on the intensity of their interstate networks and the strengths of their transit systems.

This study found, as researchers such as Muller (1995), Leinberger (1996), and Hughes and Sternlieb (1988) have pointed out, that the primary impacts of beltways on land uses occurred in the 1980s. In regions with extensive networks, such as Atlanta, Columbus, and Kansas City, the interstate highways have been one of many factors supporting the geographic spread of the region and the development of suburban activity centers at the nodes of interstate network. Even in Pittsburgh, which has a relatively limited interstate highway network and has not grown during the interstate era, suburban growth areas tend to occur near nodes in the transportation system. On the other hand, high levels of accessibility are clearly not the only factors at work. In Atlanta and Columbus, growth has generally occurred in the "favored quarter" to the north and has been slower in the southern half of the region, despite the presence of interstate highways (Parsons Brinckerhoff, 1997).

Strengths and Weaknesses

Qualitative processes can take a holistic approach that considers all aspects of the urban system if it utilizes a panel of experts with sufficient depth and breadth of knowledge. However, a group of experts on urban subsystems does not necessarily add up to an understanding of the whole process. To understand the entire urban system, the process must incorporate feedback between experts on different systems. This process is also based on the philosophy that a group of experts can produce better forecasts and impact assessments than a single person because they bring a larger set of knowledge to the process. Groups, however, do not always perform better than individual experts. If panel members hold similar views, convening them adds little to the analysis.

There is controversy about whether a Delphi or a face-to-face meeting of experts fosters the most thoughtful and creative work. While Delphi proponents argue that the anonymity of Delphi processes avoids a "band-wagon effect", Delphi critics contend that the feedback of statistical group responses creates pressure to conform to the most frequent response (Webler et al. 1991, Woudenberg 1991).

Qualitative methods involve analysis by one or more experts. They may involve interviews and case studies to produce insights about how and why land use changes, and about the behaviors of developers, businesses, and other participants in the land use market. These methods can combine theory about urban development, empirical knowledge of other places, and understanding of local situations.

Qualitative methods are not a substitute for data collection. Expert analysis must be based on a substantial amount of information. Experts bring theoretical and empirical understanding about the urban development process, but they need information about the

land use-transportation issue of interest, the context in which it would be applied, and the assumptions which are being applied in a forecast or impact assessment.

The choice of qualitative method may depend upon the availability of experts for a short-term or long-term assignment, the diversity of views desired, the type of questions being asked, the complexity of issues, and the time and resources available.

2.3 ALLOCATION RULES

When evaluating transportation-land use interactions, it is often necessary to determine the locations of population and employment growth. A method of allocating growth to zones is needed. This section considers several rules for allocating growth for zones. The simplest rule, constant share, does not consider any information about how or why the region is growing. Two methods, share of growth and shift-share, are based on the patterns of recent growth. In other words, they are trend extrapolation techniques. The simple gravity model considers specific factors that influence the attractiveness of areas such as distance to jobs.

Types of Allocation Rules

There are several types of allocation rules, which vary in the amount of data, analysis, and realism that they require or convey.

Constant Share

This simple allocation method assumes that all zones share in the growth of population or jobs in proportion to the amount of vacant land zoned for that purpose. For example, if a zone has five percent of the vacant industrially zoned land in the region, it is assigned five percent of new industrial jobs. This method requires little data and is easy to calculate. Capacity constraints are built into the process since only vacant land is considered. It does not capture the actual development process where various parts of the region grow at different rates because some areas are more attractive than others. In areas with abundant developable land, this method will under assign development to attractive areas and over assign it to less attractive areas. If these places are in different parts of the region, this will have serious consequences for transportation analysis. In addition, fast growing areas may have more development in the planning stages than the ratio assigns to them. This undermines the credibility of the forecast.

Share of Growth

This method assigns population and employment growth to zones based on the proportion of the region's growth the zone had in a recent time period, say the last five years. This allocation assumes that slow growing areas will continue to grow slowly and fast growing areas rapidly. While this is more realistic than assigning constant shares, the method does not pick up the shifts of development to new areas or the slowing of development as areas fill up or arterial streets become congested. If one time events, like the opening of a large industrial plant or shopping center, occurred in the period when data was collected, they

will distort growth rates. Furthermore, these one time events cannot be predicted for the future by this trend-line analysis.

Shift-Share

This method was developed to forecast industrial output from different regions but can also be used to forecast growth in parts of a region. The method recognizes that some parts of the region have industries that are growing rapidly (for example, high tech plants) while other parts of the region have slow growing industries (such as traditional manufacturing). In addition, the competitive advantages of parts of the region may be shifting as factors like accessibility change. Shift-share analysis uses both these factors to determine future growth rates. As in the constant share method, the shift-share analysis uses evidence from the recent past to determine the allocations for the future time period. It, therefore, has the same limitations regarding extending trends into the future. However, it considers more characteristics of the subareas than constant share methods and, hence, should be more accurate.

Simple Gravity Models

Gravity models assign population or jobs to zones in proportion to a measure of the attractiveness of each zone. For residential assignments, distance to jobs is a major factor in attractiveness. It is assumed that residential areas are more attractive the closer they are to job concentrations. Other factors such as income levels, tax rates, availability of water and sewer services, and school quality can also affect attractiveness and can be incorporated into gravity models provided the relative weight of each variable can be estimated.

Land Use Forecasting Applications

Allocation rules are part of the land use forecasting process. They are used in conjunction with comprehensive plans and other tools as the following examples illustrate.

Using the Constant Share Rule for a Supply Side Forecast

The Lane Council of Governments forecasting procedures discussed in Section 2.1 utilized a constant ratio rule for assigning population and employment growth to vacant land. This supply-side method includes no consideration of the relative attractiveness of each zone such as the accessibility of residential areas to jobs or relative attractiveness of various areas to development. It does not work well for industrial uses which tend to agglomerate rather than disperse evenly over the large supply of vacant industrial land. The Lane Council of Governments corrects for the latter problem by assigning large employers in a separate process utilizing expert opinion.

Using Share of Growth to Allocate the Output of Land Use Models to Transportation Analysis Zones

One of the difficulties of using formal land use models with travel demand models is that the current land use models use larger zones than the travel models. Users must use a

separate procedure to allocate the output of the land use model to traffic analysis zones. The Puget Sound Regional Council uses a share of growth procedure where growth rates from a recent year are used to assign the outputs of the land use model to the traffic analysis zones of the demand model. Corrections are made for zones where this assignment would exceed capacity. This method assumes that recent growth rates will continue as long as there is land for development to occur.

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Impact Assessment/Policy Analysis Applications

Allocation rules and procedures are also used to determine the location and magnitude of shifts in jobs and residents that would result from changes in the transportation system.

A Simple Gravity Model for Estimating Residential Changes Due to Highway Investments

Researchers used a simple gravity model to estimate the potential impacts of a highway extension on residential development in the Route 531 Corridor near Rochester, New York. The gravity model was chosen because it shows how growth would shift in the region due to changing travel times and it could be calculated using a limited set of data. The model assumed that the growth of each community was directly related to the amount of developable land and the attractiveness of each community. The researchers assumed that official population projections for the communities accurately reflected the attractiveness of each of the communities. They separated out the effects of travel times to job concentrations using data from the U.S. Census on travel times to six employment concentrations including downtown Rochester. Then the attractiveness measure for each community was recalculated using the estimated travel time changes if Route 531 were extended. This analysis showed that a 12 percent decrease in travel times in the corridor would produce a five percent increase in residential growth (Hirschman and Henderson, 1990).

Strengths and Weaknesses

Allocation procedures are fairly simple to use and do not require extensive data. They are, however, based on a limited set of factors that affect the development process. The constant share technique, in particular, is unrelated to the way development occurs. The trend extrapolation rules are more accurate for short time periods in places with consistent growth. If they are based on data for an unusual time period (a recession or a period of rapid growth) or are being used to forecast for a period when development patterns are shifting, they will be wrong. Simple gravity models are likely to overstate the role of accessibility to work in location decisions. Other factors that influence decisions need to be considered as well.

None of these methods consider changes in the location of existing households and firms. Over the long term, exogenous factors are likely to change spatial patterns in ways that these allocation procedures can not encompass. Even in regions with little growth, spatial patterns are being rearranged. For instance, households and firms have suburbanized in stagnant or declining metropolitan areas, leaving central cities less densely settled.

Allocation rules work best for typical or average areas and for widespread activities like retailing and residential development. Activities that have a limited number of locations, such as industrial development, are better assigned using other methods. Allocation rules based on trends are unlikely to assign enough growth to areas with lots of vacant land.

2.4 DECISION RULES

In many situations simple decision rules are used to quantify relationships between transportation and land use. An often cited rule of thumb is a minimum density of seven dwelling units per acre is needed to support intracity bus service.[2] A number of worksheets and guidebooks have been developed that allow analysts to transfer measures developed from empirical studies to the situations they are studying. These decision rules save considerable time over the collection and analysis of new data.

The standard *ITE Trip Generation Manual* illustrates both the advantages and pitfalls of using these decision rules. The manual provides an easy, standardized way to estimate the number of trips that will be generated by a new fast food restaurant with a drive up window, a single-family residential development, and many other kinds of projects. A pitfall of this method is that the cases used to develop the decision rules may differ from the case being analyzed in ways that lead to inaccurate estimates. Areas developing more pedestrian oriented facilities, for example, find that the manual overstates the amount of traffic that development will produce. This has led to the creation of new manuals that provide rules for adjusting the standard trip generating rates (JHK and Associates, 1995).

Other examples of decision rules include:

- Pushkarev and Zupan's estimates of employment and household density needed to support various types of transit service.
- Elasticities showing the effects of different densities and income levels on mode choice
- Estimates of the effects of a pedestrian friendly environment on trip making
- Estimates of amount of parking space needed based on the mix and density of uses and access to transit.

Other decision rules of land use and transportation analysis are based on analysis of current or trend information in the locality being studied. For example, in order to estimate how much land is available for redevelopment, an MPO may want to specify a threshold ratio of land to building value. To put some credence in their measure, they might examine a sample of properties that have recently redeveloped and estimate the ratio of land to building values for these projects.

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[2] This often cited rule of thumb was developed by Pushkarev and Zupan in *Public Transportation and Land Use Policy* (1977) and included a number of qualifying conditions which are often not stated along with the rule.

Applications

Using Decision Rules to Determine the Land Uses Needed to Support Rail Transit

A study in the Research Triangle Region of North Carolina made thoughtful use of rules-of-thumb to analyze the land use patterns needed to generate ridership on rail transit. The study assembled empirical information on the size and density of residential and employment areas needed to support transit and then considered how this would fit with existing and future conditions in the Research Triangle.

The study began with Pushkarev and Zupan' estimate that a low capital cost, at grade light rail would need at least 4,000 weekday passenger-miles per line-mile to justify the capital investment. They noted that this estimate was based on a centrally focused region while the Research Triangle was more dispersed. They went on to consider what types of concentrations of employment would be needed to support ridership drawing on the work of Cervero (1989) and others who have studied suburban employment centers like those in the area. They also estimated how far people would walk or ride the bus to transit drawing on the evidence from other cities. From this, they determined the residential densities needed to produce the minimum ridership. The final result was an assessment of the land use changes that would be needed to support light rail (Barton-Aschman Associates, Inc. 1990).

Strengths and Weaknesses

Decision rules from the literature are widely used because they provide definitive looking answers with little time and effort, but they can easily be misused. The context in which they were developed must be comparable to the context where they are being applied. Decision rules can appear to be more precise than they actually are because qualifications are often not noted. All decision rules, whether based on local information or studies from other locations assume that relationships are static. That is, the relationships that held in the past are assumed to continue in the future despite any changes in circumstances.

2.5 STATISTICAL METHODS

Statistical methods range from simple descriptive tools to complex models that can consider the effects of a number of variables on an outcome. Simple descriptive methods can be used to develop decision rules and provide information for understanding the current relationship between transportation and land use. The emphasis here is on the more advanced multi-variate models and their diverse applications. Two types of models are described--multiple linear regression and discrete choice models.

Multiple Linear Regression

Multiple linear regression models are often developed to predict future events such as the share of growth to assign to each zone. An equation for residential development might include variables for the amount of residential vacant land, expected density of development, current mean number of persons per dwelling unit, the proximity of the area

to employment centers, and distance to freeways or high capacity transit. Factors relating to employment are used for equations for retailing, office, and industrial growth.

Regression analysis provides an objective means of forecasting growth based on the simultaneous effect of multiple factors. This method uses statistical analysis of recent experience to determine the weight to assign to each factor. This is more accurate than treating each factor as having equal effects.

Regression analysis also can be used to test hypotheses regarding the variables that affect land uses or transportation. With appropriate data sets, a researcher can, for example, evaluate whether rail transit influences property values or determine the size of central business districts needed to support commuter rail ridership. In each of these cases, a number of different factors would influence the outcomes. Regression analysis provides a way to determine the relative role of any factor while holding constant all the other factors.

Discrete Choice (or Multinomial Logit) Models

Discrete choice models are designed to model an individual's choices in response to characteristics of that choice. They have long been used in transportation modeling. For example, a discrete choice model can be used to predict mode choice based on the cost, time, and other characteristics of each mode.

Discrete choice model can also be applied to the decisions that households and firms make, such as whether to move or where to locate. A discrete choice model can predict the probability that a household would move during the planning period based on characteristics of the household such as age of household head, presence of children, number of workers, housing tenure, and ratio of housing costs to income. Similarly, employment location choice can be modeled as a function of characteristics of the business (such as industry size), characteristics of potential zones (such as accessibility, density, and employment levels), and characteristics of space (quantity and cost) with a discrete choice framework. This model would produce demand by each employment type for space of each type by zone.

Applications

Forecasting Population and Employment

The Southwestern Pennsylvania Regional Planning Commission (1994) in Pittsburgh developed a set of regression models to predict the attractiveness of each of their analysis zones for residential, manufacturing (including warehousing), and non-manufacturing employment. The model for each type of land use included accessibility measures and market characteristics such as economic development incentives for manufacturing employment and community attractiveness measures for residential land uses. The factors included in the final models were chosen from a larger list of potential variables based on the ability of the factors to correctly predict past development patterns.

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Using Regression to Assess the Impacts of Rail Transit on Nearby Property Values

According to economic theory, the accessibility advantages of transportation investments should be capitalized into nearby property values. These effects have been widely studied. In one of the most recent studies, Landis et al. (1995) evaluated the effects of California urban rail transit investments on nearby property values. They studied five rail systems -- BART, CalTrain, Sacramento light rail, the San Diego Trolley, and Santa Clara light rail.

Landis et al. used hedonic modeling, a type of regression model that is widely used to study the property value effects of proximity to some facility such as a regional park or an airport. The researchers used data on the sales prices of properties and characteristics of that property. They estimated the sale price of homes as a function of housing characteristics (e.g. number of bedrooms, square footage), neighborhood characteristics (e.g. median income, percent of homes owner occupied), and locational characteristics (e.g. distance to rail stations, distance to rail lines, distance to highway interchanges). They developed separate models for each rail system and in some cases included city variables to capture the effects of varying city characteristics. The results showed that in regions where transit systems are well developed and integrated into the pattern of development, residential property values were higher near rail transit. In regions where rail transit provided less of an accessibility advantage, home prices were unaffected by proximity to rail stations.

Strengths and Weaknesses

Statistical tools are valuable both for predicting future outcomes and for evaluating the impacts of transportation and land use policies. They provide a means of quantifying the relationships between a large set of variables, based on theories of transportation land use interactions. Theory should determine which variables to include in the analysis.

Use of regression and discrete models depend upon considerable data and technical expertise. Regression models can be developed with aggregate data such as zonal attributes obtained from census files. Discrete choice models require individual level data that can generally only be obtained through surveys. In order to calibrate their travel demand models, MPOs conduct extensive and expensive surveys of residents about their travel behaviors. Fewer surveys have been done regarding the locational decisions of households or firms.

Statistical software packages make regression and discrete models easy to use. Because of this ease they can be abused. They can be used with inappropriate data or without checking for inter-relationships among variables that can distort the results.

These models provide information about what happens "on average." If there are many unusual cases, or if factors affecting travel behavior or land development are changing in ways not included in the model, they can provide misleading results. The results must be interpreted carefully because many people do not understand the outputs or the limitations of statistical analysis.

2.6 GEOGRAPHIC INFORMATION SYSTEMS

Geographic Information Systems (GIS) provide the ability to map, display, and analyze all manner of data with a spatial component such as land uses, census data, and road networks. A GIS typically consists of layers of graphic/geographic information that depict different aspects of a region and data bases that are related to individual features in specific graphic layers. GIS is a powerful tool for the spatial analysis of land use and transportation systems interactions. A classic use of a GIS is the creation of overlay maps of different features like wetlands and proposed road projects during the initial stages of a corridor design study. A GIS can be the source of the land use, demographic, and employment data used in transportation models, regional economic models, and other transportation related studies undertaken at the MPO or state level.

A GIS can routinely store and process large amounts of information. In addition to storing and mapping layers of data, they can be used to measure proximity, delineate corridors of various widths or other characteristics, measure accessibility, and many other spatial analytical tasks.

GIS hardware and software is available from a number of vendors. Recent advances in the computing power of PCs and the development of new and more powerful PC-based GIS software has substantially reduced the capital costs of setting up a GIS. The cost of hardware and software is, however, relatively small compared to the cost of developing and maintaining the GIS maps and data set. Substantial amounts of general GIS data, such as the Bureau of Transportation Statistics 1995 County TIGER files, are available now. Using existing data source can reduce some of the startup costs associated with the initial creation of a mapping system. Nevertheless, GIS systems require relatively large amounts of data development and maintenance.

Applications

Using GIS for a Base Case Forecast

Spartanburg County, South Carolina, is a small MPO (about 100,000 residents) using simplified attractiveness analysis based on the idea that roads, water, and sewer are the primary factors determining the potential for development. They have entered the existing and planned roadway, water, and sewer systems in a GIS. These infrastructure plans are assumed to have taken into consideration both where growth is likely to occur and where the community wants it to occur.

Next, the MPO developed a set of decision rules. For example, commercial, industrial, and multi-family developments require locations on arterial streets as these streets are necessary to handle the level of traffic generated by these uses. These developments also

require access to water and sewer. Single family-residential development at urban densities can occur on minor streets but requires water and sewer services. The MPO assumes that residential developers can afford to extend water and sewer lines up to one-quarter of a mile spreading potential residential areas beyond where these systems currently exist. Only rural residential development will occur along minor roads where there is no sewer or water service.

Using the GIS database, they can identify the sites meeting the attractiveness criteria for each type of development. They can combine this with knowledge about when extensions are planned to decide when and where development is likely to occur.

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Strengths and Weaknesses

GIS is a valuable tool with the ability to store, display, and analyze large amounts of spatial data. They provide a means of seeing, reviewing, and analyzing the interrelations between different physical systems. They can provide maps and other information to use in various public processes. They can be used with other tools such as formal land use models and regional economic models. This powerful tool, however, does require considerable staff time and effort to create and maintain the data layers and databases that comprise the GIS.

2.7 REGIONAL ECONOMIC MODELS

Regional economic models simulate an area's economy. They estimate the impact of major economic changes, such as population growth, industrial expansion or contraction, and lower transportation costs, on various sectors of the economy. The models can produce forecasts of employment and industrial output, and sometimes population, for areas such as counties, multi-county regions, and entire states. These models, therefore, provide information on the regional economy that can be used with other spatial allocation tools to make land use estimates.

The major types of regional economic models are input-output models, econometric models, and combinations of the two. This section describes the general models as well as some of the most widely used, commercially available models.

Input-Output Models

An input-output model is essentially an accounting system showing economic transactions between businesses, households, and governments. The model measures flows of goods

and services between the various sectors of the economy. These linkages reflect supply and demand relationships among industrial categories and between consumers and producers. The linkages were derived from the 1977 Bureau of Economic Analysis (of the U.S. Department of Commerce) input-output model for the United States.

Input-output models compute the changes in direct, indirect, and induced demand that a change in the economy produces. Direct effects are production changes associated with the immediate effects or final demand changes, such as the purchase of materials and labor for highway construction. Indirect effects are production changes in backward-linked industries caused by the changing input needs of directly affected industries, such as the increased purchases by cement companies working on the highway project. Induced effects are the changes in regional household spending patterns caused by changes in household income generated from the direct and indirect effects. Thus, the effects of highway construction or some other change in the regional economy are measured throughout the economy. These effects are often reported as multipliers. The multipliers may state, for example, that highway construction jobs have a multiplier of 1.5. In other words, every highway construction job results in 1.5 jobs in the regional economy because of the spending of construction firms and their employees on other goods and services.

Input-output models are typically used to assess the impacts of new transportation projects on the regional economy. They can also be used as a descriptive tool because they provide a wealth of information about the size and nature of the regional economy and its linkages within and outside the region.

IMPLAN and RIMS are two input-output models widely used for impact assessment.

IMPLAN Input-Output System

IMPLAN (Impact Analysis for Planning) was originally developed by the U.S. Forest Service in cooperation with the Federal Emergency Management Agency and the Bureau of Land Management to assist the Forest Service in land and resource management planning. The IMPLAN database consists of two major parts: 1) national level technology matrices specifying the relationships between industries and 2) estimates of sectoral activity for final demand, final payments, industry output and employment. Data is available for every county in the U.S. along with state and national totals for 528 industrial sectors.

IMPLAN is a PC-based economic impact system. There are two components to the IMPLAN system, the database and the software. The databases provide all information to create regional IMPLAN models. The data files include information for 528 different industries (generally 3 or 4 digit SIC code breakdown), and 21 different economic variables. Along with the data files are national input-output structural matrices. To create an IMPLAN model, an IMPLAN software package is also required. The software performs the calculations and provides an interface for the user to make final demand changes. IMPLAN software is available in DOS and Windows versions.

The IMPLAN model is currently available through:

MIG, Inc. (Minnesota IMPLAN Group)
1940 South Greeley Street, Suite 201

Stillwater, MN 55082
Phone (612) 439-4421
FAX/BBS (612) 439-4813

RIMS-II Regional Economic Model

In the mid 1970s, the Bureau of Economic Analysis (BEA) developed a input-output method known as RIMS (Regional Industrial Multiplier System) for estimating regional I-O multipliers. More recently, BEA completed an enhancement of RIMS known as RIMS II (Regional Input-Output Modeling System). In RIMS-II, direct requirements coefficients are derived from BEA's national I-O table, which shows the input and output structure of more than 500 U.S. industries and BEA's four-digit Standard Industrial Classification (SIC) county wage-and-salary data, which can be used to adjust the national direct requirements coefficients to show a region's industrial structure and trading patterns. Regional multipliers for industrial output, earnings, and employment are then estimated on the basis of the adjusted coefficients.

The Bureau of Economic Analysis provides the RIMS-II model in hard copy or diskette format. The multipliers are easily transformed in most computer spreadsheet software products for easier model operation. The RIMS-II input-output model is available through the Bureau of Economic Analysis (telephone - 202-606-5353).

Applications of Input-Output Models

Estimating the Transportation Sensitivity of Oregon Counties

The Oregon Department of Transportation conducted an analysis of the economic development potential of state highway corridors in Oregon as part of a general process of evaluating corridors. This analysis used the IMPLAN input-output model as a descriptive tool. The study developed a measure of transportation cost sensitivity that was responsive to the mix of industries in each county. The measure used estimates of the purchase of services from the motor freight transportation sector and the provision of transportation services by the companies themselves, both outputs from IMPLAN. The measure proved to be effective at differentiating among counties in their sensitivity to travel costs. Along with a number of other measures of economic development potential, the transportation sensitivity coefficients provided insight into the potential for highway improvements to support economic development (Parsons Brinckerhoff 1995).

The Oregon Department of Transportation can be reached at:

Oregon Department of Transportation
Transportation Building
355 Capitol St. NE
Salem, OR 97310
(888)275-6368

Estimating the Economic Impacts of Metrorail

The Northern Virginia Transit Commission used the RIMS input-output model to analyze the impacts of building and operating Metrorail on the state's economy between 1978 and 1993. The input-output model simulated the flow of expenditures on Metrorail through the state's economy. The cost of building, maintaining, and operating Metrorail and of office, commercial, hotel, and residential development associated with the rail system served as the inputs into the RIMS model for Virginia. The outputs identified the number of jobs and amount of income generated by various sectors because of the investment in Metrorail. The RIMS outputs were used to help assess the amount of property and income revenue generated by the Metrorail system (KPMG Peat Marwick 1994).

The Northern Virginia Transit Commission can be reached at:

Northern Virginia Transit Commission
7535 Little River Turnpike, Suite 100
Annandale, VA 22003-2937
(703) 642-0700

Econometric Models

Econometric models are statistical and mathematical based models that depict the decision-making process of businesses, households, financial institutions and governments and show how they interact to produce the economy's broad movements. Models can be based on national assumptions about the relationships between economic sectors or tailored to specific regions. State agencies and MPOs often use econometric models to forecast employment and population changes at the statewide or regional level.

Applications of Econometric Models

Forecasting Regional Population and Employment

The Puget Sound Regional Council (1995) in Seattle, Washington, does transportation planning for a region with 2.75 million residents. They have used an econometric model, STEP94, to estimate future population and employment levels. This system of simultaneous equations describes the economic and demographic interrelationships underlying growth and change in the regional economy. The model was calibrated using historic data from 1958 to 1993. Linkages to the national economy were estimated using projections of industrial output at the national level. PSRC uses the DRI/McGraw-Hill August, 1993 U.S. TRENDLONG forecasts as the national input data.

The Puget Sound Regional Council can be reached at:

Puget Sound Regional Council
11011 Western Avenue, Suite 500
Seattle, WA 98104
(206) 464-7090

Models Combining Input-Output and Econometric Analysis

One of the limitations of input-output models is that they are static. Their forecasts assume that changes in technology, labor supply, or costs have no effects on the relationships between industries. To correct for this problem, modelers have linked the input-output model with econometric models to produce dynamic models where the factors used in production can change over time.

Dynamic regional economic models produce socio-economic forecasts based on an historical analysis of the regional economy. The REMI model, for example, forecasts natural population growth or decline based on a traditional model of fertility and mortality. Then, based on the results of the employment forecast, the model determines if more people are needed to fill the projected jobs in the region. The equation for economic migration reflects the region's attractiveness relative to the country as a whole based on the availability of jobs and on wage rates.

The population forecast is then used to estimate consumer demand. This estimate is run through the economic portion of the model to determine if the changes in consumer demand will change the economic forecast. The revised estimates of employment and wages are then applied to the demographic portion of the model to allow for any further changes in economic migration. This cycle continues until the economic and demographic forecasts balance.

REMI (Regional Economic Models, Inc.)

The REMI model is an integrated economic/demographic forecasting model originally developed for the National Cooperative Highway Research Program in 1980. REMI builds forecasting and simulation models for specific states or county-based regions. The model forecasts employment, wages, output, relative costs, and other variables for industries in a region. A broad range of policy impacts can be simulated using REMI.

The REMI model expands on the traditional input-output methodology by including substitution among factors of production in response to changes in costs, migration in response to changes in expected income, wage responses to changes in labor market conditions, and changes in the share of local and export markets in response to changes in regional profitability and production costs.

The model includes linkages among the five following submodels:

- Output linkages (the 53 sector input-output model results)
- Population and labor supply
- Labor and capital demand
- Market shares
- Wage, price, and profit

The REMI model can simulate a wide variety of policy effects on regions because it has a large set of policy variables. They include industry-specific variables for each of the 49 private non-farm industries, cohort-specific variables for age-sex cohorts, and final demand-specific variables for 25 final demand sectors.

The REMI model operates on personal computers using FORTRAN programs. REMI models can be purchased or rented. Prices and services vary with the size of region and the length of use. The REMI model is available through:

Regional Economic Models, Inc. (REMI)
306 Lincoln Avenue
Amherst, MA 01002
Phone (413) 549-1169
FAX (413) 549-1038
EMAIL: remi@crocker.com
Home Page: http://www.crocker.com/~remi/

Applications of Combined Input-Output and Econometric Models

Base Case Forecasting

The Southwestern Pennsylvania Regional Planning Commission (1994) in Pittsburgh does regional transportation planning for a six county region with about 2.2 million residents. The region was severely impacted by industrial decline and economic restructuring in the 1970s and 1980s making the task of projecting future regional population and employment control totals more problematic than in growing regions. The MPO decided to use the commercially available REMI model. The MPO convened a group of experts from its member counties, the City of Pittsburgh, the University of Pittsburgh, and the private sector to evaluate the REMI results and suggest adjustments to the model.

The Southwestern Pennsylvania Regional Planning Commission can be reached at:

Southwestern Pennsylvania Regional Planning Commission
The Waterfront
200 First Avenue
Pittsburgh, PA 15222-1573
(412) 391-5591

Analyzing Corridor Investment Strategies

In 1990, the Indiana DOT conducted a study of the effects of a highway from Indianapolis to Evansville on local and regional development. User benefits (travel time savings, vehicle operating costs, and costs of accidents, injuries, and fatalities) were calculated with travel demand models and then input in a multi-county REMI model. The REMI output was combined with exogenous estimates of business attraction to forecast changes in employment and households for each county in the corridor.

The Indiana DOT is currently licensing REMI to produce statewide household and employment forecasts and to assess the impact of transportation investments on the economy of the state. The model will provide forecasts of economic growth measured in employment, income, and regional output. Both statewide and corridor specific REMI models will be used. Indiana DOT plans to link the REMI model with their travel demand

model to consider feedback loops from the assignment of households and jobs to transportation as well as the impacts of transportation investments on the economy.

The Indiana Department of Transportation can be reached at:

Indiana Department of Transportation
100 N. Senate Ave.
Room IGCN 755
Indianapolis, IN 46204
(317)232-5533

Analyzing the Economic Impacts of Investments in Public Transportation

The Regional Transportation Authority (RTA) in Chicago studied the economic effects of disinvestment or increased investment in the nation's second largest public transportation system. The REMI model was used to evaluate the economic impacts of four scenarios for the transit system for the next 20 years. The scenarios were Baseline/Deterioration with funding at current levels, Disinvestment with the system operating at reduced levels of service, Good State Of Repair with additional funding to provide good service quality, and Systems Expansion with funding to extend and enhance the system. The study estimated how the alternative investment scenarios would affect travel costs for both transit and highway users and then how these changes in travel conditions would affect the cost of doing business in the Chicago area and the state of Illinois as a whole.

The study used a transportation model to estimate the changes in transportation costs for each scenario. Estimates included effects on RTA and highway users as well as the capital and operating costs of RTA. In addition, changes in auto ownership costs, fuel use, parking costs, and RTA's subsidy were estimated. These changes in transportation costs were then input into the REMI model to estimate the effects on the standard two-digit sectors of the economy. Separate models were used for the Chicago metropolitan area and the state of Illinois. Impacts were measured in business sales, personal income, employment, and population (Cambridge Systematics 1995).

The Chicago RTA can be reached at:

Regional Transportation Authority
181 West Madison, Suite 1900
Chicago, IL 60602
(312)917-0700

Strengths and Weaknesses

Regional economic models are useful for assessing the impacts of transportation investment and policies on a region's economy. By simulating the flow of goods and services among economic sectors, they provide information on how changes in the transportation system would impact the regional economy. The models can produce estimates of employment and industrial output for highly disaggregated economic sectors.

Because counties are the smallest geographic area in these models, they work best at predicting changes in multi-county areas or for corridors connecting cities. They require analyzing economic regions as units (e.g. whole metropolitan areas) even when smaller areas are of primary interest. This internalizes more economic flows and will produce more accurate results, but also necessitates more data.

Input-output models are static; that is they assume constant technology, labor supply, and prices of inputs. If a region is undergoing economic restructuring, population growth or decline, or technological changes in major industries, a more comprehensive model that can factor in these changes is needed.

Use of the these models requires a thorough understanding of their assumptions in order to correctly interpret the results. For impact assessments, the policy or investment change must also be correctly identified and quantified in order for the model to determine its effects (Hasting and Brucker 1993).

2.8 FORMAL LAND USE MODELS

The following sections describe several of the land use models in operational use in the U.S. and abroad, as well as simpler models that qualify as sketch planning tools, and modeling prototypes not yet widely deployed, but which add useful contributions to the state of land use modeling. Models were selected for review if they are commercially available and in use by one or more metropolitan areas, or if they represent some aspect of state-of-the-art development in land use modeling techniques, and there is reasonable potential for their use in other metropolitan areas in the near future. The models reviewed and their developers include:

DRAM/EMPAL	Stephen H. Putman
MEPLAN	Marcial Echenique
TRANUS	Tomas de la Barra
METROSIM	Alex Anas
HLFM II+	Alan J. Horowitz
LUTRIM	William Mann
CUF	John Landis
UrbanSim	Paul Waddell

While this is not an exhaustive review of land use models, we believe it covers the major operational models in wide use today, as well as some of the emerging models. Other models not reviewed here include earlier models no longer in use, such as EMPIRIC, and many models in various stages of research and development that are not commercially available, such as the 5-stage Land Use-Transportation model developed by Francisco Martinez in Santiago, Chile; the IRPUD microsimulation model developed by Michael Weggener in Dortmund, Germany, the MASTER microsimulation model developed by Roger Macket in London, UK; and the UrbanSim model in development by Paul Waddell and Parsons Brinckerhoff for Oregon and elsewhere.[3]

[3] A refined and enhanced version of the UrbanSim model will be developed for NCHRP as part of this project.

To facilitate comparison, the model descriptions are organized into the following subsections:
Overview including contact information

Requirements for use
- Computing platform
- Budget and staffing requirements
- Data requirements

How it works
- Outputs
- Formulation
- Calibration
- Integration with travel models
- Integration with GIS

Applications
- Forecasting
- Policy analysis

Strengths and weaknesses

In addition to reviewing these models using a structured format for comparison, we close with a section on hybrid or customized modeling efforts by MPOs, and a section on integrated land use-transportation models under development.

2.8.1 DRAM/EMPAL

Overview

The Interactive Transportation-Land Use Package, generally known as DRAM/EMPAL, was developed under contract with the U.S. Department of Transportation in the 1970's by Stephen H. Putman, University of Pennsylvania (Putman, 1983). The model system contains three components: the Disaggregated Residential Allocation Model (DRAM), the Employment Allocation Model (EMPAL), and a set of travel demand models, although in common practice the users have generally substituted their own travel models for those available with DRAM/EMPAL.

One of the principal design features of the DRAM/EMPAL models is the capacity to evaluate land use-transportation interactions. This perhaps accounts in part for the surge in the adoption of this modeling system by several metropolitan areas in the past several years. Prior to 1980, several metropolitan areas had implemented DRAM/EMPAL, including the Mid America Council of Governments (Kansas City), the Puget Sound Council of Governments (Seattle), among others. Since 1980, metropolitan areas that have implemented or decided to implement the DRAM/EMPAL models for land use forecasting include Dallas-Fort Worth, Detroit, Houston, Los Angeles, Phoenix, and San Diego, and the Florida DOT. With the rising use of this modeling system, and its position as the only widely available model in the U.S. that addresses the need to evaluate land use-transportation

interactions required by ISTEA and Clean Air Act, DRAM/EMPAL has become somewhat of a de facto standard among metropolitan planning organizations.

Increasing demands are being made on the models by the planners and analysts using them, however, and appear to be taxing the ability of the models to produce forecasts and policy impact analyses that satisfy users. Putman has indicated that the development of the DRAM/EMPAL models has ceased, to be replaced by a new model system called METROPILUS (Putman, 1995), details of which are not available at this time.

Contact Information

Stephen H. Putman
S.H. Putman Associates, Inc.
Tel: 215-848-2385
fax: 215-438-5656

Client Contacts:

San Diego Association of Governments
401 B Street, Suite 800
San Diego, CA 92101
(619) 236-5330

North Central Texas Council of Governments
616 Six Flags Drive, Suite 200
P.O. Box 5888
Arlington, TX 76005-5888
(817) 640-3300

Requirements for Use

Computing Platform
DRAM/EMPAL was originally developed to run on mainframe computers, but has been ported to UNIX workstations and IBM compatible microcomputers.

Budget and Staffing Requirements
DRAM/EMPAL is typically delivered within a consulting contract that includes assistance in calibration. Consulting contracts range from $15,000 to over $100,000, depending on the size of the metropolitan area and any customization requested by the client.

MPOs vary widely in their level of support and staffing for the land use forecasting function. The smallest may have one person handling data preparation and forecasting (sometimes with other responsibilities), although this is likely to be difficult to sustain. Larger MPOs often have several full-time staff dedicated to these functions. Budgets for mid- to large MPOs such as Kansas City or Atlanta average around $100,000 per year for all related aspects of the land use modeling, including consulting. Costs for larger MPOs or those that have requested substantial consulting are well above these levels.

Data Requirements
DRAM uses the following input data for each zone:
- Employment by type
- Households by income quartile
- Vacant developable land
- 1.0 plus the percent of developable land already developed
- Residential land
- A regional matrix of coefficients converting employment by industry to households by income quartile
- A zonal travel impedance matrix (travel time or cost)

EMPAL uses the following input data:
- Employment by type in previous time period (usually lagged 5 years)
- Total land area
- Total households in previous time period
- A zonal travel impedance matrix (travel time or cost)

How it Works

Outputs
The DRAM model predicts the number of households by income quartile in each zone. EMPAL predicts employment levels by type. Employment is typically grouped into five industry categories. A separate program, LANDCON, translates the household counts and employment into residential, basic, and commercial land.

Formulation
DRAM and EMPAL are from a class of models known as spatial interaction models, derived from the original Lowry gravity model, (like that embedded in most trip distribution models), with the major enhancement being that a multivariate zonal attractiveness variable is added to the travel disutility function. More specifically, the DRAM and EMPAL models are a modified form of the standard singly-constrained spatial interaction model, with two modifications: 1) a multivariate attractiveness term is used, and 2) a consistent balanced constraint procedure is included (Putman, 1994).

- The models are aggregate, in the sense that they allocate groups of households classified by income quartile, and employment classified by five industry groups.

- The models are cross-sectional, meaning that they are calibrated on one time period (although EMPAL includes lagged employment), and predict the spatial distribution of all activity in each time period, rather than predicting changes from one time period to the next.

Calibration
The CALIB program is used to calibrate the parameters for both DRAM and EMPAL. The program uses a gradient search procedure to maximize a likelihood function. A goodness of fit measure for each model is defined as a likelihood ratio, which essentially compares how much better the estimated model predicts the observed distribution of activity than does a uniform distribution assumption. The likelihood ratio ranges between 0 and 1, with 1 representing a perfect match between the predicted and observed distribution, and 0

representing a prediction of a uniform distribution. To assist in interpretation of the calibration parameters, asymptotic t-tests are calculated, as are location elasticities for each parameter (Putman, 1995).

The calibration procedure produces a file of the prediction errors, or residuals. These are simply the ratio of the observed to predicted values of a particular category of households or employment within a zone. If the model under-predicted low-income households by fifty percent, for example, the residual would be 1.5. These residuals represent errors that the model did not predict accurately because of some combination of errors in the input data and failure of the model to represent adequately the complexity of locational behavior. In other words, both data errors and omitted variables in the model, or poor model specification, will produce prediction errors that are then used as k-factors in producing forecasts. Putman recommends attenuating the use of the residuals in the forecasts, but the use of these errors in the forecasts appears to be somewhat arbitrary.

Integration with Travel Models

DRAM/EMPAL has been interfaced or is being interfaced with TRANPLAN, EMME/2, and MINUTP transportation planning packages, as well as customized transportation software developed in some MPOs. The nature of the interface is a utility to read the travel impedance matrix in the format of the particular transportation planning package, since this is an input into the DRAM/EMPAL models.

By explicitly incorporating a zonal impedance matrix in both the residential and employment allocation models, the DRAM/EMPAL models provide a capacity to evaluate the feedback effects of transportation system alternatives on future land use patterns. Thus when a roadway or transit system alternative is implemented in a future year network, and congested travel times are generated from the transportation models, these revised travel impedances enter the DRAM and EMPAL models as inputs and cause reallocations of population and employment. This procedure, in theory, allows planners to measure the effects of a freeway extension on new development, or of transit system development on densification of land use.

In practical operation, the linkage between the land use and travel models is typically hindered by the need to run the land use models with a less detailed zonal system than that used by the travel models. This limitation introduces the requirement that the zonal impedance matrix produced by the travel models be 'squeezed' or aggregated, into the larger zonal system used in the land use models, which inevitably loses information about accessibility patterns. Once the DRAM/EMPAL models have been run, the output must then be disaggregated into the more detailed zonal system used for travel forecasting. This disaggregation is done mechanically by most MPOs using these models, and with a wide array of approaches and input data. Most commonly, a simple accounting technique is used to proportionally allocate the population and employment to traffic zones using land area, occasionally with some prioritization based on local inputs. Almost no systematic assessment of the errors produced in these aggregation/disaggregation procedures exists (Tayman, 1995).

Until recently, there also existed no systematic evaluation of the degree to which iteration between the DRAM/EMPAL models with travel models produced convergence. A project during the past two years has examined this, and suggested a convex combinations

procedure for ensuring convergence (essentially a link-level moving average of travel times) (Putman, 1995).

Users of the models interviewed as part of this project indicated, almost without exception, that the models were not being used in an iterative manner with the transportation models, however. Even with the new procedures developed by Putman, significant operational constraints remain, including the level of time and effort required for each iteration of the existing travel models.

Integration with GIS
To date, we are not aware of any integration of DRAM/EMPAL with GIS software, but there is substantial interest in GIS integration from current model users. It would require minimal effort to reformat the output files into a form compatible with GIS packages such as Arcview, Mapinfo, Atlas GIS, or Transcad, and we expect that utilities to accomplish this reformatting are likely to be available either from S.H. Putman Associates or from the user community. More direct integration, or analytical use of the GIS will likely be difficult to accomplish within the current structure of the program.

Applications

Forecasting
Forecasts of the DRAM/EMPAL models are typically run for 5 or 10 year intervals in the future, out to 20-25 year forecast horizons generally required for transportation planning. As noted earlier, the forecasting process in practice generally uses the calibration residuals, although there is no standardization in terms of the way in which they are used. Some MPOs use the residuals without modification or attenuation, while others modify the residuals heavily to force the model to produce results they will find acceptable[4].

In application, the programs provide several ways for users to constrain the forecasts for particular zones. In addition to the manual adjustment of the residuals, or j-factors discussed above, the programs offer users the ability to constrain totals using four different methods:

- Absolute constraints on the amount of employment or households of a particular type in a particular zone.
- Absolute constraint on total employment or total households (not by type) within a zone.
- Maximum value for a particular household or employment type in a zone.
- Minimum value for a particular household or employment type in a zone.

The programs reallocate activity to satisfy these user-imposed constraints and the regional control totals, providing a relatively easy way to reallocate activity subject to constraints.

Although some users appear relatively satisfied with the forecasts produced by the DRAM/EMPAL models, a large fraction of those surveyed reported various levels of dissatisfaction with the results. Common complaints included the accuracy or

[4] Acceptability may be defined in terms of objective reasonableness or political acceptability, which clearly are not identical. The models can be, and too often are, used in practice as sophisticated calculators, manipulated to produce a particular political objective.

reasonableness of the forecasts, the need to manually intervene using the k-factors and constraints to produce satisfactory forecasts, the complexity of the software to operate, the inability to assess the impacts of numerous public policies that could impact land use significantly, the absence of a land market component that would incorporate land prices, and lack of integration with GIS.

Policy Analysis

The DRAM/EMPAL models were developed to accomplish two objectives: produce reasonable baseline forecasts for input into travel demand models, and evaluate the impact of gross changes in accessibility on land use. As a result, the models have been used and are promoted for analyzing the impact of transportation improvements and policies on land use outcomes such as the location of population and employment.

Some of the practical limitations on iteration and convergence between the travel models and land use models noted earlier raise questions about the accuracy of these kinds of policy analyses. The difference in zone size, requiring aggregation of travel times and disaggregation of population and employment, provides one complication. Failure to iterate between the land use and travel models, either because adequate documentation of new procedures to achieve improved results have not been widely circulated or because it is inherently difficult to iterate the models with the current generation of land use and travel model software, effectively undermines the viability of policy analysis of transportation impacts on land use.

Planners are often asked to assess many other kinds of policy impacts, such as changes in comprehensive land use plans, new economic development strategies or investments, new airport or other major infrastructure construction, or redevelopment initiatives. The DRAM/EMPAL models were never designed to assess these kinds of impacts, and have no behavioral content to make realistic impact assessments of these kinds of policy questions feasible. What planners often do, given these circumstances, is make assumptions about the impact of a particular policy, and then impose the result of the assumption as a constraint on the forecasts. Although it is relatively easy to impose such constraints, consumers of the forecasts may frequently interpret the forecasts as having more policy analytical capability than they actually do. This kind of use of the models should be well documented by planners who should spell out the assumptions and the constraints that were imposed on the models.

Strengths and Weaknesses

Several concerns about the DRAM/EMPAL model system have been raised by practitioners applying the models and by academics examining the underlying theory and structure. Some of these concerns, and our recommendations in response to them are:

- The capacity of the DRAM/EMPAL models in evaluating land use-transportation interactions is rarely exploited fully in practical application. For most MPOs the time and cost of running the travel demand models multiple times for each horizon forecast year is often excessive, and frequently only one iteration is performed per horizon forecast year. We recommend that the convergence procedures recently developed by Putman be tested by more MPOs currently using the DRAM/EMPAL models, and that the models be run in a iterative manner until the results of the land use and travel models

converge. Otherwise, there is no confidence that the results will be consistent, and the intent of the ISTEA and CAAA requirements for integrating these procedures will not be met. One could have little confidence in the predicted impacts of transportation system changes on land use.

- The models require a relatively high level of effort and resources. A staff of full time analysts with at least one with modeling capability is likely to be required, in addition to substantial consulting time to assist in the calibration and operation of the models. We recommend continued effort to simplify, streamline, and document all land use models, not just DRAM/EMPAL. Simplification of the models may entail simplification of the software, not necessarily the behavior or the data required. It may well be the case that the current models lack too much behavioral content to produce acceptable forecasts and policy analyses in many areas.

- Employment by industry in each zone is converted into households for allocation using a regional employment to household by income matrix, which imposes crude regional generalizations on each zone. This approach seems particularly unrealistic when one reflects on the frequency of multiple-earner households, multiple job workers, and job changes not accompanied by residence changes. In reality, the connection between employment and households is complex, and this key aspect of DRAM is particularly unrealistic. No recommendation is made on this point, since this concern arises from the basic structure of the model, and would be impossible to change without dramatically restructuring the model.

- Important household/demographic characteristics are missing, such as household structure/children present, stage of life cycle, number of workers, and ethnicity - all of which have been widely documented to affect location choices and travel behavior. Although some testing of additional disaggregation has been completed, it has apparently not led to substantial improvement in the forecasts. We expect that this is more a function of the model construction than the insignificance of these factors in residential location. A very substantial body of empirical literature supports the importance of these factors in residential location.

- These is no representation of the land market; land price effects of changes in transportation services or policies cannot be estimated. Households and businesses compete for land, with the successful bidders determining the land use and location patterns that ultimately result from the market clearing process. Without a market representation, it is difficult to capture key aspects of the urban development process, or to test many public policies that impact prices of land or development. Again, it is unreasonable to consider any recommendation on this point, since the basic formulation of these models is inconsistent with models that incorporate land market behavior. We recommend instead that users be cognizant of these limitations, and not use the models in inappropriate ways.

- Structures are not separately accounted for from the activities that occupy them. Housing and commercial space are not endogenous to the models, making the models less transparent in their behavior than models that account for land, structures, and activities, and the relationships between them, including prices. The previous recommendation applies here as well.

- The models have no way to account for adjacency or spillover effects, such as the spillover of residential development from one zone to an adjacent or nearby zone as development opportunities within a zone diminish due to buildout (DRAM), or agglomeration effects across adjacent zones, such as occur in the evolution of an employment center which occupies several zones (EMPAL). It is possible that such effects could be tested within the current model structure, but it is more likely that alternative model structures such as nested logit models of location choice would lend themselves to these concerns.

- In normal practice, there is an inconsistency between the zonal system used for DRAM/EMPAL and that used for transportation modeling. This has led to the use of allocation techniques to disaggregate the land use forecasts to traffic zones, and aggregation techniques to squeeze the travel time matrix generated by the travel models for use in the land use models. This inconsistency may cause not only a loss of information in the interaction of the models, but may also affect the accuracy of the forecasts. Where possible, the zonal system used in the land use models should be disaggregated to the level used in the travel models.

- Putman and others have noted that the models do not perform well with very disaggregate zonal systems, or where there is sparse activity within certain zones, causing pressure to aggregate the zonal system, which runs counter to the need for consistency between the zonal systems used in the land use and transportation models. A more thorough assessment of these concerns should be undertaken, in order to clarify the less problematic approach: aggregate zonal system with its problems or a more disaggregate zonal system with its own problems.

- The models are static cross-sectional, and do not realistically reflect the fact that only a fraction of the households and businesses move in any given time period, and that the land and housing markets may never reach equilibrium, but are continually adjusting towards equilibrium. Urban development is an incremental process, in which changes occur at the margin, based on the existing distribution of activity, infrastructure, housing, and nonresidential space. More rigorous testing of the behavior of the models over long periods comparable to the forecast periods should be undertaken and reported.

- There is a possibility that these models may not accurately estimate the sensitivity of land use to transport changes, if important attractiveness terms are omitted, or as a result of the zonal aggregation issues discussed above. A systematic effort to evaluate the accuracy of the models in measuring land use impacts of transportation system changes should be relatively straightforward to undertake, and would be invaluable to the large user community for this model system.

In summary, DRAM/EMPAL is the most widely used land use model in the United States. Because it requires considerable time and expertise to use, only large MPOs have considered using it. It is Lowry gravity model which was designed to make base case land use forecasts to input into travel demand models and to evaluate the impact of gross changes in accessibility on land uses. MPOs and DOTs are asked to assess the impacts of many policy issues that DRAM/EMPAL was not designed to address. Although a variety of

methods have been developed to use DRAM/EMPAL for policy analysis, none of them are very satisfactory.

2.8.2 MEPLAN and TRANUS

Overview

MEPLAN and TRANUS are two model systems that are closely related, and most of the subsequent description applies to both. Some specific differences are mentioned in the text, although perspective users should not assume that the programs operate identically or produce identical results. These models are the result of a series of developments initiated by Marcial Eschenique in 1967 in the U.K. They have been extended throughout the past three decades by Eschenique and others, including Tomas de la Barra, the author of the TRANUS model system. The models have been applied in a variety of planning activities throughout Europe, Latin America, and Asia, but have been largely ignored to date in the United States. Several features of these models are now generating interest in the U.S., among them:

- They have the ability to explicitly represent the interactions between the location of activities, land use, and the transport system in a comprehensive framework. They are based on accepted theories of macroeconomic behavior, and include markets for land, floorspace, and labor.
- They incorporate transportation modeling components that ensure internal consistency between location and travel choice decisions.
- They use an extension of economic input/output modeling approach to represent the interactions between economic sectors, as well as between economic sectors and households and land markets. The demand for goods and services are implicit in this framework.

These features have attracted attention for such applications as regional modeling, statewide freight modeling, and a wide range of policy and environmental analyses.

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Requirements for Use

Computing Platform
MEPLAN operates on IBM-compatible microcomputers, as well as some Unix workstations, minicomputers, and mainframes. TRANUS operates only in the Windows 95/Windows NT environment.

Budget and Staffing Requirements
MEPLAN:
Licensing and consulting rates are available from Marcial Eschenique & Partners Ltd. Recommendations for staffing include a team of a planner, a transport engineer, and an

economist. The components of the package are priced separately; the cost of all modules is around $40,000.

TRANUS:
The cost of the TRANUS package is $6,000. Consulting rates for assistance in calibration and implementation are available from Modelistica or Rickaby Thompson Associates. Staffing recommendations were not identified, but are likely to be similar to MEPLAN.

Data Requirements
Both MEPLAN and TRANUS are described by their authors as very flexible in terms of the level of detail and structure of the models. This means that the input data requirements are to some degree a function of the objectives of the user. General data requirements include:

- Land use by category
- Floorspace by category
- Population by category
- Employment by category
- Land prices by land use category
- Floorspace prices by floorspace category
- Input-output economic structure, aggregated to level of detail desired by user
- Exogenous forecast of basic (export-oriented) employment
- Travel networks
- Policies such as pricing, zoning, taxes

A review of the TRANUS documentation reveals that several data are required for model calibration. Similar requirements exist for MEPLAN, although the documentation is not as descriptive of the model structure and typical data requirements as the TRANUS manual. These data are required for each zone and sector (e.g. economic sector, exports, households by type, land and floorspace):

- Exogenous production by zone and sector
- Induced production by zone and sector
- Exogenous consumption by zone and sector
- Unit price by zone and sector
- Value added to each unit of production by zone and sector
- Optional value representing the relative attractiveness of the zone for production of the sector
- Exports by zone and sector
- Imports by zone and sector (including quantity, price, and an optional relative attractor variable)
- Restrictions to the internal production by zone and sector

How it Works

Outputs
The models predict the following by zone and by sector:

- Land and floorspace consumption and prices by land use category
- Changes in induced production and demand (including labor) by sector
- The distribution of system-wide increments of growth in population and employment
- Flows between zones, expressed in whatever terms the input-output matrix is built in (typically dollars for sectoral flows, acres for land, and square feet for floorspace, but they can be any unit of measure desired)
- Generation and distribution of goods and person movement by mode of transport and trip purpose.

Formulation
The models are deeply rooted in discrete choice analysis and random utility theory. Most of the choice modeling calculations are based on an extended form of the well-known logit model. Although the original work of Domencich and McFadden focused on the problem of mode choice in transport, this theoretical backbone has been extended to all decision levels in the MEPLAN and TRANUS frameworks, from modal split to assignment, trip generation, location of activities and land and floorspace choices. The traditional logit formulations have been further extended in TRANUS through the scaling of utilities, a controversial practice that appears to reduce the amount of work required in model calibration but perhaps violates some theoretical tenets of the logit model.

These models integrate economic and land use modeling through the concept of markets for space (land and floorspace), transport, and factors of production such as labor. The use of markets requires the reconciliation of demand and supply, and the clearing of markets through adjustments in prices. This feature makes the models much more amenable to use for policy analysis, where policies impact prices or impose constraints on supply, which in turn influences prices. The consistent internal accounting of supply and prices also provides information that is useful for economic evaluation of alternatives using cost-benefit analysis.

Several characteristics of these models are distinct from the class of spatial interaction models (such as DRAM/EMPAL):

- Evolutionary or dynamic implementation: the models deal with temporal increments in the key inputs, which can be applied to specific zones to the system as a whole. Location choices are predicted using lagged accessibilities and prices, to approximate the concept that there is not instantaneous adjustment in locations, and that there is imperfect information flow. This results in an incremental model that is based on the assumption that the urban system adjusts towards equilibrium, but never reaches it. It also supposes, of course, that the lagged structure of the model realistically and appropriately captures this concept.

- Economic interactions between businesses and households distributed across zones are used as the basis for predicting the distribution of travel and commodity flows between zones. The models use internally consistent measures of accessibility in choice modeling.
- Input-output modeling is used as a computational framework for representing the interactions between economic sectors, households by type, and land markets. But rather than having fixed values in cell of the input-output table, demand functions are used to incorporate elasticities of demand in the model. The coefficients describe the interactions between sectors; demand is elastic with respect to prices and incomes (Hunt and Simmonds, 1992). These demand functions provide a sensitivity to changes in prices and incomes, modifying the demand for space, for example, across locations.
- The models gain appreciably from the benefits of central tendency in the data. Sectoral aggregation is a practical necessity in these models, and the variances associated with it can be accommodated within the modeling framework by using relatively large zones. This probably limits the model from being applied to a fine zonal structure in urban areas, where few sectors might be represented in each zone.
- Economic trade is differentiated between transportable inputs and outputs, such as commodities and labor, and non-transportable factors of production, such as land or floorspace.

Demand for transport is derived from the intersectoral flows, or trade, between economic sectors and between economic sectors and households. These flows are translated into person trips and commodity flows in a land use-transport interface. Trips are distributed across modes and routes on a multimodal transportation network using a stochastic user equilibrium assignment technique. TRANUS employs a combined model of route and mode choice; both are logit-based formulations. The MEPLAN model employs a more traditional approach of sequentially modeling mode and route choice, using a variant of Dial's multipath assignment technique for the latter.

Calibration
Calibration is carried out in several ways. Data from a base year is calibrated cross-sectionally to derive constants, coefficients, and parameter values. Once these relationships are stable, the model is stepped through time with no changes in exogenous inputs to ensure that the model is stable. Then the model is applied through successive time periods, with changes in exogenous inputs. The model is reviewed for evidence of pathological or illogical performance, although this part of the process is subjective, and success is dependent upon the experience of the analyst. In any case, substantial developer involvement is likely to be needed in order to make the models operational.

The model calibration process for both models has been described as a lengthy and iterative semi-manual process of validating the model by fine-tuning the model parameters (Wegener, 1995). This may be considered a positive or negative feature of the model, depending on one's perspective. Wegener, for example, argues that too much attention is generally paid to cross-sectional calibration, with too little attention paid to the validation of their long-term behavior.

Integration with Travel Models
These models both have a completely integrated transportation component. The location, activity, and transport models are iteratively run in tandem until a user-specified convergence is reached. It does not appear possible to replace the transport component of these models with external travel models, such as those employed by MPOs in the U.S.

Integration with GIS
Both programs include some capacity for displaying transportation networks, including band-width plots. They also have some capacity for thematic mapping of results, although it is more efficient to do so using a GIS in tandem with the package. Both models employ ASCII text files for input and output, making it straightforward to exchange data with other applications. The TRANUS package has limited capabilities to interact directly with ArcView.

Applications

Forecasting
Both programs step through time in user-specified intervals. Five years seems to be the most commonly used interval. Constraints can be imposed as minimum or maximum values on any sector in any zone. Little information is available to evaluate the accuracy or reasonableness of the forecasts produced by these models, other than some comparative work that was done by the International Study Group on Land Use and Transportation Interaction (ISGLUTI) a decade ago (Webster and Paulley, 1989). None of the tests were conducted in the U.S. context, and it is difficult to extrapolate from the comparisons that were made. Substantial testing and comparison of these models to DRAM/EMPAL and others in the U.S. context is underway, however.

At the time of submission of this report, a full-scale application of TRANUS at the state and sub-state levels is underway in Oregon for the Oregon Department of Transportation. Peer review of the statewide model calibration occurred in the fall of 1997, and work on the substate model presently underway. Both packages have been applied to the Sacramento region by the University of California at Davis, and preliminary reports are available describing their performance.

Policy Analysis
These models are much more appropriate for a variety of policy analyses than spatial interaction models. By incorporating markets indigenously, prices, quantities of land, and floorspace are predicted by the model. The models are constructed in a way that lend themselves to policy analysis as employment and population having elastic demand with respect to the prices of land, floorspace, and travel. Thus, changes in policies that affect prices directly or indirectly through restricted supply can be modeled.

Several kinds of evaluation measures are computed to assist in policy evaluation. These measures are usually comparisons between two alternatives, and may compare:

- Physical changes such as land use and development
- Economic benefits to consumers and producers
- Social and environmental indicators:
    - Which population groups gain or lose

- Residential densities
- Average trip lengths and times
- Fuel consumption and pollution due to transport

Strengths and Weaknesses

Virtually no experience with the MEPLAN and TRANUS models exists within the U.S., although that will change, with work in Sacramento by University of California at Davis and the full scale application in Oregon underway. The following recommendations are based on the information that is available about these models at this time:

- The structure of the models appear to be better suited for regional and intercity modeling than for metropolitan land use modeling. This recommendation is based on the use of regionalized input-output models for zonal distribution of economic and population activity, which appears to be better suited to an inter-urban rather than an intra-urban scale.

- If restricted to a relatively small numbers of zones (e.g. 25-50), they may be less suitable for metropolitan modeling where there is demand for greater zonal resolution. This is especially true with reference to the integration with travel models, for which such a sparse zonal system would suggest a very coarse sketch planning network, that could be less than satisfactory for metropolitan travel modeling. Currently, a 150-zone application is being tested in Oregon.

- The models require a rather large volume of data, many of which are not ordinarily collected by MPOs. The requirements, however, are comparable to other land use-transport models. Although the models' authors indicate that the model complexity is flexible and can be adjusted to the user's needs, excessive simplification of the models undermines their usefulness and potentially their accuracy. The authors of these models should provide a standard framework for MPO use, and documentation to identify sources for all necessary input data. Work in Oregon will address the statewide application and documentation; a substate application may approximate the application conditions found in metropolitan areas and permit similar documentation.

- The calibration process for the models is very complex and time consuming, and requires developer assistance.

- The calibration process focuses heavily on the base year, giving it a cross-sectional orientation. Procedures to calibrate and validate the models longitudinally should be developed, if feasible.

2.8.3 METROSIM

Overview

METROSIM was developed by Alex Anas, at the State University of New York at Buffalo. The model is being extended and revised from earlier models by Anas, and its current implementation as METROSIM is considerably closer to being a fully operational land use model. At present, however, it is still not a fully developed operational model system for

practical implementation and use by most MPOs.

METROSIM represents an evolution from several earlier models developed by Anas since the early 1980's, including:

- CATLAS, a model of residential location, housing and mode choice developed for the Chicago area.
- NYSIM, which was applied to the New York region, and added non-work travel and commercial real estate markets.
- CPHMM, a prototype dynamic housing market model applied to Chicago, Houston, Pittsburgh, and San Diego MSAs.

METROSIM includes basic and non-basic employment, traffic assignment and building conversions. It is described as a unified model in the sense that its submodels are solved simultaneously (Anas, 1995).

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Requirements for Use

Computing Platform
Development has been made principally on a SUN UNIX workstation. Status of conversion to microcomputer platform is unknown.

Budget and Staffing Requirements
The model could be considered a prototype at this time, since it has been evolving through a series of research and planning projects and has not been distributed as a commercial software package to date. Pricing and staffing estimates should be obtained from the model developer.

Data Requirements
The key data required as inputs into METROSIM are:

- The Census Transportation Planning Package (Urban elements 1, 2, and 3)
- Networks by mode
- Data on real estate parcel characteristics and values (model can be calibrated in a simpler version without these data)

How it Works

Outputs
The following outputs can be produced by METROSIM:

Basic and Non-Basic Employment:
- Land use
- Floor space occupied
- Wages paid
- Rent paid per square foot
- Workers employed

Non-Basic Employment:
- Price index of goods and services
- Customers served

Commercial Real Estate:
- Occupied and vacant commercial space
- Rent and market value per square foot
- Construction and demolition rate per year

Housing (Single and multiple family) Real Estate:
- Occupied and vacant housing units
- Rent and market value per unit
- Construction and demolition rate per year

Vacant Land:
- Amount
- Market value

Households and Travel:
- Distribution by residence location, job location and mode of travel
- Non-work trip distribution by location of residence and mode of travel

Formulation
METROSIM is described as a unified economic model, based on random utility and microeconomic theory. It has submodels for basic industry, non-basic industry, real-estate, vacant land, travel, and traffic assignment. It is described as capable of either static or dynamic implementation, with the static version producing one long-term forecast, and the dynamic version operating in annual increments until a long run convergence to a steady state is achieved. The theoretical structure of the model is based on equilibrium. This appears to be based on the assumption of perfect foresight, and a solution of a long-run steady state equilibrium in order to compute annual increments, an approach developed in the CPHMM model, the most recent precursor to METROSIM.

The model uses a joint or nested logit formulation for predicting simultaneous or sequential choices of residence location, job location, tenure, housing type, mode of travel to work, route to work, shopping trip frequency, shopping destinations, and mode and route to shopping destinations. The unit of observation appears to be a single-worker household, although adjustments in the model computation are made to account approximately for multiple-worker households. Household choices are subject to a budget constraint, which accounts for housing costs, travel costs, and the costs of goods and services. The real

estate markets are solved simultaneously to predict rents and values, and the land use components of the model are iterated with traffic assignment until they converge.

Calibration
The calibration process for the model is cross-sectional, using one base year. It appears to involve a complex process of fixing certain assumptions and then minimizing an objective function within each submodel. Finally, fixed-effects parameters, or coefficients describing the residual attractiveness of every alternative in the choice set, are computed. It is likely that MPO application of this model for general planning use will require substantial consultant assistance.

Integration with Travel Models
METROSIM is a unified model that incorporates travel model predictions, including traffic assignment. It is therefore very integrated. It is not at all clear whether or how the model could be adapted to interface with a user's travel models, if that were desired. It is more likely that the model system should be treated as a self-contained system for use in a variety of policy analyses.

Integration with GIS
No integration with GIS has been made to date.

Applications

Forecasting
METROSIM produces either a long-run steady state equilibrium forecast or an incremental annual set of forecasts. Too little information is available at this time to evaluate the robustness or accuracy of the model for forecasting or policy analysis.

Policy Analysis
The model structure lends itself well to a variety of policy analyses, for many of the same reasons as TRANUS and MEPLAN, although METROSIM takes a substantially different approach. Having endogenous land, labor, and travel markets with price adjustments generating equilibrium provides a well-integrated modeling environment to assess the impacts of policies that impact supply or prices in any of these markets.

The model system is very comprehensive and complex, although its data requirements are not excessive considering the complexity of the models. What is needed is more testing and documentation of the results in a way that provides potential users of the model a basis for evaluation.

Strengths and Weaknesses

The model is well founded in economic theory, and implements a simultaneous equations system to estimate land prices and achieve equilibrium. It is an elegant approach, and in the theoretical arena, perhaps defines the state of the art in land use modeling. But it does face some implementation obstacles that may limit its potential for development into a fully functional tool for short and long-term forecasting and policy analysis. Some of these obstacles include:

- The equilibrium approach, though theoretically appealing, involves assumptions such as perfect foresight and complete adjustment within each time period, that have not yet been shown to produce more reasonable forecasts in an operational model than models based on incremental change and dynamic adjustment without imposing an equilibrium restriction. Building booms and busts would seem to offer substantial empirical evidence contrary to both the perfect foresight and equilibrium assumptions.

- As an equilibrium model, all households and businesses are assumed to adjust within each time period to achieve equilibrium. This approach appears less realistic than one in which households and businesses make decisions about moving based on their changing needs, the conditions of their current location, and the attractiveness and availability of alternatives. In addition, the high information and transactions costs of moving suggest that there is imperfect adjustment within any time period. Mobility rates of 50 percent over 5 years may be typical for average households, but decline rapidly over the course of the life cycle. None of these effects or imperfections in the market adjustment process is easily represented in the models as they are now constructed.

- The joint choice formulation is very complex, requiring a simultaneous equation system of nearly 1,000 equations to be solved for equilibrium. The approach may limit the potential disaggregation of household and housing types, and make the model complex to calibrate.

- The model calculates alternative-specific constants for every combination of the many choice dimensions in the model, conceivably tens of thousands of alternatives. There is no indication of how stable these alternative-specific constants are over time. They essentially represent the residual effects not otherwise captured in the model, much as the k-factors do in DRAM/EMPAL. Many of the same questions raised about the k-factors would apply to these alternative-specific constants.

- The model assumes that the household has only one worker, making the joint determination of residence and workplace (and many other choices) possible. Since roughly half of all households today have more than one worker, the viability of this structure is questionable. Multiple worker households would be difficult to deal with in the joint or nested choice structure, since the residential location and workplace choices are made on the one hand by the household, and on the other hand by the individual worker.

- METROSIM is calibrated cross-sectionally, but applied for long-term forecasting, as are all of the other models reviewed here. We recommend more testing and evaluation of the METROSIM model, with particular emphasis on validating the longitudinal behavior of the model.

- There are many aspects of the METROSIM model system that help to push the state of the practice towards state of the art. It is likely that the random utility modeling framework used in METROSIM, and also present in TRANUS and MEPLAN, is likely to provide a more realistic and flexible platform for improved land use models than does the spatial interaction framework embedded in DRAM/EMPAL and HLFM II+.

2.8.4 HLFM II+

Overview

HLFM II+ was developed by Alan Horowitz, and could be described as a simple spatial interaction model. It is from the same class of models as DRAM/EMPAL, but lacks some of the refinements in the latter model. It is being targeted to smaller MPOs with small budgets and staff for land use modeling, and those that want to avoid some of the complexities associated with DRAM/EMPAL.

Few MPOs are using the software. Some, such as Indian Nations Council of Governments in Oklahoma, appear to be satisfied with its forecasting capability. Others, such as the Baltimore Regional Council, have encountered substantial difficulty in producing reasonable forecasts.

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Requirements for Use

Computing Platform
HLFM II+ operates on microcomputers under Windows 3.1.

Budget and Staffing Requirements
HLFM II+ is licensed for $300. Staffing requirements are minimal, as the data requirements and calibration are not very demanding.

Data Requirements
The following data are required at a zonal level:

- Basic employment
- Population to employment ratio
- Net developable area
- Service developable area
- Persons per dwelling unit
- Intra-zonal travel time

How it Works

Outputs
The following variables are forecast for each zone:
- Population
- Basic Employment
- Service Employment

Formulation
It uses a simple Lowry gravity based model of land use, coupled with a highway side travel model based on QRS-2. It models total households, and Basic, Retail, and Other Employment. Zonal attractiveness is based on available vacant land in each zone, and accessibility. It is a cross-sectional model, as are all standard spatial-interaction models.

The following are the principal model parameters:

- Auto cost per minute
- Value of time
- Central tendency (gravity parameter)
- Retail/service employment ratio
- Retail/basic employment ratio
- Persons/dwelling unit
- Area/service employee
- Service/total employment ratio
- Service/population

Calibration
The program is provided with default values for the parameters, but these may be changed by the user. No systematic or statistical calibration procedure appears to be available.

Integration with Travel Models
HLFM II+ comes with QRS-2 (Quick Response System), a sketch planning tool for transportation modeling. It incorporates only a highway component. It can be interfaced with other transportation modeling packages by reading the travel time matrices from the desired system.

Integration with GIS
No integration exists with GIS, to our knowledge. As with other models, the outputs could easily be reformatted to read into existing commercial GIS software.

Applications

Forecasting
The forecasts are influenced primarily by accessibility (travel disutility) and vacant land in each zone. For small, monocentric urban areas without substantial interaction with other urban areas, this formulation may be adequate to capture simple incremental growth and dispersion of population and employment. Most urban areas are likely to find the model too

simplistic in its formulation to capture the primary factors influencing the distribution of activity.

Policy Analysis
With a very simplistic model structure, there is no significant capacity in the model to undertake systematic policy analysis. It would be possible to assess the impact of highway system changes on total population and employment, at a sketch planning level.

Strengths and Weaknesses

The primary advantages of this model appear to include its low price ($300), adequate documentation, availability for the Windows platform, and ease of use. Several concerns about the model, however, may erode these advantages for some MPOs:

- It only represents the highway mode; there is no mode split component and no representation of the transit system.
- There is no disaggregation of households by type (e.g., by income or stage of life cycle).
- The gravity models in the land use component and in the trip distribution models are inconsistent (a criticism that also applies to DRAM/EMPAL).
- The model has inadequate representation of zonal attractiveness, using only vacant land as the attractiveness variable. Since other factors affect land use patterns besides vacant land and accessibility, such as income, housing prices, crime, and schools, the vacant land variable in practice is modified to approximate a K-factor to adjust for these omitted effects.
- The model is validated to a base year rather than calibrated from historical data and then validated using current data.
- There is little behavioral content to the model, so it does not lend itself to use for a wide variety of policy analyses.
- This model system as it is distributed should only be considered for sketch planning purposes in areas that conform to very simple monocentric urban development and where there are no issues like redevelopment or inner-city decline. In general, MPOs should be wary of models that appeal due to low price and simplicity. If they are too simple, they will not be able to produce realistic forecasts or meaningful policy impact analyses.
- Portland, Oregon Metro and the Capital District Transportation Committee in Albany, New York, have developed and modified their own version of a simple spatial interaction model to an incremental form, by fixing in place most population and employment, and only allocating the incremental households and employment using the gravity model. This technique may prove useful as a sketch planning tool because it provides a qualified improvement over the traditional cross-sectional implementation. It would not, however, necessarily provide realistic policy impact assessment of changes in

accessibility, since some of the impacts would occur through mobility among existing businesses and households - which this technique assumes are fixed.

2.8.5 LUTRIM

Overview

The Land Use-Transportation Interaction Model (LUTRIM) developed by William Mann is a recent addition to the set of options available to MPOs attempting to address land use-transportation interactions. William Mann, in his TRB paper "Land Use/Transportation Integrated Model - LUTRIM" (1995) claims that "the program can be used as a land use model, a travel forecasting model or both to measure impacts of transportation improvements on land use forecasts... LUTRIM (Land Use/Transportation Integrated Model) is the first and only software in the world to completely integrate the 4-step transportation planning process with a land use model as the fifth step, all within one computer program." These assertions appear to be unsupported and potentially misleading, adding to the confusion among MPOs and other planning agencies grappling with the need to comply with ISTEA and CAAA requirements. It is being reviewed here only because it is being actively marketed to professionals in transportation and land use planning.

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Requirements For Use

Computing Platform
The program is available for IBM compatible microcomputers.

Budget and Staffing Requirements
Cost of the program was not known, but expected to be inexpensive. Staffing requirements would be minimal.

Data Requirements
The data inputs to the model are:
- A previously adopted land use forecast
- Friction factors from gravity model calibration for trip distribution
- Socio-economic bias factor, from gravity model calibration for trip distribution
- Travel time matrix from travel models

How it Works

Outputs
- Population
- Basic employment
- Population-serving (retail) employment

Formulation
LUTRIM predicts households, basic and household-serving employment based on changes in transportation accessibility. It uses local trip distribution gravity parameters to calculate accessibility to jobs and households. The underlying assumption is that changes in the accessibility to households will cause changes in the distribution of household-serving employment. Similarly, changes in the accessibility of employment should generate changes in the distribution of households.

The program is quite simple in concept, and takes the unusual approach of calibrating the model not to historical or current data, but to a previously produced land use forecast. In other words, the model is trained to reproduce the land use forecast with which it is calibrated. William Mann's explanation of this approach is that he does not want to have to tell politicians that their assumptions about urban development are incorrect, so he prefers to use the "accepted forecasts" as a given. While this approach totally invalidates the use of LUTRIM for generating new forecasts (it has almost no behavioral content, no disaggregation of households, and is calibrated to a prior forecast), Mann claims it is useful for testing the sensitivity of land use to changes in accessibility. This assertion is questionable as well, since the prior forecast to which the model is calibrated may have been heavily biased, and may be totally unrealistic - so that any relationships calibrated from the forecasts may be highly inaccurate. Since the model uses future data for calibration, there is also no way to validate the model.

Calibration
The model is calibrated by estimating a linear regression equation predicting the household growth ratio predicted in a previously approved land use forecast with an accessibility to jobs ratio also derived from the previously adopted forecast, and the congested travel times from the travel models. This single linear relationship is the basis of the model's predictions.

Integration with Travel Models
None.

Integration with GIS
None.

Applications

Forecasting

The model is claimed to predict impacts of changes in accessibility on land use. Since it is calibrated using a prior forecast rather than historical data, one cannot place much confidence in the predictions of the model. They are merely a reflection of the last forecast - not produced with this model.

Policy Analysis

The model is being marketed to MPOs for use as a sketch planning tool to analyze land use impacts of transportation system changes.

Strengths and Weaknesses

The LUTRIM software is being represented by its author as an integrated land use-transportation model, which it most definitively is not. It is also represented as being useful for testing the land use impacts of changes in accessibility, which it is marginally capable of doing, but using a simplistic technique that is predicated on the use of an existing land use forecast. This approach is, in our view, an inappropriate and potentially irresponsible technique that should be scrutinized closely by potential users.

Although it may be a marginally useful tool for an MPO with a high-quality existing land use forecast to test the sensitivity of land use to transportation improvements, there would be no way to know how much confidence to place in the results. It is also likely that the model will do far worse in more complex regions in which a variety of factors other than accessibility influence urban development patterns and trends. Inner city decline, segregation of neighborhoods by class, redevelopment, employment center creation and growth, are all unlikely to be dealt with appropriately by LUTRIM.

This program represents a misguided attempt to provide planners simple sketch planning tools to address the requirements of ISTEA and the Clean Air Act Amendments. Many planners are frustrated by the requirements and do not have adequate budgets or expertise to develop or evaluate adequate tools for these purposes. These planners are susceptible to programs such as this that make promises well beyond their ability to deliver. The potential damage from inappropriate use of sketch planning tools such as this is substantial.

2.8.6 California Urban Futures (CUF) Model

Overview

Although it is not a land use model designed for integration with transportation models and use by Metropolitan Planning Organizations for regional forecasting, the California Urban Futures Model (CUF), designed by John Landis at the University of California at Berkeley, has some features that warrant attention in this review. It is the only model we are aware of that is designed to operate within a GIS platform. It is designed to analyze alternative land use policy scenarios on the distribution of development, and is driven by a combination of existing land use, land use policies, and the profitability of development, operating at the

scale of municipalities and 'developable land units' (Landis, 1995). The municipal orientation is based on the model's purpose to assess the impact of land use controls exercised by city and county governments in California.

Its author claims that the CUF model "is the first large-scale metropolitan simulation model to use a geographic information system for data integration and spatial analysis, not just display. It is the first operational metropolitan planning model to simulate the interaction between public land use policies and private land developers regarding the location, scale, and density of proposed developments. Finally, it is the first large-scale planning model specifically designed to evaluate regional, subregional, and local land-use alternatives." (Landis, 1995).

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Requirements for Use

Computing Platform
The model was developed on a UNIX workstation running the Arc/Info GIS.

Budget and Staffing Requirements
The model has not been applied other than by its author, in the San Francisco Bay area, although some work to integrate hydrologic modeling with it is underway by Bob Johnston, at the University of California at Davis. It is not sufficiently developed at this stage to consider it a fully operational land use model for use by MPOs in integration with their transportation models. Therefore, no cost estimates are available.

Data Requirements
The primary data inputs into the CUF Model are a series of GIS map layers containing for each Developable Land Unit:

- City boundaries
- Sphere of influence boundaries
- Wetlands
- Slope
- Agricultural land type
- General Plan use category
- Current land use
- Major highways and roads
- Site distance to nearest city boundary
- Infill percentage
- Market housing density
- Typical new home price
- New home construction costs

In addition to these map layers, trends in county and city population growth and related variables are used in a "bottom-up population growth submodel" at the city and county level.

How it Works

Outputs
The following are predicted for individual Developable Land Units, and summarized by city and county:

- Residential land absorption
- New housing construction
- Residential density of new development

Formulation
There are four components in the CUF Model (Landis, 1995):

The *Bottom-Up Population Growth Submodel* provides the demand side of the model system, generating population forecasts by city and county in five-year increments. It is a regression model based on city size and growth history, outward expansion potential, and the adoption of policies promoting or inhibiting growth.

The *Spatial Database* provides the supply side of the model system and is based on the Developable Land Unit (DLU), a GIS polygon resulting from the intersection of all the layers in the GIS database.

The *Spatial Allocation Submodel* is a set of procedures for allocating the projected growth into the DLUs. It serves a market clearing function, by matching demand to sites in order of the profitability of residential development on that site. The underlying assumptions are that 1) land developers and home-builders are price-takers with respect to new homes and vacant land, and 2) private housing developers will develop land in the order of profitability in accordance with prevailing or permitted densities.

The *Annexation-Incorporation Submodel* has a set of rules that spells out the way new or existing cities annex developing land.

There is no commercial development nor transportation component in the model system.

Calibration
Information on calibration procedures not readily available.

Integration with Travel Models
The CUF does not have any travel time or other inputs sensitive to changes in the transportation system, so is not suitable for integration with travel models as presently structured.

Integration with GIS
This is the only land use model that is completely integrated with GIS. It operates within the Arc/Info GIS environment. In addition to the obvious use for visualization, it uses the GIS to

integrate the multiple mapped layers into a single database, based on the intersection of the layers, called Developable Land Units. Some proximity calculations are also carried out by the GIS.

It is likely that land use models will increasingly make use of GIS in this way, serving as a data management and integration center for the land use and travel models. Such integration through the GIS could significantly facilitate the integration of the land use and travel models.

Applications

Forecasting
The CUF model makes predictions on five year increments, to the desired forecast horizon. Since its primary use is for comparison of alternative land use policy scenarios, its use for baseline forecasting is not well documented. For use in the land use modeling context of MPOs, the model would need substantial restructuring and extension, to include at a minimum, endogenous calculation of land market prices, addition of a commercial real estate market component, a transportation market component, and a more rigorous demand side. Nonetheless, there are elements in this model that should be examined for new model development or the extension of other existing models.

Policy Analysis
Since it was designed to evaluate alternative land use policies, the CUF Model excels in the degree to which the model provides users multiple ways to introduce relevant land use policies into a forecast scenario. Without the components identified above, however, questions remain about the validity of the policy forecasts generated by the model as it is presently structured.

Many policies impact development through prices, either through restricting supply or by adding to costs for development. Without a price adjustment mechanism to reconcile demand and supply, the CUF Model cannot measure the impact of the price changes on household preferences for housing at alternative locations.

Strengths and Weaknesses

Two primary contributions of the CUF Model should be highlighted, and where possible, incorporated into other land use modeling efforts:

- The use of GIS as a repository for data used in the land use (and potentially transportation) models, as an analytical environment to measure proximity and adjacency for use in the modeling, and for visualizing the wide array of detailed inputs, outputs, and errors in the land use and transportation models.

- The articulation of an explicit developer component in the land use models. Conversion of vacant land is generally assumed as a byproduct of allocation of population or employment in other land use models. It would be far more realistic to include a developer component that would arbitrate the conversion of land into developed uses, subject to profitability and therefore influenced both by demand and by other financial considerations such as tax incentives and development impact fees.

2.8.7 UrbanSim

Overview

UrbanSim is a new urban model developed by Paul Waddell, University of Washington, under contract to Parsons Brinckerhoff. The development of UrbanSim has been funded by the Oregon Department of Transportation, and the National Cooperative Highway Research Program, with subsequent funding from the State of Utah Governor's Office. *UrbanSim* is a software-based system designed to be used for integrated planning and analysis of urban development, incorporating the interactions between land use, transportation, and public policy. It is designed to interface to existing travel modeling procedures in use by a Metropolitan Planning Organization.

Key features of the model include:

- The model simulates the key decision makers and choices impacting urban development; in particular, the mobility and location choices of households and businesses, and the development choices of developers;
- The model explicitly accounts for land, structures (houses and commercial buildings), and occupants (households and businesses);
- The model simulates urban development as a dynamic process over time and space, as opposed to a cross-sectional or equilibrium approach;
- The model simulates the land market as the interaction of demand (locational preferences of businesses and households) and supply (existing vacant space, new construction, and redevelopment), with prices adjusting to clear market;
- The model incorporates governmental policy assumptions explicitly, and evaluates policy impacts by modeling market responses;
- The model is based on random utility theory and uses logit models for implementation of key demand components;
- The model is designed for high levels of spatial and activity disaggregation, with a zonal system identical to travel model zones;
- The model presently addresses both new development and redevelopment, using parcel-level detail.

Key features of the software implementation of the model include:

- The software is currently compatible with Windows95/NT;
- The user interface focuses on policy assumptions and the creation and evaluation of scenarios;
- The model is implemented in Java using object-oriented programming to maximize software flexibility;
- The model integrates a GIS Viewer using MapObjects from Environmental Systems Research Institute;

- Model results are written as dBase files for external use.

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Requirements for Use

Computing Requirements
UrtbanSim was implemented in software using Java, which runs on Windows95, NT, Macintosh, and Unix platforms. The first version has been compiled to maximize performance, limiting the compiled version to Windows95 and NT platforms. The program has memory requirements that scale with the number of zones. 64MB RAM should be considered a minimum.

Budget and Staffing Requirements
The UrbanSim software is planned for release at no cost via the Internet, through a project web page at the University of Washington: http://urban.u.washington/urbansim. The software is distributed under Copyleft licensing that prevents commercialization of the code, and requires that any enhancements of the software be freely shared under the Copyleft licensing.

The software has been designed for ease of use, but the preparation of data inputs requires facility with GIS tools such as Arc/Info. Calibration of the model using local data requires facility with statistical packages such as SAS or SPSS for estimation of multiple regression components, and a logit estimation software package such as Limdep or Alogit. Ongoing use of the model once set up and calibrated should be manageable with staff that are responsible for managing land use forecasting. Coordination with travel models is necessary.

Data Requirements
The input data used in the land use model system are described in the following sections. The data include:

- Regional Control Totals
- Existing Land Use
- Land Use Plans
- Households
- Businesses
- Environmental Constraints

- Development Costs
- Accessibility

Existing land use is typically in the form of a parcel-level GIS database, but this can be adjusted to accommodate data limitations. Land use plans would normally be used in a GIS form, as would environmental constraints such as floodplains, wetlands, steep slopes, or slide zones. Development costs incorporate hard construction costs for each type of land use, and soft development costs that are a form of land policy, such as development impact fees, or tax abatement programs.

Household data is taken from travel surveys and census data (STF3 and Public Use Microdata). Business data is used at the establishment level, and requires geocoding to traffic analysis zone.

Transportation model outputs are used to compute accessibility measures that influence location choices for businesses and households. These can take the form of travel times from zone to zone, or to capture multi-modal accessibility, logsum values from the mode choice model are used.

How it Works

Outputs

- Acreage by land use
- Housing units by housing type
- Square feet of nonresidential space by type
- Property values
- Businesses and employment by sector
- Households by type (income, age, presence of children, household size)
- Accessibility measures to employment by type and population by type

Formulation

The UrbanSim model is based on the recognition that the process of urban development as it evolves over time and space is the composite outcome of the interactions of individual choices and actions taken by households, businesses, developers, and governments. The structure of this model includes components reflecting the behavior of households, businesses, developers, and governments, all interfaced through the land market. This behavioral approach provides a transparent theoretical structure that is much less like 'black-box' or abstract urban models that do not clearly identify agents and actions being modeled. This design was intended to more explicitly incorporate policies and evaluate their effects within the operation of the urban markets for land, housing, commercial space, and transportation. The model draws on random utility theory for its theoretical foundation, and builds on techniques of disaggregate choice modeling widely used in mode choice models.

Exogenous inputs to the model include base year land use, population and employment, regional economic forecasts, transportation system plans, land use plans, and land development policies such as density constraints, environmental constraints, and development impact fees. The user interacts with the model through the user interface to create scenarios that combine alternative packages of assumptions and exogenous inputs. The model is then executed using a given scenario, and the results of one or more scenarios can be examined and compared in the viewer component of the user interface.

The model endogenously predicts the location of businesses and households; the location, type, and quantity of new construction and redevelopment by developers; and the prices of land and buildings. Two modules, demographic and economic transition, predict changes in the distribution of households and business by type (e.g. age, income, businesses by industry) at the regional level, consistent with the aggregate control totals.

In the household mobility and location module, the model simulates household decisions about whether to move or remain in their current residence, and if they choose to move, their selection of a housing type and zone. These choices are modeled in much the same way as mode choices of commuters, using multinomial or nested logit estimation techniques. In the business mobility and location module, businesses make similar choices regarding mobility, building type and location choice. Household and business characteristics influence choices, as do locational attributes such as accessibility and prices.

In the development component, the model simulates developer choices to convert vacant or developed land to urban uses, including the type of improvements and density, based on their profitability expectations and subject to constraints imposed by governmental policies such as zoning and infrastructure availability. These profitability expectations are influenced by prior prices and revealed demand in the location and building type preferences of businesses and households.

The model simulates land market clearing by adjusting prices to reconcile the competing demands for locations and structures among households and businesses against the supply of space in each zone. The ratio of demand to supply in each zone for each type of space (housing and commercial structures by type) induces proportional price adjustments for these structures. The adjusted prices produce new market signals to consumers in the subsequent year, thereby influencing preferences for zones and building types.

These interactions of households, businesses, developers, and governments produce outcomes representing the distribution of population and employment, as well as the prices, uses, and density of land development. These results are written out for any desired year that the travel models will be run. The data are fed into the traditional four-step travel models to produce new travel times, costs and patterns by mode. The analysis then uses these travel times to compute new accessibility indices in subsequent years, until the travel models are run for the next target year.

The model is based on a one-year timetable, which has several advantages. First, many of the actions modeled take place over durations of less than or approximately one year, including household and business location changes. Longer time frame actions, such as the introduction of major transportation system changes, are handled by introducing them

in a particular year, from which time the model can account for the influence of this change over subsequent years.

Calibration

The model is calibrated using multiple regression to estimate bid price functions that measure how the underlying preferences and budget constraints of different groups predict bids for properties. Logit models are estimated using logit techniques for predicting the choice of alternative locations based on the consumer surplus of the alternative. Consumer surplus is defined as the difference between a consumer's bid for an alternative and its market price. Calibration is performed with recent historical data, and where it is possible to construct longer historical data series, a historical validation exercise is recommended.

Integration with Travel Models

UrbanSim integrates with travel forecasting models through a longer-term temporal dynamic to account for changes in the transportation system, and reflect these through accessibility indices in the model. Although travel times are only updated for years in which the travel models are run, two considerations apply. First, UrbanSim uses accessibility indices to measure the relative accessibility to various activities from each potential location, which are computed as entropy measures of the activity at each location discounted by the travel time between the source and each potential destination for the activity, such as shopping. The activity levels are updated annually by the model, so that although the travel times remain constant until the subsequent travel model run, the accessibility indices change according to the changing distribution of activities. Second, major transportation improvements are likely to be fairly discrete in time, such as the opening of a new section of a freeway. It is up to the user to determine the appropriateness of the travel model years with respect to the significance of the transportation system changes in intervening years. If the user desires to run the travel model for every year, the urban model is capable of accommodating it, though this is likely to be highly inefficient and quite unnecessary.

Integration with GIS

The software implementation of UrbanSim includes the core model components, a GIS Viewer, a database interface, and a user interface. The GIS viewer is developed using the MapObjects GIS component from Environmental Systems Research Institute, and provides basic visualization of the inputs to the model and outputs from it. The GIS Viewer is an integrated component that does not require a GIS software package to be installed on the user's computer.

Substantial GIS preprocessing is used to integrate the relevant themes of data for loading into the model. Polygon overlay of parcels by environmental constraints, and linkage of land use plan constraints on development and redevelopment are examples of the nature of the spatial data processing that is used to develop the model inputs. Further development of a more elaborate GIS preprocessor for developing inputs to the model and elaborating on the limited viewing capability now available is planned for the near future.

Applications

Forecasting
UrbanSim has been designed for strategic long-term planning and policy analysis. The traditional approach to creating a baseline scenario is recast as an exercise in developing a baseline scenario, to which policy alternatives can be effectively compared. A baseline scenario is then, simply a set of policies and infrastructure choices that the user wishes to specify as a baseline. It may be a do-nothing alternative, or it may represent the composite of the policies and plans most likely to be adopted. Forecasts can be run to the typical 20-25 year time horizon.

Policy Analysis
UrbanSim was specifically designed to address growing demands for policy analysis. Its use of scenarios is intended to facilitate the efficient testing of alternative planning or policy scenarios by running simulations for each scenario and comparing the outcomes on a series of objective outcome measures. The model lends itself to evaluation of transportation plans and policies on land use and housing market outcomes, as well as the impacts of land policies such as urban growth boundaries, development impact fees, comprehensive plans, and environmental restrictions on land development.

Strengths and Weaknesses
UrbanSim is a very recently developed tool, which leaves little room for evaluating its strengths and weaknesses. In its design, it is well suited to addressing the kinds of concerns that MPOs in areas dealing with significant land policy choices are facing. It also lends itself to assessing the impact of alternative transportation strategies on land use and market outcomes.

A significant drawback of the model is that the realism of the model obtained through very disaggregate data sources such as parcel data limits its usefulness in areas with little existing data. It also imposes significant weight on the careful development of the input database.

2.8.8 Models Developed or Adapted by Users

Almost none of the models reviewed, including the widely used DRAM/EMPAL, have been implemented and used by Metropolitan Planning Organizations without substantial adaptation. These revisions or additions include programs to interface the models to the organization's existing data and travel models, and perhaps most frequently to disaggregate the land use model to a level of zonal detail consistent with the travel models.

Disaggregation Programs

Typically disaggregation programs are fairly simple in concept, and reflect the implementation of a set of decision rules for allocating population and employment from larger to smaller zones. They are generally based on available vacant land within the smaller zones, with varying degrees of prioritization of the zones for allocation of growth based on attractiveness factors such as accessibility. Where land use plans are available,

these are sometimes used to constrain the allocations to the smaller zones to be consistent with adopted plans.

All MPOs using the DRAM/EMPAL models require the use of such disaggregation methods, since the models are not typically implemented at the level of zonal detail required by the travel models. Unfortunately, there is no standardization in the development and application of these tools, nor are they well documented. To our knowledge, none of the tools that fall into this category are calibrated systematically, nor are the predictions validated to assure that systematic biases are absent. It remains unclear how much error is introduced into the planning process using these disaggregation techniques, nor what the cumulative impact is of re-aggregating the travel model output into the less detailed zonal systems used in the land use models. Although Stephen Putnam has completed a study on the convergence of the DRAM/EMPAL land use models with travel models, the impact of the disaggregation/aggregation step in the iterative process remains unclear.

Adaptation of Existing Models

Some MPOs have modified existing models such as DRAM/EMPAL. A few examples are:

- The Puget Sound Regional Council developed a variation of the DRAM/EMPAL model that operates on a five year increment based on lagged levels of each variable, thus approximating a more dynamic behavior in the model application.
- The Mid America Regional Council has adapted the EMPAL model structure to use on the residential components.
- The San Diego Association of Governments has developed a hybrid approach that interfaces DRAM/EMPAL and PLUM, in order to refine the land use sensitivity and detail in the models.

In-House Model Development

Some MPOs have technical staff that have taken on the challenge of developing their own models. One of the most complete and well documented of these is the Association of Bay Area Governments POLIS model. The Southwestern Pennsylvania Regional Planning Commission developed MERLAM (Mature Economic Region Land Use Allocation Model) to reflect conditions in a region that has undergone economic restructuring and population loss. Another is RELM (Real Estate Location Model) currently under development at Portland METRO. There are many other in-house model development efforts that are not well known, and are rarely documented or publicized. This unfortunate reality means that many MPOs are investing substantial quantities of time and resources to develop better or more tailored tools, without the benefit of knowing what has already been accomplished elsewhere. Without substantial documentation and testing, however, the transferability potential of these models is relatively low.

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2.9 CONCLUSIONS

Under ISTEA, DOTs and MPOs need a new paradigm for evaluating the inter-relationships of land use and transportation. The old paradigm assumed that land use planning drove transportation planning. The goal of transportation was to serve the planned land uses. Policy-oriented "plancasts" that assumed the build out of comprehensive plans were acceptable forecasts under this paradigm. Examining the land use impacts of transportation on a case-by-case basis in environmental impact studies was also standard practice.

The new paradigm requires thinking about the reciprocal connections between transportation and land use in all transportation planning. DOTs and MPOs must evaluate the land use impacts of state and regional transportation plans. They must consider the consistency of transportation and land use plans. To do these tasks, the new paradigm must consider a more comprehensive range of facts and broader definition of accessibility that includes the majority of trips that are not related to work. The paradigm must include the behavior of the development sector as well as households, firms, and government.

Some DOTs and MPOs are experimenting with this new paradigm. They are applying the current analytical tools in new ways and developing more sophisticated methods of analysis using the capacities of GIS and other computerized tools now available to most planning organizations. They are also expanding the human element in the analysis process by involving a broader range of experts from the public and private sectors.

The following chapter outlines a recommended approach for understanding transportation and land use interactions. Chapter 4 re-evaluates the tools reviewed here in light of this approach. We recommend appropriate applications of these tools to fit the problems and issues faced by MPOs and DOTs.

3.0 BEHAVIORAL FRAMEWORK

This chapter describes the process of urban growth and change by focusing on the key actors in urban development, the locational decisions they make, and the factors that influence these decisions. The interactions of households, businesses, developers, and government determine the physical arrangements of land uses in urban areas. Households, businesses, and government are the demand side of the equation. They need new buildings in which to live or conduct businesses. Developers supply these buildings by preparing land for development and redevelopment and constructing or renovating buildings. Governments affect the supply and costs of developable land through their land use, infrastructure, and economic development plans and policies.

The reason for introducing this behavioral framework is that its use enables us to break up the complex interaction of transportation and land use into elements which can be more easily understood, described, and ultimately, evaluated in the context of a specific transportation project or plan. Through this framework, one can better understand the ways in which urban development and land use change occur. In this way, transportation investments can be seen more clearly for what they are--one of many factors that influence the spatial and economic evolution of cities and regions.

3.1 THE KEY ACTORS IN URBAN DEVELOPMENT

Four sets of actors interact to determine the spatial pattern of urban areas. Each of the actors has different goals and motivations. The actors and their primary motivations are as follows:

- Households seek to find housing and neighborhoods that satisfy their preferences and needs for space, style, and location and also fit within their budgets.

- Businesses seek locations that enable them to maximize profits. For retailers and other population-serving businesses, this means finding locations that maximize their market potential. For industrial and large office buildings, this may mean finding locations that minimize their costs of production. Location decisions may also be based on the ease of external transactions, amenities, proximity to labor with specialized skills, and other factors.

- Developers seek to make a profit by subdividing or consolidating land and constructing or rehabilitating buildings that satisfy the needs and preferences of households and businesses. Because most developers require outside financing, lenders have a significant role in deciding the type and location of projects. In this guidebook, lenders and developers are considered simultaneously since they depend upon each other for a project to move forward.

- Local governments develop plans and policies to advance community goals and maximize long run returns to their community from growth. These plans and programs include land use regulations, infrastructure provision, development charges, economic development programs, and land acquisition for rights-of-way and other purposes. Local governmental actions, combined with state and federal regulations, attract or

discourage development by influencing the supply of land available for development/redevelopment or the cost of development.

3.2 THE LAND MARKET

Households, businesses, and developers interact within land markets to determine the amount and prices of developed land. The price for land acts as a sorting mechanism to determine the type and location of development. Households, businesses, and developers are willing to pay for land up to the amount they anticipate they will receive in future benefits. Some stand to benefit from certain locations more than others and will outbid all others for these sites. For instance, high value-added industries and businesses will outbid all others for the choice sites. Retail businesses needing high levels of accessibility and visibility will outbid other businesses with lower needs for land at the intersection of major streets or highways.

Local governments are directly involved in the urban land market when land is needed for schools, roads, parks, and other public uses, but the primary role of government is to set policies or rules within which the land use market operates. This section focuses on the rule-making aspects of government since, except for parks, open space, and transportation systems, the amount of land within urban areas used by government is small.

Each of the actors in the land use markets depends upon or responds to the desires and actions of others. Developers cannot make a profit unless they build the type and price of housing that consumers want. Heads of households think about how long it will take to get to their workplaces when they seek new housing. Offices need to locate where they can attract workers. Stores can only succeed if they locate where shoppers can reach them.

Households create demand for new housing. This demand may be due to population growth, reduction in household sizes, lifestyle changes, or desires to live in different types or locations of housing. Many people seek new homes and buy lots or homes in subdivisions created by developers. The balance shop for used housing built by developers in a previous development cycle (Kelly, 1993; Miles et al., 1996). Thus, the fundamental interaction between supply and demand for housing occurs between people and developers of single-family and multi-family housing. There also is much turnover in existing housing as people move from one location to another. The market for housing includes the choice between new and existing housing.

But, people also consider businesses and government when making locational choices. Recent evidence suggests that in large urban areas households sort themselves out so that they are within a reasonable distance from work (Levine, 1996; Song 1994). In smaller urban areas, where almost any location has good automobile access to jobs, accessibility may not be a critical locational factor except for households commuting from outside the urban area. In addition in all areas, potential residents consider the costs and quality of public services, especially schools, when deciding where to live (Dowding et al, 1994). Residential locational choices are also constrained by governmental actions like zoning and the provision of infrastructure which limit the areas where development can occur and by impact fees and other charges for development that affect the cost of housing.

Business growth and change creates demand for new offices, stores, warehouses, manufacturing plants, and other buildings. Developers create industrial and office parks, shopping centers, and freestanding buildings to serve these needs. Some businesses do their own development, others work with developers to create space they need, and many lease space built by others.

Business locations are affected by residential location patterns. All businesses need to be able to attract workers. Customer-serving businesses consider the location of potential customers when deciding where to locate. Some businesses locate in highly accessible locations, such as downtowns, to attract the widest pool of workers. Others locate near the residences of certain elements of the workforce. Some base their choices on the residential preferences of their key executives.

Business location decisions are also shaped by government policy. Businesses consider the quality of public services and the taxes they will pay when making locational decisions (Bartik, 1991; Phillips and Goss, 1995). Some businesses seek tax abatements and other incentives for locating in particular community. Business locational choices may be constrained by zoning and other regulations. Some jurisdictions are quite flexible about zoning for commercial and industrial development because they want the jobs and taxes they generate. Other jurisdictions restrict industrial development because of pollution, traffic, and other negative externalities (McHone, 1986). Businesses depend upon the roads and other transportation facilities built by government for access to workers, goods, services, and customers, and for visibility. Businesses will outbid households for locations along arterials and highways and especially at the nodes in the transportation system (Downs, 1982). Businesses require access to water and sewer systems, with some manufacturing plants needing extensive water and sewer capacity (Miles et al., 1996).

Table 4 summarizes the interaction between households, businesses, and developers as well as the governmental policies and plans that influence their choices.

Table 4
Summary of How Households, Businesses, Developers Interact in the Land Use Market

Actor	Response
How household location decisions are affected by other actors	
Businesses	Households need access to businesses as providers of jobs, goods and services.
Developers	Most households seeking new homes buy lots or houses in subdivisions created by developers. Their choices are limited to the locations, types, costs, and quality of new housing that developers provide. The same is true of renters.
Local government	Households seek locations where the quality of public services, especially schools, and the level of local taxes match their preferences. Household locational choices are constrained by zoning and other land use regulations, infrastructure provision, and governmental charges for development.
How business location decisions are affected by other actors	
Households	All businesses need access to employees. Retail firms consider the size and type of market they will reach when deciding on locations.
Developers	Businesses may buy or lease space in buildings, office or industrial parks, shopping centers, and mixed use developments created by developers. Larger businesses may function as their own developers or work with developers to create the space they need.
Local Government	Zoning and other land use regulations may constrain where businesses can locate. Regulations and charges can affect the cost of business development. Businesses require access to transportation networks, water supply, and sewer systems to varying degrees. Businesses consider the quality of public services, especially education and infrastructure, and the level of local taxes in deciding where to locate within a metropolitan area. Some businesses seek economic development incentives such as tax abatements when deciding where to locate.
How developer decisions are affected by other actors	
Households	Developers consider the needs and preferences of households in deciding what type and the location of residential subdivisions and houses. Developers consider the locations, incomes, and lifestyles of households in deciding where and what types of retail developments to construct. Developers consider the residential preferences of key decision-makers in deciding where to locate offices and large scale developments.
Businesses	Developers consider the needs and preferences of businesses in deciding where and what type of business facilities to develop.
Local Government	Zoning and environmental regulations may constrain where developers can develop. Developers are required to get permits and pay fees to subdivide or develop land and construct buildings. The ease of getting permits and the cost of fees affects profitability and thus locational choices. The transportation system is a key factor in determining profitable locations. The plans to expand and extend water and sewer facilities affect the location, cost, and timing of development.

3.3 THE ROLE OF GOVERNMENT IN THE LAND MARKET

Local governments shape the land use market by managing growth to maximize the long-run fiscal returns to their communities or to achieve a long-run vision for their community. Strategies can vary widely, even within a single metropolitan area, because of differing community characteristics. For instance, some communities zone abundantly for industrial development because they believe industry provides good jobs for their residents and pays more in property taxes than it costs in local governmental services. Other communities provide little or no land for industrial development because they want to avoid the pollution, traffic, and other costs of that type of growth. Communities will bid for the non-polluting light industries that are most desirable. The losers in the bidding process end up taking the less desirable industries (McHone, 1986; DiPasquale and Wheaton, 1996).

Local government plans and policies can affect the supply of land available for development or the cost of development, as shown in Table 5. Some actions may have both affects, but are listed in the table under their primary area of impact.

Table 5
Summary of How Governmental Agencies Directly Affect the Land Use Market

Change the Supply of Land Available for Development	Change the Cost of Development
<u>Land Use Regulations</u> Comprehensive land use plans Subdivision ordinances Zoning Growth limits Urban growth boundaries Transfer/purchase of development rights Property tax reductions for certain uses, like agriculture Environmental regulations like wetlands protection and flood plain restrictions Public ownership--parks and open space Land acquisition (right-of-way, etc.) <u>Infrastructure Provision</u> Water and sewer expansions and extensions Transportation improvements Urban service areas and phasing of improvements Adequate public facilities ordinances	<u>Economic Development Programs</u> Tax incentives Density bonuses Public-private partnerships Land assembly Infrastructure provision <u>Charges or Requirements for Development</u> Development permit fees Ease and length of time required to obtain permits. Special assessments Impact fees and exactions Required on- or off-site improvements Real estate transfer taxes Design standards Parking requirements Inclusionary zoning

Changing the Supply of Land Available for Development

Local governments affect the supply of developable land through land use regulations that specify where and under what conditions development can occur and through the provision of infrastructure, such as water, sewer, and transportation systems, which are essential for urban levels of development. These policies influence the market mainly by restricting the supply of land available for development. They can not force development to occur in locations where the market does not support development.

Local governments regulate land uses in order to avoid incompatible land uses, efficiently provide public services, conserve natural resources and environmental qualities, improve economic opportunities, preserve quality of life, and avoid burdening current residents with the costs of growth. Most communities have long-range or comprehensive land use plans that set out their goals, objectives, and policies. Policies are implemented through subdivision, zoning, and other ordinances that identify where particular types of development are allowed, the process for obtaining approvals, and the conditions that may be placed on development (Porter, 1997; Nelson and Duncan, 1995).

These regulations can limit the amount and location of land available for certain uses. Traditional zoning ordinances regulate the types, intensities, and bulk of uses allowed within each zone (Kelly, 1988). Recently many communities have adopted additional growth management tools to more effectively manage where and when growth occurs. Urban growth boundaries specify where urban and rural land uses are allowed. Urban service areas have the same effect, but may also include a timing element that specifies the order in which areas will receive urban services. Growth limits regulate the timing of growth by setting limits on the rate of development. Agricultural preservation programs, such as exclusive agricultural zoning, lower property tax rates for lands actively farmed, and programs to buy or transfer development rights, keep land out of the urban development market. Land purchased for parks, open spaces, or rights-of-way is not available for development (Kelly, 1993; Nelson and Duncan, 1995; Porter, 1997).

Policies regarding the provision of urban infrastructure constrain the supply of developable land since urban development cannot occur without access to water, sewer, stormwater, and transportation systems. Development requires capacity in central facilities, like water and sewer treatment plants, and extensions of services to the areas where development is occurring. Developments which generate high levels of traffic such as large manufacturing plants, shopping centers, and multi-family housing requires access to roads with the capacity to handle these traffic volumes. Because it is expensive to add central facility capacity and extend infrastructure, developers prefer locations where these facilities are available, provided these areas are otherwise attractive to development. The supply of developable land is, therefore, constrained by the public and private resources available to extend roads and other infrastructure systems (Kelly, 1993; Nelson and Duncan, 1995, Miles et al., 1996).

Local governments develop capital improvement plans to identify the construction schedule for improvements to water, sewer, roads, and other infrastructure. Some areas have developed detailed plans specifying a phasing of service expansions over a number of years. These plans aim to most cost-effectively extend services, but they may not coincide with developer plans. In other areas, statewide growth management plans, such as

Florida's and Washington's, or local ordinances require that public facilities needed by growth be provided concurrently with growth. Both the phasing of development and adequate public facilities ordinances affect the locations where development can occur. If communities lack the resources to provide the facilities needed for growth, and the developer cannot afford to provide them, development must go elsewhere (Kelly, 1993; Miles et al., 1996; Nelson and Duncan, 1995).

Policies Affecting the Cost of Development

Governmental policies can also raise or lower the cost of developing in certain locations. On the one hand, economic development programs can lower the cost of development in areas where local governments want development to occur. These programs encourage businesses to expand or locate within a community by providing direct assistance to businesses. State and local governments can provide financial incentives such as property tax abatements, provision of land at below-market prices, and subsidized loans. They can expedite the provision of roads, water, and sewer to make a site viable for development sooner through the use of either public funds and/or impact fees. They can encourage growth in certain locations by providing incentives such as density bonuses or lower impact fees. They can support development in areas where private investments are unlikely to occur without public assistance through public-private joint ventures where the public sector assumes some of the costs or risks of the project (Bartik, 1991; Miles et al., 1996; Porter, 1997).

On the other hand, many regulations and fees add to the cost of development. Building permits take time and money to obtain. The amount of uncertainty and difficulty of obtaining permits affects the feasibility of projects because time is money to developers. Special assessments to finance infrastructure or real estate transfer taxes can add to the cost of development. Developers have long been required to provide infrastructure on-site and may face mandatory or negotiated requirements for off-site improvements. In the 1980s and 1990s many communities in growth areas began charging developers impact fees to cover a share of the costs of road, water, sewer, schools, or other infrastructure needed because of growth instead of relying on negotiated exactions to provide these facilities. In some communities, impact fees, while providing assured funds for improvements, have added to the cost of development. The cost of development is also affected by requirements for design reviews, landscaping, minimum quantities of parking, and the inclusion of affordable housing in projects (Miles et al., 1996; Robinson, 1990).

Impacts of Governmental Policies Depend Upon Regulatory Environment

Developers are keenly aware of the policies that limit land supply and affect costs since both factors affect the profitability of potential projects. When developers consider projects that deviate from those specifically allowed in plans, they must consider the probabilities and difficulties of getting approval for their proposal. The risks depend upon the regulatory approaches of individual communities and of regions.

Some communities choose to manage growth extensively, either because of local commitment to growth management or statewide land use requirements. In growth management communities, amendments to comprehensive plans or zoning can be difficult

to obtain, urban service or urban growth boundaries can limit the areas open to urban development, infrastructure extensions usually follow the planned sequence, and other regulations constrain what developers can do. While limiting developer options, these regulations also provide developers with considerable certainty that projects that fit within regulations will be approved and citizen opposition will be minimized. Developers, for example, like the predictability of Oregon's land use planning system (Abbott et al., 1994; Miles et al., 1996).

Other communities are more market-oriented. These communities will usually have comprehensive plans, zoning, infrastructure master plans, and other land use regulations, but these policies are easier to change to accommodate new development that fits within the community's objectives. For example, in areas where municipalities receive a share of the sales tax collected within their jurisdictions, communities are often anxious to attract commercial activities and will rezone land to accommodate this type of development. Along with the flexibility of market-oriented communities, there is more uncertainty about what governments will approve, what conditions they will attach, and how citizens will react. When projects are examined on a case-by-case basis, there are more opportunities for unusual projects to be approved, but there is also more risk that delays will occur and that requirements will change (Kelly, 1993; Miles et al., 1996; Porter, 1997).

3.4 HOUSEHOLD LOCATIONAL DECISIONS

Household locational decisions are complex because there are many types of households--two parent households with and without children, retired couples, young singles, unrelated roommates--to name a few, and many types of housing--apartments, townhouses, condominiums, starter homes, older single family homes on small urban lots, rural residential homes with acreage, and others. This suggests that the housing market has many niches catering to people with different characteristics, life-styles, and locational preferences. This section mainly looks at factors that determine general residential location patterns without considering all the possible permutations.

Another complexity is that a home is more than a place to live. When people buy or rent housing, they are obtaining a bundle of goods that includes interior living space; housing amenities; access to jobs, shopping, and social contacts; community characteristics; public services such as schools and parks; and externalities like neighborhood image, noise, and smog (Rossi, 1980). Location is only one of many factors that households evaluate when deciding where to live.

In addition, residents make a series of decisions about housing, including whether to move or stay, buy or rent, and what type, quality, and location to choose. This section briefly discusses the decision to move or stay and then focuses on the factors that affect locational choice.

The Decision to Move or Stay

People move because of dissatisfaction with their current location or because a new location offers benefits not available at their current location. They are pushed to move by changes in their personal or household circumstances or changes in their neighborhood.

Households are pulled to new locations by their aspirations for better housing or by opportunities that more closely match their needs and preferences.

One of the chief causes of dissatisfaction with current housing is changes in the size and structure of a household, such as marriage, divorce, birth of a child, children leaving home, retirement, and death. These family life-cycle changes generate the need to adjust housing to match the space needs of the changed household (Rossi, 1955/1980). Many people move because of job changes. This particularly affects interregional moves, but also explains some moving within a region (Cadwallader, 1992). Another reason for dissatisfaction with housing is change in the neighborhood. A turnover in residents, shift in land uses, or increases in crime can make the neighborhood a less desirable place to live. These stressors within the household or the environment in which they live push households to consider alternatives to their current living situation (Wolpert, 1966; Speare, 1974; Speare et al., 1975).

People may also move because a move will make them better off than they are at their current location. A different house or location may better satisfy their long-term housing aspirations or meet their current needs. A move may occur because of a rise in household income, the amassing of sufficient resources to make the move, or a change in housing prices or availability. Because moves have substantial monetary and psychic costs, the new housing must offer benefits that outweigh the costs of moving (Michelson, 1977; Quigley and Weinberg, 1977).

For those households with children of school age, there is ample evidence that perceptions about the quality of schools influence locational decisions, as well as housing prices. Judgments about school quality are often based upon published measures of scholastic performance of the different school systems in the metropolitan area. Such statistics are available from the schools and often are distributed in newspapers and magazines. Other observable characteristics which are perceived to be indicators of school quality include the age and physical condition of school buildings. Last, discussions about "school quality" turn on the socioeconomic characteristics of the pupils in the system, with households frequently seeking schools whose students are in families that are equal or higher than they in social status and/or similar in racial or ethnic composition.

Overall, a combination of household characteristics, like age of household head, size, and income levels, interacts with the housing opportunities available in a region to determine whether a household will move. Housing opportunities are a product of the type and quality of housing stock, the characteristics of neighborhoods, and conditions in the housing market. Some households may desire to move but may be unable to do so because they cannot afford the type of housing they desire, the type of housing they desire is not available, or they are limited in their choices due to discrimination or other factors. Some markets provide lots of choices and others few. Once a household decides to move, it must determine where it will locate.

Factors Influencing the Locational Choices of Households

The standard model of urban development posits that households make a trade-off between the amount of housing they can buy and the costs of commuting to that location

(Alonso, 1960; Muth, 1969; Mills, 1969). As incomes have risen, Americans have preferred suburban locations because of larger lots, newer and better quality housing, environmental amenities, and better public services (Straszheim, 1987). Another theory suggests that households sort themselves out so that they live where the quality and costs of public services match their preferences. For example, some people may focus on quality schools, while others seek low property taxes or lack of regulation (Tiebout, 1956). This section will consider the evidence about the relative effects of housing costs, access to jobs, public services, and other factors in the locational choices of households.

Housing Costs

Because most households have budgetary constraints, housing costs are a primary factor in the locational choices they make. Housing costs vary with diverse factors of current location including size, quality, type, and age of the unit and the characteristics of the neighborhood where it is located. Studies find that housing affordability is a primary determinant of the location of households, and it is one of the reasons that households have moved to the urban fringe (Levine, 1996; Levernier and Cushing, 1994; Vance, 1991).

Access to Jobs

Some observers contend that with high levels of accessibility available virtually everywhere in metropolitan areas access to jobs does not matter much in household locational decisions (Giuliano, 1995; Gordon and Richardson, 1997). Households rarely state being close to work or the need to shorten their work trips as a primary reason for choosing their residential location (Clark and Burt, 1980). In addition, simulations of where households would live if they were optimizing travel times between home and work, indicate that the average household lives two to three times farther from work than the spatial structure implies they must (see Giuliano and Small, 1993 for a review of these studies), though any analysis of such averages may obscure variables, such as income, which may explain observed behavior.

Comparisons of actual and optimal commuting times show that commuting times or distances are not the only determinant of residential location. This could occur because housing and neighborhood characteristics are more important to households than the distance to work, households consider accessibility to an array of jobs when locating either because they anticipate job turnover or the household includes multiple workers, accessibility to destinations other than work may overshadow concerns about the work trips, or racial discrimination limits the housing choices available to them (Hanson and Pratt, 1988; Giuliano and Small, 1993).

Nonetheless, a variety of studies suggest that people have limits on the distance they are willing to live from work. The 1990 Census, for example, found that travel times for commutes increased on average by only 40 seconds from 21.7 minutes to 22.3 minutes between 1980 and 1990, a period when suburbs continued to grow (Pisarski, 1996). This suggests that people sort out their residential and job locations so as to keep travel times fairly constant. Giuliano and Small (1993) found that in the large Los Angeles region commuting times are shorter (averaging about 23 minutes in 1980) than they would be if households located randomly. Other studies in various large metropolitan areas using different techniques have shown that access to jobs is a primary determinant of household

location (Waddell, 1993; Song, 1994; Levine, 1996). Waddell, in particular, concludes that household and job location choices are jointly made.

This conflicting evidence suggests that, while households do not locate so as to minimize distance from work, there are limits on how far most people are willing to live from work. These limits can affect both where they choose to live and where they look for work (Hanson and Pratt, 1988). Because of the high levels of accessibility available in most urban areas, many, but not all, households have a fairly large set of choices about where to live. Some households may be more restricted in their choices because of the costs of housing and of travel or because of discrimination. In smaller urban areas where nearly every location has good automobile access to jobs, access to jobs may not be a significant determinant of household location within the urban area, but it may still influence the size and shape of the commuter sheds of these regions.

Access to Goods and Services

People need to get to many destinations other than jobs including stores, entertainment, cultural activities, and social contacts. The 1990 National Personal Transportation Survey found that households in urbanized areas made only 21 percent of their person trips, but utilized 37 percent of the vehicle miles of travel, for work trips. The more numerous, but often shorter or non-motorized trips, were made for personal and family business like shopping, social and recreational activities, and civic/education/religious purposes (Vincent, Keyes, and Reed, 1994, Table 1-14). The large number of these non-work trips indicates that access to non-work destination is likely to figure in households locational decision-making. It is difficult to measure this in studies because of the diverse needs of different types of households. The types of accessibility that young singles desire, for example, can be substantially different from those of households with children or those composed of retired persons.

Type of Community Residents

Much sorting of residents goes on so that people with similar incomes, life styles, and race often live together. Households buying homes usually want to live where most of the housing is single-family and owner-occupied. Families with children like to live where there are similar families. Some people avoid areas with large numbers of ethnic or racial minorities. These choices may reflect the physical attributes of the neighborhoods people desire, the costs and quality of community services, as well as prejudices that people hold (Levine, 1996; Waddell, 1993; Levernier and Cushing, 1994; Luce, 1994).

Amenities and Quality of Life

Households are generally seeking a certain type of environment which provides them with what they consider "quality of life." Exactly what this means varies among households. Some people like dense, bustling urban environments while others prefer quiet residential neighborhoods with large yards. These quality of life factors can be attributes of neighborhoods, such as the proportion of owner-occupied housing, the crime rate, or the density of development, or characteristics of individual sites, such as trees and views (Miles et al., 1996).

Public Services and Property Tax Rates

Dowding et al. (1994) reviewed the literature on the effects of tax rates and public services on household location and mobility and concluded that household locational decisions are shaped by the cost and quality of public services. Studies most consistently show that the quality of public schools influences locational choices. Results are not consistent for the effects of other services, such as police protection, and the property tax rates. Some of these effects may be capitalized into the price of housing (e.g. homes cost more in areas with quality schools or less where property tax rates are low.)

Summary

Table 6 lists the major factors that households consider in deciding where to live and rates the relative importance of these factors. Individual households and types of households may, however, weight these factors differently than described here. When analyzing locational choices in a particular region, it is important to consider that context. The types of households who live in that region can differ from national averages or vary significantly among communities. The characteristics of the communities, such as the age and type of housing stock, and local traditions about where to live can influence choices (Hanson and Pratt, 1989).

Table 6 indicates that accessibility is only one of several factors that influence the locational choices of households. Given the tight time schedules of many families, especially those with two earners, access to destination other than work, such as stores, daycare centers, entertainment, and recreational opportunities, may matter as much as access to work when deciding where to live. In addition, an analysis of the residential locational decisions must go beyond thinking about accessibility to consider the cost of housing in various communities and neighborhoods, the fit between housing types and household characteristics, the quality of the schools, the types of people who live there, and other factors that figure in the choices that households make.

Table 6
Factors Influencing the Location Decisions of Households

Relative Importance	Factor	Comments
Highly Important	Housing costs	Most households must balance costs with the housing and community characteristics they desire.
Moderately Important	Access to jobs	Access to jobs is a significant determinant of residential location in large metropolitan areas, but may not matter in smaller urban areas where nearly every location has good automobile access to jobs.
	Access to goods and services	Preferences vary by household types. Singles like living near entertainment. Empty nesters near leisure and culture. Corporate executives want good access to airports.
	School quality	Important to households with school age children.
	Type of community residents	Although some people like diversity, most people want to live near people who are like them.
Somewhat important	Amenities and quality of life	Households seek locations with views, attractive design, distance from industries and traffic, low crime rates, and other indicators of quality of life.
	Quality of non-school public services	There is some evidence that households consider the quality of public services like police protection when selecting communities.
	Property tax rates	The evidence is mixed on whether taxes matter in household location decisions.

3.5 BUSINESS LOCATION DECISIONS

Business firms seek locations where they can make a profit. For some this means being close to critical inputs such as raw materials or specialized labor. For others access to customers is most important. Some firms want to be near similar firms, and others want to distance themselves from competitors. This section focuses on the general factors that influence the location decisions of firms, with some attention to the varying needs of retail, office, and manufacturing. This simplifies the actual decision process and ignores the substantial differences among firms, even within one of the general categories. For example, Raper and Ihlanfeldt (1993) note that within the office sector, location needs vary with the type of industry, the organizational structure of the firm, the size of the staff, the type of employee, and the length of the firm's tenure in its current location.

Factors that Influence Business Location Decisions

Access to Labor

Access to a suitable labor pool is important to all types of firms. Surveys of businesses report that the cost and availability of workers is ranked highly among the factors that determine firm location (Button et al, 1995; Calzonetti and Walker, 1991; Forkenbrock and Foster, 1996). Firms needing highly skilled workers have traditionally located in the central business district in order to have access to the widest pool of skilled labor. However, as the population has suburbanized, many firms have found that they can access the types of workers they seek in the suburbs. Suburbs can provide access to a pool of educated, clerical workers as well as professional and technical workers (Ihlanfeldt and Raper, 1990; Hanson and Pratt, 1989).

Cost of Space

Firms must weigh the advantages of particular locations with the cost of leasing or owning that location. The availability and lower costs of space outside the central business district is one of the factors that has supported the suburbanization of businesses (Leinberger and Lockwood, 1986; White, Binkley, and Osterman, 1993). Surveys of business firms indicate that the cost of space is one of the most important factors in deciding on a location (Button et al, 1995; Calzonetti and Walker, 1991).

Transportation Access

Because firms need access to materials, workers, customers, and information, the firm's access to the transportation network affects its cost of doing business. Many firms desire convenient access to limited access highways and to airports. Some also rely on rail and seaports and need good access to these freight facilities. Surveys of firms find that access to highways is one of the most important factors determining the location of firms (Lyne, 1988; Button et al, 1995; Calzonetti and Walker, 1991).

Highway access is critical to most firms, because it is the dominant form of transportation. Businesses ranging from a Wal-Mart store locating in a small city to major office developments in the suburbs of a large metropolitan area increasingly locate near the Interstate Highway System or other limited access highways. The interchanges of these high speed highways have given some suburban locations the level of accessibility that previously only occurred in central business districts (Muller, 1995; Leinberger, 1996; Hughes and Sternlieb, 1988). In addition, high speed highways have supported the development of national retailers in non-metropolitan areas that attract customers from large regions (Taylor and Marche, 1994). These highways have also supported the movement of manufacturing to suburban and rural sites where they can build land-intensive facilities on large sites while still having access to large numbers of workers (Vance, 1991).

Highways must not only be present, but the flow of traffic must also be predictable. Reliability of travel times has increased in importance as businesses have shifted to just-in-time deliveries. Forkenbrock and Foster (1996) contend that in rural areas, immediate proximity to interstate highways is not critical for manufacturers, even when they rely primarily on trucking, because of the high quality of travel on other highways. Rather

access to markets and to labor, both of which depend on the quality of the transportation system, are the most important locational factors according to larger manufacturers surveyed in two midwest states. However, in urban areas where there is congestion, proximity to higher quality routes may matter more.

Airport access is also important for some businesses, and airports have increasingly become the focus of industrial and commercial complexes. Not only is more freight moved by air, but business travel is also rising with the globalization of the economy. Just-in-time deliveries and small batch productions have increased the use of air freight and the need for access to airports (Golledge and Stimson, 1997, Kasarda, 1996).

Agglomeration Economies

Although jobs have become decentralized, there still is a tendency for businesses to cluster together in centers. There are several reasons why this may occur. First, firms may locate near similar types of firms, such as in industrial areas or auto rows. Manufacturing firms locate near similar firms to have access to a large, skilled workforce, to intermediate inputs, and to markets. Retailers of the same product locate together to facilitate comparison shopping (Heilbrun, 1987).

Second, firms may be taking advantage of the economies of a concentration of activities that provides them with access to specialized workers and services and to larger markets (Shukla and Waddell, 1991). Retailers, for example, cluster in shopping centers because these concentrations can attract customers from a wider market (Stearns et al, 1995).

Third, firms may locate in proximity because of inter-industry linkages. By locating near suppliers and markets, they can reduce transportation and communication costs (McMillen and McDonald, 1996; Lee, 1992).

Finally, some locations attract a large number of firms because of their prestige or because a concentration of employment supports restaurants, shops, daycare centers, and other facilities desired by workers and visitors to the area (Leinberger and Lockwood, 1986; Archer and Smith, 1993).

The reasons for clustering together can vary between industries. Both manufacturing and office firms require suppliers and access to labor pools that agglomerations can provide (Ihlanfeldt and Raper, 1990; Shukla and Waddell, 1991). Face-to-face communications are still important for many offices, despite new communication technologies that have supported moving routine functions out of expensive central areas. The costs of these transactions can be minimized by locating near the offices of people with whom one must meet (Clapp, 1993; Gottlieb, 1995; Mills, 1992). Retailers want the access to a large customer base that an area with multiple shops provides, but in many cases, they do not want to be too close to their competitors.

Access to Markets

Access to the people or firms who purchase a product is especially important to retailers and manufacturers. Retailers must identify a market area taking into consideration the characteristics of current and future residents, the nearby land uses, transportation

networks, and the competition from existing and future outlets. Successful retailers are attuned to changes in their potential markets, such as shifts in residential patterns and consumer preferences (Ghosh and McLafferty, 1987). Likewise, manufacturers consider access to the purchasers of their outputs an important factor when making a location decision (Button et al., 1995; Calzonetti and Walker, 1991, Forkenbrock and Foster, 1996).

Government Services and Taxes

Current research indicates that governmental services and tax rates are factors used to differentiate between sites with metropolitan areas. Bartik (1991) and Phillips and Goss (1995) have reviewed the literature on this subject and conclude that the long-run elasticity of business activity with respect to state and local taxes for intrametropolitan location decisions is between -1.0 and -1.5. In other words, once a firm has decided that it wants to locate within a particular metropolitan area, the choice of sites will be based on profitability of various sites, with local taxes being one of the factors that can tip the decision in favor of a particular location. The elasticities means that a community with one percent lower taxes than another community, but the same levels of public services, will have one to one-and-half percent more business activity. A community with higher taxes can, however, compensate for these tax levels by providing higher levels of services that matter to businesses (Bartik; 1991).

Most studies show that manufacturing is more sensitive to taxes than non-manufacturing. Manufacturing is more capital intensive and, therefore, likely to pay more property taxes than other types of businesses. Manufacturing is also an exporting business that must compete with firms in other locations and needs a low-cost location to maintain a competitive edge (Bartik, 1991).

Communities of all sizes have economic development programs to encourage the expansion of existing businesses or attraction of new firms. Programs can be aimed at attracting business in general to a community or at encouraging redevelopment and revitalization of certain parts of the community. These programs affect the location choices of many firms by making it easier or less costly to locate in certain locations (Bartik, 1991; Porter, 1997).

Public services matter to firms for several reasons. Firms purchase some public services, such as water and sewer, as inputs to production. The amount and quality of these inputs can be critical for some manufacturing firms. Firms also use some public services, such as highways, without directly paying for them. Locations with better access to highways can lower their production costs. In addition, public services like schools matter to potential workers. Public safety is important to many firms to attract customers and workers. Firms may be able to attract a higher quality workforce or one willing to work for less in locations where public service quality is high (Bartik, 1991; Luce, 1994, Gottlieb, 1995).

Amenities, Prestige, and Other Quality of Life Factors

Many business decisions-makers also consider the quality of the environment of workplaces, the prestige of their location, and their personal preferences in deciding where to locate. A nationwide survey of new manufacturing plants, for example, found that personal reasons were the fifth most important reasons for choosing a particular region,

ranking behind only markets, labor, land, and taxes (Calzonetti and Walker, 1991). Firms outside of manufacturing tend to locate in attractive, higher income areas within metropolitan areas (Luce, 1994; Leinberger, 1996; Miles, 1993).

Summary

Table 7 summarizes these factors and the relative importance of each in firm locational choices. Individual firms, or even industries may, however, place different weights on these factors. These variations in emphasis need to be considered when considering the location of the particular types of firms in a region.

As with households, accessibility is only one of many factors that affects business location choices. Businesses cannot operate without access to workers, customers, and suppliers, but the relative importance of these types of accessibility for businesses vary with the type and size of a firm. Certainly the prime locations for commercial development are highly dependent upon the highway network. But not every intersection of major arterials and freeways is a prime business location.

Businesses consider a variable list of other factors when deciding where to locate. Many manufacturers seek locations with low land costs, good truck access, a supply of skilled labor, and space that provides them with the efficiency and flexibility of operations needed in a changing and competitive market. Retailers want to locate close to their customers in easily accessible places. Offices seek locations with a mix of accessibility, proximity to needed labor (clerical or professional), and lower rents. Typically many of these attributes, such as the supply of developable land, lower costs of development or leasing, access to labor, good access to highways, are more readily available on the urban fringe than in already developed areas (White, Binkley, and Osterman, 1993). Nonetheless, some businesses prefer more central locations for the access, prestige, and agglomeration economies they provide and changes in business types, accessibility levels, and other attractiveness factors can spur redevelopment and infill in already developed areas.

Table 7
Factors Influencing the Location Decisions of Businesses

Relative Importance	Factor	Comments
Highly Important	Costs and availability of space	Firms make trade-offs between the cost of space and other locational characteristics that they desire.
	Access to labor	Firms have different labor needs that influence where they locate. Some locate in the CBD to have the greatest access to a high skilled labor force. Some prefer suburban locations where there are stable clerical and support workers. Some locate near residential areas preferred by key technical and managerial staff.
	Access to customers	Critical to retail and customer serving offices. Also important to many manufacturing firms.
	Access to highways	All types of firms need access to the dominant mode of transportation to attract workers and customers and to receive and send deliveries.
Moderately Important	Near like firms	Many firms agglomerate near similar types of firms in retail centers, office parks, industrial parks, and downtowns. This improves their access to workers, customers, and intermediate inputs, and facilitates an exchange of information.
	Near suppliers, support services	This is most important for manufacturers and somewhat important for offices.
Somewhat important	Amenities, quality of life, prestige	This is important for firms with many professional workers and technical workers.
	Quality of public services	Public services are important for business activity and growth. Some manufacturers have specific requirements for large amounts of water and sewer capacity.
	Property tax rates	Manufacturing is most sensitive to local tax rates.
	Access to airport	This is highly important for headquarters or operations of national/global firms.
	Economic development incentives	Incentives are highly important to some firms. They can also influence the amount and location of redevelopment.
	Location of competitors	This is important especially for retailing.

3.6 DECISIONS OF DEVELOPERS

Developers typically are businesses (but can also be institutions, governments, and individuals) that convert land from one use to another. Businesses do this conversion with the aim of generating a profit. Most projects start with vacant or agricultural land and end up as new homes, offices, stores, and other buildings, but some projects recycle land and/or buildings to another use. Before building anything, developers go through a multi-stage process of estimating the feasibility of the project, lining up lenders and participants in the process, and working with the appropriate governments to obtain needed permits.

Developers may start with land and seek to find the right product, such as an office building, retail spaces, flexspace, or housing, to build on that site. More frequently, developers may have a product they want to build, such as moderately-priced single-family housing, and they are looking for the right location. Either way, they must decide what to build and where to build it based on their assessment of what households and businesses want. In making these decisions, developers (and their lenders) weigh the price they expect to receive for the product (either selling price or rental prices) versus the cost of producing the product (Landis, 1995; Miles et al., 1996).

These decisions depend in part upon the types of developers in the region. Developers vary in size, with some building a few homes a year and others hundreds of homes or diverse products. Some developers build only one or two products, and this limits their decisions to the type, location, and quality of these products. Other developers may build all kinds of projects depending upon clients wishes and market conditions. These developers have more complex decisions to make about what and where to build.

Because the vast majority of land in urban areas is devoted to residential development, they have the most extensive land use impacts. The decisions developers make about what type of housing and where to build it determine where most development occurs in a region. However, non-residential developments have more specific requirements and constraints on where they are viable. Non-residential development typically outbids residential development for the sites that best serve their needs, unless land use regulations prohibit them from developing at these sites.

Development does not occur unless there is demand for it. The regional economy and the types of changes occurring within that economy are major determinants of demand for new buildings. Demand is obviously greater in a growing region than in a stable or declining one. But even within a stable or declining area, changes in household sizes, incomes, or lifestyles or adjustments in the types of businesses produce demand for new development. In addition, some structures become undesirable, uneconomical, or obsolete. They are vacated or demolished, and when it is profitable, new development replaces them.

Developers conduct formal or informal market analysis to determine what type of product (e.g. upscale houses on large lots or starter homes on smaller lots) will sell. The market for different types of development depends on the population, employment, and income trends in communities and the nature and amount of development that has already occurred.

Factors that Influence the Price Development Will Yield

Developers must balance the prices they expect to receive for a product with the costs of building it. Both prices and costs can vary with location. The prices that development can command depend upon the needs and tastes of the consumer. While prices will vary with the type and quality of the product, this section focuses on the aspects of price that vary because of location.

Accessibility and Visibility

Accessibility to highways and to other forms of transportation, as well as visibility from highly traveled routes, makes sites more valuable and attractive for non-residential uses. Firms seek locations in highly accessible corridors and nodes of the transportation network in order to reduce the cost of obtaining inputs to production, expand the available pool of labor, or extend the range of their markets. Thus developers of non-residential properties are willing to bid more for these sites because they can also obtain a higher rate of return.

While households generally will be outbid by firms for the most accessible sites, households are also interested in proximity to jobs, shopping, entertainment, and other activities. Given the diversity of household types, and the predominance of multiple workers in households with more than one adult, it is often difficult to determine exactly what types of accessibility are important. Some observers of the development process think that higher income households are increasingly interested in living in "24-hour suburbs" where they can both live and work (Equitable Real Estate Investment Management, 1997).

Community and Site Characteristics

The right location can increase the amount of return that a developer can get. Characteristics of the community, such as social and economic status of residents, the types of existing land uses, and goals of the community can influence the amount that households and firms are willing to pay to locate within the community. In addition, trees, water, views, and other features of the site can substantially affect the prices that development can command.

Growth Corridors

Many regions have outward moving segments or corridors that are favored by higher income households, suburban offices, and more upscale retailing. Developments in these favored quarters will yield higher prices than the same development elsewhere. Leinberger (1996) locates a region's favored quarter by finding locations with good access to the interstate highway system where the higher income households live. Suburban offices and retailing have often developed at the nodes of the highway system within the favored quarter. Often the region's major industrial area is in the opposite (and downwind) direction from the favored quarter (Miles et al., 1996).

Competition in the Market

Prices for new development depend in part on the locations of existing and planned developments with which the development will compete for rent or sales. Prices are

affected by current vacancy rates, the length of time it takes to sell homes or lease business sites, and the number of other developments of similar quality and character coming on the market (Miles et al., 1996).

Factors that Influence the Cost of Development

The flip side of prices is costs. Developer profits depend upon finding not only locations where a product will sell, but also where it can be build at a cost that yields a profit. In the real world, where choices are often limited, the developer is not able to minimize costs; rather the private developer may choose to develop when and where costs are manageable.

Land Availability and Costs

Land availability depends upon current uses, ownership, and government regulations. Where land that can be developed is scarce, prices will be higher. Many projects require large sites which are easier to assemble if the property has only one or a limited number of owners with whom to negotiate (Miles et al. 1996).

Land costs will vary by location because the attractiveness of a location is capitalized into the price of land. For example, the levels of accessibility and visibility are reflected in prices. Retail and office firms that need high levels of access will outbid others for sites near freeway interchanges, while manufacturing and wholesaling will opt for cost sites that have good access, but lower levels of visibility, and therefore lower costs.

Site Characteristics

Parcels can vary considerably in the proportion of buildable land they have and, therefore, the cost of development. Costs vary with the size, slopes, wetlands, soils and other natural features that limit the amount and type of development that can occur. In addition, if the land is already developed there are added costs of demolishing and removing existing structures and possibly of environmental cleanup. Many urban areas have sites where the land is worth more than buildings, making the site ready for redevelopment to a new use.

Often land that has been passed over in previous building cycles have constraints that have made them costly to develop. These constraints could include slopes, wetlands, lack of water or sewer services, land ownership patterns, lack of access, or small parcel sizes. These areas could become more attractive to development if prices for development rise enough to compensate for the additional costs or where the accessibility or attractiveness of the area changes over time. Infill and redevelopment on these types of site can occur in both urban and urbanizing areas.

Governmental Regulations, Permitting Process, and Economic Development Incentives

Local attitudes toward development, as reflected in community regulations and the process of getting permits, can substantially affect the cost of development. Land may cost more in communities that limit supply, and development will cost more when there are more requirements to be met, longer approval times, or higher costs for permits (Dowall, 1984).

Communities can restrict development by limiting the amount of land zoned for it, putting limits on the amount of new development that can occur, setting design standards and other requirements, or making it difficult to get permits. Communities can actively encourage development by zoning land for its use, putting in infrastructure, providing incentives such as tax abatements, and streamlining permit processes. Communities can also take a more neutral response weighing the costs and benefits of individual proposals. Individuals and groups within communities can also oppose certain types of development, raising the time and cost of getting approval or killing projects.

Land regulations can cause a shift in the type of product that developers provide. When governmental costs and requirements go up, developers may shift to higher income housing as lower cost housing becomes less profitable (Dowall, 1984; Feitelson, 1993).

Developers generally prefer sites where government regulations allow the proposed use, all other things being equal, since there is less risk involved in making an application. But often, all other things are not equal, and developers will pursue projects that require changes in land use regulation. Developers take these risks because they feel that the market makes the location a profitable place to develop even though the current land use regulations do not allow it (Dunphy, 1995). Ihlanfeldt and Raper (1990) argue, for example, the amount and location of land zoned for office development is usually based on past demand for office space. But current office demands may have different requirements. Most communities believe that office development is desirable since it does not pollute and generates more in taxes than it costs the community. Therefore, many communities will readily rezone for office projects.

Availability and Costs of Infrastructure and Other Public Services

Costs also depend upon a community's infrastructure capacity, their plans to provide additional infrastructure as they grow, and the ways they finance additional capacity and system extensions. Developers consider whether communities can provide the necessary infrastructure and public services and how much these services will cost them in impact fees and other charges when deciding where to locate. Communities may have plans to develop new infrastructure in stages, not allow development outside urban service boundaries, or require that adequate services be available in order to permit development, all of which can influence the cost of development (Nelson and Duncan, 1995: Landis, 1995; Miles et al., 1996).

One of the factors that can support infill and redevelopment is that infrastructure is already available. Although connecting to existing infrastructure can lower costs, it may be offset by the need to update aging infrastructure or other costs of redevelopment including land assembly, the demolition of existing structures, and environmental cleanups.

Summary

In sum developers consider the factors outlined in Table 8 when deciding what and where to develop. Not all developers will weigh the factors identically, but the table identifies those which are generally more important than others in the decisions about where to develop.

Table 8
Factors Influencing Developer Decisions About What and Where to Develop

Factor	How Factor Affects Developer's Decisions
Sales and rental prices	Critical determinant of profitability. More desirable locations command higher prices.
Accessibility and visibility	Necessary for retail and most office development. Access to highways important to manufacturing that relies on trucking. More accessible residential locations are more desirable than less accessible locations.
Site characteristics	Can influence both prices and the cost of development.
Growth corridors (e.g. desirable community characteristics)	Development is more likely to occur where there is momentum, but as an area becomes built out or preferences change, these can shift. Developers who correctly anticipate shifts can make more money.
Competition in the market	Profit levels depend upon the competition from existing development and the products that other developers might build.
Land availability and costs	A major factor in deciding what and where it is profitable to build.
Zoning and other regulations	Impacts depend upon whether a community is market-oriented (i.e. adapts regulations to fit with developer proposals) or growth-management oriented (development must fit within plans).
Cost and difficulty of getting permits	Can add to the costs and risks of a project, influencing the type of projects proposed.
Development incentives	Can encourage development where it would not occur without public support, such as redevelopment and infill projects or housing in downtowns.
Availability and cost of infrastructure	Key component of deciding where and what to build.

3.7 CONCLUSIONS

The interaction of supply and demand for housing and business properties in the land market produces the pattern of development within a region. Within this market households and firms make demands for new buildings and locations while developers provide these products within the supply and cost constraints of government.

Households weight the costs of different locations with their needs and preferences for living space, neighborhood type, quality of schools and other public services, and access to jobs, goods, services, recreation, and friends. Various types of households weight these factors differently as they consider what type and location of housing will best satisfy their needs and be within their budgets. Firms also balance the costs of various locations with their needs to be accessible to workers, customers, supplies, and information and to be attractive places to work and shop. These needs often lead them to cluster with other businesses in downtowns, suburban activity centers, and office and industrial parks or to

outbid other uses for the highly accessible and visible places even though space may cost more in these locations.

Developers provide the bulk of new developments which compete with vacancies in the existing stock of buildings to supply the spaces needed by households and firms. Developers make a profit by carefully evaluating the needs and preferences of their customers. Developers' projects are constrained by the land use regulations and ability of governments to provide needed infrastructure.

Within this behavior framework, transportation investments are seen as one of many factors that influence the location of household and firms. Transportation investments can influence land use patterns because accessibility does matter to households and firms. Transportation projects can create nodes, such as highway interchanges, airports, and transit stations that attract development, if other conditions are right. Transportation investments can also lead to development occurring sooner or being of a different type than would have occurred otherwise.

However, this framework shows that accessibility has many forms. It is more complex than the link between home and work that has been emphasized in urban models. Different niches in the land market have different accessibility needs, and households access to jobs and firms access to workers is only part of the story. Access to the many other goods and services that households and firms need must be also be considered and the relative importance of these types of access considered for the types and households and firms that are participating in a particular land market.

In addition, other factors like the desirability of certain locations, the costs and availability of developable land, the difficulty of developing that land due to physical and regulatory constraints, and the costs of extending sewer and water services may have as much or more to do with where, when, and what type of development takes place as the level of accessibility.

The next chapter considers how this behavioral framework can be used with the types of tools discussed in Chapter 2 to produce better land use forecasts and impact or policy assessments.

4.0 USING THE BEHAVIORAL FRAMEWORK IN LAND USE ANALYSIS

With few exceptions, MPOs are not responsible for land use planning in any substantive way. Similarly, few states consider land use planning a function of state government. However, both MPOs' and DOTs' responsibilities include the need to understand the land use impacts of their transportation decisions. The focus of this chapter is on the main types of planning actions which link transportation and land use and the ways to apply the behavioral framework and the analytical tools to these activities.

The main planning functions of MPOs and DOTs are:

1. **Base case land use forecasts.** These forecasts are used as inputs into travel demand modeling and to provide a point of reference for impact assessments and policy analysis.

2. **Impact assessments.** These processes estimate the land use impacts of expansions or additions to highway networks, transit systems, airports, and intermodal freight facilities. An impact assessment may involve a single project, such as the building of a new highway interchange or a transit center, or it may include multiple projects, such as the analysis of alternate investment scenarios for a regional transportation plan.

3. **Policy assessments.** These are evaluations of the land use impacts of transportation policies or new technologies, such as transportation demand management, congestion pricing, parking pricing and management, or intelligent transportation systems. This process is similar to that for impact assessments of transportation projects, but there may be little or no experience with the policy to draw on for guidance about probable impacts. In particular, there may be more uncertainty about the type and magnitude of the transportation changes that the policy will produce, making it difficult to predict the land use changes that follow from new travel behavior.

Today the state-of-the-practice in these activities is badly flawed in many instances. Base case forecasts often consist of compilations of land use plans. Land use impact assessments in MIS/EIS documents often are based on plan designations or on inappropriate assumptions about the behavior of the key actors affecting land use outcomes. Few tools have been developed with the tasks of analyzing the land use impacts of regional or state transportation plans or doing policy assessments explicitly in mind. Many current tools are too blunt or are lacking in any notions of the actors, prices, and factors shaping the land use market.

This section presents more disciplined ways of doing these land use analyses that incorporate a useful and realistic behavioral framework. The methods presented are not an exact recipe but rather an outline with suggested ingredients which MPOs and DOTs can use to adapt, add to, or replace the types of analysis they already do. The methods

described here stop short of integrated modeling approaches. Instead they are ways for MPOs and DOTs with less complex tools and more limited data sets to incorporate land use markets and the choices of households, firms, and developers into their analysis.

4.1 GENERAL ISSUES IN LAND USE ANALYSIS

Technical and Policy Aspects of the Process

The processes of land use forecasting, impact assessment, and policy analysis involve both technical and public policy issues. Technical expertise is needed to collect, analyze, and interpret information, but much of this technical work requires making public policy assumptions. For example, the analyst must decide the densities to assume for single-family residential housing. The analyst may find that housing is built at less than planned densities. Should the assumed densities reflect the current or planned lot sizes? In addition, the market-based forecast may indicate that the type and location of development within a region will differ from that desired by local jurisdictions. These questions and conflicts must be resolved. Rainford and Masser (1987) have identified three general approaches to land use analysis that differ in the ways they handle these issues.

- Technical analysis relies on the technical expert to make a forecast or impact assessment using the best analytical tools available. The analysis may be based on regional trends, demand for new development, or other processes that the technical expert concludes are the best methods available. The problem with this approach is that every forecast requires making assumptions, and here the responsibility is handed over entirely to technical experts. Many of these assumptions have policy implications and ought to be considered in a policy context. Leaving policy-makers out of the forecasting loop leaves them no role except to question the results, especially if the results diverge from their hopes for their communities.

- Policy-oriented analysis relies on public policies in comprehensive plans and other land use regulations and negotiations with local jurisdictions. Public policies impact the supply of land by regulating allowable uses. The demand side of the land use market, however, can easily be ignored in these forecasts. When the forecasters leave out the market for land development, the feasibility of the forecasts is likely to be questioned. This leaves lots of room for second-guessing the forecasts.

- Consensus analysis involves technical experts and policy makers in a discussion of assumptions and procedures. The goal is for everyone to understand the process and agree on the assumptions that are built into the forecasting process. The aim is to produce forecasts that are realistic and credible because they incorporate sound data and analysis plus an understanding of the particular policy context in which the forecast is being made.

Most land use forecasts made for transportation modeling purposes in the United States have been policy-oriented (Harvey and Deakin, 1993). Land use policies have driven the forecast because the aim has been to determine the transportation system needed to support the planned land uses. ISTEA requires rethinking of this approach to integrate the analysis of land use and transportation policy and planning. The best practices in land use

analysis processes combine technical analysis with understanding of public policy. Consensus forecasts can accomplish this by using technical and policy advisory or review committees. In particular, we recommend that policy makers be involved in establishing the assumptions that underlie the forecast or impact assessments and then in evaluating the results to see if they are reasonable within the assumed policy framework.

Integration of Land Use and Transportation Analysis

Ideally, land use and transportation analysis would be integrated. The analysis should be an iterative process that moves back and forth between the land use analysis and the travel demand model. The UrbanSim model that is being developed as another product of this study will be an integrated model. Some of the formal land use models, such as TRANUS and DRAM-EMPAL, are or can be integrated with transportation demand models. A highly structured Delphi process could also be used interactively with the results of a travel demand model to predict land use outcomes.

The objective of this guidebook is more modest. The guidebook describes processes for estimating the land use impacts of transportation projects, assuming that the transportation project produces a one-time shock in the urban system that is reflected over time in new land use patterns (though the majority of transportation projects do not have this "shock" effect). We use this simpler approach because most states and MPOs lack the data, models, and budgets for an interactive analysis. In addition, there is an immediate need for better methods of evaluating the impacts of transportation projects on land uses, using methods that emphasize that transportation is only one of many factors that impacts the decisions about where firms and households locate.

4.2 DIFFERENT TYPES OF LAND USE ANALYSIS USE SIMILAR METHODS

The remainder of this chapter describes the processes for doing land use analysis. The steps are similar regardless of the planning issue being addressed. The basic steps are:

1. Understand existing conditions and trends.
2. Establish policy assumptions.
3. Estimate regional population and employment growth resulting from change in accessibility.
4. Inventory land with development potential.
5. Assign population and employment to specific locations.

The following sections describe the process for doing each of these steps and identifies and evaluates analytical tools that are appropriate for each step. For each step in the process we identify products, basic questions, appropriate tools, and issues that must be considered. The process is presented in full for the base case forecast. The presentations for impact assessments and policy analysis discuss how these processes differ from the base case forecast. These sections assume that the reader is familiar with the base case forecast section.

Products. This section briefly describes the type of report that each step should produce. Any land use analysis should be well documented laying out the assumptions, procedures, and results.

Basic Questions. This section identifies questions that need to be answered in each step. These questions are general; other region specific questions that address unique conditions may also be needed.

Appropriate Analytical Tools. This section includes a matrix and discussion identifying recommended tools. Tools are divided into primary and secondary categories. Primary tools can be used to answer the basic questions that must be answered by that step in the process. Secondary tools are used to do partial analysis. For example, secondary tools might be used to analyze historic data to help inform the process of establishing policy assumptions or to determine the threshold for a decision rule that is part of the allocation process. Secondary tools might also be used to study special cases that may not follow the patterns assumed by more general analysis, such as determining the locations of large employers. By itself, a secondary tool is probably not adequate to answer the basic questions. Even the results obtained from primary tools should be reviewed and may need adjustments to compensate for the fact that none of the tools perfectly represents the complex world of urban development.

Issues. This part discusses some of the strengths and limitations of the process as well as variations that might also be considered.

4.3 BASE CASE FORECASTS

Base case forecasts predict the location of households and firms in a region assuming continuation of current trends in development. The forecast is made for the traffic analysis zones used by the transportation demand model[5].

Step 1: Understand Existing Conditions and Trends

One of the major tasks of a land use analysis is assembling and managing the data needed to carry out the analysis. At this stage the data needs to be analyzed to understand existing land uses and recent trends.

Decisions must also be made about the level of detail that will be used in the forecast. What categories of households, firms, housing, and land use will be used? This can be simple or complex depending upon the complexity of the region, the level of detail that the travel demand model can handle, and the resources available for the forecast. Groups should be as homogeneous as possible in their location choices. Households can be divided into groups based on income levels, size, age of household, number of workers, and other factors that are known to affect locational and travel behavior. Firms are often separated into broad categories such as population serving (retail) and basic (export-

[5] New models will eventually analyze these trends at the household or business level. However, existing tools are just beginning to handle this level of dissaggregation. Thus, we have assumed that zonally-based models are the state-of-the-practice, at this time.

based), but division into more detailed economic sectors are possible. Housing can be categorized by multi-family and single-family and by densities within these categories with the selection of categories depending upon the types of housing likely to be built in the region.

Because the base case forecast is used as input for travel demand forecasting, the land use forecasting results must be organized into the zonal structure used by the travel demand model. Data on initial conditions should also be organized and analyzed for these zones, as a point of comparison. At this stage in the process decisions must be made about whether the entire process will be carried out at traffic analysis zone level of disaggregation or whether the forecast will be made for a smaller set of larger zones and then allocated to more detailed traffic analysis zones at the end of the process.

Product

The product of this step is a summary of trends in population, employment, land development, and public policy that affects development. The findings should be presented in a variety of formats including maps, graphs, tables, and text to help inform the remainder of the process.

Basic Questions

What are the existing land use conditions in each analysis zone?

- What is the current pattern of land uses?
- Where and what type of land is available for development--both vacant and underdeveloped lands?
- What development is already being planned for developable land?
- Where are major employment centers, large scale residential developments, and major investment sites?
- What are the characteristics of current residents?
- What types of housing exist?
- What does it cost to buy or rent housing?
- What types of retail, office, and industrial buildings exist?
- What does it cost firms to buy or lease space?
- What type and how many jobs currently exist?
- Where is employment in each economic sector located?

What are the recent trends (5-10 years) in population, housing, and employment?

- Where is the population growing? Where is it declining?
- Are the characteristics of the population changing?
- What housing is being built by type, quality, price, and location?
- What types and sizes of non-residential development are occurring?
- Where are jobs being created?
- Are the numbers and types of jobs changing?
- How much land is being used for each major type of development?
- What factors are driving these trends?

What are the current plans and policies to influence growth and development?

- What are the comprehensive or long range land use plan policies?
- What are the zoning designations? What uses are allowed in each zoning category?
- Do any communities have growth limits? How stable are these?
- Are there designated urban growth boundaries or urban service areas?
- Are there agricultural preservation programs?
- How effective are these policies and plans at shaping land uses?
- What environmental regulations limit development?
- What land is in parks, open space, and other large public uses?
- How much capacity is available in water, sewer, and stormwater systems and what are the plans to expand and extend these systems?
- What are the plans to improve roadway and transit systems?
- Are there requirements that infrastructure be provided concurrently with development? How do these requirements work?
- What types of economic development programs are used to encourage economic growth?
- What are the rates for development permits, impact fees, and other charges?
- What other plans and policies affect the supply of land available for development or the cost of development?
- Do jurisdictions rely primarily on the land use market or on regulations to determine approved uses?

Appropriate Analytical Tools

This step of the analysis is basically descriptive. GIS is the primary means of storing, displaying, and analyzing trends for the diverse sets of data needed for a base case forecast. A more thorough analysis is possible with GIS than is possible using only maps and tabulations of data, although these manual methods may suffice for small areas. Older data sets, that are not geocoded into GIS files, may still require traditional data base management and display in tabular form. Some qualitative research or statistical analysis may be needed to gain a more thorough understanding of trends. These recommendations are summarized in Table 9.

Table 9
Recommended Tools for Understanding Existing Conditions for a Base Case Forecast

Tools	Primary Tools	Secondary Tools
Qualitative Methods		
Delphi/Panel		
Interviews/Survey/Case Studies		◆
Allocation Rules		
Decision Rules		
GIS	◆	
Statistical Methods		◆
Regional Economic and Demographic Models		
Formal Land Use Models		

The types of data needed for a base case forecast are described below. The format, geographic scale, and other characteristics of the data can vary widely especially for information that must be collected from local governments. Data from federal agencies is generally available in digital formats. Data from local governments can be in any form from GIS-compatible formats to maps and lists. It can take considerable time and effort to assemble this data in a consistent and useable manner. Table 10 lists the data and potential sources to measure existing conditions. Table 11 lists data and sources for measuring trends.

Table 10
Data to Measure Existing Conditions by Analysis Zones

Data Needed	Potential Sources
Existing land uses	Planning departments, building departments, county assessors, aerial photographs from private or public sources
Vacant and underdeveloped land	Planning departments, county assessors, aerial photographs
Permitted uses	Comprehensive plans, zoning codes, and other land use ordinances
Physical limitations to development	Planning departments, U. S. Geological Service maps and data, Soil Conservation Service Maps, FEMA maps, Floodplain maps, National Wetlands Inventory from U.S Fish and Wildlife Service
Parcel sizes and configurations	Planning departments, county assessors, tax maps
Development already planned	Planning departments
Population by occupation, income, household size, race	U.S. Census Bureau, Bureau of Transportation Statistics, Private data vendors, City and county forecasts from State forecasting agencies, State and local forecasts from Bureau of Economic Analysis
Housing by type and price plus vacancy rates	U.S. Census Bureau, Bureau of Transportation Statistics, Department of Housing and Urban Development, Board of Realtors, Multiple listing service, private data vendors, utility companies (vacancy rates)
Current employment by type	State department of employment (ES 202 reports); survey of employers, County Business Patterns, Economic Census from U.S. Census Bureau
Vacancy rates for non-residential development	Realtors, developers, building and office management associations, National Association of Industrial and Office Parks
Major highways and roads	U.S. Census Bureau TIGER files, Bureau of Transportation Statistics Tiger Files, MPO files and base maps, DOT files and base maps
Traffic conditions	DOTs, MPOs, city and county transportation departments
Accessibility measures	MPO travel models, base maps

Table 11
Data to Measure Recent Trends by Analysis Zones

Data Needed	Potential Sources
Population growth and decline	U.S. Census Transportation Planning Package, estimates from building permit activity, State population forecasting agency
Amount, type, cost, and quality of housing development	Building permits, Board of Realtors, private vendors
Non-residential development by type, size, and price	Building permits, Board of Realtors, private vendors
Employment changes by type	State department of employment; survey of employers, private vendors
Land consumption rates for various types of development	Planning departments, aerial photos

A number of public plans and policies that can affect the supply of land available for development will need to be assembled and compiled in standard formats. The plans and policies needed include those listed in Table 12. Some local governments may have the spatial data, such as zoning and water systems, available in GIS formats. Other data may need geocoding.

Table 12
Plans and Policies to Assemble for Land Use Forecasting

Comprehensive or long range land use plans
Zoning maps and ordinances
Other land use regulations and design standards
Maps of current and planned water, sewer, and stormwater systems
Schedules for extending water, sewer, and stormwater systems
Roadway and transit plans
Economic development plans
Schedules of permit and impact fee charges
Information on the scale of off-site improvements required of developers

Issues

Decisions must be made about the amount and type of data that is needed for the analysis. It is important to have appropriate data for the analysis but not to become overwhelmed with collecting and managing this information. Some compromises may be needed between the ideal data and what is available and useable within the time, money, and staffing resources of a project.

Step 2: Establish the Policy Assumptions of the Forecast

A base forecast assumes continuation of current patterns of growth and decline. The information gathered in step 1 can be used to identify trends such as rates of growth,

density of development, water and sewer extensions, transportation investments, and other factors affecting the pattern of land uses. One task at this step is to identify the policies that have been shaping development and that will be held constant for the forecasting period. Another task is to identify trends in infrastructure development and specify what this means for future expansions of water and sewer systems and for transportation facilities. The assumptions must include a schedule of specific transportation projects in order to use the forecast for transportation planning.

We recommend a joint effort of technical staff and committees and policy makers for this process. Technical people can help with understanding the nature of trends, their implications for the future, and the ramifications for the forecasting process of making various assumptions. Policy makers should be involved because the assumptions are critical to determining the outputs. If everyone agrees on the inputs and the forecasting process, there is less room to quarrel with the outputs.

Product

The product of this step is a list of policy assumptions that shape the forecast. This will include assumptions about zoning, environmental regulations, scheduling of sewer and water extensions, and the scheduling of major transportation projects.

Basic Questions

What are the current policies that should be assumed to continue in the base case?

- What policies (e.g. zoning, environmental regulations, infrastructure provisions) are currently constraining the supply of land available for development and should be held constant in the forecast?
- What policies are affecting the current costs of development (e.g. impact fees, economic development programs, infrastructure provision) and should be assumed to continue for the forecasting period?
- How much change, if any, should be assumed for impact fees and other development charges?
- What new highways or expansions to highway capacity should be assumed to occur during the forecasting period?
- What changes in the transit system should be assumed for the forecast period?
- What other changes in transportation infrastructure should be assumed?
- Are there other current transportation policies, such as transportation demand management programs or parking management, that should be part of the base case assumptions?

Appropriate Analytical Tools

Basically, this is not an analytical process. Instead it requires that decisions be made about the appropriate assumptions. Some secondary analysis might be done to better understand which policies have been shaping the pattern of development and how they have done this. This reality check on the effects of policies is needed to better understand the shape of future development. This might be done using qualitative tools such as interviews with developers to better understand how they factor zoning and infrastructure

extension plans into their calculations. Alternatively, if enough data is available over time, it might be analyzed using GIS or with various statistical methods. Table 13 summarizes these recommended tools..

Table 13
Recommended Tools for Establishing Policy Assumptions for a Base Case Forecast

Tools	Primary Tools	Secondary Tools
Qualitative Methods		
Delphi/Panel		
Interviews/Survey/Case Studies		◆
Allocation Rules		
Decision Rules		
GIS		◆
Statistical Methods		◆
Regional Economic and Demographic Models		
Formal Land Use Models		

Issues

It is tempting to assume that policies such as zoning and economic revitalization programs will effectively shape development since policy makers adopted them for this reason. Yet, zoning can be quite malleable in some communities, and the private sector may not be responsive to policies, such as those that encourage redevelopment. It is critical to make realistic assumptions about the policies that influence the supply of developable land. It is probably not realistic to assume that future development will conform to current policies if past development did not do so.

Step 3: Estimate Regional Population and Employment Growth

A land use forecast starts with estimates of regional population and employment growth to use as control totals. Ideally, these totals are estimated using a process that considers the economic connections of the region or state to the larger national economy. This process requires extensive data on historic population and employment trends and the relationship of the local economy to the national economy. It also requires economic models that can analyze these trends.

The standard procedure for many MPOs is to use state or federal forecasts of regional population and economic growth. State law may mandate the use of these forecasts. In other cases, regions make their own estimates of regional control totals using demographic or economic models. Some regions use commercially available regional economic models, such as REMI, while others have developed their own models.

If an agency makes its own estimates of regional growth, the agency's policy-making body typically approves these estimates. When giving their approval, policy-makers need to understand that even the most complex models cannot accurately foresee the future. Forecasters cannot predict all the changes in economic cycles and people's behavior that underlie population and employment growth. Policy-makers should understand the assumptions behind the projected rates of growth and the uncertainties in these forecasts, and use this information to evaluate the reasonableness of the forecasts.

Product

The products of this step are estimates of the number of households and jobs in the region at the end of the forecasting period. The numbers of households and jobs should be divided into categories that were determined in step 1.

Basic Questions

How much will the region grow or decline over the planning period?

- How much will regional population increase due to natural population growth?
- How much will regional population change due to migration in and out of the region?
- How will the income levels, size, and life cycle stage of households change?
- What changes in the number of jobs in each of the economic sectors are expected for the region?
- What are the growing and declining economic sectors within the region?
- What changes in the number of households, by age, income, and other characteristics, are expected for the region?

Appropriate Analytical Tools

The primary tools for forecasting regional economic growth are regional economic and demographic models which simulate the region's economy. The most advanced practices integrate employment and population models. These models mirror the real world situation where growth in households and employment reinforce each other. Because regional economic and demographic models are based on economic theory they are consistent with the behavioral framework.

Special studies using surveys or interviews may also be conducted to better understand particular industries or population groups. These studies are valuable when there are sectors of the economy or of the population that are not well understood and are not expected to follow trends. These studies could be used for new groups of people moving into a region, for newly developing types of firms, or special cases such as large employers.

Because there are many uncertainties in these estimates and their accuracy is important for the forecasts that follow, they should be reviewed by a panel with expertise in economic and demographic forecasting and local conditions. Table 14 summarizes the tools used for secondary analysis.

Table 14
Recommended Tools for the Estimating Regional Population and Employment Growth for a Base Case Forecast

Tools	Primary Tools	Secondary Tools
Qualitative Methods		
Delphi/Panel		◆
Interviews/Survey/Case Studies		◆
Allocation Rules		
Decision Rules		
GIS		
Statistical Methods		
Regional Economic and Demographic Models	◆	
Formal Land Use Models		

Issues

There is considerable uncertainty in long-term forecasts of employment and population. The forecasts require that assumptions be made about how the economy and population will change over time. It is not possible to predict all the changes in the business cycles that will occur or their impacts on a region.

In fact, long range economic forecasts are not designed to predict economic cycles at all. There are short range econometric models whose forecasts explicitly include economic change on a three month basis. Such models typically are not necessary or appropriate in this context.

Nor is it possible to foresee all the ways that people will change their behavior, such as having different family sizes, workforce participation rates, or immigration rates. Further, technological predictions are highly problematic. While long range economic forecasts may implicitly incorporate the effects of technological change on employment by sector, technical staff still have to sort out the ways in which the location of employment and households may change as a function of technology. Understanding the impacts of telecommuting, is one example of such a challenge. Thus far, many planners' predictions of the effects of telecommuting on travel behavior have been overestimated.

To compensate for these uncertainties, forecasters sometimes make a range of forecasts based on plausible assumptions about future job and population growth and then select a middle level projection as the official rate. Given the opportunity to select among a range of forecasts, planners typically select the mid-point as their consensus. It may be useful, however, to carry the high and low projections forward in the planning process to understand the effects that these may have. This would be particularly important if the high or low forecasts involve relatively more growth in one age group or one or more employment sectors. If this were the case it would be appropriate to locate this economic activity (as we describe in subsequent steps.)

One approach to long range forecasting involves the assignment of probabilities to this range of forecasts. This technique would not only apply to assumptions about population and employment growth and change, but also to all other important assumptions around which there may be some uncertainty or difference of opinion. By introducing a high, middle and low value for the particular variable, and assigning a probability to the likelihood that it will occur, planners can explicitly take into account the many uncertainties which are known to permeate every aspect of the long range planning process.

An example of this in a transportation planning context occurred in the Twin Cities (Minnesota) region in the late 1980's, in connection with long range plans for the expansion of its international airport. Planners and analysts assigned a high, medium and low range value to each of the many variables of which assumptions were required in the prediction of passenger demand. Many of the important findings and conclusions of the long range forecast were expressed in ways which represent a range of possible outcomes and the probability of each.

Step 4: Inventory Land with Development Potential

The purpose of this step is to identify the supply of land that is available for development and the limitations on the development potential of that land. Limitations can include physical constraints like steep slopes, land ownership patterns, and any of the policy assumptions that limit the number and type of households and firms that could locate on the land.

The process starts with an inventory of undeveloped parcels, developed parcels that could be further subdivided or consolidated, and parcels that are ready for redevelopment to another use or a different density. Then any physical constraints that could limit development, such as wetlands, floodplains, unstable soils, and steep slopes, must be considered. The effects of these constraints must also be gauged. Some conditions may mean that no development is possible, others that only certain types or quantities are feasible, and others that development is possible if market conditions are right.

Then the public policy assumptions (from step 2) that limit the location, type, and density of development on these lands must be applied. If the assumed public policies prohibit development on certain lands (such as policies prohibiting development of prime agricultural lands), this acreage must be deleted from the base of developable land. If the assumed public policies restrict the types and densities of uses, these restrictions must also be applied when determining how much development could occur. If public policies affect the timing of development (for example, infrastructure phasing), these must also be noted. Finally, the amount of land needed for streets and other public facilities must also be estimated and deleted from the supply of land available for private development.

Projects that are already committed or in the planning stages should also be considered at this stage. Land that will be used by projects that are in the development pipeline should be removed from the developable base. Likewise, the amount of growth that these projects can accommodate should be subtracted from the numbers of households and jobs that need to be assigned in the next step.

Product

One product would be maps showing where development could occur by type and density. Another product would be tabulations of the potential number and types of jobs and households that each analysis zone could absorb, given the limitations imposed by public policies and other factors. (The next step will sort out which households or types of firms would outbid others for these locations if competing uses are possible.)

Basic Questions

How much land is available for development and what restricts the amount and type of development that can occur on this land?

- How much vacant land is available in each zone?
- How much infill potential is in each zone?
- How much redevelopment potential is in each zone?
- What are the physical and current land parcelization patterns that limit development on these sites?
- Where do the assumed public policies (step 2) prohibit development? How much will this reduce the supply of developable land in each zone?
- Where do the assumed public policies limit the type, quantity, and density of development that could occur?
- How much land will be needed for streets and other public facilities to serve growth? How much does this reduce the supply of developable land in each zone?

Appropriate Analytical Tools

GIS is the main tool for organizing, sorting, and displaying the lands available for development. This must be supplemented by processes for deciding what lands to include as available for infill and redevelopment. Decision rules that establish thresholds, such as the minimum size of site to consider for infill, are often used. These decision rules should be based on actual practices in the region, where possible. This information could be obtained by interviewing developers who do infill and redevelopment or examining the characteristics of places where infill and redevelopment has occurred. Secondary research may also be needed on the amount of land that is needed for streets, parks, schools, and other public facilities. The public policy assumptions may specify some of these needs, such as the amount of parks per residents. Other thresholds may be based on analysis of recent conditions, such as the amount of land used for streets in recent developments of various sizes. Table 15 summarizes the recommended tools.

Table 15
Recommended Tools for the Inventory of Developable Land for a Base Case Forecast

Tools	Primary Tools	Secondary Tools
Qualitative Methods		
Delphi/Panel		
Interviews/Survey/Case Studies		◆
Allocation Rules		
Decision Rules		◆
GIS	◆	
Statistical Methods		
Regional Economic and Demographic Models		
Formal Land Use Models		

Issues

Decisions must be made about the complexity and level of detail to consider at this phase. In the past, many base case forecasts have taken the simple approach of only considering the capacity of vacant parcels. These forecasts have over-estimated the demand for vacant land because a considerable amount of development in many regions occurs in areas that are already partially developed. Thus, more thorough processes need to consider when and where infill and redevelopment is feasible. Since land in various market areas is finite, the more that is developed, the costlier remaining sites become.

When demand for development is high, prices go up and parcels that have been previously passed over because of slopes, ownership patterns, or other limiting factors may now be ready for development. In addition, changes in population or employment patterns may make some parcels ripe for infill or redevelopment to serve the needs of the types of residents or firms now wanting to be in the area. An assessment should be made of where and under what conditions the land market will support development of land with the following types of factors: physical constraints that do not rule out development, land ownership patterns that raise the cost of development, lots that could be subdivided or assembled, redevelopment sites, and sites where infrastructure extension costs are high.

Lastly, in any area, markets for uses change. Analysts must consider the possibility that marketable parcels will develop differently at different points in time.

Step 5: Assign Population and Employment to Specific Locations

The final step is to assign the growth in households and firms (estimated in step 3) to specific zones within the limits of those zones to absorb new development (estimated in step 4). The analysis must determine how much, what type, and what density of growth will go into each zone.

The process described here assumes that only the incremental growth needs to be assigned to new locations. This assumes that existing buildings, except for those redeveloped, are occupied by the same number of households and jobs at the end of the planning period as at the beginning. There are times when different assumptions should be made. The issues section below discusses additional procedures to deal with situations where changes in already developed zones need to be considered.

The questions of how much, what type, and what density of growth occurs in each zone are interrelated and are affected by the cost of development, the attractiveness of the area, the demand for various types of product, and the supply of land available for that type of development. For simplicity, we will consider each of these issues separately in the basic questions below, but it should be clear that the answers to one affects the others.

Product

The final product is the forecast of the location of households and job within a region. The forecast should identify the number, type, and density of new housing and jobs in each zone in the region using the categories of households, jobs, and land uses that were determined at the beginning of the forecast. Both tabulations and maps can help make the results understandable and accessible to a variety of users.

Basic Questions

What type of development will occur in each zone, given any constraints on allowed types of development analyzed in step 4?

- What types of housing do households want?
- What types of housing do developers find it profitable to build?
- What types of business development does the market support?
- Where multiple types of uses are allowed, which uses will outbid others for available locations within each zone?

At what density will each type of development occur, given the constraints on densities analyzed in step 4?

- What densities of housing do households want?
- What densities of housing do developers find it profitable to build?
- What densities of business development does the market support?
- How much will land ownership patterns, slopes, NIMBYism, and other factors limit the densities of development?

How much development of each type and density will occur in each zone?
Underlying these questions are basic questions about the cost of development and the prices that new development can command in rents or sales.

- How do public policies, including impact fees, other development charges, costs of extending infrastructure, and economic development programs, affect the cost of development in each zone? How do these costs affect the type, density, and quantity of development that will occur in each zone?

- How do the costs of development on larger vacant tracts of land compare with those of infill and redevelopment? How will this affect the decisions that developers make?

- How do accessibility and other attractiveness factors affect the sales or rental prices for development in each zone? How do these attractiveness factors affect the type, density, and quantity of development that will occur in each zone?

Appropriate Analytical Tools

A number of different tools can be used to answer these questions by explicitly or implicitly considering the demand and supply for new development and the costs and prices of that development. The choice of primary tools will depend upon the resources available for the forecast, the skills of the forecasters, and the complexity of development in the region. In many cases a mix of methods may be used which could include two or more of the primary methods, or a single primary tool supplemented by secondary analysis such as decision rules. Each of the potential tools is discussed below, beginning with the primary tools. Table 16 summarizes the recommended tools for assigning households and firms and the following text discusses each of these in more detail.

Table 16
Recommended Tools for Assigning Households and Firms in a Base Case Forecast

Tools	Primary Tools	Secondary Tools
Qualitative Methods		
Delphi/Panel	◆	
Interviews/Survey/Case Studies		◆
Allocation Rules	◆	
Decision Rules		◆
GIS		◆
Statistical Methods	◆	
Regional Economic and Demographic Models		
Formal Land Use Models	◆	

Delphi/Panels. A group of experts in the development process, including planners, developers, and lenders can decide the most likely pattern of development, given the policy constraints that are assumed for the forecast and the development potential of the region. These experts would forecast land uses by combining their knowledge (and the information prepared for them) about trends, the local land market, and the factors affecting that market. This process should include people with diverse perspectives on development in the region in order to generate the fullest understanding of the factors affecting the land market.

Differences in individual forecasts can be reconciled either through the anonymous Delphi process using questionnaires or in face-to-face meetings. In some cases there may not be

agreement among the experts on locational patterns. It is important to understand the reasons for this divergence in viewpoints as technical staff and policy makers will need to decide which view they believe is more valid. The number of zones used in this qualitative process will need to be limited in order for the panel to process the information and make decisions. Thus the Delphi or panel may need to be combined with another method to make the final allocation to traffic analysis zones.

Allocation Rules. Allocation rules that are based on empirical evidence about development trends can be used to allocate the growth of dispersed activities like residential development and retailing. They work best in typical areas. These trend extrapolations reflect market forces that are currently shaping the region and assume the same forces will influence development during the planning period. Their use should be tempered with an analysis that considers potential shifts in trends due to changes in market forces or shifts in development to new areas as older areas fill up. For example, the assignments may need to be adjusted upwards in zones in the path of growth that are not yet growing rapidly, but are likely to do so during the forecast period. Activities that are "lumpy," like large industrial employers, work less well with allocation rules, and may need to be assigned with an alternate process, such as panels of experts.

Statistical Methods. Multivariate statistical methods provide a means of understanding the interplay of a number of factors affecting land use decisions and can be used to assign households and jobs to zones. Regression models have been used most often because they utilize aggregate data which can often be obtained from secondary sources. In essence, regression models assume that analysis of recent trends reflects the forces at work in the region's land use market.

Discrete choice models analyze the patterns resulting from individual choices and can directly incorporate costs and prices. These models, however, require extensive data from individual households or firms which can generally only be obtained through surveys.

Because statistical methods include multiple variables, they can represent more of the complexity of supply, demand, and policies than simple allocation procedures. But they also require more data and skill to use effectively. Like allocation procedures they can be questioned for assuming the continuation of current trends in the land market.

Formal Land Use Models. Whether purchased commercially or developed in-house, formal land use models are designed for the assignment phase of the process. Most current models use various measures of accessibility and attractiveness factors of zones to determine which zones are most likely to develop. They do not explicitly consider the market for land and structures. These models require a significant commitment of staff, time, and other resources to acquire and maintain the necessary data; to develop, calibrate, and run the mode; and to interpret the results. The theoretical underpinnings, assumptions, strengths, and limitations of the model must be understood and communicated to users of the forecast.

Interviews, Surveys, and Case Studies. These methods may be used to inform aspects of the forecast that are less well understood or undergoing change. For example, if the MPO or DOT has not previously evaluated redevelopment and infill, they may want to

interview developers doing this type of work to help identify the factors that led them to choose this type of development over development on vacant land.

Decision Rules. In order to keep the process manageable, some of the questions may be answered with decision rules based on recent data in the region. For example, rather than considering how the market sorts out of the density of development, a rule may be developed that sets residential development at an appropriate percentage of planned densities. This method assumes that if builders are now building at 75 percent of planned densities, they will continue to do so in the future because this density reflects what consumers want and what various constraints on development allow.

GIS. GIS can be used to develop accessibility measures, analyze and display the spatial pattern of factors that affect the choices that households, firms, and developers make, and map the allocation of households and firms.

Issues

This step in the forecasting process is the most challenging in that it involves management of a large number of factors and making a series of difficult judgments and conclusions. One of the most problematic issues faced by planners at this stage is the acceptance of outcomes which either are contrary to policy, conventional wisdom or intuition. For example, in dealing with the significant issue of population or employment decline in certain zones and communities within metropolitan areas, planners and policy makers may resort to "plancasting" even in a base case allocation, because of the political or institutional difficulty in acknowledging decline. Or, planners may find that the techniques they have selected to aid them in the assignment process produce results which are counter-intuitive. The challenge under these circumstances is to review the likely reasons for the forecast (that is, the variables or inputs which seem to have produced the results). While models for forecasting techniques are most easily accepted when their results are intuitively appealing, the lack of intuitive appeal may not be a sign of weakness in the forecasting process but rather evidence of a change or a trend which up until that point had gone unnoticed. These infrequent events are among the most important ones in the forecasting process.

The above allocation process assumes that existing buildings, unless they are demolished for redevelopment, will be utilized by the same number of households and workers at the end of the forecast period as they were at the beginning. This does not imply that the same people and firms are there; only that the buildings are in continuous use by the same number of people, on average.

It would be more realistic to assume that some people move within the region, opening up existing housing to new households who may have different characteristics than the original residents. The same is true of firms. This type of analysis could be added at the beginning of the assignment process, using spreadsheets to keep track of the portions of the population and jobs that move out of their initial zone and need to be reassigned in the allocation process. This step only makes sense if the forecast is identifying the locational choices of a number of types of households and firms and a change in type of resident or employer could produce different densities of development. In addition this additional work would only be helpful where parts of a region are expected to change significantly in

character. In these cases, accounting for the changes would be important because the types of households and firms within zones have transportation implications.
In addition, parts of many older regions are undergoing decline with increasing shares of vacant housing and businesses. Statistical analysis of trends can be used to identify areas where population decline is occurring and their rates of decline. Households could be subtracted from these areas based directly on the rates of decline or on modified rates that take into consideration factors that might change these rates such as public policies that make the areas more attractive places to live. If job loss is associated with particular sectors, such as manufacturing, the number of jobs in zones where these industries currently exist can be reduced proportionately.

Because of the high level of policy maker interest in urban and suburban redevelopment, it is essential to collect data on actual trends whenever possible. At a regional level, redevelopment is spatially concentrated in a relatively small number of areas, but because these areas are frequently the focus of public investments, including transportation, designed to further the prospects of redevelopment, it is important to try to get the facts straight.

In those regions and communities where historic land use data is available in a GIS format, it is relatively easy to identify the locations and pace of redevelopment activity, particularly since the data is typically organized at a parcel level. Where GIS data is not available, or not available in a time series format, a review of building permit data may be warranted. Another approach may be the use of interviews with knowledgeable experts. Since almost all cases of this kind of data collection can be laborious, it may be helpful to focus on a small number of places whose characteristics are illustrative of redevelopment potential.

An assessment of the trends in new development is made more difficult by the fact that much redevelopment does not involve a change in use. Many relatively small commercial buildings are replaced by larger or more valuable ones. These changes may go unnoticed in a survey of land use over time.

Example — Metro, Portland, Oregon

This example illustrates some innovative techniques for dealing with redevelopment, infill, constraints on redevelopment, and density levels. It is a forecast made within a land market with strong land use planning. Within this regulatory environment, it is reasonable to assume that land use policies in comprehensive plans will largely determine future types of development and have an effect on development density. It also illustrates the interplay between the technical and policy aspects of the issues.

Metro uses GIS and its regional land information database, which it began assembling in 1987, as a major tool for this process. The regional database is regularly updated using aerial photography, assessor's data, local plans, building permits, wetlands inventories, slopes, soils, and other data. Metro has also developed a regional econometric model to forecast regional population and growth.

Policy Assumptions

The forecast assumes that the Metro 2040 Growth Concept, a regional growth management strategy that was adopted by the Metro Council in December 1994, determines the allowed land uses and sets maximum densities. Cities and counties are currently changing their comprehensive plans to comply with this Growth Concept.

The forecast also assumes that except for redevelopment and infill, there will be no changes in housing and employment densities in already developed areas. In other words, existing buildings continue to be occupied by the same number of households and jobs, although not necessarily the same people or firms. With this assumption, the forecast only needs to allocate the growth in population and employment.

Regional Employment and Household Forecast

Metro developed an econometric model to produce low, medium, and high forecasts of population growth. The basic components of the model are shown in Figure 3. This model and the resulting forecasts were reviewed by a committee of business, government, and academic experts in economic and demographic analysis and forecasts.

Inventory Land with Development Potential

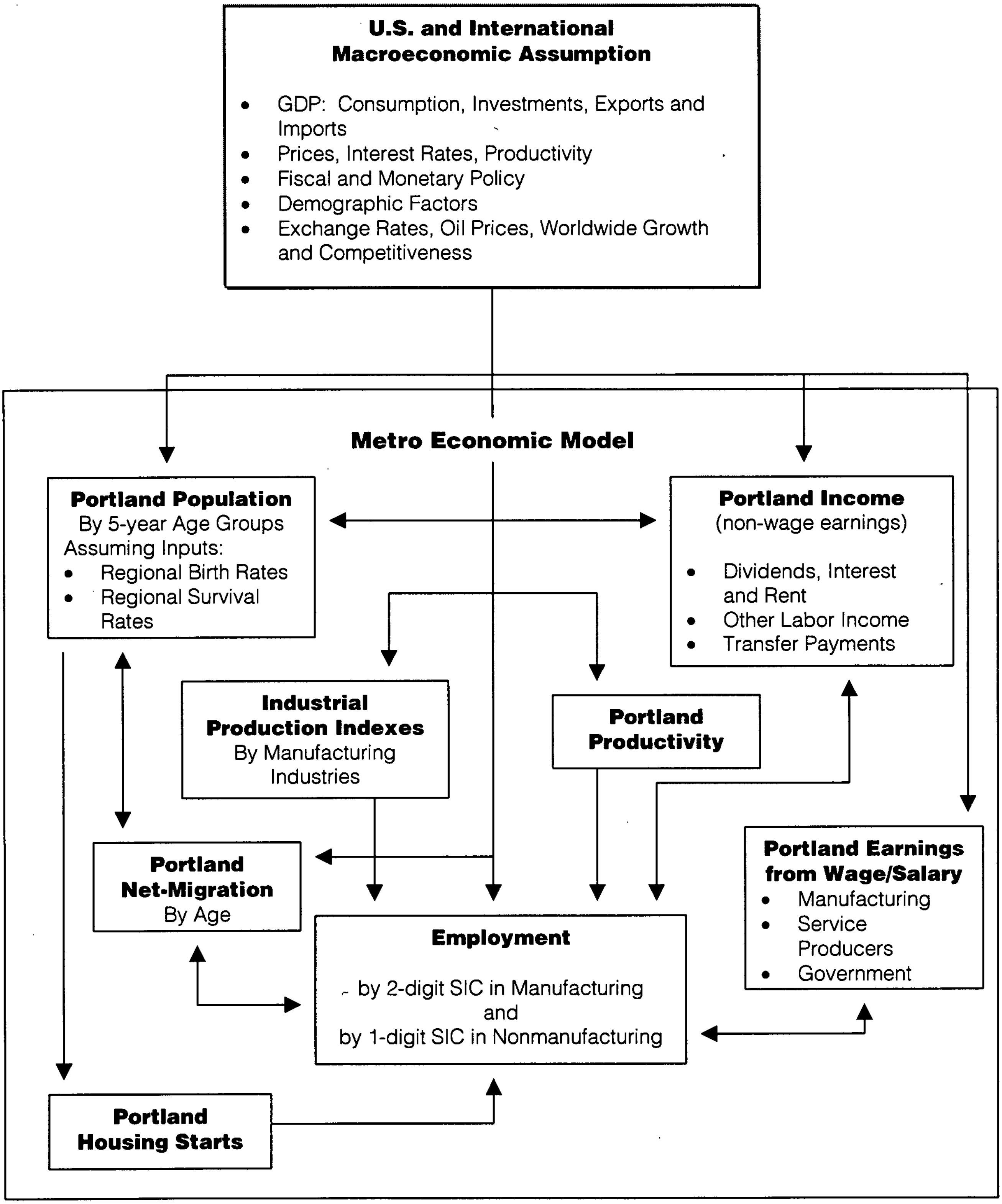
Metro utilized their GIS to inventory lands with development potential and to identify constraints to development. Metro's process combined many of the steps of inventorying development potential and setting some of the parameters of the allocation process, such as the estimated density of development, into a capacity analysis. This differs from the process described above in that some of the decisions that are described as being part of the allocation process were included in this step by Metro.

Vacant Land. Vacant lands were identified by using the GIS data base to identify all land that was not developed or used for streets, parks, or other public facilities.

Environmental Constraints. Some environmentally constrained land was eliminated from the vacant land base. This included land with slopes of over 25 percent, in the 100-year floodplain (except in areas that are already developed or committed to development), flood prone soils identified by the Natural Resource Conservation Service (with some exceptions like those for floodplains), wetlands identified by the National Wetlands Inventory and local inventories, and riparian corridors of 50 to 200 feet in width.

Public Facilities. The supply of developable land was reduced to provide land for streets, schools, parks, and other public facilities. A survey of recent subdivisions was used to determine that about 22 percent of the land in subdivisions of more than one acre and 10 percent of the land in smaller subdivisions is typically consumed by streets. The amount of land for schools and parks was estimated based on population growth estimates and current supply of land owned for these purposes. The supply of vacant, developable land was reduced by these proportions.

Figure 3. Metro Regional Economic Model



Redevelopment and Infill. The amount of land available for development also included redevelopment and infill possibilities.

Two methods were used to estimate redevelopment potential depending upon the size of the lot. Lots of an acre or less were only evaluated if they were designated as mixed use or industrial. The parcel was considered redevelopable if the value of the improvements was below 50 to 70 percent of the average value of improvements on surrounding sites (with the exact figure depending upon land use designation). For larger parcels in all land use categories, the parcel was considered redevelopable if the building was worth less than the land.

Residential infill potential was measured by identifying residential lots that were three to ten times the minimum lot size set in zoning and that had no environmental capacity constraints. The number of potential new lots was estimated assuming that no more than three lots would be created by partitioning and that high value lots ($300,000 or more) would not be subdivided. It was also assumed that the rate of infill would be about 13 percent, matching the rate of residential infill for a recent 12 month period. Employment infill was estimated at about 10 percent, less than the one-third of all employment that it was estimated was occurring in current or expanded structures, since redevelopment would accommodate a significant share of this job growth.

Density of Residential Development. Metro had conducted studies showing that actual residential development densities were lower than planned densities. Assuming this would continue, they evaluated factors that contributed to this underbuild. These included small parcel size, landlocked parcels, partially developed parcels, areas with slopes of less than 25 percent (steeper sloped lands were eliminated in the environmental constraint section), market conditions, and neighborhood opposition to dense developments. Because of these factors, the density for residential development was assumed to be 27 percent less than specified in the Metro Growth Concept.

Density of Employment. Comprehensive plans specify uses but not densities for employment. Density levels were set at approximately the current rate of space utilization. During the process, Metro revised the density of industrial upwards because local planners reported that considerable high tech industrial development was occurring at much higher employee densities.

Assign Population and Housing to Zones

When Metro arrived at this stage they had already made most of the decisions about what type and how much development could occur in each zone. All that remained was to decide how much of this capacity would be utilized by households and firms. This was done in three steps using allocation rules and review by a panel of local planners. Jobs and housing were first assigned to six market areas based on analysis of growth trends for single family housing, multi-family housing, and all non-farm employment. Planners adjusted these numbers and then jobs and housing were allocated to twenty districts based on a similar trend analysis. Again these were adjusted. Finally, jobs and housing were dispersed to individual grids (16 acre areas) using a GIS program. The grid assignments

were then aggregated to traffic analysis zones, and the zonal forecasts were evaluated and adjusted by the panel of local planners.

Strengths and Limitations

The strengths of this forecast are in its efforts to understand actual versus planned densities, redevelopment, infill, and the constraints posed by environmental conditions and other physical barriers. However, the forecast does not deal explicitly with prices. Instead, this process assumes that the interactions between the market and policies are implicitly revealed through recent development patterns. These patterns are used to establish criteria for determining how much land is available for development. This assumes that recent market conditions will hold for the planning period.

The allocation process also assumes that developments will be the types expected in the plans, although densities were set to be lower than plans envision. There was no consideration of how the market for development might support different outcomes than what the plan proposes.

Interplay of Technical and Policy Aspects of Forecasting

The Metro forecasting process also illustrates an interplay of technical and policy aspects of forecasting. The recently adopted Metro 2040 Growth Concept was assumed as the policy framework for the forecast. The need for additional policy assumptions arose during the process. These were discussed with technical advisory committees during the process but ultimately assumptions were decided by elected officials. The MPO staff prepared a discussion draft of these estimates using assumptions based on their research into current conditions and trends. A document describing the process, the estimates it produced, and the assumptions made then went to the Metro Council (Metro, 1996). The Council made final decisions on the following issues:

- The regional population and employment forecast numbers
- Identification of unbuildable land
- Estimates of the amount of land needed for streets, parks, schools, and other public facilities
- Determination of the residential density that would be built
- Assessments of the feasibility of local governments enacting new zoning and the market responding to it
- Determination of the effects of physical barriers to development
- Estimations of the amount of infill and redevelopment
- Evaluation of the impact of farm use tax assessments on development capacity.

Following council decisions, the MPO staff revised the forecast using the assumptions set by the Council (Metro, 1997).

4.4 DETERMINING LAND USE IMPACTS OF A TRANSPORTATION PROJECT

An impact assessment for a transportation project estimates the size and nature of any land use changes caused by the project within a defined study area. These changes in land use could occur for several reasons.

- The growth that would have occurred anyway could be arranged in a different pattern, with changes in the types, densities, or locations of new development. New commercial activities might choose sites that the project makes more accessible rather than other sites in the study area. For example, additional highway capacity could cause a shift of some residential development from urban to rural areas because of the improved access to jobs and other destinations from the rural area.

- The transportation project could cause some households or business to locate in the study area instead of in other places in the region or other regions. If access is improved to land on the urban fringe that is otherwise ready for development, developers may capitalize on the improved access and build homes in these areas instead of elsewhere in the region. The expansion of an airport might attract businesses dependent upon air service to locate in the study area instead of near another airport.

- The transportation project could stimulate changes in existing land uses and intensities in already developed areas. For example, residential properties near a new interchange might be redeveloped into commercial buildings, because the changes in accessibility will make the land more attractive to commercial users who will offer higher prices for the land.

None of these changes will automatically follow from changes in accessibility. There must also be demand for new development, locations within the study area must be attractive to development, and land use regulations must allow the development. All of these factors must be systematically evaluated in an impact assessment.

It is appropriate here to review information presented in previous chapters that relates to the role of accessibility and its influence on locational decisions. As previously stated, accessibility is a complex notion. Further, it is only one of many factors that influence the locations of households and firms.

Households, for example, have many accessibility needs. Access to employment is most conventionally recognized, but in today's world of multi-worker households, in which employment changes occur more frequently than was the case a generation ago, accessibility to employment location has taken on a more generalized form and plays a corresponding diminished role in household decisions about where to live. Accessibility to activities such as shopping, recreation and social life also are important and have different meanings to individuals of different ages and incomes.

In addition to all these ways in which accessibility still matters to households, other factors also clearly influence their locational choice. The most important are the price of housing and where housing is available within household budgets, given their base needs and preferences. If price constraints do not significantly narrow a households choice set, other

factors such as preferences or prejudices regarding race, ethnicity, life style, and amenities also contribute to the locational decisions.

In a similar way, accessibility takes on different meanings to different types of businesses. Businesses vary in the extent to which they value accessibility to customers, suppliers, labor markets and competitors. Nevertheless, as for households, accessibility is only one of many factors influencing business costs and business location decision making. Furthermore, the transportation costs play a smaller role today in the overall costs of doing business than they did a generation ago. One evidence of this is the declining proportion of national and metropolitan economic activity accounted for by the wholesale and distribution sectors of the economy. In less than a generation, wholesale and distribution activity's proportion of all economic activity has shrunk by a factor of 50 percent. This is not merely the result of businesses internalizing their transportation costs; if anything, the trend has been in the other direction.

Thus, both for households and businesses, transportation accessibility has become both more complex and more generalized a notion; thus, it is more difficult to define and apply in the context of location choice models. This trend is likely to continue.

Some Differences from the Base Case Forecasting Process

An impact assessment uses a process similar to that used in a base case forecast. The process includes understanding existing conditions, establishing policy assumptions, estimating study area population and job growth, and assigning that growth to locations and types of development with the study area. But there are some critical differences because an impact assessment considers whether a transportation project will result in changes in the location of households and firms.

As discussed in Chapter 1, land use changes are the result of changes in travel behavior generated by the project. Thus, one difference between impact assessments and base case forecasts is the additional step of evaluating how the transportation project changes accessibility and travel behavior. Another difference is that an impact assessment measures differences in land use patterns between a future with the transportation project and one without it. This comparison distinguishes between land use changes that would have occurred anyway and those related to the transportation project. Two forecasts of future land uses--one with and one without the project--are needed to make this comparison.

Basic Steps in Impact Assessments

With these differences in mind, the steps in an impact assessment process are:

1. Understand existing conditions and trends.
2. Establish policy assumptions.
3. Measure the transportation outcomes with and without the project.
4. Estimate total study area population and employment growth with and without project.
5. Inventory land with development potential.

6. Estimate how the project will change the location and types of residential and business development within the study area.

Geographic Scale of Projects

We have assumed that base case forecasts are done at the metropolitan, state, or possibly substate level. Transportation projects can come in a variety of sizes that have implications for the level of detail in the analysis and the applicable tools. This guidebook considers three geographic scales of impact assessments--local, metropolitan, and inter-metropolitan.

Local. These are smaller projects that have land use impacts discernible at the community or county level. They can occur in metropolitan and non-metropolitan areas. These could include a new highway interchange, a bypass highway that moves through traffic off the main street of a community, or a transit center. Local impact assessments require a fine grained analysis of existing conditions and potential impacts that may consider potential land use changes on specific parcels of land.

Metropolitan. These are larger projects with the potential to change the location of activities within a metropolitan area. Major new highways, major transit investments such as high capacity transit systems, and airport expansions require metropolitan level analysis. These studies are usually carried out at the same level of detail as an MPO base case forecast. In addition, the detailed analysis of a local study may be required in the immediate vicinity of the project because of concerns about localized impacts.

Inter-metropolitan. These projects improve links between metropolitan areas or between metropolitan areas and non-metropolitan areas. Land use impacts may occur in both urban and rural places. Examples include high speed rail or highway improvements. The building or expansion of intermodal freight facilities may also have inter-metropolitan impacts.

With these different geographic scales in mind, we turn to a discussion of the details of the steps. This discussion focuses on how impact assessments differ from base case forecasts, including differences because of the scales of analysis. Most of the following discussion focuses on the local level since it requires different tools than a regional base case forecast. Where a metropolitan or inter-metropolitan level of forecast has a different emphasis or requires different tools than used in a base case forecast, this is also noted.

Step 1: Understand Existing Conditions and Trends

The analysis of existing conditions for a local impact assessment evaluates how the land market in the study area compares with that of the larger region. The assembly and analysis of data on existing population, employment, housing, and public policies provides basic information on the current demand for development within the study area and the relative attractiveness of the area to development. In addition, information must be collected on existing travel conditions and accessibility levels of the study area.

The process is like that of a base case forecast. Information is collected, analyzed, and assembled into a report on existing conditions and recent trends. Data is needed on

current land uses, plans, and policies and on recent trends in population, housing, and employment.

Product

The product of this step is a report on existing conditions and trends for the study area. The report will compare these conditions and trends with those of a larger region or state to provide a context for the impact assessment.

Additional Basic Questions for an Impact Assessment

What are the existing travel conditions in the study area? What have been the trends in these conditions?

- What are the existing transportation facilities in the area?
- What is the travel behavior of residents and firms?
- What are the levels of congestion?
- What are the levels of accessibility to, from, and within the study area?
- What transportation improvements, other than the specific project, are planned for the area?

Is the study area growing faster or more slowly than the region (or state) as a whole?

- What factors are limiting development in the study area? Is the level of accessibility currently constraining development?
- What factors are supporting development in the study area?
- Are there unique local conditions, including individual firms, developers, or land owners, that could have a substantial impact on future development?

Appropriate Analytical Tools

A finer grained analysis of existing conditions is needed for local impact assessments than is required for regional base case forecasts. This could include information on specific parcels of land. This analysis needs to look for particular conditions that are supporting or constraining development within the study area and for development opportunities within the study area that may have been overlooked because of poor accessibility. As in a base case forecast, these questions are answered by assembling secondary data and interviewing people knowledgeable about the area. More emphasis may be placed on interviews in a local impact assessment than in a regional base case forecast because of the need to understand the localized conditions.

Table 17 summarizes the recommended analytical tools. GIS can be helpful for analyzing and displaying the variety of geographic information, although manual methods of tabulating data and mapping may suffice for projects with small study areas.

Table 17
Recommended Tools for Understanding Existing Conditions for an Impact Assessment

Tools	Primary Tools	Secondary Tools
Qualitative Methods		
Delphi/Panel		
Interviews/Survey/Case Studies	◆	
Allocation Rules		
Decision Rules		
GIS	◆	
Statistical Methods		◆
Regional Economic and Demographic Models		
Formal Land Use Models		

Step 2: Establish the Policy Assumptions

Policy assumptions establish a framework for the impact assessment. Decisions must be made about the policies that are assumed to affect land uses. These include zoning, sewer and water extensions, and transportation projects. As in base case forecasts, impact assessments generally assume that development will continue as it has in the past, except for the introduction of the new transportation project being studied. The assumptions must list specific transportation projects that are assumed to be built within the study period. One option is to adopt the same policy assumptions used in the base case forecast for the regional or state-wide transportation plan. This facilitates use of data and results from the earlier study.

Sometimes, impact assessments explicitly include different policies than a base case. For example, the assumptions may include a change in zoning near transit stations or interchanges. If this is done, it is important to distinguish the role of the project with and without the added policies.

Product

The product for this step is a list of the policy assumption being used in the analysis.

Step 3: Measure the Transportation Outcomes With and Without the Project

Transportation projects change travel behavior and this in turn produces changes in land use. Thus, an important step in an impact assessment is an understanding of how travel behavior would change because of the project. The project might affect the movement of people (e.g. a transit project), goods (an intermodal freight facility), or both (highway projects). This has implications for the size of the impact area and the types of movement to analyze. Transit projects, for example, tend to have localized impacts while highway

projects tend to have more diffuse impacts because of the number and nature of travelers who use the facilities.

Travel models predict how many trips are made, where (and in some models, what time) the trips occur, the modes of travel used, and specific routes used. The models can estimate the number of trips and their location, length, and mode with and without the project. Travel models can also identify overall congestion and specific points of congestion. The models can also produce estimates of zonal impedance which can be used to measure accessibility to employment and population from the study area.

Product

The step produces forecasts about where and to what degree travel behaviors and accessibility will change because of the project.

Basic Questions

How will study area travel behavior change without the project? What differences will the project make in travel behavior?
- How will the number of trips in the study area change?
- Will the modes of travel change?
- How much will travel speeds and times change?
- How much and more will the distribution of trips by time of day change?
- How much and where will be congestion levels be changed?
- Will the movement of freight change?

How will accessibility to, from, and within the study area change with and without the project?
- How much and where will access to jobs change?
- How much and where will firms access to workers change?
- How much will access to other major destinations change?

How will the cost of travel change for study area residents or businesses with and without the project?
- Where, how much, and for which people will the cost of travel change?
- Where, how much, and for which firms will the cost of freight movement change?

Appropriate Analytical Tools

The key tools are travel demand models and freight models. These models consider a series of decisions that the traveler or shipper must make. The following discussion briefly describes the steps in a typical travel demand model.

The first step determines how many trips will be generated by the land uses in each zone. Trips are typically divided into categories such as home-based work, home-based shopping, home-based other, non-home-based trips, and truck trips. Trip generation rates can vary household characteristics, such as the number of people in the household and the number of automobiles owned.

The second step links trips producers, such as households, to destinations, such as stores. These estimates are based on the number of origins and destinations in a zone and some measure of the cost or distance of travel between the zones.

The third step determines the modes of travel used. Mode choices are based on travelers personal characteristics, the costs of travel, and time involved in travel.

The fourth step assigns trips to paths in the transportation network. Trips are first assigned to the shortest link, but if this route becomes congested because of the number of trips assigned to it, some may be reassigned to less congested routes.

A variety of commercial and agency developed models are available to estimate travel demand. These models have been criticized for their focus on motor vehicle trips, inability to analyze the linking of trips into multiple purpose chains, insensitivity to many socio-economic characteristics, insensitivity to factors affecting pedestrian and bicycle trips, lack of feedback between choices, and absence of time-of-day analysis (Beimborn et al., 1996; Harvey and Deakin, 1993). There are a number of efforts underway to improve travel demand models. To learn more about the models and their strengths and limitations, consult one of the following:

Travel Demand Model Development and Application Guidelines, prepared for the Oregon Department of Transportation by Parsons Brinckerhoff, June 30, 1995.

A Manual Of Regional Transportation Modeling Practice for Air Quality Analysis, prepared for the National Association of Regional Councils, by Deakin, Harvey, and Skabardonis, July, 1993.

Issues

One of the inputs into a travel demand model is a land use forecast. Thus, the outputs from the models are based on constant assumptions about land uses. The analysis assumes the same pattern of land uses is generating trips even as it handles different transportation networks. The lack of integration between transportation and land use modeling processes means that the cumulative impacts of land use changes resulting from transportation system changes are not considered.

Step 4: Estimate Total Study Area Population and Employment Growth With and Without the Project

Estimates of the amount of population and employment growth expected in the study area put some boundaries on the size and nature of the land use impacts. If the study area is in a growing region or a growing part of a region, a transportation project has the potential to cause significant changes in land uses. In contrast, if the study area is expected to have a low growth rate, even with the project, there is much less potential for land use change.

Another objective of this step is to determine whether the transportation project causes any shift in population or jobs to the study area from other parts of the region or state. The analysis of shifts in population and jobs is most important for projects at the local and

intermetropolitan scales. At the local level, a transportation project may induce households or jobs to move from other parts of the region to the study area. For example, a highway project that improves accessibility to vacant land on the urban fringe could make that area more attractive to residential developers and cause a shift in development from another part of the region. At the metropolitan and intermetropolitan levels, the analysis can consider both whether the entire study area might grow faster as a result of the project, and whether growth is shuffled around among counties within the study area. For instance, improvements in an intermetropolitan highway corridor may induce growth only at the points along the corridor that are most attractive to development, causing some counties to grow more rapidly than they would without the improvements.

Product

This step will produce an estimate of the number of people and jobs expected in the study area at the end of the planning period with and without the transportation project. This will indicate the magnitude of growth expected and also whether the study area (and perhaps individual counties) will have more or less population and job growth because of the transportation project.

Additional Basic Questions for an Impact Assessment

In addition to needing to know how much population and employment growth is expected in the study area, an impact assessment must consider the following question:

Will the transportation project induce any increases (or decreases) in population or jobs in the study area over what would occur anyway?

Appropriate Analytical Tools

The appropriate tools for this analysis vary with the scale of the study area and whether there are existing employment and population forecasts that can be utilized.

There may be requirements that official state forecasts be used. It is important to check the policy assumptions of any forecasts to determine if they are the same as those of the project and also to determine whether the forecast includes the transportation project being studied. If the forecasts are based on different assumptions, then adjustments will be needed to reflect the policy assumptions of the analysis.

The following methods can be used to estimate the control totals with and without the project.

Qualitative Methods. A Delphi or panel can be used for estimating total population and job growth for any size of geographic area. This is a useful technique for evaluating the suitability of an existing forecast and considering how the project (or its deletion, if it is assumed in the forecast) would affect these forecasts. A variation on this approach is for the analyst to interview experts and use this information to help produce the forecast. In addition, case studies of other places with similar projects can be used to estimate the amount of population and job growth, provided similarities and differences between the study area and the case study locations are carefully assessed.

Qualitative methods may be the only method available for local impact assessments. As in a base case forecast, they can also be used as a secondary tool providing insights on newly emerging businesses or population groups, especially if the changes in accessibility could influence their location. Quantitative methods tend to miss these changes because they rely on historical data which does not capture the behavior of new groups.

Statistical Methods. Regression analysis of recent growth trends is useful for predicting underlying patterns of growth, especially for larger areas. This tool can predict how growth would occur if transportation investments follow past patterns. However, if the transportation project being evaluated deviates from past investment, trend analysis will not pick up the ways the accessibility improvements of the project could change the forecasts. In these cases, the analysis of total expected growth with the project will need to be done by another method, such as one of the qualitative approaches.

Regional Economic and Demographic Models. Regional economic and demographic models that consider the impacts of transportation on the economy are well suited for estimating population and employment growth with and without a transportation project for metropolitan and intermetropolitan impact assessments. Since they typically use counties as the unit of analysis, they are not as useful for predicting study area total growth for local impact assessments when the study area is smaller than a county. For these smaller studies, the county estimates would need to be further broken down into study area and non-study area estimates of growth using another method, such as one of the qualitative approaches.

Formal Land Use Models. Formal land use models can be used to predict total population and employment growth for study areas that are smaller than the area covered by the model. A metropolitan land use model could produce estimate of growth with and without the project for a local impact assessment within the metropolitan area. Likewise a statewide model could estimate total growth for an intermetropolitan corridor. The accuracy of these forecasts improves when the study area encompasses a number of zones within the model, as there is more uncertainty in the estimates for a single zone than in a collection of zones.

These recommendations are summarized in Table 18.

Table 18
Recommended Tools for the Estimating Total Study Area Population and Employment Growth for an Impact Assessment

Tools	Primary Tools	Secondary Tools
Qualitative Methods		
Delphi/Panel	◆	◆
Interviews/Survey/Case Studies	◆	◆
Allocation Rules		
Decision Rules		
GIS		
Statistical Methods		◆
Regional Economic and Demographic Models	◆	
Formal Land Use Models	◆	

Step 5: Inventory Land With Development Potential

The inventory of land with development potential is similar to that for a base case forecast. The process identifies vacant land or land that could redevelop or infill, subject to the assumed policy constraints and the need for lands for public facilities.

Product

The product of this step is an inventory of the land available for development in the study area, including an assessment of regulatory constraints on the types and densities of uses.

Analytical Tools

As in other steps, a more detailed analysis may be needed for local impact assessments. In particular, more emphasis may be needed on the potential for redevelopment and infill in already developed areas near the project, because highly accessible places can develop higher value, higher intensity uses.

The effects of policy constraints must also be carefully considered, because they may prevent changes in land uses from taking place despite improvements in accessibility. If one of the policy assumptions is that current zoning will remain in effect, then the impact assessment should evaluate whether there would be pressure to change that zoning because of the changes in accessibility. The process should also consider any reduction in the amount of developable land because of land required for the project.

The appropriate tools for carrying out this analysis are the same as in a base case forecast, as shown in Table 19. GIS is the primary tool for analyzing and displaying the data, although manual methods may suffice for some local impact assessments. Interviews and decision rules can provide information or rules for identifying developable land, when the criteria for doing so is not obvious, such as which lands are ready for redevelopment. More

emphasis may be placed on interviews in a local impact assessment because of the heightened need to understand the local actors in the land market.

Table 19
Recommended Tools for the Inventory of Developable Land for an Impact Assessment

Tools	Primary Tools	Secondary Tools
Qualitative Methods		
Delphi/Panel		
Interviews/Survey/Case Studies		◆
Allocation Rules		
Decision Rules		◆
GIS	◆	
Statistical Methods		
Regional Economic and Demographic Models		
Formal Land Use Models		

Step 6: Estimate How the Project Will Change the Location and Types of Population and Employment Growth in the Study Area

This final step in the process estimates where and what type of development will occur with and without the transportation project. The objective is to understand how land use patterns would be different with the project. This step assigns the estimated change in jobs and households to specific areas with developable land. The expected growth may be rearranged because of the project, additional growth may be attracted and must be located, and existing uses may change.

This analysis takes into consideration both present and future travel conditions in the study area. It may be that accessibility is not an impediment to growth in the study area at the present time, but increased travel demand could lead to levels of congestion during the study period that discourage households or firms from locating in the area. Thus, some time during the study period, the level of accessibility without the project could limit growth.

Product

The product of this step is forecast of the types, quantities, and location of new development in the study area with and without the project. This report shows how the project would change development from what would have occurred anyway during the study period.

Basic Questions

In addition to the questions of a base case forecast, an impact assessment must consider how households, firms, or developers will react to the changes in accessibility or transportation costs that the project produces.

- Which locations, if any, will become more (or less) attractive to households?
- Which locations, if any, will become more (or less) attractive to firms?
- Where will the profitability of development change?

Appropriate Analytical Tools

The tools for carrying out this analysis are similar to those in a base case forecast, where they are discussed in more detail. The primary tools are Delphis or panels, allocation rules, and statistical methods. A panel of experts can analyze the information on developable land, growth trends, and changes in accessibility and make forecasts of whether the growth patterns will change because of the project. Allocation rules that consider levels of accessibility, such as simple gravity models, can assign people and jobs to specific zones. Statistical methods that combine information on the factors affecting people's and firm's choices, including changes in accessibility, can project where people and firms will locate within the region.

The primary assignment process can be supported by information gathered in interviews, from case studies of places with similar projects, with decision rules developed from local or national data, and by spatial analysis using GIS, as summarized in Table 20.

Table 20
Recommended Tools for Assigning Households and Firms in an Impact Assessment

Tools	Primary Tools	Secondary Tools
Qualitative Methods		
Delphi/Panel	◆	
Interviews/Survey/Case Studies		◆
Allocation Rules	◆	
Decision Rules		◆
GIS		◆
Statistical Methods	◆	
Regional Economic and Demographic Models		
Formal Land Use Models		

Examples

The Boston Central Artery Project

The Boston Central Artery Project includes two components. The first component is a new eight to 10-lane Central Artery being built mostly underground to replace the existing route between I-90, the Massachusetts Turnpike, and Charlestown. After the underground artery is built, the existing elevated route will be removed freeing 22 acres of land for new development and recreational use. The second component is an extension of the I-90

Turnpike to Logan Airport via a Seaport Access Road passing through commercial land in South Boston and a four-lane tunnel across the Boston Harbor.

Understand Existing Conditions and Trends
The study area was divided into subareas and recent trends in population and job growth and the types of employment were determined using secondary data. An inventory was made of existing businesses, development projects being proposed, and potential development sites.

The study team interviewed developers, brokers, property owners, merchants, shippers, and business owners to understand their needs and the role of transportation in their decision-making. The team analyzed Dun and Bradstreet time series data on business growth and turnover as well as previous studies of the office, retail, tourism, and convention activity. They considered case studies of other downtown construction projects.

The study then evaluated the differences in downtown and suburban markets for office, retail, industry, tourism, and residential development and concluded that the market was highly segmented. For example, the downtown office sector was highly specialized in finance, banking, and law while suburban offices were used by computer firms, defense contractors, and others.

Establish Policy Assumptions
The study assumed the same land use regulations and city policies to support housing with and without the central artery project.

Measure the Transportation Outcomes With and Without the Project
The regional transportation model was used to estimate transportation impacts. It found that there would be considerably more congestion and time delays on routes to Logan Airport and the downtown if the project were not built. These congestion levels would discourage business development because of the higher costs of travel for deliveries, workers, and visitors.

Estimate Study Area Population and Employment Growth With and Without the Project
A metropolitan area REMI model was used to estimate population and job growth for the metropolitan area. Because the project would improve access to Logan Airport and the specialized services of the downtown, impacts would be felt throughout the metropolitan area. If the project were not built the study area would lose about 20,000 jobs and the metropolitan area would lose slightly less, about 18,000, because of some shift in jobs to the suburbs. However, most of the jobs would go to other less congested financial centers in the nation, rather than locating in the Boston metropolitan area, because downtown and suburban office spaces do not serve the same markets.

Inventory Land with Development Potential
The project included an inventory of all known development projects plus other sites where development could occur. The size and nature of the projects that could develop on these sites, as well as the probability that development would occur within the study period, were estimated and reviewed by experts in the development community.

Estimate the Changes in Population and Employment Locations
The REMI model predicted that most of the employment growth in the region would be in the finance, insurance, real estate, and service sectors. Since this is the type of employment in which the downtown specializes, there would be less economic growth in the region without the project. There would also be less growth in industries that require access to Logan Airport and in tourism because of the severe levels of congestion.

The Avenue of the Saints

The Avenue of the Saints impact assessments illustrate the steps in an inter-metropolitan impact analysis. The study examined the need and feasibility for a four lane interstate highway connecting St. Paul, Minnesota and St. Louis, Missouri. The study was undertaken because the lack of a north-south interstate in this area was assumed to be a factor affecting the attractiveness of the region for economic growth. The study focused on job growth and estimated impacts at the county level for four potential routes. Given this emphasis and the fact that the corridor traveled through five states, the analysis did not include the steps of understanding land use regulations, inventorying land with development potential, or assigning growth to specific locations. Rather it focused on the first steps in the process of understanding existing conditions and estimating how much the four proposed routes would change job growth in the study area (Wilbur Smith Associates, 1990).

Understand Existing Conditions
The study examined existing travel conditions within the corridors, surveyed travelers to better understand their trip length and purposes, measured demographic and economic conditions using census data and data from state agencies, and determined the dominant industries in each of the cities along the route. This analysis indicated that the region's employment was concentrated in manufacturing and employment in this sector was generally declining.

Measure Transportation Outcomes
A travel demand model was created for the corridor areas. A trip table was calibrated using data for 1986. Then a new trip table was created for 2010 based on changes due to population growth and trend-based projections of increases in vehicle miles of travel. These trips were assigned to the 2010 network, which included current routes and the particular alternative being studied. The new trip assignment was then used to estimate changes in travel, such as reductions in vehicle miles of travel and vehicle hours of travel compared to a no-build situation.

Estimate Employment Growth
A five-state IMPLAN model was used to estimate job growth. The analysis used the improvements in travel time predicted by the travel demand model and the IMPLAN estimates of the role of trucking in the corridor economies to estimate the level of final demand and job growth for the counties adjacent to each of the alternative routes. In addition, the study estimated growth in tourism and roadside businesses. Because the routes would increase daily vehicle miles of travel by 15 to 58 percent over what would occur anyway, it was estimated that there would be similar increases in gasoline stations, motels, restaurants, and other services that serve travelers. Direct impacts were estimated and run through the IMPLAN model to determine how these expenditures would affect the

economy in the counties immediately adjacent to the routes. The study concluded that building any of the routes would support economic growth in the study area, but this growth would largely be at the expense of development in other parts of the affected states.

4.5 DETERMINING LAND USE IMPACTS OF MULTIPLE TRANSPORTATION PROJECTS

ISTEA mandates that MPOs and DOTs consider the effects of their regional or state transportation plans on land uses. Regional and state transportation plans involve multiple transportation projects, rather than a single project as in the previous discussion. The goal is to determine how the bundle of transportation projects would change the location of households or firms over what would occur without the projects. This type of land use analysis follows the same steps as the impact assessment for a single transportation project, namely:

1. Understand existing conditions and trends in transportation and land use.
2. Establish policy assumptions.
3. Measure the transportation outcomes with and without the planned projects.
4. Estimate total study area population and employment growth.
5. Inventory land with development potential.
6. Estimate how the bundle of projects will change the location and types of residential and business development within the study area.

The scale of the analysis for plans with multiple projects is typically metropolitan, regional, or statewide. Because of these large geographic scales, the focus would be on how development might be redistributed in the region, rather than on whether the region might attract or generate more growth.

Multiple projects could have competitive or synergistic effects on land use. Various parts of a region could have improved accessibility because of the planned transportation projects, creating competition among areas for new development. For example, expanding the capacity of more than one suburban highway could make multiple areas more attractive to development. If the supply of land that could be developed exceeds demand, the land use analysis must sort out which areas might develop sooner or more fully than others. This could depend upon the timing of the projects as well as the non-transportation factors affecting the location of development. Alternatively, multiple transportation projects could collectively support the same patterns of land use. For example, a mix of transit improvements and selected highway projects that relieve congestion in key points, but do not support decentralization, might support more development near transit lines.

With these exceptions the process follows the steps and utilizes the tools of an impact assessment at a similar geographic scale.

4.6 DETERMINING LAND USE IMPACTS OF TRANSPORTATION POLICIES

Increasingly MPOs and DOTs are being asked to consider the land use impacts of changes in transportation policies such as parking pricing, congestion pricing, and the implementation of different technologies such as automated highway systems. This process utilizes the same steps as an impact assessment of a transportation project, with the major difference being that the transportation outcomes can be more difficult to predict. The basic steps are:

1. Understand existing conditions and trends in transportation and land use.
2. Establish policy assumptions.
3. Measure the transportation outcomes with and without the policy change.
4. Estimate total study area population and employment growth.
5. Inventory land with development potential.
6. Estimate how the policy will change the location and types of residential and business development within the study area.

The difficulty with determining the land use impacts of transportation policies is that there may be limited experience to draw on. Without a clear sense of the ways that travel behavior and accessibility will change, it is difficult to determine the land use impacts. For example, Deakin (1994) reports that travelers could react in the following ways to congestion pricing:

- Make no changes in their travel behavior by paying the charges and continuing to make the same trips.
- Make more trips because the congestion relief makes it easier to travel.
- Make no changes in travel behavior, but cut their automobile costs in other ways, such as buying a more efficient car or keeping their old cars longer.
- Change their times, routes, or modes of trip making to avoid paying higher charges.
- Reduce the number of trips they make.
- Change where they shop, work, or live.

Travelers are likely to select from a similar menu of choices for other policies that change the price of travel. Given this wide variety of options, it is difficult to say which choices will predominate, if any. Harvey (1994) noted that it is clear that people do change their travel behavior in response to price changes, but the magnitude of effects on vehicle occupancy, trip timing, trip chaining, and changes in job or residential location are only partly understood. Furthermore, the types of effects are likely to differ with the context, such as the number and types of facilities that are priced and the alternatives that are available. Harvey concludes that there is a need for more empirical research to estimate the sensitivity of people to pricing and for improvements in travel demand models to more fully incorporate the potential effects of changes in the price of travel.

Changes in transportation pricing also raise concerns about household and firms leaving areas where prices become higher. If a parking or congestion charge affects only certain areas, it could make them less attractive to live, work, or visit. Deakin (1994) found that business people in the San Francisco Bay area thought that businesses at marginal

locations might move out of the central area or go out of business if transportation costs rose. The business people also thought the firms with large numbers of low to moderate-income employees would especially feel the effects and would need to boost salaries or benefits in order to remain in central locations. On the other hand, businesses with mainly high-income employees would benefit from pricing, and priced areas might become more attractive to them. Thus, a policy analysis must consider whether some types of households and firms will move because of the policy and the ways that this will change locational patterns.

Otherwise, the process and the tools for this analysis are the same as for a impact assessment at a similar geographic scale. Given the speculative nature of much of the analysis, there is likely more use of expert opinion for this type of analysis, as the following example illustrates.

Example — Automated Highway Systems

The following example illustrates how a group of experts have estimated the effects of Automated Highway Systems (AHS) on land use. The National Automated Highway System Consortium (1997) commissioned a series of papers by experts on transportation and land use interactions to estimate the potential effects of AHS on land uses. The experts met and delivered their papers before an invited audience. They had the opportunity to debate and/or modify their conclusions. The papers and resulting discussion were published. This process exemplified the use of a modified Delphi process, a technique well suited to an issue of this kind. No AHS applications exist, so the land use impacts must be estimating by drawing on evidence about similar technological changes, both historic and recent, and understandings of how transportation changes affect land use patterns.

This impact assessment is based on general concepts of AHS and does not consider any specific context. Evaluations of applications in any particular place would need much more detailed information about the specific AHS application and the context in which it would be used. Nonetheless, this example illustrates how the expert thinking follows the steps outlined above, except that no estimates are made of population and employment growth or supply of developable land because of the general nature of the analysis.

Understand Existing Conditions and Trends

Given the generic nature of the analysis, the analysis of existing conditions focused on how investments in highway and high capacity transit have recently affected land use patterns. Papers by Davis and Seskin, Downs, Giuliano, and Rutherford as referenced above considered the role of transportation in influencing land uses relative to other factors such as economic growth, demographic change, and land use regulations.

Establish the Policy Framework

The authors noted that several families of AHS implementation are being considered and the land use impacts would vary considerably with the type of implementation. Several of the experts considered the impacts of land use regulations. Downs, in particular, cautioned

that residents and firms at the destinations served by AHS are likely to successfully resist changes in land use that would add to congestion in their immediate neighborhoods.

Determine How AHS will Change Travel

This critical step requires making educated guesses about the travel outcomes of AHS since the type and scope of AHS that might be implemented is unknown. The experts agreed that AHS must provide substantial savings in travel time relative to its costs in order for it to have substantial effects on land use. In other words, it must be a breakthrough in transportation technology, not just an incremental change in the use of highways. The experts did not think this would occur. Rather, they anticipate that AHS will be implemented incrementally and serve mainly as a refinement in the movement of private vehicles. Downs anticipates that AHS will be opposed, and possibly never implemented, because of the large amounts of traffic that will clog streets at the destination end of trips and the high costs of building the systems.

Estimate the Impacts of AHS on the Location of Households and Firms

The experts draw on a variety of theories and empirical evidence to estimate how AHS will affect urban form. Davis and Seskin contrast the historical evidence on transportation improvements that radically altered urban form, such as the introduction of railroad freight movements and streetcars for commuters, with the recent evidence that highways and transit add only incrementally to accessibility and, therefore, have limited effects. Landis draws on economic bid-rent theory that holds that households and firms trade-off land and building costs with transportation costs. Both the theory and empirical evidence suggest that lowering transportation costs leads to lower density, larger urban areas. Beimborn turns to travel choice theory which posits that people choose travel modes based on their characteristics, like speed, cost, and reliability, and not because of biases in favor of certain technologies. Beimborn further considers lessons from other transportation technologies that share characteristics of AHS, such as personal rapid transit, pallet systems that carry automobiles and trucks on trains, toll roads, and HOV lanes. Rutherford notes that most experts on urban development agree that current land use patterns have so much momentum that changes in transportation technology are unlikely to shift the course of development.

From these diverse perspectives, the group of experts draw similar conclusions. If AHS represents a new technology that provides considerable time saving for longer distance travel, it could radically change urban form. The likely results would be even lower density urban areas with new suburban subcenters along AHS routes, more exurban living, and possibly the development of new towns. If AHS only provides incremental changes to existing highways, as the experts envision it will, the impacts will the same as for other highway improvements. People will be able to live further out in the countryside in the affected corridors and some development may concentrate near the facilities.

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Abbreviations used without definitions in TRB publications:

AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
IEEE	Institute of Electrical and Electronics Engineers
ITE	Institute of Transportation Engineers
NCHRP	National Cooperative Highway Research Program
NCTRP	National Cooperative Transit Research and Development Program
NHTSA	National Highway Traffic Safety Administration
SAE	Society of Automotive Engineers
TCRP	Transit Cooperative Research Program
TRB	Transportation Research Board
U.S.DOT	United States Department of Transportation

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