Forecasting Indirect Land Use Effects of Transportation Projects

Requested by:

American Association of State Highway and Transportation Officials (AASHTO) Standing Committee on the Environment

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1.0 INTRODUCTION

1.1 WHY THIS STUDY?

Few contemporary issues in the urban transportation field elicit such strong reactions and polarized factions as claims of indirect land use effects and the induced travel demand it results in. Expanding road capacity is said to spawn new travel and draw cars and trucks from other routes. Consequently, road improvements, critics charge, provide only ephemeral relief—within a few years' time, most facilities are back to square one, just as congested as they were prior to the investment due to land use shifts and other effects. Failure to account for indirect demand effects likely exaggerates the travel-time savings benefits of capacity expansion and ignores the potentially substantial land use shifts that might occur because of the marginal increase in accessibility provided. Unfortunately, there is limited guidance and wide disagreement amongst transportation agencies on how to properly account for this important component of project planning.

Besides the practical concerns indirect land use effects and induced travel have on project planning and design, there are also important legal reasons to pursue this topic. Provisions in the National Environmental Policy Act (NEPA) of 1970 have been interpreted in federal regulations by the Council on Environmental Quality (CEQ) and the Federal Highway Administration (FHWA) to necessitate an analysis of indirect demand effects. Several high-profile EISs and EAs have been challenged on the grounds that these documents failed to sufficiently address indirect land use effects adequately. Some of these challenges have stopped major projects in their tracks until the courts' remedies could be applied. For example, in 2004 a federal district court found that the EIS for the Chittenden County Bypass project around Burlington, Vermont inadequately addressed the potential for the road to create indirect land use effects: the project continues to be on hold at the time of this writing (Senville et al v. Peters et al 2004). The Prairie Parkway in suburban Chicago is another high-profile example of a roadway project that has experienced long-term delays over this issue. Regionwide metropolitan transportation improvement plans have also come under scrutiny. For example, in the San Francisco Bay Area several environmental advocacy groups filed a lawsuit against the Metropolitan Transportation Commission (MTC) on the grounds that the long-range transportation plan failed to address the potential induced demand and land-use effects of expanding road capacity on congested corridors. Indeed, cases involving indirect land use effects constitute a significant portion of the legal challenges filed under NEPA thereby making DOTs throughout the country very sensitive to the need to adequately account for them.

Despite this, a review and synthesis of current guidance documents and of current practice at the outset of this study revealed a largely ad-hoc field lacking focused guidance and research-based understanding of land use responses to transportation improvements. Given the difficult and obscure nature of this field of research and practice there are few current best practices that have been well-summarized.[1] We believe the largely ad-hoc state of the discipline helps foster the lack of public buy-in to the forecasts which in turn spurs many of the aforementioned legal issues.

[1] The Draft Baseline Report emerging out of Executive Order 13274 (2005), however, provides a good summary of the way analyses are currently conducted.

Overall, there is also a gulf between the findings of a few researchers on indirect land use effects, published primarily in scholarly journals, and the world of packaged models used by MPO and state DOT practitioners. These models generally do not incorporate the findings of these studies. The more advanced modeling work (e.g. cellular automata models of growth or microsimulation-based travel models) is impervious to induced travel demand and its related land use effects and is usually used in regional transportation systems-level planning work (hereafter referred to as the "system planning mode") rather than project impact evaluation work (hereafter referred to as "project evaluation mode"). Furthermore, such approaches lack the ability to absorb policy-type directives, an important component of indirect land use effects analyses.

To help bridge such gaps this report provides practitioners updates on recent research findings on indirect land use effects and presents several important emergent areas of practice *not* addressed in the current literature. We also highlight where current practice needs sharper and more detailed guidance. Current practice, as evident in selected guidebooks and from interviewing practitioners, falls under the families of methods shown in **Table 1.** This table also notes if the approaches are typically used in the up-front, system planning mode or in the project evaluation mode or not used much in either**.** Current approaches to the land use/transportation interface vary significantly between these modes as **Table 1** suggests. The table provides examples of each approach and comments subjectively on their relative strengths or weaknesses. Those approaches with the most promise are shown in bold type and guided the team's efforts to generate new or additional guidance or to move beyond current practice. By providing detailed information on methods and processes grounded in research, this guide aims to strengthen the field of indirect land use forecasting and move it beyond its current ad hoc and litigious nature.

This report addresses indirect land use effects only, not cumulative impacts. It also does not address environmental effects that might result from any indirect land use effects. Analysts will need to derive such impacts through further analysis, bearing in mind the additional environmental regulatory factors and actions that could influence the environmental effects.[2]

1.2 HOW TO READ THIS REPORT

This report should be read as an adjunct to NCHRP 466, *Desk Reference for Estimating Indirect Effects of Transportation Projects*, developed by Louis Berger and Associates in 2002. NCHRP 466 is the core practitioners' guidance document and has helped structure several state-level guidebooks. We cross reference that document in our report so both can be used as side-by-side guidance documents. Our report will supplement the approach of the NCHRP 466 and drill down to provide more guidance and information on selected land use forecasting methodologies.

One purpose of our report is to better inform current practice with useful research findings. Another is to guide practitioners about what approach to use when current guidebooks provide insufficient direction. The most appropriate choice will depend on the amount of change

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[2] In a recent legal decision (DOT v. Public Citizen, 2004) analysts are cautioned not to assume that indirect effects would automatically result from the transportation action (i.e. but for the project, this would have occurred) without considering the actions of other parties and agencies in making the anticipated outcomes actually occur.

in land use that is initially anticipated, the planning context (rural through urban), the project's complexity, the resources available for the study and other factors. **Table 2**, in Chapter 4.3, provides general guidance on these choices.

Chapter 2, Research Approach, briefly describes the sources used as background research for this report. Chapter 3 first provides a refresher on definitions of the terminology of direct vs. indirect vs. cumulative effects etc. and then describes findings from a review of current guidebooks and interviews. Some guidebooks provide in-depth coverage of particular topics and, by noting these, Chapter 3 can provide the practitioner with useful, specific references.

Table 1: Approaches Used in Forecasting Indirect Land Use Effects

APPROACH	SYSTEM PLANNING MODE	PROJECT EVALUATION MODE	EXAMPLES	COMMENTS / JUDGMENTS
PLANNING JUDGMENT				
Political/policy marketplace-fair share driven or policy goal driven forecasts including economic development	Frequent	Frequent	Many MPO and project-level forecasts	Applies to econ. dvpt justified projects esp. but also struggling urban cores; important to inform/ improve practice by simple plausibility tests
Planning judgment	Typical	Typical	Majority of local comp. plans/studies	Interview/immersion-based; will not suffice for major impacts/controversy
Planning judgment w/process guidance	Typical	Typical	State guidance manuals	Good on process; light on substance
Planning judgment w/rules of thumb	Frequent	Limited	Various rules in scattered publications	Rules of thumb sporadic/limited (e.g. study area size, typical space needs)
Planning judgment w/factors list	Frequent	Frequent	Many State or Fed. DOT Manuals	Factors typically discussed in narratives
Planning judgment w/factors list w/prioritization or weighting or defaults or elasticities	**Infrequent**	**Infrequent**	**ODOT Manual**	**Most useful for this approach**
COLLABORATIVE JUDGMENT				
Delphi technique/panel	**Infrequent**	**Frequent**	**Best Practices Guidance (NCHRP # 8-36)**	**Difficulties in validating and gaining convergence; useful w/other appr.; politically attractive**
Visioning (unconstrained allocation)	Frequent	Infrequent	Visioning guides inc. FHWA	Popular; promotes vesting but undermined by superficiality
Visioning (w/Legos/Index/Places type tools)	Increasing	Not used	Manuals, software	In vogue in planning mode; generic algorithms not robust at project level
Scenario building	Increasing	Not used	Little guidance; FHWA support; some software - (e.g. Quest , PlanMaster)	Promising for planning; demanding, complex process

Table 1 Continued: Approaches Used in Forecasting for Indirect Land Use Effects

APPROACH	SYSTEM PLANNING MODE	PROJECT EVALUATION MODE	EXAMPLES	COMMENTS / JUDGMENTS
ALLOCATION MODELS				
Rule based allocation models (simple)	**Increasing (MPO level esp.)**	**Infrequent**	**No meta-studies; local apps; some software (e.g. ULAM, LUCI)**	**Promising area for research-based guidance in Impact mode; proliferation of homegrown approaches**
Rule based allocation models (complex)	Increasing (larger MPOs)	Infrequent	No meta-studies (e.g. Whatif?, TELUS)	Promising area for research based guidance in Impact mode
TRANSPORTATION DRIVEN MODELS				
Heuristic, post-processing of travel demand model outputs	**Very rare**	**Infrequent**	**Elasticities or regression equations for transit ridership**	**Promising area to apply research findings**
Basic travel demand models (conventional)	**Common for region in long range plans and TIPs; rare for local app.**	**Rare; sometimes applied in corridors to pick up episodic impacts**	**Guidance not widely available; modeler specific**	**Promising area for guidance on feedback loop**
Advanced Travel demand models (activity and tour-based microsimulations)	Very rare (experimental)	Not used	Leading edge work – (e.g.TRANSIMS)	Potential unclear – requires major resources and sophistication
INTEGRATED TRANSPORTATION / LAND USE MODELS				
Econometrically driven	**Rare (large MPOs, academia)**	**Not used**	**TRANUS, MEPLAN, DRAM-EMPAL/ITLUP, URBANSIM**	**Good potential in Impact mode but requires major resources and sophistication; almost all these models iterate and converge to some balance ignoring induced effects, (which are very crudely addressed, if at all)**
Agent-based models	Rare (large MPOs, academia)	Not used	LEAM	Some potential in Impact mode – requires major resources and sophistication; beta-testing mode

Chapter 4 on Applications is organized in the sequence of approaches highlighted in **Table 1** and is the primary chapter in this report. Its first three sections are foundational and should be well understood by all who will use this report as an applications guide. The remaining sections of Chapter 4 discuss more resource-intensive land use forecasting techniques and should be read by anyone contemplating their use or those who are interested in understanding the full spectrum of techniques available. Chapter 5 summarizes some of the limitations of this report and notes what kinds of work and research are particularly useful and necessary to advance the practice of documenting and analyzing indirect land use effects.

REFERENCES

DOT v. Public Citizen. 124 S. Ct. 2204 (2004).

Indirect and Cumulative Impacts Work Group. *Executive Order 13274: Indirect and Cumulative Impacts Work Group Draft Baseline Report*. United States Department of Transportation, Washington, D.C.(2005).

Senville et al. v. FHWA and VTrans. 2:03-cv-279 (2nd Cir. 2004).

The Louis Berger Group, Inc. *Desk Reference for Estimating the Indirect Effects of Proposed Transportation Projects, NCHRP Report 466*. Transportation Research Board,Washington, D.C. (2002).

2.0 RESEARCH APPROACH

The research team used both primary and secondary sources to describe the state of the practice for forecasting indirect land-use impacts. Secondary source materials referenced included academic and professional journal articles as well as existing guidance documents. Guidance documents put out by state and federal agencies, research organizations, and other entities are important indicators of the state of the art of conducting indirect land use impact studies. Those guidebooks help to define the state of the practice across the country as various agencies and practitioners implement the methods and techniques these studies advocate. Chapter 3 synthesizes the ideas, techniques, and recommendations from these guidance documents.

Guidance documents provide insights on how their authors believe indirect land use effects studies *should* be conducted. How closely, however, do practitioners actually follow such guidance? To help answer that question we conducted detailed interviews with six representative practitioners of indirect land use effects analyses. The practitioners were identified through pursuing the sources of case studies cited in the literature or were themselves cited as authors or experts. The limited number of interviewees reflects our decision to aim for depth not breadth. More broad-based interviews had already been conducted for Executive Order 13274 in 2005. Chapter 3 provides a summary of the findings from both our interviews and those conducted for Executive Order 13274.

Chapter 4 presents in more detail the six approaches that were highlighted in **Table 1**. Chapter 4 also includes selected material on planning judgment and collaborative judgment from good, recent guidebooks, as amended through the research and experience of the authors. The presentation of the other four approaches is based on new material developed specifically for this report.

- The section on elasticities and induced travel is a synthesis of current research and includes a meta-analysis of findings from empirical work as well as modeling.
- The section on allocation methodologies is similarly based on a review of current practice and selected models used to allocate growth in initial system planning mode work but that can also be used to allocate it in indirect land use effects analysis.
- The section on four-step travel demand models is our effort to formalize and provide guidance on some of the (limited) current practice that uses such models to assist in indirect land use effects analysis. The promise of this approach, particularly for system planning mode work, is clear but even the leading-edge work here requires important caveats.
- The last section in Chapter 4 on integrated transportation-land use models was also developed for this report and summarizes our own authors' review and experiences with current leading-edge work.

3.0 FINDINGS

This Chapter defines indirect land use effects, presents highlights from current guidebooks and practitioner interviews, and then summarizes the gaps which this report tries to fill.

3.1 WHAT ARE INDIRECT LAND USE EFFECTS?

Our aim here is to provide a brief overview of the legal terminology in this report. A more detailed discussion (along with a summary of relevant case law) is available in Course Module 1 of NCHRP report 466. Much of the information in this section comes directly from *A Guidebook for Evaluating the Indirect Land Use and Growth Impacts of Highway Improvements* for the Oregon Department of Transportation prepared partly by one of this report's authors (ECONorthwest et al 2001).

3.1.1 Difference between Direct and Indirect Effects

While there are many differing opinions on what constitutes indirect effects, the legal definition used in federal regulations is the most pertinent and well-developed. The federal statute most relevant to the assessment of indirect land use effects is the National Environmental Policy Act (NEPA) of 1970, as amended. NEPA says that the reasonably foreseeable effects of transportation projects need to be disclosed and taken into account during the environmental impact assessment process. NEPA, however, does not specifically break down the said "effects" into direct and indirect subcategories, per se. Instead, the 1978 CEQ regulations developed for NEPA made that important distinction official. The CEQ stated that direct effects, "…are caused by the action and occur at the same time and place (CEQ 1978). Compare this to indirect effects which, "…are caused by the action and are later in time or farther removed in distance, but are still reasonably foreseeable". Moreover, indirect effects, "…may include growth-inducing effects and other effects related to induced changes in the pattern of land use, population density or growth rate, and related effects on air and water and other natural systems, including ecosystems (CEQ 1978)." The CEQ differentiates direct and indirect effects from the term cumulative impact. A cumulative impact, "…is the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions (CEQ 1978)."

According to the CEQ definitions, the distinction between direct and indirect effects is made on four dimensions: time, space, probability, and causality. Direct impacts of a project happen sooner, closer, and with more certainty than indirect effects. Indirect effects are not directly caused by the project, but by intervening factors that the project affects. Indirect effects typically occur away from transportation alignments and in the future, but they may also occur along an alignment or in anticipation of a project. Indirect effects of transportation projects typically occur through the action of an intermediary, usually a household or business, acting in response to anticipated or actual changes in transportation system performance.

A good example of a direct land use impact on of a highway project is acquisition of land for right-of-way: the land use change (from, say, residential to transportation right-of-way) is (a) close to the project (it is in the right-of-way), (b) happens at the time of the project (the project cannot be started without the land use change), (c) is certain, and (d) is caused directly by the highway project.

An example of an implied, indirect land use effect is the claim that a highway project improving travel time to a central city will eventually cause a jurisdiction to rezone undeveloped land near, but not adjacent to, the project for residential development. The causal link is much more tenuous than the right-of-way acquisition. The possible impact is (a) distant from the improvement (the land is not adjacent, and perhaps over a mile away from the right-of-way), (b) may not occur, perhaps, for many years, (c) is uncertain (maybe it will happen, maybe it will not), and (d) the result of many intervening forces (e.g., the highway project affects travel time, which affects land value, to encourage property owners and developers in outlying areas to petition for zone changes, to allow more residential development).

3.1.2 External, Secondary, Induced, and Cumulative Impacts

Such examples make clearer why research to analyze indirect effects has been difficult: the aspects of indirect effects are multi-dimensional and continuous. There is no obvious point along the continuum at which an indirect effect can be predicted with certainty. Moreover, the distinction between indirect and cumulative impacts can blur as one considers longer term impacts.

Furthermore, there is a good deal of imprecision in the use of terminology. The literature refers to indirect effects in a number of ways: not only as *indirect*, but also as *external* or *secondary*, and often (either as a synonym or subset) as *induced* or *cumulative*.

- **External impacts** is a term primarily used by economists but seldom used in analysis of transportation impacts.
- **Secondary impacts** are generally synonymous with *indirect effects*.
- **Induced impacts** have various definitions, depending on who is using the term. As applied to land use impacts in transportation evaluation, induced impacts are synonymous with indirect effects: they are removed in time and space from the direct impacts of the transportation project on land use. Induced impacts are most often cited when discussing how a transportation project might contribute to population, land development, or property values growing more quickly than they would have otherwise (what CEQ regulations refer to as "growth-inducing effects"). For this guidebook, however, in an effort to reduce confusion, we shall consistently use the term "indirect land-use effects" to refer to those specific indirect effects that are growth inducing or may change the pattern of land use, population density, or growth rate.
- **Cumulative impacts** are not difficult to define in theory and in practice, but they are hard to measure. In concept, the aim is to consider not just the marginal impacts of a proposed highway transportation project, but the collective impacts of all

transportation projects and other actions, public and private, that are past, present or reasonably foreseeable. The premise is that there are thresholds which, once crossed, cause incremental impacts to be greater than the sum of their parts. Some analysts assume a broader definition that counts as cumulative any effects that accrue over time, even if they are linear. For example, the marginal impact on the existing transportation system of adding one new office development may be small, but if many such developments are added, the small impacts sum to a big one. This guidebook does not address methods for evaluating cumulative impacts.

3.2 WHAT DO EXISTING GUIDANCE DOCUMENTS SAY ABOUT FORECASTING INDIRECT LAND USE EFFECTS?

Guidance documents put out by state and federal agencies, research organizations, and other entities on how to conduct indirect land use impact studies are important indicators of the state of the practice for this field. These documents often represent the most advanced understanding of the subject matter at the time of their publication. Comparing earlier with more recent studies can provide insights into how the discipline has evolved over time. As the methods and techniques they advocate are increasingly implemented across the country (or at least within the state where they are adopted) they help define the state of the art. This section of the report will synthesize the ideas, techniques, and recommendations these (often) trend-setting documents advocate so that the reader can develop a better understanding of the guidance currently available for documenting and analyzing indirect land use impacts. **Appendix A** is a summary of each of the eight guidance documents that are the sources for this synthesis.

3.2.1 Method Used to Review and Evaluate Other Guidebooks

3.2.1.1 Selection of Guidebooks to Review

Our research team's approach was as comprehensive as possible when assembling the guidance documents to review, but included only guidance documents offering fairly substantial recommendations on how to conduct indirect land use effect analyses: guidance documents offering only a limited description of the topic or those mainly citing other sources for guidance (e.g. Washington, Idaho, and Florida) are not summarized here.

The relatively recent proliferation of guidebooks on indirect land use impact studies parallels the increasing importance of indirect land use impacts to FHWA, Smart Growth advocates, environmentalists, and citizen/neighborhood groups. In response to lawsuits from such groups, DOTs have raised the profile of this issue. The first true guidance documents on the subject only began to appear in the mid-1990s. Nonetheless, the sub-discipline has advanced substantially since then, and some states and organizations have already revised their earlier approaches. In these cases, we reviewed in detail the most recent guidance document from each organization. The guidebooks reviewed were:

- *Guidance for Preparers of Growth-related, Indirect Impact Analyses* (Caltrans 2006)

- *NCHRP Report 423A: Land Use Impacts of Transportation, A Guidebook* (Parsons Brinckerhoff Quade & Douglas, Inc. 1998)
- *NCHRP Report 466: Desktop Reference for Estimating the Indirect Effects of Proposed Transportation Projects* (The Louis Berger Group, Inc. for NCHRP 2002)
- *A Guidebook for Evaluating the Indirect Land Use and Growth Impacts of Highway Improvements* (ECONorthwest and Portland State University for the Oregon Department of Transportation 2001)
- *Secondary and Cumulative Effects Analysis Guidelines for Environmental Impact Statements and Environmental Assessments* (Maryland State Highway Administration 2000)
- *Land Use in Environmental Documents – Indirect and Cumulative Effects Analysis for Project-Induced Land Development, Technical Reference Guidance Document* (Wisconsin Department of Transportation 1996)

3.2.1.2 Framework for Reviewing and Evaluating the Selected Guidebooks

A common framework was developed to facilitate the comparison of these diverse guidance documents. The framework captures the key guidance elements in each document and cites our evaluation of the strengths and limitations of their recommendations. The items we evaluated included:

- Purposes of the guidebook;
- Analytical frameworks (the steps for conducting the analysis);
- Level of prescreening and right-sizing guidance (how to determine the level of detail needed for the analysis and the proper tools to use);
- Level of guidance for drilling down into forecasts and plans;
- Land use forecasting methods and tools discussed;
- Other guidance provided on assessing land use impacts of projects;
- Research components (if included);
- Any other useful elements that were part of the guidance;
- Whether limitations of the guidance were discussed;
- And the overall land use and transportation planning perspective of the document.

The remainder of this section is organized around this framework.

3.2.2 Guidebook Purposes

Although the purpose of all of this guidance material is to provide a sound methodology for estimating the indirect land use effects, some guidance documents carry more weight than others. For example, the 2003 interim guidance from the Federal Highway Administration

(FHWA) carries the most authority and influences all the other guidance documents put out by individual states and research groups (at least in terms of how to do an analysis that satisfies federal environmental requirements). FHWA's interim guidance, however, is very general and leaves considerable latitude for states and other guidebook authors to inject their own opinions and ideas on what constitutes a sound analysis.

As noted above, currently, Wisconsin, California, Maryland, North Carolina, and Oregon have issued substantial original guidance documents on conducting indirect land use effects studies. Such state guidance documents carry considerable weight in the states within which they apply. Other states such as Washington, Idaho, and Florida have guidance that heavily references other materials. The state documents are sometimes very specific on how to do analysis to meet federal and state laws (especially in Maryland, Wisconsin, and Oregon), and the state DOT's and their contractors often must follow the recommended methods very closely. State guidebooks also stress that the methods used should be compatible with time and budget constraints.

The guidance from research organizations such as NCHRP, while advisory, is often the most robust and rigorous. Rather than being driven solely by meeting statutory requirements such guidance also tends to be the most theoretical and to include a great deal of background information, which, to some extent, downplays the importance of budget and time constraints in favor of conducting more thorough analyses. In all, research organizations have produced three major guidebooks (all sponsored by NCHRP): The Louis Berger Group's *NCHRP Report 403: Guidance for Estimating the Indirect Effects of Proposed Transportation Projects* and *NCHRP Report 466: Desk Reference for Estimating the Indirect Effects of Proposed Transportation Projects* from 2002 (an update and expansion of NCHRP report 403) as well as Parson Brinckerhoff's *Land Use Impacts of Transportation: A Guidebook* (NCHRP Report 423A) from 1999.

3.2.3 Analytical Frameworks

Documents provide an analytical framework that outlines the steps necessary to set up and conduct the indirect land use effects analysis and the order in which those steps occur. The lone exception is FHWA's interim guidance which is organized in an FAQ format that is compatible with its more general focus.

The number of steps in these analytical frameworks ranges from 6 to 11. **Appendix B** shows these analytical framework steps side-by-side for all the documents reviewed. A useful baseline analytical framework is the eight-step process developed by Louis Berger Group, Inc. for NCHRP report 466 and 403. Their framework is composed of the following steps:

1. **Scoping:** Define the basic approach, effort required, and geographical boundaries of the study area.
2. **Identify the Study Area's Directions and Goals:** Compile information regarding the study area with the goal of defining the context for assessment.
3. **Inventory the Study Area's Notable Features:** Gathering and synthesizing additional data on environmental features. Identify specific environmental issues by which to assess the project.

4. **Identify Impact-Causing Activities of Proposed Action & Alternatives:** Describe in full the component activities of each project alternative.
5. **Identify Potentially Significant Indirect Effects for Analysis:** Catalog the Indirect Effects associated with project activities and alternatives; identify potentially significant effects meriting further analysis.
6. **Analyze Indirect Effects:** Use qualitative and quantitative techniques to estimate the magnitude of the potentially significant effects identified in Step 5; describe future conditions with and without the proposed transportation improvement.
7. **Evaluate Analysis Results:** Evaluate the uncertainty of the results of the Indirect Effects analysis is evaluated for its ramification on the overall assessment.
8. **Assess Consequences and Develop Mitigation:** Evaluate the consequences of indirect effects in the context of the full range of project effects. Develop strategies to avoid or lessen any effects found to be unacceptable. Reevaluate the effects in the context of those mitigation strategies.

Most of the other guidebooks present a version of this basic process although some treat specific key elements, such as defining the study area as a separate step. California's recent guidance document breaks down scoping (i.e. prescreening) into two separate steps: one for determining whether an analysis is needed and , if an analysis is necessary, another to decide on the level of effort and land use forecasting approach and tools to be used.

Despite the overall similarities, there are some key differences among the analytical frameworks. Many of the other frameworks do not emphasize in as much detail as NCHRP Report 466 the inventorying of "notable features". The Wisconsin guidebook and NCHRP Report 423A lack steps discussing prescreening. NCHRP 423A does not discuss how to set up the study area nor does it focus on assessing the impacts of land use change on resources.

3.2.4 Level of Prescreening and Right-Sizing Guidance

Prescreening and right-sizing techniques are critical for balancing study needs with time and budget constraints to establish the proper level of effort needed for a successful indirect land use effects study. Prescreening determines whether an indirect land use impact analysis is needed at all. Right-sizing determines the level of effort and tools to use once the need for a study is established.

Three guidebooks provide extremely limited advice on prescreening (Wisconsin, NCHRP Report 423A, and Maryland). Oregon's guidance documents present a list of factors to consider when determining whether a project might have any indirect land use effects. These factors include:

- Aggregate travel time change
- Estimated project cost
- Project length
- Number of vehicles/trips affected

- Capacity of project relative to existing capacity
- Whether land use policies support the project
- Whether other services are located nearby
- The strength of market demand for development
- Professional opinion

The use of flow charts is a bit more structured method that is employed in the California and North Carolina guidance documents as well as in NCHRP Report 466. Flow charts walk practitioners through the factors that are tip offs to possible indirect land use effects. If a particular factor (worded as a question) does not apply, the practitioner is led to a box saying that no analysis is needed.

Overall, guidance on right-sizing analyses is still rather weak. *None of the guidance documents reviewed recommend specific land use forecasting methods/tools in a given project context or under certain time and budget constraints.* Nevertheless, many guidebooks do provide suggestions on how to meet this need. NCHRP Report 466 and the North Carolina and California guidance present a table that considers different project factors and then makes recommendations on whether a quantitative or qualitative analysis would be more appropriate for each situation. NCHRP Report 423A recommends specific primary and secondary tools for various steps in their framework, presumably after considering budget, time, and accuracy issues. Other guidance documents are somewhat less helpful. The FHWA and Wisconsin guidance documents simply list factors that should be considered when picking tools. Maryland's guidance is more authoritative saying that simple (non-model based) quantitative methods should always be the primary method used if data is readily available. The exception is with highly controversial projects in which the guidance says an expert panel should be used instead. Thus, Maryland's guidance on which tools to choose is driven primarily by data availability and amount of controversy.

3.2.5 Level of Guidance Provided for Drilling Down Into Forecasts and Plans

When relying on information provided by other agencies, it is important to check the assumptions that went into the creation of the imported data. This is particularly crucial when relying on an MPO's or other local agency's population and employment projections to inform the no-build growth forecasts. The projections and/or the plans they are based on may contain assumptions that the improvement under consideration would be built and might therefore already allocate more growth to areas around the improvement. This, of course, would defeat the purpose of using this data to estimate no-build population and employment. Four of the guidebooks do not emphasize this important possibility. Oregon's guidance is very strong on this subject. Similarly, NCHRP Report 423A actually includes a section on how regional projections are made and states that future transportation improvements should be included in those projections.

Another important item to consider is how reliable or effective local plans are as tools for guiding development. Have local governments stuck to their plans or have they exhibited a willingness to change them in the face of development pressure? Four guidebooks (California, North Carolina, Oregon, and NCHRP Report 466) issue strong warnings that the implementation history of plans should be considered during the analysis. Maryland's and Wisconsin's guidance is less explicit about this consideration.

Another important technical nuance regards understanding the differences between gross and net densities since mixing up these terms can have a huge impact on population projections. NCHRP Reports 466 and 423A both point out the importance of understanding these terms.

3.2.6 Land Use Forecasting Methods and Tools Discussed

Land use forecasting methods are the predictive tools used to assess what the indirect land use impacts of transportation improvements might be. The guidebooks present a wide variety of these land use forecasting methods. However, not all guidebooks describe all the available land use forecasting methods. The guidebooks that tend to be the most comprehensive and provide a full menu of options are those from research organizations such as NCHRP. The guidebooks published by the states, with the exception of California and North Carolina, tend to provide practitioners with a more limited choice of land use forecasting methods. These methods are in effect pre-approved by each state and are likely the result of individual philosophies on the viability and accuracy of certain forecasting methods and, even more importantly, consideration of budget and time constraints. Some states such as Oregon provide only a single forecasting methodology (a generally qualitative analysis of factors influencing the extant and location of indirect land use effects). Maryland favors qualitative methods and simple quantitative measures (when data is available) but strongly discourages the use of modeling and other more involved quantitative methods.

Overall, the guidebook authors seemed to see their role as primarily giving practitioners a taste of the available options rather than giving them manuals on how to implement each tool they recommend. Few of the reports offer sufficiently detailed descriptions of the land use forecasting methods to enable practitioners to conduct an analysis using only the information provided in the guidebook. Practitioners interested in using the tools mentioned have to consult outside references. The NCHRP guidebooks are particularly helpful in this respect since they typically provide a number of references for the tools that are mentioned.

The state guidebooks (with the exception of North Carolina) also do not delve into the strengths and weaknesses of each forecasting tool. However, NCHRP's Reports 466 and 423A do consider the strengths and weaknesses of various tools in some detail. These reports also provide some background on the rigor, data needs, potential errors, and defensibility of the methods listed.

3.2.7 Other Guidance Provided on Assessing Land Use Effects of Projects

Many guidebooks offer helpful pointers on when indirect land use effects are more likely such as the evident importance of interchanges on access controlled highways for determining where growth will occur. Most guidebooks also explore the differences in indirect land use effects that one might expect in urban versus rural areas. The California guidance is particularly instructive about the differences in impacts for four types of areas: urban, suburban, urban/suburban fringe, and rural areas.

The FHWA guidance and NCHRP Report 466 both cite case law to argue that, when economic development is mentioned as a reason for constructing the improvement, then indirect land use effects must be considered. NCHRP Reports 423A and 466 also include detailed tables that cite the likely indirect land use effects for a variety of transportation improvements.

NCHRP Report 466 also identifies three general categories of indirect land use effects: (1) those stemming from projects planned to serve a particular land development project, (2) projects likely to produce complementary land development (highway-oriented businesses), and (3) projects likely to influence intraregional location decisions.

The Wisconsin guidance on defining study areas provides a special technique for considering projects where the likely indirect land use effects will be from vacation/second homes and other tourist-related businesses.

3.2.8 Research Components Included

The majority of guidebooks do not present any original research on indirect land use effects. At best, outside studies are referenced, case studies are cited, and/or case law is detailed to explain why analysis of indirect land use effects is an important issue. This lack of cutting edge research in the guidebooks is not surprising since indirect land use effects have only emerged within the last five years as a popular subfield for serious academic research.

A very notable exception is Oregon's guidebook which is informed heavily by two original research studies conducted by ECONorthwest and Portland State University that are included in the appendix of this Oregon document. One study used historic aerial photography to document changes in development patterns around highway infrastructure over time with the goal of making a predictive model for development. The other study focused on whether new highway projects promote development inconsistent with local plans. These studies back up the authors' guidance and determine what factors to consider in their forecasting methodology.

3.2.9 Other Useful Components Included

Many guidebooks go above and beyond simple descriptions of the basic elements of their analytical frameworks and provide components that enhance a particular step of the analysis beyond the treatment in other guidebooks or provide insightful background information for contextualizing the study. NCHRP Report 466 is unique in the number of checklists, flowcharts, and other supporting documents it offers. As with the California and Wisconsin guidance, NCHRP Report 466 also maintains a strong environmental focus and even provides some basic background information on environmental issues. Along with NCHRP Report 423A, NCHRP Report 466 describes the fundamental concepts of how the development process works and who the major actors are. Both of these NCHRP reports also describe the differences between considering indirect land use effects of individual improvements and those that result from planning an entire transportation system.

Some state level guidance documents, such as California and Oregon, also cite hypothetical examples with sample analyses to give practitioners a better understanding of what a final document prepared under state and federal requirements might look like.

The Oregon guidebook and NCHRP Report 423A both look in-depth at population and employment forecasting issues. The Wisconsin guidebook takes an in-depth look at how to define the study area and includes a matrix matching different study area definition methods with project context factors. Wisconsin also includes a thorough discussion of planning terminology and documents that can be helpful to DOT or consultant practitioners who do not have a background in the planning field.

3.2.10 Limitations of Guidance

Some of the guidance given in the state guidebooks may be overly limiting. Oregon's reliance on a single recommended land use forecasting technique, as good as it may be, will likely not be the most appropriate method for every possible context. Maryland's rejection of modeling and insistence on using only existing data for the analyses (not generating any new data) discourages practitioners from doing more thorough quantitative work when the situation warrants it. Wisconsin's recommendation of producing "low, medium, and high" growth scenarios implies a rather mechanical exercise in covering the bases rather than the depth of analysis needed for true scenario-building. In our report we incorporate the guidance of land use forecasting, particularly Oregon's, that offers sound ways to pinpoint likely indirect land use effects. Nevertheless we have not hesitated to fill in for their limitations.

3.2.11 Overall Land Use / Transportation Planning Perspective of Guidance

Given their purpose most guidebooks present an incremental perspective focused on satisfying NEPA and state statutory requirements. Only a few guidebooks take a broader perspective and consider the need for better integration between land use planning and transportation planning that would simplify and reduce the extent of indirect land use effects analyses. Oregon's guidance is an exception, for state law requires that transportation and land use planning in Oregon are well integrated. NCHRP Report 466 states that land use planning should lead and the transportation infrastructure should follow as a general principle. This report does not dwell on this issue since it is less a key objective of this document, which focuses on project level impacts, usually an after-the-fact analysis, rather than on up-front, systems-level planning.

3.3 WHAT METHODOLOGIES ARE CURRENTLY USED IN PRACTICE TO FORECAST INDIRECT LAND USE EFFECTS?

Guidance documents provide insights on how leading professionals believe indirect land use effects studies *should* be conducted, but do practitioners actually follow their recommendations? To help answer that question, six representative practitioners in the field were interviewed about how various methodologies are currently employed.[3] These in-depth interviews supplement the more generalized study conducted for Executive Order 13274 in 2005 which drew on surveys of 50 practitioners, a literature review, and an analysis of 31 Environmental Impact Statements (EISs). The primary findings of the Executive Order are summarized below:

- Confusion about the definitions of when growth is "reasonably foreseeable" and what actually constitutes "induced growth" as opposed to growth that would have occurred anyway
- A still immature practice that presents considerable variability in the level of detail of indirect land use effects analyses with the majority of studies treating this issue in a very cursory way
- A tendency among some to ignore indirect land use effects if direct impacts are found to be insignificant (even if direct impacts are not significant, indirect land use effects might still be a concern and should be analyzed).
- A tendency for highway projects to be the more contentious in terms of indirect land use effects than transit and airport projects.
- Divergent viewpoints between resource and transportation agencies on whether transportation projects more or less respond to growth (transportation agency view) or facilitate new growth (resource agency view)
- Different means of setting study area boundaries (boundaries of natural systems versus pre-determined buffer distances or use of jurisdictional boundaries), based on the different perspectives of resource and transportation agencies
- The analysis timeframes typically focus on recent historical trends and look 20 years into the future, sometimes less
- Divergent views whether agencies should determine what impacts are significant or just provide the information to the general public and interest groups for them to determine if impacts are significant
- Differences in opinion on appropriate mitigation strategies and transportation agencies' responsibilities for such mitigation (Indirect and Cumulative Impacts Work Group, 2005)

The findings of our report generally conform to the findings from the Executive Order study. Our interview questions, however, tended to focus more on the specifics of land use forecasting. **Appendix C** shows the primary questions that guided the interviews. The questions dealt with five general categories: general background information, prescreening and right-sizing, the analytical process, attention to details, and practitioners' opinions. We have used these categories to structure our investigation, the results of which are summarized below.

[3] Interviewees included Jeff Buckland (urban planner, Parsons Brinckerhoff, Inc.), Kumudu Gunasekera (PB Consult, Inc.), Allan Hodges (Senior Professional Associate, Parsons Brinckerhoff Inc.), Jonathon Page (Project Manager, Parsons Brinckerhoff, Inc.), Lawrence Pesesky (Vice President for Transportation Planning, Louis Berger Group, Inc.), and Samuel Seskin (Transportation Planning Director, CH2M HILL, Inc.).

3.3.1 Prescreening and Right-Sizing Techniques Employed

Early identification of whether indirect land use effects are likely to exist (prescreening) is crucial. If they are, further analysis is justified. If not, further study is a wasteful pursuit. To help clarify how to make this determination, the survey asked practitioners how they prescreen projects. Three of the interviewees responded by saying that they themselves do not prescreen projects: since they are all consultants, they defer to their clients (state DOTs) judgment whether an indirect land use impact study is needed. Other consultants, however, do prescreening. One practitioner said he always uses the extensive prescreening information provided in the North Carolina guidebook. A second practitioner considers three key elements: demographics (is there regional population growth?), type of project (is capacity being added?), and the extent of the existing transportation network. Another practitioner said that he used a general rule of thumb: the more an area is already built out then the less likely indirect land use impacts are to occur. Though there is likely some truth to this, it ignores how indirect land use changes still might occur in urbanized areas.

Once prescreening shows that indirect land use effects are a possibility, the next critical step is to determine what level of analysis is warranted (right-sizing). One practitioner said that right-sizing was always project context-dependant. He considers the type of project, its environment, budget realities, and data availability when making this decision: this is the viewpoint closest in line with what the guidebooks say. That said, many of the consultant practitioners noted the power of DOTs to choose what type of analysis is most appropriate. One interviewee deferred completely to the DOT's suggested method. Other practitioners developed recommendations for the DOT to consider. In developing these recommendations, specific project characteristics were less important to these individuals while data availability and fiscal considerations were the driving forces behind their suggestions. When asked whether, if data and funding were available, they would always choose a quantitative over a qualitative method, they indicated favoring a quantitative approach. One interviewee, however, stressed the importance of conducting interviews with local professionals no matter what forecasting approach is used.

3.3.2 Analytical Frameworks Used and Tools Employed

This section gets to the heart of how the practitioners conduct indirect land use effects analyses: their analytical framework and how they handle each element of that process, including land use forecasting tools. Despite the strong attention available guidance documents pay to establishing a typical process framework, few of the practitioners interviewed actually followed the step-by-step analytical frameworks these documents presented. Instead, the practitioners tend to mold the analysis to their knowledge of the situation at hand rather than follow a pre-determined formula or process. The practitioners said they tended to cover the same general steps as in the guidebooks, but they did it in a less formal order than the guidebooks present. To their credit, many of the guidebooks recognize this will be the case and acknowledge that the analytical process that actually unfolds will be more iterative than the guidebooks describe.

The practitioners interviewed cited a variety of build/no-build forecasting tools. One practitioner often employs gravity models, especially on complex and controversial projects.

Many of those interviewed used regional traffic model outputs in more creative and less formal ways than discussed in the guidebooks. Based on build/no-build accessibility differences obtained from the model, the practitioners used a variety of assumptions to determine if growth would actually occur in the more accessible areas. These analyses often began by consulting local plans and zoning ordinances to see the level of development allowed in the relatively more accessible areas. Some of those interviewed also considered flood plains and other areas off limits to development when determining the capacity for each area to take advantage of accessibility differences.

Qualitative methods were generally less employed although one practitioner had helped coordinate a three round Delphi panel for an indirect land use effects study. A method, called a blended average (the mean and median of the panel members' results divided by 2), was used to determine the panel's final forecast, although the statistical concept behind this method was unclear. Though some interviewees preferred quantitative methods if data was available, the value of qualitative input was not lost on them. One practitioner noted that he always solicited input from a wide variety of local experts to inform his forecasts.

In some cases the lead agency creates a situation by specifying indirect land use effect forecasts be constrained by fixed control totals for future population and employment. Fixing the amount of growth that can occur in an area defeats the purpose of doing an indirect land use effects analysis that seeks to determine the potential for new growth due to a transportation improvement. Nonetheless, two practitioners asked about this constraint lamented that they often had to work within fixed totals rather than having the freedom to project growth based on accessibility differences.

3.3.3 Attention to Important Details

When conducting a land use forecast, one must consider a number of items to ensure the most accurate results that are practicable. One of the chief concerns is that a clean no-build baseline forecast is used. Using plans and population and employment projections that assume the project in question will be built could corrupt the assessment of no-build conditions. Those interviewed were asked whether plans and forecasts used for baseline estimates were checked for assumptions about the improvement being built and, if so, how they corrected for this issue. Two practitioners stated that they do not check plans for these assumptions. Of those who do check assumptions, two methods were used to correct for potential errors and develop a clean baseline. One method uses an expert panel to determine a clean baseline forecast in the absence of the improvement. The other method uses an area nearby that has had no planned transportation improvements as a control area to compare with and inform the adjustment of the study area plans and baseline projection.

Another crucial detail of indirect land use impact forecasts is awareness of the provision or planned provision of public water and sewer. Water and sewer infrastructure are critical to the establishment of denser urban development and therefore have a big influence on the growth potential of an area. Surprisingly, half of the respondents said that they do not typically take sewer and water infrastructure into account in their analyses. One individual said that, since he looks at the land use plans for an area, this should implicitly account for sewer and water provision. While this is likely true (urban development will likely be planned for areas with adequate infrastructure), it is not always the case and more reliable investigations are desirable.

Another concern is the jurisdiction's history of implementation plans. Has the jurisdiction generally stuck to the land uses and densities called for in their plans or have exceptions to the plans and inconsistent re-zonings routinely been made in response to development pressure? Whether they investigate the planning history of the jurisdictions they are working in the majority of practitioners interviewed did investigate this important detail although two did not. One practitioner noted that determining the strength and consistency of local planning is a sensitive political issue. The local jurisdictions whose planning histories are being scrutinized are often highly involved in the project and negative findings about their capabilities could cause animosity.

3.4 IMPLICATIONS OF THE FINDINGS FOR THIS REPORT

The above findings about current approaches suggest that the Applications Chapter must adequately cover some of the gaps in the current guidebooks and practice. Such as:

- Translating relevant research into practice
- Clarifying the question of the timeframe
- Clear advice on the right-sizing of the study area
- Determining whether the original projections accounted for the project to be analyzed i.e. clarity on the baseline case
- More specific guidance on the land use forecasting methods. Advice on how to productively combine various approaches
- Specifying, where feasible, the kinds of data needed and the costs involved in pursuing various approaches
- Emphasizing the key factors in prescreening that are often overlooked such as the availability of sewer and water service or the jurisdiction's track record of abiding by their adopted plans or zoning
- Stressing the contradiction of using fixed study area control totals for indirect land use effects analyses

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4.0 APPLICATIONS

4.1 HOW TO USE THIS CHAPTER

Although a preferred process can fit a particular problem, we do not believe that there is a single, preferred *methodology* that can apply in all contexts. Methods clearly should differ based on a project's scale, development context, resources available, probable extent of impact and so forth. Nevertheless, we do not contend that all the current methodologies for analyzing indirect land use effects are equally useful. We do believe that there are preferred methodologies. They tend to be approaches that use, whenever possible, quantitative measures that capture the effects of *accessibility* on land use change – e.g., through the use of travel demand models or elasticities that reflect current research. Consequently, we specify the most appropriate approach by context and resources available and our report is therefore more directive in its recommendations than the checklist approach that characterizes most current guidebooks.

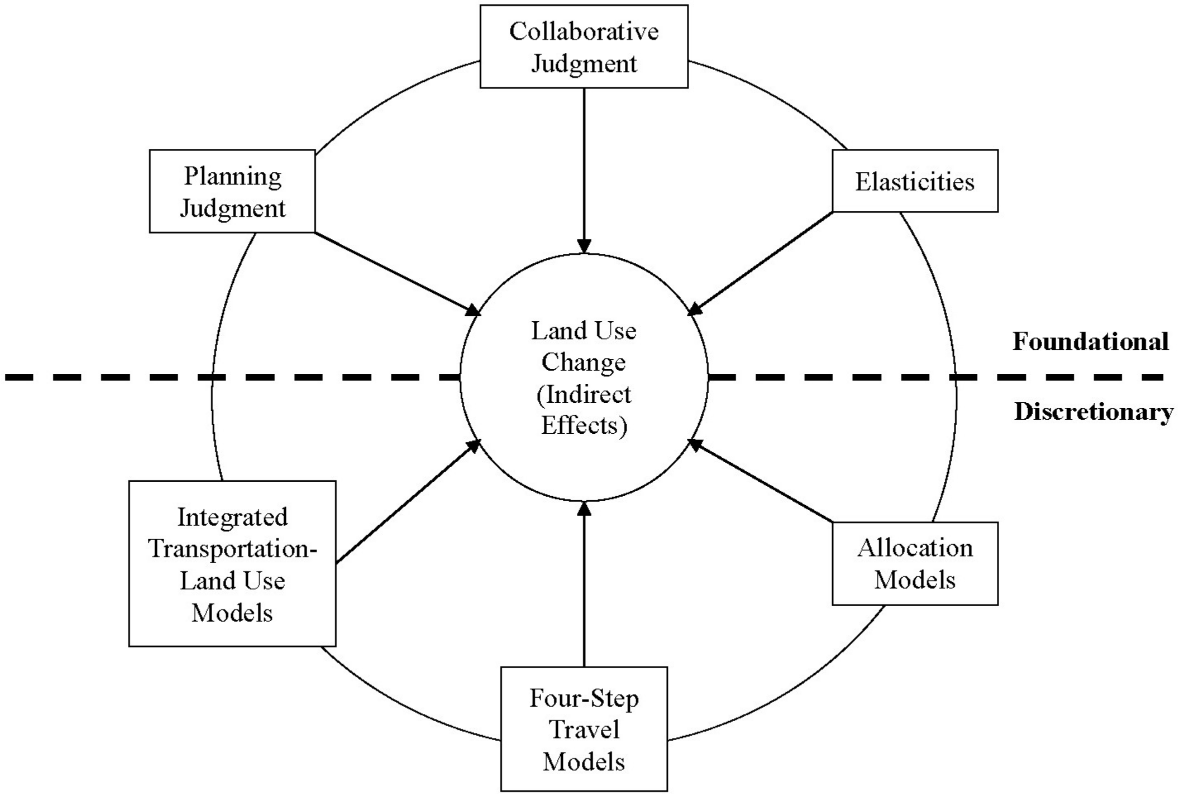
This chapter starts with a framework for conducting indirect land use effects analyses that collapses the steps specified in most guidebooks into fewer steps. This framework offers flexibility and options regarding the level of detail and how to use the six approaches presented in **Figure 1**. Before describing the overall process, we provide a brief introduction to these six tools which are an integral part of that process. A more thorough discussion of each of the tools and approaches follows along with a step-by-step description of how to implement each tool.

Indirect land use effects practitioners should read Sections 4.2, 4.3 (the framework's outline) and 4.4.1 through 4.4.3 on using the foundational tools within the framework. Sections 4.4.4 through 4.4.6 focus on discretionary tools and are optional readings depending on the approach selected.

4.2 AN INTRODUCTION TO SIX ESSENTIAL LAND USE FORECASTING APPROACHES

Figure 1 identifies six approaches or tools for forecasting land use change in response to transportation improvements. The top three are *foundational* – basic approaches that should be used, to a greater or lesser degree, in all efforts to forecast land use change or indirect land use effects. Where projects have little impact or resources are very limited, these tools suffice to provide a defensible answer to the key indirect land use effects questions of *How much change?* and *Where will it go?* The lower three are *discretionary* approaches – tools that in combination with the top three help answer these questions with more rigor. There are many viable combinations of these approaches, hence the connecting circle in the diagram that suggests interactions. The sequence of boxes from planning judgment clockwise is also that of the approaches presented in this chapter.

Figure 1: Framework for Forecasting Indirect Land Use Effects



The following is a brief description of each of the six approaches:

- **Planning Judgment** is a structured process for analyzing and forecasting land use change that relies on an understanding of the basics of transportation/land use interactions, basic data sources, asking the right questions and using rules of thumb from research to make informed judgments. If more sophisticated tools are not available, Planner judgment may be the most expedient approach to use. The section on this approach is the lengthiest and presents all the main considerations needed to engage in an indirect land use effects analysis. This section is essential reading in this report.
- **Collaborative Judgment** extends the solo planner's understanding through soliciting advice from others knowledgeable about the study area. Most guidebooks stress the need to get such input in informal or formal ways, and in this report we treat such information as a necessary check on *all* tools used. When no other resources are available, collaborative judgment may be the only sufficient approach for indirect land use effects. In such cases, it is particularly important to structure this input so that the weight of given individuals, personalities and agendas are evened out. Delphi panels, a specific form of Expert Land Use panels (ELUs), address this need and are the focus of this section.

- **Elasticities** bridge the gap between practice and research by providing a synthesis of the best theoretical and empirical research that allows analysts to better sort out the complexities of induced demand, indirect land use effects, and induced investment effects. The elasticities relate change in highway capacity (e.g., assessed through Vehicle Miles Traveled [VMT]) to change in travel behavior and in land use effects. They can be used to check the results of other approaches for reasonableness or as a standalone tool in combination with the above two approaches.
- **Allocation Models** can allow the analyst to distribute a defined amount of indirect land use change at a disaggregate level (e.g. to TAZs) by making areas more or less attractive for development based on a number of factors that include accessibility. Typically a set of allocation rules that work through GIS-based spatial datasets, these models can also help define the amount of growth that is induced, as well as distribute it but in such situations they must be used in careful combination with other tools. Planner and collaborative judgment are necessary in the creation of the rules and the evaluation and tweaking of the results.
- **Four Step Models** refer to the standard travel demand models that simulate travel behavior by generating, mode-splitting, distributing and assigning trips (the four steps) to a travel network. These computer-based models can provide very useful information for inferring land use change by accounting for changes in accessibility, and can even be used to allocate land use change by modifying interim model outputs and rerunning the model to explore the effects of indirect land use effects on transportation facility performance. While complex procedurally, the four step model process can be coordinated with and informed by any of the three foundational tools. Because of their widespread availability, our report includes detailed advice on using conventional models.
- **Integrated Transportation-Land Use Models** combine the interaction of land use and transportation in one seamless modeling process and would thus seem to be the ideal way to address indirect land use effects. Unless structured to do so, however, they will not necessarily provide this information adequately. Their extensive data needs and complexity (e.g., linked submodels) make them attractive where these resources exist and where the project warrants such an intensive effort. Our report provides only an overview of these tools and an examination of findings on its effectiveness on indirect land use effects.

The above listing constitutes a spectrum from less to more complex approaches. There is some correspondence in the application of the tools in this spectrum to the anticipated amount of change in land use, from few to many resources, from rural to urban contexts, and from innocuous to controversial projects. The overall process for indirect land use effect analyses we describe next is partly designed to help one choose the right tool for the job.

4.3 AN OVERALL FRAMEWORK FOR INDIRECT LAND USE FORECASTING

The reference point linking the overall indirect land use forecasting process with recommended approaches is **Figure 2.** The central stem of the diagram is grounded in the planner judgment approach, which most comprehensively covers the considerations needed in executing an indirect land use effects analysis. In essence, all analyses of indirect land-use effects require planning judgment: the question is really about how much data and analysis is going to be assembled to inform that judgment and how automated the process will be. Hence planning judgment is the backbone of our recommended approaches.

The approach outlined in **Figure 2** is organized around three primary decision points, (A – C on the diagram), corresponding to three sequential steps in any analysis – the overall extent of induced *travel,* the overall extent of indirect *land use change* that accounts for a portion of this travel, and the *location* of this land use change. (The fourth decision, on mitigation, is outside the scope of this report and is not always a part of the indirect land use effects exercise.)

The right hand side of the diagram lists four other approaches that we describe in detail in this chapter and the arrows between them are meant to suggest their potential for use in combination. Because access to an integrated transportation/land use model would provide such a separate and comprehensive analytical framework for indirect land use effects analysis, it is treated as a separate column down the left side of the diagram.

In the rest of this section, we walk the reader through the overall process/approaches flow chart in **Figure 2** (more details on the specific process to follow once a tool has been chosen is depicted in **Figure 4**).

Step 1: Prescreening

This is the initial assessment of how significant the amount of induced *travel* the transportation improvement is likely to generate. Acknowledging and accounting for the phenomenon of induced travel is essential to understanding and measuring possible indirect land-use effects. A simple conceptual diagram of these relationships is shown in **Figure 3**. Experiences show that expanding road capacity generates new trips (induced travel) which in turn increases peak travel times along affected corridors and erodes the new peak-time accessibility gains. This induced travel is not entirely attributable to land use changes: other, more immediate factors intervene such as mode shifts and peak contractions,[4] which serve to erode the accessibility gains that would contribute to increased longer term indirect land use effects. Thus, to properly account for the potential indirect land use effects and ensure they are not overstated, one must first net out the negative impact that other sources of induced travel have on a project's accessibility changes.

[4] Peak contracting is the opposite of peak spreading. With peak spreading, commuters, to avoid congestion, leave earlier or later for work and thereby "spread" out the timeframe for higher volumes of commuter traffic. With the added capacity and reduced congestion of a new improvement, drivers who had previously left earlier or later for work often respond by returning to traveling at the peak time (i.e. the peak volumes contract to a shorter timeframe).

Figure 2: Relationship of Various Approaches to the Forecasting Process for Indirect Land Use Effects

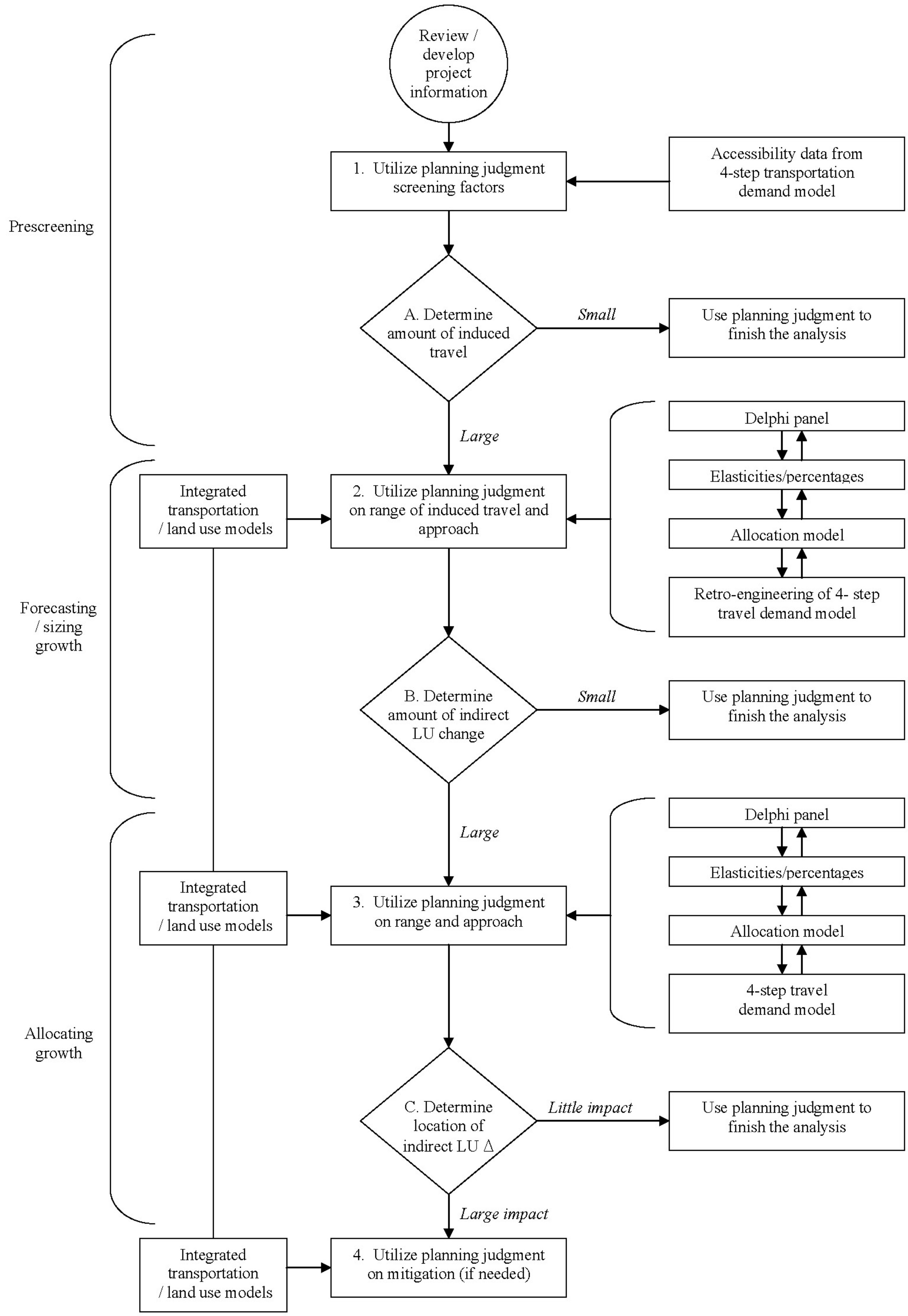
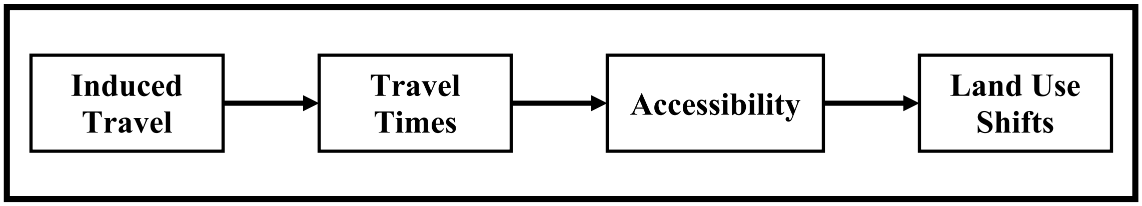


Figure 3: Induced Travel as a Precursor to Land Use Shifts



The importance of understanding the relationship between induced travel and indirect land use effects being noted, the following list summarizes the main factors that should be considered when prescreening for a project:

- Change in accessibility (or time travel impact) after accounting for other sources of induced travel
- Market strength of the study area (forecasts, land values)
- Development-related policies (current plans and zoning, key utilities availability)

If the extent of change in accessibility is not intuitively obvious, and if a four-step model is available for the project, the analyst might generate the accessibility indices for TAZs with and without the project. The outcome of this assessment (decision point A) is a judgment on whether the impact is likely to be large or small. If small, the analyst can proceed to complete the work following the guidance in the planning judgment section. If large, the analyst proceeds to quantify the induced travel impact using more robust forecasting approaches.

Step 2: Forecasting Indirect Land Use Change

This, of course, is the critical step. Here the choice of approach is made. To help in this effort, the Applications Matrix in **Table 2** relates the six tools highlighted in **Table 1** to the, extent of change, range of contexts, project complexity, and anticipated impacts on resources so as to provide guidance on the appropriate use of each tool.

The list of approaches moves from simple to complex. The simpler approaches apply to projects where the impacts are fairly obvious and minimal or where the resources to conduct more complex analysis are unavailable. The simple-to-complex range often correlates with a rural through urban geographic spectrum. On the other hand, "simple" projects that become controversial (because of cost, opposition, environmental sensitivity etc.); often shift to more complex approaches as additional resources to address them with more rigor are secured.

Readers can relate their own practical needs to **Table 2** to better understand the applicability of these various approaches. Even a cursory look at **Table 2** shows that planning judgment is the most widely applicable while integrated transportation-land use models are the least. Indeed the sequence of rows in **Table 2** more or less reflects the relative applicability of the various approaches. The first three are likely to be invoked frequently, often in combination, whereas the last three are more specialized and discretionary options.

Table 2: When and Where to Use Various Approaches for Indirect Land Use Effects Analyses

Approaches	Amount of Land Use Change Anticipated		Context			Project Complexity		Resources			Comments
	Little	Much	Rural	Sub-urban	Urban	Simple	Compl-ex / Contro-versial	Low Cost	Little Data	Little Staff	
Planning Judgment	●	●	●	◉	○	●	○	●	●	●	Provides guidance on entire process and default values for simple applications
Collaborative Judgment	○	●	○	●	◉	○	●	◉	◉	○	Structuring process correctly is critical; use in combination with other approaches
Elasticities	◉	●	◉	●	◉	●	◉	●	●	●	Useful parameters; use in combination with other approaches
Allocation Models	○	◉	◉	●	◉	◉	○	◉	○	○	Easy to construct but require careful testing and calibration
Four-Step Travel Models	○	●	○	●	◉	○	●	○	○	○	If model is available, then resources available will likely be high
Integrated Transportation-Land Use Models	○	◉	○	●	◉	○	●	○	○	○	Most costly, complex, and time-consuming method

● = Applies strongly ◉ = Applies somewhat ○ = Applies weakly

The diagram in **Figure 2** shows 5 basic options connected to this second step in the process but they can be combined. Remember that we have only determined a rough order of magnitude in prescreening. It must now be quantified. Most practitioners also find it necessary and valuable to solicit expert opinion whether or not other quantitative tools are used. While this may be in a less formal mode than the Delphi panel discussed in collaborative judgment, the informed review by objective experts of an allocation tool, or four step and integrated model outputs is necessary. Similarly, using the information from the elasticities section is always a useful check on the reasonableness of the extent of induced travel and indirect land use effects projected.

The most significant choice on quantification of induced travel is to go with an integrated transportation/land use model, a tool discussed in Section 4.4.6. If elected, this will become the primary vehicle also for the spatial allocation of the land use change. Only analysts with access to such preexisting models for their region should go this route given the daunting expenses, resources and time commitments of setting up such a model. The analyst should revisit the cautions in this section on ensuring that the preexisting model does or can readily simulate the feedback loop associated with indirect land use effects. Those that do not may significantly overstate the capacity available on the project – i.e. the new or improved highways - as much as by a factor of 2 (Rodier 2004).

Step 3: Allocating Growth

The relative amount of indirect land use effects, having been established in the previous step, the analyst is here concerned with what types of land use might go where. In simple contexts, guidance in the planning judgment section may suffice. The use of Delphi panels can be extended from only considering the amount to now include the type and location of indirect land use effects, informed by accessibility change data from a four step model, if available. Elasticity calculations, described in more detail later in this report, can be used to convert projected traffic volumes (expressed as Average Daily Trips or ADT) into land use by applying traffic generation factors to the various land uses that are anticipated to occur in response to the project.

If an integrated model is elected, it is not necessary to set up or run an allocation model. If there is a preexisting allocation model that has proved reliable, however, and the project is high profile or controversial or exceedingly complex and significant, the allocation model can be run as a check on the integrated model's results. The integrated model's use completely substitutes for retro-engineering a 4-step model as discussed in Section 4.4.5.3.

4.4 HOW TO USE THE SIX LAND USE FORECASTING TOOLS

Subsections 4.4.1 through 4.4.6 are the heart of this report, for they walk the reader through details of each of the six land use forecasting approaches summarized in Section 4.2. Each section includes an overview of the approach. Depending on the complexity of the approach, more upfront explanation of necessary concepts may be provided. Step-by-step guidance is also provided for each approach. Where the approaches do not lend themselves to a step-by-step description, we give more generalized guidance. We also provide information on the resources and inputs needed to execute the approach. A final subsection called Additional Information adds relevant caveats, generalizes the guidance, and often presents case studies.

4.4.1 Planning Judgment

4.4.1.1 Overview

Of the families of methods outlined previously in **Tables 1 and 2**, those relying on planning judgment are probably the simplest and quickest. They do not *require* huge amounts of data or specialized software, though they can incorporate what data and tools are available.

The name makes its fundamental analytical technique clear: planners (perhaps with the assistance of technical experts from other disciplines) make judgments about impacts, rather than having models provide estimates of those impacts. Those judgments are based on experience, on the professional literature (both theoretical and empirical), and on an assessment of local conditions (trends and forecasts). Most of the computations happen in simple tables and spreadsheets, not in transportation or land-use models or in *ad hoc* spatial models built on a GIS platform (we address these as a separate family of methods under the heading Allocation Models, below).

We do not make the assumption that by being less quantitative, the planning judgment method is uniformly inferior to those methods that have broader foundations in data and models. Our experience is that a well-reasoned line of logic, supported by back-of-the-envelope estimates of key causal variables, may produce more likely forecasts (and more understandable and defensible ones) than those based on modeling. Thus, methods based on planning judgment can be optimal in many circumstances. They can provide estimates as good (i.e., as likely to be true and defensible) as more sophisticated methods and can do so for less time and money.

We consider planning judgment as foundational, in large part because all the other families of methods build from some of the fundamental principles described in this section. Consequently this section on these principles is longer than the others in this chapter. This is the section that gives advice on how to think clearly about the analytical framework, definitions, and the evaluation process. Later sections on other families of methods assume that the foundational work described in this section will have already been done as part of any project analysis.

The methods in this family vary primarily in terms of the amount of time, data, and analysis that gets used prior to making the judgments. Before listing the techniques we think appropriate, we list one that is not. We list it for completeness and to establish one of the bookends on all the approaches described in this report. We call it **pure judgment**.

Pure judgment fails to meet the minimum requirements for public debate: planning decisions need written findings, findings must be defensible, and defensibility requires supporting logic and facts. A planner investigating indirect land use effects is unlikely to prevail by simply asserting that he or she knows what will happen. Some causal chain, with supporting theory or facts, needs to get written down and made available to public scrutiny. That process of writing a report with supporting evidence, by our definition, moves the analysis from pure judgment to defensible analyses stemming from one of the methods this guidebook describes.

The techniques described in the following section all couple planning judgment with a defensible story about impacts. That story must be written, usually in a technical memorandum or report, and it usually contains a simple description of driving factors and impacts (causes and effects, independent and dependent variables). The story is supported by theory, parameter estimates reported in other studies, local data sources, or anecdotal observation.

The following sections illustrate the key techniques for addressing two different but related needs: (1) how to identify the components of a causal model (driving factors and impacts) and (2) how to work from driving factors to estimates of impacts.

4.4.1.2 Techniques for Identifying Driving Factors (Causes) and Impacts (Effects)

1. **Experience of the analyst**. This is an obvious starting point, but will rarely be a self-sufficient approach since it provides no citation to authority.
2. **Collective experience of many analysts (expert opinion).** This technique may be sufficient in part because the experts will probably support their conclusions by reference to sources in points 3, 4, and 5 below and in part because the group process creates the appearance and, to some extent, reality of openness, impartiality, and correctness.

3. **What other reports have done.** Someone has been there before you: what did they do? Conferences, networks, and internet search engines make all those local efforts much more accessible than they were 15 years ago.
4. **Independent assessment of the professional literature.** Experts and reports of similar types of jurisdictions should be able to provide citations to key journal articles that can strengthen the theoretical foundations of the causal model.
5. **What guidebooks say.** In the best case, guidebooks would have used methods 1 – 4 to create a summary of best practices. If that were true—and especially if that were generally acknowledged as true by practitioners, planning agencies, stakeholders, and the courts—then a local government or planning agency could get quickly to a relatively solid and defensible model of cause and effect by using the recommendations from a guidebook. At a minimum, it would make sense to start with the guidebook and then modify the prescribed model to fit local conditions based on information gathered through any of techniques 1 through 4.

Specifying the causal model is the first step of an evaluation. The next step is to use the causal model in some way (if only as a reference for the selection of a subset of explanatory variables) to estimate impacts on land use of a transportation project. What is the range of techniques available to estimate impacts?

4.4.1.3 Bases for Estimating Effects

1. **Policy.** A term planners sometimes use is "plancast": the future will be this way because the plan says it will. If much analysis about demographic, market, and policy forces went into the plan, a plancast may be defensible as a most likely future under some specified set conditions. It may be, however, that the plan is more an aspiration than a likelihood. If policy is to be used for estimating impacts (either base case or with the proposed transportation project), then the analyst should go back to evaluate the basis for the forecast and make an assessment of likelihood (which, in a good plan, will be part of the plan itself).
2. **Historical patterns.** The first method, Policy, relieves a planner of part of the burden of forecasting, the forecast in the plan is just accepted as one possible future. But an alternative development forecast (with or without the transportation project) will require some other method or parameter specification. Historical patterns (trends in rates or growth, shares, amounts) are the most common of all forecasting methods and a good place to start: what happens if the future looks exactly like the past? Like the past but adjusted for the likely effects of expected changes in key driving factors?
3. **Interviews; expert judgment.** This technique suffers the same limitation of pure judgment: if experts justify their answers with just "Because I am an expert and I say so," their pronouncement is less compelling. More likely, however, is that experts will explain their expectations about future changes in development in terms of driving factors (causes). They will help an analyst create a story about likely effects. (Techniques for using experts and interested parties, especially in groups, are described in more detail in the approach after this one: collaborative judgment*.)*

4. **Rules of thumb.** There are many sources for these rules, but some sources are more reliable and defensible than others. An analyst should be careful of adopting a rule of thumb just because it is available. We have seen ample evidence of things used as rules, even in technical areas, that on further scrutiny had no basis in fact. Rules of thumb depend strongly on definition and context. For example, many planners will cite that transit needs an average density of X dwelling units per acre. Upon scrutiny, what does that mean, exactly? Most fundamentally: what type of acre (gross or net; residential or total) and over what area (an acre, a quarter mile, a corridor, a region)? And, do the type of dwelling units matter, or just density? And what about things not in either the numerator or the denominator like income: does the rule apply to average income areas, or does it assume that density is correlated with and capturing the effect of income? In short, dig into the definition and facts behind the rule of thumb and the implicit assumptions about when it applies.
5. **Independent assessment of the professional literature.** This task is a big one if started from scratch. In the internet world, however, few people really start from scratch any more. This guidebook summarizes some of the literature on impacts and gives citations to that literature. That door opens to many more.
6. **New empirical work.** This technique goes beyond what we have described as techniques based on planning judgment. This guidebook deals with them in subsequent sections.

4.4.1.4 Best Practices for Planning Judgment

Overview of the Method

The elements of the lists above overlap. One can imagine many combinations. A local government might work primarily with a method in some other analysis that passed muster with a state or federal agency (3), and do its estimates of impacts with a combination of plancast and historical trends (1 and 2). Or, a local government might work primarily from a guidebook for developing its list of causes and effects and its analytical structure (5), and may then estimate impacts based on a combination of all the techniques listed (1 through 5).

That latter method comes close to what we would describe as a "best practice" in the family of techniques called planning judgment. Relying on an earlier guidebook provides relatively quickly a logical causal structures and evaluation methods. By reviewing all of the sources listed above, this approach then fills in the typical and somewhat inevitable gaps in the specification of the magnitude of impacts. We will describe this approach in more detail in the rest of this section. A best practice method assumes that:

- A jurisdiction has the desire, capacity, budget, and schedule to allow it to conduct the steps as described. If not, it can start with the method we recommend in this section, but then do less research on documenting the magnitude of the impacts. The initial scoping steps are essential – clear project description, back-of-the-envelop estimates of project impacts on land use, sorting out the with- and without-project conditions and forecasts, coordinating without other parts of the analysis, and so on. If a jurisdiction or agency cannot commit to those steps, any further attempts to estimate indirect land-use impacts is no more than a *pro forma* pretense.

- A jurisdiction will not use any of the other methods described later in this guidebook. If it is going to use more sophisticated quantitative methods, then we recommend that it still work up at least some of the description of the logic of cause and effect contained in this section and then move to the descriptions of the relevant tools to be used to estimate impacts.

Applicability

The techniques described in this section are the most basic of all those described in this guidebook. They are suitable for any jurisdiction, but especially for those with these correlated characteristics:

- Smaller than a Metropolitan Planning Organization (less than 50,000 population)
- Rural
- Low (or even negative) growth rates expected
- Small staff; limited expertise with modeling or transportation economics
- No in-house travel demand model
- Small budgets; little discretionary funding.

The type of the project also makes a difference. Techniques using planning judgment will be more applicable as stand-alone techniques for projects that:

- Are not likely to be a big impact (because of size, type, design)
- Have little controversy or likelihood of extended public debate
- Have no requirement for an Environmental Impact Statement

We see no obvious reason to believe that one type of transportation improvement is more fit for evaluation by planning judgment than another; in other words, more to interchanges than widenings or more to arterials than collectors. That is *not* the same as saying that different types and sizes of projects will not have different impacts on land use; they will. Regardless, the method we describe below applies to any type of project to get a fix on the magnitude of those impacts.

Although the technique works for both the project evaluation and system planning modes, it is easier for judgment and intuition to work at the concrete project level. Moreover, the bigger the jurisdiction and the bigger the system, the more likely that travel-demand models are available, and the more likely that model-based methods from other families will be used.

4.4.1.5 Resources and Inputs

A significant advantage of the techniques in this family is that they make the least demands on local resources. They require little more technically than word-processing and spreadsheet software. Transportation planners with little background in land use can do the analysis credibly. The analysis can be done relatively quickly and cheaply yet is also scalable. The same steps that are used for relatively small-scale projects can be used to structure a much more intensive and expensive exercise that includes more data, analysis, coordination, and public outreach.

4.4.1.6 Step-by-Step

The steps in this section come from *A Guidebook for Evaluating the Indirect Land Use and Growth Impacts of Highway Improvements* (2001) prepared by ECONorthwest and Portland State University for the Oregon Department of Transportation. One of the author's of this NCHRP report was also the principal author of the ODOT guidebook.

Our claim is not that it is the best guidebook available on indirect land-use impacts of transportation projects, but with regard to "planning judgment," the ODOT guidance is certainly among the best.[5] It gives a logical description of cause and effect, as well as simple guidance on how to make reasonable judgments about impacts based on relatively sparse local data. Furthermore, two things about the content and organization of the ODOT guidance illustrate its emphasis on practical applications:

- It starts with a *framework* for thinking about impacts that includes a relatively detailed description of regulatory definitions, their problems, and guidance from the professional literature.
- It includes a sample analysis in two parts: the analyst's notebook (what data got collected, and what conclusions they led to) and the report that the resulted from that analysis. For a transportation planner assigned the task of writing the "indirect land-use impacts" section of an EIS, this detailed example could be very helpful. Practitioners are referred to the ODOT document for the full text of the example.

The rest of this section draws liberally from the ODOT guidance, which is funded by ODOT and the FHWA and available for free download online. It is a public document, so for ease of reading we dispense with extensive quotation marks and footnoting and simply note that almost all of the text that follows comes from that report with modifications to make the concepts more clear and generalizable.

Before Step 1—before starting any project evaluation—one should have a basic understanding of principles, definitions, and analytical options:

- **Principles.** There is substantial agreement that transportation improvements *can* directly or indirectly affect land development. The effects are well documented in the

[5] See also, *Guidance for Preparers of Growth-related, Indirect Impact Analyses* by Caltrans (2006)

literature of transportation, land use, and urban and regional economics. Because they provide better access to and effectively reduce the cost of a scarce resource – land, most transportation improvements will sooner or later affect land-use patterns (type, intensity, design). It is primarily the access improvements (measured, in large part, by a reduction in travel time) that create the incentives for land development. Nevertheless, transportation improvements can provide other amenities that contribute to livability and property value (e.g., walkable neighborhoods, main streets, open space and bike paths). It is worth noting here that the indirect land use effects on land development of many future transportation improvements will be smaller than previous improvements because (1) the network of highways in urban areas is now extensive, (2) the interstate system is largely completed, and (3) most highway projects predominantly provide improvements in safety and small improvements to overall travel time (and, thus, small improvements in accessibility).

- **Definitions.** Federal regulatory definitions are easier to state than to comply with in any technically rigorous way. *Direct land-use effects* occur in the short-run (usually during construction, as residences and businesses are displaced) and adjacent to transportation improvement. These impacts are typically covered in the right-of-way report of an EIS or EA. By definition, *indirect land-use effects* are the longer-run and wider-spread changes to development patterns and comprehensive plans that are *induced* by the transportation improvement.

  A big conceptual problem, rarely directly addressed in evaluation of indirect land use effects, is that indirect land use effects may already be measured, given the modeling and forecasting assumptions, as part of the direct effects analysis or during earlier project planning. Since (1) indirect land-use impacts are driven by changes in travel performance, (2) travel performance is typically estimated on larger projects using travel demand models, and (3) travel demand models require, as basic inputs, forecasts of population and employment for different alternatives, it will be difficult to describe indirect land use effects if population, employment, and travel demand forecasts have not been done for both "build" and "no-build" alternatives (actions). This issue is so important, in fact, that a first step for any analysis should be to find out the status of these forecasts; if they are not complete, do what is possible to move them forward, or to reschedule the evaluation of indirect land-use impacts until they are available, at least in draft form. Coordination and consistency with those other components of the evaluation is critical to the quality of the analysis of indirect land use effects and to the efficiency with which is it produced.

- **Analytical Options.** The analysis of *indirect* land-use impacts is intended to describe how land use will be different under at least two alternatives: one with the proposed transportation improvement, and one without it. An analysis typically looks at the past to be able to suggest more authoritatively what could happen in the future. There are two general categories of forecasting techniques:
  - Projection of a trend. One extrapolates from historical data by means that are mathematical (e.g., regression), graphic (e.g., trend lines), or descriptive (e.g., case studies). Projection need not mean that past trends are future trends: adjustments can be made for expected changes in demographics, market

conditions, or public policy. All of these techniques require the collection and evaluation of local data.

- o Reliance on the findings of other studies. One can get this type of information through a formal literature review, interviews of experts, and so on.

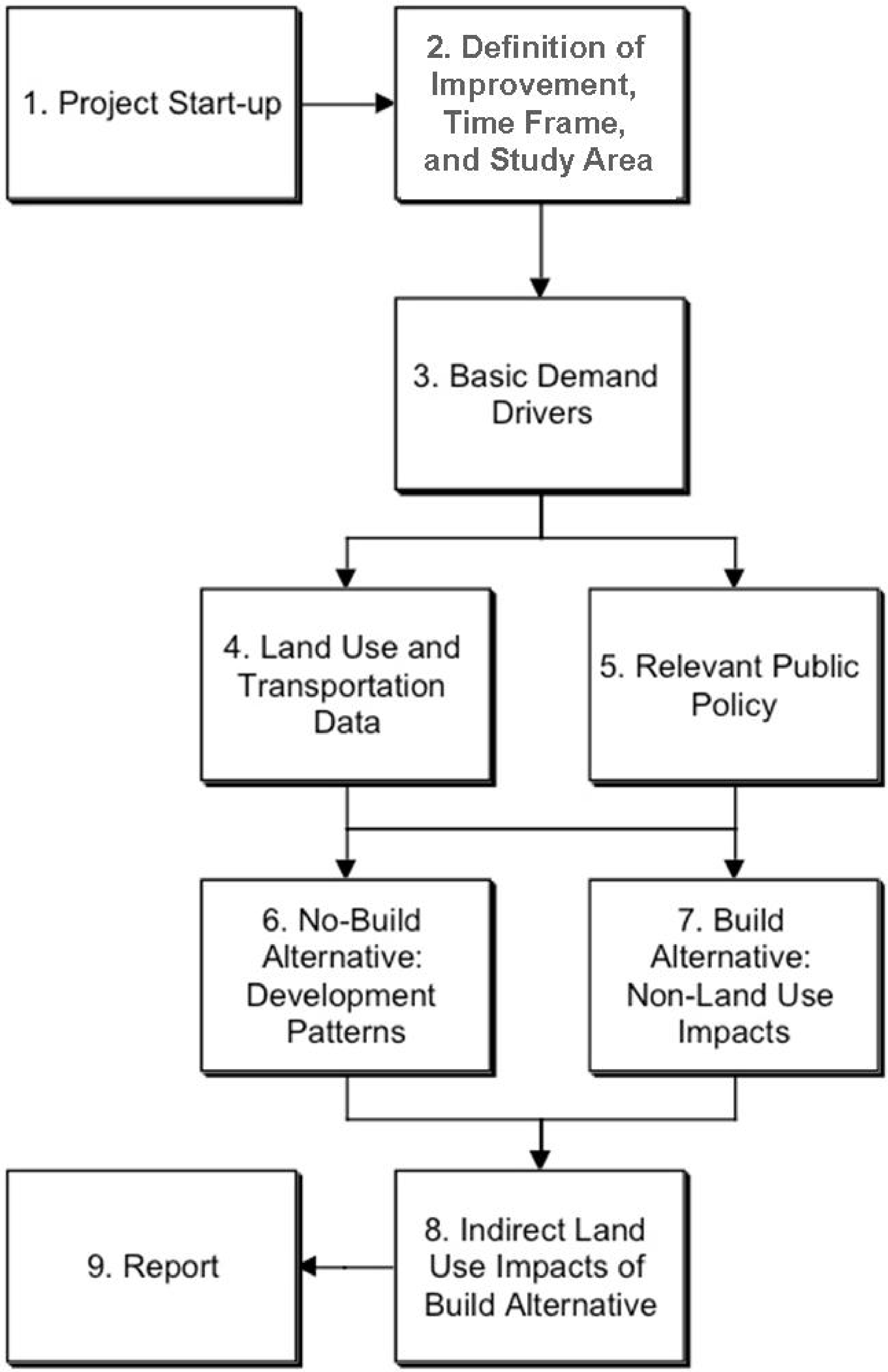
Figure 4 shows the steps recommended for a basic analysis that is ultimately grounded more in planning judgment than modeled output. Note that the steps below, especially steps 1 through 3, are one way to address the coordination and collaboration requirements of SAFETEA-LU sections 6001 and 6002. Steps 1-3 are, in essence, also the prescreening steps referenced in **Figure 2**.

Step 1: Get Integrated Into the Project Evaluation Early

If a transportation project is big enough to warrant a detailed evaluation of indirect land-use impacts, then it probably will require an EIS or EA. At the beginning of the environmental documentation phase of the project, an analyst should make a preliminary, qualitative assessment of the following questions: We recommend writing down the answers in a short memorandum (1–2 pages): that ensures the task gets done, sharpens the thinking, allows the ideas to be shared, and provides documentation. For a form to help with this task, see Appendix D of ECONorthwest and Portland State University (2001).

- **How big is the transportation improvement?** Size matters and can be measured in a number of ways (project cost, length, number of vehicles affected). The one that makes the most difference is aggregate change in travel time (travel time savings times number of vehicles).
- **How big are the potential indirect land-use impacts?** Their potential magnitude will depend on the size, type, configuration, and location of the transportation improvement, on market forces, and on pubic policy (land use plans and public facility capacity). For example, it is easy to see that a big highway expansion in a developed urban area has a greater potential for indirect land use effects than a signalization project at a rural crossroads where market forces and limited public facilities make such indirect land use effects unlikely.
- **Would the potential indirect land use effects be consistent with the local land use plan and policies?** If not, then (a) they are probably less likely to occur, and (b) if they do occur, they will have a greater impact. Even if the potential indirect land-use impacts are consistent with the plan at a general level (for example, the highway improvement reduces congestion somewhat, but the land use development that will occur in response to that improvement is the same type designated on the plan map—plan or zone changes are not likely), it may be that the improvement will have some effect on the rate of that development, or its design.

Figure 4: Recommended Evaluation Steps



Ultimately, whether to conduct an analysis of indirect land use effects, and the level of that analysis, is a judgment call. As a practical rule of thumb, if other procedures have already classified the project as one that requires an EA or EIS, then a good assumption is that there should be a section addressing land-use impacts, including the indirect ones.

Summary of Step 1

1. Review project prospectus; contact staff that prepared the prospectus.
2. If EIS or EA, meet with project team early in the process—preferably before or during the project scoping phase.
3. If one is not included with the project prospectus, develop a preliminary analysis of indirect land use effects.

Step 2: Define the Transportation Improvement, the Primary Study Area, and the Time Frame for the Indirect Land Use Effects Analysis

The definition of the improvement (the build alternative or alternatives) should come from elsewhere in the project: it is not the job of the land-use analyst to determine and explain why a particular transportation project has a reasonable chance of having benefits in excess of costs, and therefore, deserves more detailed evaluation. Justification for the improvement will usually relate to congestion relief, accident reduction, or system preservation.

The primary study area for indirect land use effects should be, in general, a function of travel time savings and travel volumes. The larger the improvement and travel time savings, the larger the primary study area.

For large projects on routes with a high percentage and amount of through trips, the area of impact could be much larger. Improvements at one point on a major corridor may allow travel-time savings to distant areas. Fortunately for the analysis, the *relative* improvement in travel time of any given project gets smaller the longer the trip length, so savings to distant travelers can be assumed to have little impact at distant locations. For example, a lane addition that reduces peak-hour travel time by two minutes is reducing the travel time for someone 30 miles (or 40 minutes of travel time) away by only about 5%, which is probably not enough to postulate measurable changes in development patterns at that distant location. While no research-based measure is available, in **Table 3** we provided some guidance on the magnitude of time savings and its relevance to indirect land use effects. Section 4.4.3 on elasticities provides more specific guidance that allows the analyst to move from indirect travel impacts to indirect land use effects.

As a practical matter, an analyst of indirect land use effects should consider accepting the primary study area as an approximation of the area of indirect land-use impacts. The advantages are (1) consistency (all impacts nominally have the same study area), and (2) leverage of data collected by other researchers working on the project for this area (so the analyst can save time and increase comparability). That said, however, there are good reasons why the impact areas for different impacts of concern will not be coterminous (e.g., for a new interchange, the impact areas for noise, water quality, and land use are likely to be different). Particularly if the primary study area was not established with indirect land use effects in mind, the analyst should not shy away from expanding the primary study area boundary despite the need for more data collection and analysis.

Since we relate indirect land use effects to induced travel and since recommended approaches (e.g. applying elasticities) and examples can pivot off projected traffic volumes, the question of the timeframe within which the indirect effect occurs is pertinent. Since traffic projections, particularly if modeled, may be 20 to 30 years in the future, the analyst should consciously think about whether this timeframe is the appropriate one for the analysis. We could find no guidance on this issue in the many guidebooks we reviewed. It is a tricky question. Clearly, very large projects can have foreseeable impacts for decades after construction, especially in strong markets and with supportive public policies. Conversely, smaller projects in weaker markets and without supportive public policies may see their land use effects play out within 5 years after construction of the improvement. In this report we follow the convention of using examples with 20 or 30 year travel projections (e.g. in Section 4.4.3.2 on applying elasticities). Analysts, however, must always consciously evaluate the appropriateness of the timeframe within which the indirect effects are forecast, apply it in their analysis, and explain this logic in their own reports.

Summary of Step 2

1. Review definition, need for project, project study area.
2. Conduct field visit/evaluation of proposed study area. A map with hand written annotations about existing land-use patterns is helpful.
3. Review preliminary traffic analysis. Pay close attention to travel time savings and changes in access. Larger travel time savings, new transportation corridors, and significant amounts of vacant land within 1/2 to one mile of the project suggest a larger study area for indirect land use effects.
4. Establish a time-frame for the analysis paying close attention to market demand, other infrastructure, and public policy.

Step 3: Get Agreement on the Basic Demand Drivers (i.e., the Population and Employment Forecasts):

Land use and transportation planning is driven by population and employment forecasts. The description of population and employment forecasts can end up located in different parts of a project evaluation: under their own headings, or as part of traffic, land use, or socioeconomics. The forecasts may be derived from: (1) official forecasts, often by the state or MPO and disaggregated to local government boundaries (e.g., counties); (2) forecasts in a local comprehensive plan usually at the jurisdictional level but perhaps also for large sub-areas; and (3) forecasts in the traffic model disaggregated to smaller areas such as TAZs. Ideally, all these forecasts should be the same.

If forecasts differ significantly for the total study area level or jurisdictional level, the analyst must drill down to uncover the reasons behind these differences and validate the initial forecasts being used. We insert the word "initial" here since of key importance is the determination of whether the project is large enough to warrant different forecasts of population and employment for the no-build and build alternatives. As noted elsewhere in this section, getting clear on this point is essential; lack of clarity leads to sloppy analysis. If a transportation improvement is not big enough to cause technical professionals (land use and transportation planners, economists, demographers) to believe that there will be a measurable difference in the amount of population and employment by TAZ, then the case for indirect land-use impacts is weak. Interviews must be conducted with these professionals to ensure the issue of different forecasts has been consciously considered rather than simply ignored. Because no empirical method exists to make this determination, the analysis must rely on professional judgment.

The documentation of forecasts is typically poor, which makes it hard to determine whether they already include as *direct* impacts, either implicitly or explicitly, what might otherwise be double-counted as *indirect* land-use impacts. The forecasts of population and employment are driven primarily by assumptions about the continuation of, or changes in, demographic and economic trends. They usually give some consideration to existing land use, land use plans, and public facility constraints and planned expansions, especially for transportation. It is often difficult to determine the extent to which the base forecasts have already considered indirect or cumulative impacts. If an analyst believes that a build alternative will cause indirect land use effects, the analyst should address whether those impacts suggest that population, employment, and traffic forecasts for the build alternatives should be different from the forecasts for the no-build alternative.

Moreover, the analyst must be clear about the grain of the analysis: what is the size of the sub-area for which population and growth are being forecast? It is generally accepted by urban economists and federal transportation agency staff that most new transportation projects will not have measurable impacts on the overall regional, as defined by MSAs, economy. The argument is that (1) the new projects are usually a miniscule part of the regional transportation capacity, and (2) if transportation problems constrain growth in one part of a metropolitan area, that growth will occur in another part of the same region that has fewer constraints. The larger the region, the stronger the argument. In dense conurbations where regions abut each other and where the transportation projects are major in scale (e.g. 20 mile or more radial interstate improvements) particular care must be taken with control totals. If, for example, such major improvements are *between* regions (as defined, for example, by MSAs) then some redistribution between them could be considered.

If the population and employment forecasts are being done for a large area (e.g., metropolitan area or large city), then the analyst has the flexibility to argue that the project may contribute to redistribution of population and employment at a finer grain (without changing the overall regional forecasts), and that such a shift would be consistent with a finding of potential indirect land-use impacts (i.e., development patterns could be different if the improvement is built). But if the forecasts of population and employment are at the relatively fine grain of a Transportation Analysis Zone (TAZ) typical of urban transportation models, then it is harder to argue (but not impossible, as the following paragraphs describe) that redistribution within the TAZ will occur and result in indirect land-use impacts.

The advice here is to make sure that any evaluation of indirect land-use impacts is clear about what assumptions were made in the original forecasting of traffic volumes as related to population and employment, including assumptions about changes in land use plans or development patterns. Even if there is only a single forecast of population and employment for all alternatives at the sub-area level (e.g., TAZ), there may still be variation in the distribution of population and employment, and the details of land use and design, in each sub-area.

Even though change in transportation system performance is the key way that transportation improvements affect land use, at a small scale both highway design and the ancillary improvements that accompany it (parking, auto access via turn lanes and curb cuts, bike paths, pedestrian access, signage) can contribute to changes in development patterns and the rate of development. Thus, a description of indirect land-use impacts should include a description of those effects.

Step 6 discusses a related point about whether the base population and employment forecasts assume a future transportation system that includes the proposed transportation improvement.

Our strong recommendation: *the analyst should spend some time early in the study trying to identify the sources of the population and employment forecasts, how they were done, and what assumptions about land use and future transportation capacity and improvements are embedded in them.* That effort may pay off in Steps 6, 7, and 8, and may provide logic and internal consistency to the land-use analysis.

Summary of Step 3

1. Obtain official long-range county population and employment forecasts.
2. Obtain the relevant jurisdictional coordinated forecasts.
3. Obtain sub-area population and employment allocations (TAZ level). If no sub-area allocations will be developed for the project, contact the jurisdiction's transportation department.
4. Review all available methodological materials for the forecasts. If not available, or if the available materials are too general, identify the individual(s) who are most familiar with the forecasts and conduct personal interviews.
5. Make and document a decision about the appropriate use and level of geography of population and employment forecasts.

Step 4: Gather and Organize Data about Land Use and Transportation in the Study Area

Once the primary study area for indirect land use effects is defined, the analyst needs to gather data. Step 4 is about technical information; Step 5 addresses policy information.

Here, as elsewhere, there is overlap among steps. Step 4 focuses on data that an analyst would get from all sources *prior* to the draft technical reports that the project might generate. For example, the analyst would get basic transportation information from a city, county, or regional transportation system plan or comprehensive plan in this step. Think of Steps 4 and 5 as ones for getting the base data together, and Step 7 as one for doing a final pass at data and forecasts before doing the evaluation in Step 8.

There are several ways to organize a data list (the data sources needed to complete the analysis): by type (e.g., maps, photos, electronic files), by source (e.g., city, service district, state agency), or by topic (e.g., land use, public facilities, transportation). The organization here is by topic; we describe the types and sources of the data as a subset of each topic.

The focus of the analysis we are describing is on impacts to *land use* that are *indirect*. Most of the information listed below will need to be gathered by analysts responsible for *direct, non-land-use* impacts. On a large project, that means that an analyst may be getting most of the information below from secondary sources such as drafts of other technical reports or from other analysts (who will share raw information they have collected in advance of their draft technical report). A single analyst may be responsible for both the direct and indirect land-use impacts, or for other topical areas: in that case, the tasks of data collection are as follows:

- **Development capacity (from a local buildable land analysis).** An obvious starting point for any evaluation of land use or transportation planning is a base map. The analyst should be able to get this from others in the project. Property boundaries are useful. If necessary or possible, land capacity data can be supplemented with data being collected from the environmental analysis. The analysis should include a description of physical constraints (e.g., rivers, hillsides, and other physical barriers to development). Data on buildable land should be for an area larger than the primary study area because part of the concern about indirect land use effects is that new development will shift to areas around the new project from areas elsewhere. If a separate right-of-way analysis is being conducted, coordinate with the person doing it: he or she should have detailed maps regarding direct ROW impacts on land use.
- **Development history; development trends.** This information can help make a judgment about the demand for land and buildings, and the likely land-use changes under the no-build alternative. Information should try to include (1) a description of historical (last 5-10 years) development trends (primarily from building permits, by type and size; assessment data; and secondarily from interviews); and (2) a conversion of population and employment forecasts to demand for land by type. The analyst should first review the jurisdiction's buildable lands analysis (if one exists) and apply methods consistent with that study.
- If the data are not complete, primary data collection should be attempted if time and budget allow. This could occur through review of assessment records, GIS databases, building permit data, aerial photos, or field visits.
- The use of secondary data could (and probably should) be supplemented by interviews or focus groups with local planners and real estate experts: some of this information is provided in the case studies within the ODOT report.
- **Development forecasts.** It may be the case that a forecast of future development patterns for the study area has already been completed. In states with strong local planning programs, the local comprehensive plan may be exactly that forecast of

future development. As noted earlier, there is no substitute that we can see for an evaluation of the assumptions and quality of the local forecasts.

- **Transportation.** The information about transportation in the study area should be available from a number of sources: directly from a local transportation system plan or regional transportation plan; indirectly from a state DOT or an MPO; and, most directly, from other members of the evaluation team who have collected information on existing and forecast future transportation conditions. Any recent environmental documents should be reviewed to identify whether or not traffic volume forecasts differ for build and no-build alternatives. For many projects, this may be difficult to determine because travel patterns could change with the action alternative (e.g., with a bypass). A widening project may be the easiest type of project for a comparison of traffic volumes under a build and no-build alternative. For many projects, forecast volumes will be the same for the build and no-build alternatives. If multiple new projects are slated within the project area or beyond, care must be taken to incorporate them properly into the accessibility calculations for the cumulative impacts analysis rather than into the indirect effects analysis.
- **Other public facilities.** In most cases transportation improvements alone do not induce a lot of growth by themselves: other public facilities (especially sewer, water, and other utilities) must also be available at a reasonable cost. Look at local public facilities and capital improvement plans. In the absence of any of these documents, a jurisdiction should have maps of facilities and lines.

Data on other development issues may also be useful for this step. The main issues are environmental constraints, most of which will already be covered at some level in the buildable lands analysis. Other issues could be second-order socioeconomic impacts or impacts to specific populations (for example, impacts on persons with disabilities). Many of these impacts will be considered in other technical reports.

Summary of Step 4

1. Gather and review relevant plans and policy documents. At a minimum, these should include comprehensive land use plans and transportation system plans. Note that Step 4 occurs in parallel with, and overlaps, Step 5: both involve gathering data, and many of the source documents will be the same for both Steps.
2. Work with the local jurisdiction to obtain and analyze geographic information system (GIS) data. Of particular interest are maps and tabular summaries in the study area showing:
    - Land-use patterns
    - Vacant lands
    - Location of building permits issued in the past 10 years
3. Review the local land use capacity analysis, if one exists. If a capacity analysis does not exist, use a back-of-the-envelope technique. If no base data exist, useful rules of

thumb can be found in *Planner's Estimating Guide: Projecting Land Use and Facility Needs* (Nelson 2004).

4. If possible, make estimates of development capacity in the study area. Interviews or a focus group with local realtors, developers, and bankers can help in understanding the development climate, particularly for redevelopment.
5. Evaluate the data in the context of the proposed improvement and the boundaries of the study area identified for indirect land-use impacts in Step 2. Make adjustments to the study area boundaries if necessary.

Step 5: Gather Data About Public Policy, Primarily About Land Use and Public Facilities:

A key element of this analysis is a review of the local comprehensive land use plan and any related documents. These documents should provide a general indication of what land-use patterns are desired in the study area, what density or intensity of uses are expected, and what types of land use are allowed. Some plans will be explicit on land-use patterns that are not desired. An analyst should look at existing services, Capital Improvement Programs (CIPs), and service extension policies.

The review should include an evaluation of plans and policies regarding the following topics. As in Step 4, for a larger project, a lot of this information should already be assembled by other analysts working on the project:

- Sewer (availability and capacity)
- Water (availability and capacity)
- Other utilities (e.g., electricity, telecommunications, etc)
- Zoning/comp plan designations in the study and project area
- Vacant land and its zoning/designations/services (water, sewer, and others) in the study area
- Location of city limits and urban growth boundaries in the larger region
- Land capacity and estimated year of buildout (i.e., when buildable land is developed) under current policies and growth forecasts
- Recent and anticipated economic growth in the study area and larger region
- Recent and anticipated land development in the study area and larger region
- Recent and anticipated land development along other highways/major arterials in the larger region
- Recent and anticipated transportation improvements in the study area and larger region

The last four of these at least partly fall under the category of *cumulative effects*, but are important for understanding indirect land use effects too. In writing the assessment of impacts, analysts will need to at least partly separate indirect from cumulative impacts. In some cases they may be able to discuss them together under one heading.

Summary of Step 5

1. Gather and evaluate other policy documents not described in Step 4: capital improvement programs, long-range water and sewer master plans, regional transportation plans, economic development plans, and any other relevant documents.
2. Look for factors that will potentially encourage or constrain future development in the study area.

Step 6: Describe Likely Development Patterns in the Absence of the Improvement

It is typical for the analyst in charge of indirect land-use impacts to also be the one in charge of direct land-use impacts. Thus, the rest of this section describes general procedures for describing the no-build development pattern: the analyst of indirect land use effects may be able to simply refer to other studies, or may have to conduct some or all of the following analysis. The key variables that go into such an assessment should be described in the various planning documents: population, employment, and land availability are the most important factors. Accessibility and availability of public facilities are other important factors.

The more difficult transportation and land-use issues should be addressed in the jurisdiction's Long Range Transportation Plan (LRTP) or Transportation Improvement Plan (TIP), assuming one exists. The LRTP or TIP should consider the relationship between land use and transportation. The population and employment allocations used for the transportation modeling that is included with all LRTPs or TIPs should reflect the jurisdiction's best judgments about how land use and transportation will interact at the community or regional level.

For the no-build alternative the analysis uses the data collected in the previous steps to make an assessment of the kind of development which could occur in the study area if the improvement is not built. In general, the presumption in states with good local planning should be that the development would be roughly consistent with the comprehensive plan and other relevant policies, but this does not have to be the case. For example, if the plan calls for the development of an area with no arterial access and the proposed transportation improvement provides that arterial access, then one can reasonably argue that the no-build is inconsistent with the plan, or at least less consistent than the build alternative.

A key judgment that the analyst must make is whether the forecasted development pattern (as embodied in the comprehensive plan or some other planning document) assumes that the highway improvement will be built or not. In some cases, like a new bypass, the answer will be clear: the bypass is either in the plan or it is not. For others, judgment is required. For example, if a 20-year plan assumes that a collector street will become an arterial, and the proposed improvement is to expand the capacity of that collector, then one can reasonably argue that the improvement is already in the plan, and that the effect of no-build will be *less* consistent with the plan than the build alternative. It may mean that the description of the no-build alternative calls for an adjustment to the map, tables, and text of the comprehensive plan: in other words, without the proposed project, the future land use pattern is *different from* the pattern assumed in the comprehensive plan. In a case such as this, the plan provides the *build* forecast and the forecast for indirect land use effects needs to be subtracted from this total to obtain the *no-build* forecast: the reverse of a "typical" analysis. We cannot say this enough for our comfort: these fundamental issues about what assumptions, implicit or explicit, are in the forecast, must be made clear and are the foundation for any credible description of indirect land-use impacts.

How to treat the comprehensive plan is problematic. The analyst can either accept or reject the plan as a base-line depiction of future land-use patterns. The argument for acceptance is both technical and political. It will almost certainly be the case (at least for any city of over 10,000 people) that the comprehensive planning process that created the forecast of future land-use patterns will have been much more extensive than the evaluation the analyst can do as part of a project evaluation.

An analyst, following the steps described here may find that the future land-use pattern in the comprehensive plan was inconsistent with its own assumptions. That inconsistency might be purposeful (e.g., a city is using the plan as a guide for what it *wants* to achieve, not what it *expects* to achieve) or inadvertent. In either case, the analyst is in the position of having to say, for at least some sub-area covered by the comprehensive plan, that the plan may *not be the best description of the most likely future development pattern.* Strong evidence must be available if the analyst intends to make this case.

Consider an example. Suppose that (1) a city land-use plan implies by plan designation that an area within the city limits will develop residentially; (2) its LRTP or TIP shows an improvement of a collector to an arterial serving the residential area, and an improved freeway interchange where commercial zoning and development already exists; and (3) the transportation project being proposed and evaluated is that collector improvement. The land-use analyst looks at this configuration and decides that in cases like this one some of that vacant residential land may end up developing commercially. The analyst's options are:

- Accept the plan as the basic land use pattern for the build alternative. The underlying assumptions would be that (1) the plan and implementing zoning will remain unchanged despite possible market pressures for such change that the access improvements would contribute to, and (2) the plan has considered those pressures. In that case, the plan already includes any indirect land use effects—with the exception of those consistent with zoning that might occur faster with improvements than without them.
- Assume that the plan has not considered that the project could increase the probability for land-use change, and that indirect land use effects must still be described. This choice has some political problems. It implies that the transportation plan—which already includes the transportation improvements being proposed—either (1) is more of a vision to inspire than a prediction of what will occur, or (2) did not adequately evaluate future land-use patterns in the context of future transportation improvements. The analyst, however, needs to know more about other factors before reaching this conclusion or making this assertion.

The first choice means that the land-use impacts of the build alternative are already described in the plan, and that the analyst must generate a clean <u>no-build alternative</u> to determine what, if anything, the market would develop under the given zoning but absent the planned improvement. The difference between these two land use patterns would constitute the indirect land use effects of the improvement. The second choice could create some friction with local governments, but is the more common one: most EISs and EAs assume that indirect land use effects are something created by the build alternative and are not already envisioned in the land use pattern of the comprehensive plan; they then describe how the indirect land use effects would increase the probability of land-use change under the build alternative(s).

The previous point may seem fussy, but ignoring its points means risking some logical inconsistencies in the analysis. Here is the logic:

- In concept, the proposed improvement has either been envisioned in the plan or it has not.
- If the plan makes no mention of the improvement in maps or text—either explicitly or implicitly (by showing, for example, that the street classification for the street with the proposed improvement has been upgraded to the level implied by the improvement)—then the official local development forecast (as reflected in the plan, plan map, or technical reports that support the plan) is a first approximation of the no-build development pattern. Moreover, the plan should likely be amended before the project is built.
- If, however, the opposite is true—i.e., the plan does assume, explicitly or implicitly, that the improvement will be made—then the official local development forecast *must be adjusted* to account for the no-build assumption that the improvement will not be built.
- In either case, the analyst has the option of saying that the analysis on which the planned land use pattern is based is either wrong or not detailed enough to capture the project impacts. That conclusion leads to the need for the kinds of adjustments in the prior bullet point.
- Whichever way the no-build alternative is analyzed in this step, the build alternative in Step 8 gets decided in the opposite way (i.e. the evaluation of indirect land use effects is either additive or negative, depending on whether the project, and its indirect land use effects are included in the local comprehensive land use plan). That logic leads to a consistent evaluation framework: here is the development pattern *without* the improvement; here is the development pattern *with* the project. The difference between these two measurements is the indirect land-use impact.

The details of forecasting techniques for describing how development and land use will play out over a 20-year period are beyond the scope of this report. Large cities (50,000 or more) are also in MPOs, which have ample experience with 20-year planning.

As in Step 3, our recommendation here is for the analyst to be clear and consistent about assumptions. The land-use analyst must understand the data and assumptions the traffic analyst has used regarding future land development and growth (assumptions about the comprehensive plan, zoning, vacant lands, service capacity, and so on), and how the traffic analyst has incorporated these data and assumptions into forecasts. The analyst may find things that the traffic analyst has overlooked or misinterpreted, and may help the traffic analyst make more realistic assumptions based on what is or is not in the comprehensive plan and LRTP/TIP. Discussion of these issues among project analysts may lead to a revised, more realistic forecast for both the no-build and build alternatives.

Summary of Step 6

1. Carefully review the local land use plan, LRTP/TIP, and CIP to determine if the proposed transportation project is included in any or all of the plans.
2. If the plan(s) include the project, determine whether the plan explicitly considered the project in its population and employment forecasts and future development patterns. It may be useful to talk to staff that assisted in the preparation of the plans.
3. Make a determination of whether the development patterns envisioned in the plan include indirect land use effects of the project. If so, then the plan envisions a future that includes and may require the build alternative. In that situation, it is more logical to assume that the no-build alternative will cause land use development to be *less* than what the plan envisioned than to think that the build alternative will cause the land development to be *greater* than what the plan envisioned. Development may occur more slowly or in different areas under the no-build alternative.
4. If the plan(s) are ambiguous, it is probably more likely that they did not include the project's indirect land use effects in their description of future development patterns.

Step 7: Summarize From Other Project Analyses the Relevant "Other" Impacts of the Improvement

Steps 4 and 5 focus on data that an analyst would get from all sources prior to the draft technical reports that the project might generate. Think of those steps as ones for getting the base data together, and Step 7 as one for doing a final pass at data and forecasts before doing the evaluation in Step 8.

By "relevant other impacts" we mean all impacts that influence the estimate of *indirect land-use impacts*, but are not themselves indirect land-use impacts. The logic here is solid and consistent with definitions promulgated by CEQ and adopted in this report: *indirect land use effects are caused by direct impacts, typically happen after direct impacts, and (logically) cannot and should not be estimated until direct impacts have been estimated.* It makes no sense, for example, to estimate the indirect land-use impacts without knowing what direct land-use impacts would occur under each alternative. Similarly, at least provisional estimates of population, employment, and travel impacts must be available to the land-use analyst. The same is true, to a lesser extent, for certain socioeconomic and environmental conditions and direct impacts.

Despite the logic of this sequencing, it is common for project analysts to try to do many things at once, often in response to the pressure of deadlines. An analyst may find that the description of indirect land use effects is due at the same time as all other impact reports. The only way that can occur and be defensible technically is for the analyst to work with others on the project to get raw data and assessments for the factors of relevance to forecasting indirect land-use impacts. We divide those impacts into two main categories: travel and other.

Travel

The analysis in Step 6 should clarify whether changes in transportation system performance are already (at least implicitly) in the local plan for future development (because the transportation improvement has been presumed as part of the plan—if the project is not in the plan then the plan probably needs to be amended before the project can be built). The analyst must consistently apply the decision made in Step 6. The transportation forecasts need to be consistent with that decision. Ideally the analyst would be given two sets of travel performance estimates: one reflects a system without the improvement, one with the improvement. The reality in many cases will be that, because future development patterns are assumed to be the same with the no-build as with the build alternatives, there is only one set of forecasts.

If modeled results are available, the analysis should describe the change in travel time (relative to the no-build alternative) in the aggregate, by sub-area, and as a percent of average trip time. Note that travel time benefits are only one criterion, and may not be the most important one, for some projects. If no model was used, then the analysis should use expert opinion (project planners and engineers have to have some idea of what the project benefits will be or a Delphi panel process can be invoked-see Section 4.4.2) to draw conclusions about the magnitude (absolute and relative) of changes in system performance. For example, even without a model it is likely that the transportation planners proposing the project will have some estimate about changes in mobility (i.e. speed of movement, defined as the facility's actual traffic volume divided by its theoretical capacity - v/c ratio – that is used to establish the familiar Level Of Service ratings) that are expected with and without the project. Modeled results should be available in all metropolitan areas large enough to be designated MPOs (50,000 people); in rural areas, states may have some applicable models, but probably not adequate for neighborhood-level evaluation of land-use impacts.

In theory, a measurement of aggregate change in travel time should capture a lot of the benefits of a change in access: all other factors being equal, travel time will change with a change in access (a new road, interchange, curb, or barrier). In practice, these changes may be small when measured by a model, or difficult to estimate with much precision if no model is available. For example, differences in the number of curb cuts will be below the scale of evaluation of a typical travel-demand model, but can be very important to individual property owners. Thus, localized access issues should be considered in addition to more aggregated measures of changes in travel time. Moreover, safety is a critical issue with curb cuts and related changes in access.

Travel time and traffic volumes (and perceived/real economic impact) are key transportation measures for estimating impacts on residential development, as well as commercial development. Retailers want to know about visibility: how many people will go by their stores. Larger volumes that result from highway improvements could support an increase of demand and prices bid for retail properties along a corridor, which in turn contributes to the potential for land-use changes. Key questions are whether (1) that potential is sufficient to cause property owners and developers to build faster and differently than they would have, and (2) whether the comprehensive plan would have to be changed in any significant way (e.g. zoning, comprehensive plan designations, city limits, UGBs) to allow that change in development.

In summary, the key transportation variables of interest for the land-use analyst are change in travel time (per average trip, or by trip type if available), traffic volumes, and mobility.

In the rare case of an extreme increase in accidents, improvements in safety may also affect land-use patterns. Because such cases are probably rare, and because improvements in safety may in some cases be included with changes in travel time as a project objective, the land-use analyst can probably ignore safety: its indirect land use effects on land use will usually be minimal. Safety, however, is frequently a major objective of some types of access management projects.

Other

The two principal "other" reports that are relevant to the land use analysis are the Socioeconomic report and the Right-of-Way (ROW) report of a typical environmental assessment. The Socioeconomic report should provide information about future household characteristics, which may suggest something about future land uses. The ROW report, however, will almost certainly have pertinent information. It should show direct land acquisitions, displacement of businesses, partial takings, changes in access, and assessed value. It will show the direct impacts, from which the land-use analyst can begin to infer the longer run, indirect land-use impacts.

The various Environmental reports are probably less useful for analysis of indirect land-use impacts in practice than they are in theory. They might be more useful if they showed constraints on land development, but (1) a city or county's buildable land analysis (Step 4) may already do that, and (2) the constraints they identify are normally limited to the alignment (though if indirect and cumulative environmental impacts are considered, then a wider area may be evaluated).

In summary, the advice here is to look at the summaries of direct and indirect effects that other discipline specialists on the project are generating, and identify if the impacts described therein could have indirect land use effects.

Summary of Step 7

1. Meet with staff working on the other technical reports early in the project. Consider scheduling the indirect land use analysis at a point in the project when data and analysis from the other relevant technical reports are available, at least in draft form.
2. Obtain drafts of the transportation, right-of-way, and other relevant technical reports as soon as they become available.
3. Incorporate relevant elements of the various technical reports into the indirect land use impact analysis.

Step 8: Describe and Estimate the Indirect Land-Use Effects of the Improvement

Steps 2–5 give the analyst base information. In Step 6 the analyst describes the development pattern under the assumption that the proposed transportation project is not built. In Step 7 the analyst assembles all the information about how the proposed projects could change factors related to land use. Now, in Step 8, the analyst uses all this information to describe how land use and development patterns could differ from the no-build (or build if the analyst will argue the plan's patterns already include the project) description if the project is built. That difference will include some direct land-use impacts (e.g., right-of-way acquisition) that may contribute to, but must be kept separate from, the indirect land-use impacts. Here is where the analyst would use elasticity parameters gleaned from Chapter 4.4.3 to gauge the extent of possible change in land use. Step 8 has three sub-steps:

8a. Describe the expected change in development patterns, or the factors contributing to the potential for that change to occur.

8b. Make a judgment about whether those changes are consistent with the future envisioned by the comprehensive plan.

8c. Discuss how those impacts could be mitigated, and what assumptions about mitigation are embedded in the description of the future development pattern.

<u>Step 8a: Address the Issue of Increased Potential of Land-Use Change</u>

This step should correlate the expected changes in key driving factors that influence development patterns to the magnitude of those changes. Remember the logic: (1) What does the transportation project do to highway performance (accessibility, travel-time, volume, mobility, and safety) that is different from what that performance would be without it? (2) How do those changes in travel performance (induced travel) influence factors that help shape development patterns? (3) What other factors influence development patterns? (4) What factors have already been considered, implicitly or explicitly, in the forecasts and estimates of direct impacts? (5) Given (a) the possible changes in development patterns and other factors, (b) the expected magnitudes of those changes, and (c) the relative importance of those changes, what is the qualitative assessment of the indirect land-use impacts of the project?

The land use reports for most EISs we have reviewed talk about a transportation project increasing the potential for land-use change. The *potential* of land-use change has become a term of art: it is meant to convey that land-use change becomes somewhat more likely, but that it is in no way inevitable. The uncertainty about the change results from the complexity of land markets and land development (which is affected by multiple factors), and the fact that public policy can have a strong effect (or not) on development. That potential may eventually manifest itself as more growth than forecasted, higher density than forecasted, or a change in land use.

For example, suppose a state highway is widened at the urban fringe, that the city's long-run plan is to protect the area as environmentally sensitive open space, and that the city's capital improvement program is directed toward other locations in the city. The improvement probably contributes to *potential* for land-use change. But that potential can be resisted by public policy. Despite the potential, the land along the new highway might stay undeveloped if the city follows its policy. Alternatively, political pressures might result in a policy change.

An analyst trying to move beyond a generic finding of "potential" to a specific finding of land-use change is on a slippery slope. It could require, for example, making a finding that a city, despite policies that direct future development to other areas, will not be able to stick with those policies; that it will succumb to the petitions of property owners and developers who want use of the new transportation capacity. That example explains why most EISs limit their discussion to potential for change, and possible futures. However, it should be the analyst's goal to move beyond "potential" to at least specifying the probability of specific outcomes.

The analyst must also be clear about what "change in land use" means. Is it a change from existing use? From the uses specified in the comprehensive plan? From some other description of expected change? The correct answer has, in our opinion, two parts: How does the land-use change from (1) what is expected to occur under the no-build alternative, at all time periods? and (2) from what the plan says is the desired future land use? These two may overlap substantially or completely.

The previous point is a reminder of the importance in Step 8 of referring back to assumptions in Steps 3 and 6. In particular, do the population, employment, and land use forecasts presume, even if only implicitly, the construction of the transportation improvement that is the subject of this study? If so, then the build alternatives probably already include indirect land-use impacts, and the job of the analyst is to show how land use would be different under the no-build alternative. Step 6 described this process in more detail.

The key variables that might contribute to measurable changes in local development patterns in response to a transportation improvement are:

- **Change in accessibility.** This is typically the most important variable. Step 7 explains the key measures: average trip time, volumes, and mobility (v/c). For more detail, an analyst could report a matrix of changes in trip time for different origin-destination pairs (if the data are available).
- **Change in property value.** If information about travel times is hard to come by, the land-use analyst may be able to get local experts to comment on likely changes in land prices—i.e., to implicitly make some assumptions about changes in travel performance and then make a judgment about implications for development. Such estimates are a double-count of the potential created by the travel improvement (it is the improved accessibility of the transportation improvement that makes land more valuable, and creates potential for it to be used more intensively).
- **Expected growth.** If the forecast were for no population and employment growth for a city, then the analyst should consider expected sub-area growth: it is possible for a city to have a low growth rate in the aggregate, with most of that growth going to one sub-area, with the result that the sub-area is growing rapidly. Even a region recording population loss can experience indirect impacts as businesses and residents abandon older inner-city and "Main Street" areas for new more accessible locations along the new improvement. In contrast, a growing city experiences pressure to develop where good access and services are available. If the data are available (from either planning documents or interviews with local development experts), expected sub-area growth should also be considered here. In high growth areas, however, development can occur in areas with some inadequate services in anticipation that they will be provided later.
- **Relationship between land supply and demand.** How much vacant, buildable land is there in the study area compared to the rest of the city or larger region? What is the demand for land at the regional, city, and study area level? How does the study area buildable land compare to available land region-wide? The more limited the supply is

relative to demand, the more likely improved access would increase the probability of development. This comparison, whether quantitative or qualitative, should be carried out at the most disaggregated level possible: not only by geography, but by type of land use (e.g., there may be ample vacant land in total, but a shortage of commercially zoned vacant land).

- **Availability of other services.** Access alone is not sufficient to trigger development: other key public facilities like sewer and water often must be available to the study area at a reasonable cost. If they are, improvements in access are more likely to facilitate land-use change. If water and sewer are or will soon be made available, then it is very likely that the land is already planned for urban use: the improvement may do nothing more than allow the planned land uses to develop. Such development might, however, occur sooner with the project than without it, which, in turn, might cause fiscal problems for the jurisdiction if it had not planned for this sooner-than-anticipated growth. Note though that the potential for suburban development is not necessarily dependant upon sewer and water connections: densities upwards of a half acre can be achieved using wells and septic, depending on health department regulations.
- **Other market factors.** Where has growth been going; where do local real estate experts expect it to go? How does the study area market compare to markets in other sub-areas? What is the extent of underbuilding relative to allowed densities? Is accessibility (travel time) a limiting condition on development in the study area?
- **Public policy.** All the previous factors are indicators of the potential for land-use change; most are market driven. But for that potential to result in change it must not only be big enough—it must also be allowed. There is ample evidence that land use near high capacity transportation facilities in urban areas has not changed despite the potential that the accessibility creates. A key reason is that public policy does not allow land uses to change because, for example, a park is a public trust, or an urban growth boundary protects farmland, or a neighborhood does not want its zoning changed to increase density. Public policymakers can clearly resist pressure for development. The question for the land-use analyst is whether policies exist on the books to offer that resistance, and whether those policies will be enforced, bent, ignored, or changed. Answering the last part of that question is difficult, both technically and politically. An analyst can use only what scant data might exist (e.g., number of zone changes), or can use more qualitative analysis (e.g., interviews of local officials or state agency personnel with local oversight responsibilities). Whatever the analyst writes should be well-supported (documented) by as much evidence and logic as possible.

Table 3 gives guidance on the variables: how to measure them and how to interpret them in the context of increased potential for land-use change. The table is illustrative only, though we understand analysts will be tempted to defer to the numbers in the table for lack of any others. There are, however, many different ways to measure the factors of interest, and different levels of geography at which they can be measured. The main point of **Table 3** is to illustrate that measurements can be made of a small number of factors, and qualitative judgments can then be made about how strongly those factors will contribute to the increased potential for land-use change. Ultimately, it falls to the analyst to make those judgments, using the scale in **Table 3** or some other one.

Some comments on **Table 3**. We feel relatively confident about columns one and two: research suggests that they are the right categories of impacts to consider, and the right data sources. We are also comfortable with the underlying logic of the table that leads to column four: i.e., the idea that an analyst would make measurements of key causal variables and then make a judgment about how big an effect those measurements would have on the potential for land-use change.

That leaves column three, which is the most debatable part of the table. We found nothing in the literature that attempted to go to this level of specificity. We have suggested the reasons, which are mainly variations on "it is too complicated to predict." But it did not seem right to for this report to take readers up to the ledge and then push them over: we had to jump first. Column three of **Table 3** is our jump. It shows one way that measurable variables can be interpreted to get a qualitative assessment of the potential for land-use change that a transportation project might create. States may choose to adjust proposed threshold values to better reflect local conditions. Using this table in tandem with findings on induced growth/indirect land use effects elasticities in Section 4.4.3, **Table 6**, is a good way to check the results obtained by the planner judgment approach.

Other variables and measurements are possible. For example, a simpler algorithm would be for an analyst to rate a transportation project as big or small, and note that bigger projects have more potential to change land use. That method would indirectly capture (albeit, crudely) the effects of travel time savings and increases in property values.

<u>Step 8b: Address the Issue of Changes in Planned Land Use (Consistency With Plan)</u>

In the context of **Table 3**, the question for the analyst here is: is the increased potential for change estimated to be enough to expect land use development patterns to differ if the project is built; and, if so, do those differences conflict with the land-use plan? The conclusion may be that the improvement simply allows the plan to be achieved.

For build alternatives, the analysis should make a qualitative assessment of whether service and policy conditions constrain or support the achievement of the land-use pattern envisioned by the comprehensive plan. In general, the presumption should be that in recently updated comprehensive plans the amount of growth is consistent with the level of services to be provided. The analysis should assess whether the comprehensive land-use plan assumes, either explicitly or implicitly, that the transportation link under evaluation will be improved to support the achievement of the development patterns the plan calls for.

Table 3: Assessing Indirect Land-Use Effects

Change	Data sources	If value is…	…then potential for land-use change probably…
Change in accessibility *Measured as change in travel time or delay, if available. Otherwise, assessment of v/c or change in access*	For large projects or jurisdictions: Travel demand models Otherwise: expert opinion, probably from other ODOT or consultant transportation planners or engineers working on the project	Less than a couple minutes of time savings for an average trip, or no change in v/c 2-5 minutes 5-10 minutes More than 10 minutes	None to very weak Weak to moderate Strong Very strong
Change in property value *Measured in dollars*	Assessment data Expert opinion	No change 0% to 20% increase 20% to 50% increase More than 50% increase	None to very weak Weak to moderate Strong Very strong
Forecasted growth *Measured as population, employment, land development; for region, city, or sub-area*	Official population and employment forecasts (should be a regionally "coordinated" forecast if possible) Check to see that travel demand forecasting being driven by same pop and emp. forecast	Average annual growth rate (population/employment) of less than 1% 1%-2% 2-% - 3% Over 3%	None to very weak Weak to moderate Strong Very strong
Relationship between supply and demand *Measured as population, employment, land development*	Planning documents, (See Step 4 re development capacity, history, trends, and forecasts) Interviews with realtors, brokers, developers, planners	More than 20-year supply of all land types, all sub-areas 10 to 20-year supply Less than 10-year supply Less than 10-year supply and specific identified problems in the study area	None to very weak Weak to moderate Strong Very strong
Availability of non-transportation services *Measured number of people or employees that can be served; or barriers to service provision*	Local planning documents, Interviews with local planners and engineers Other reports generated as part of the highway project evaluation	Key services not available and difficult to provide Not available and can be provided Not available, easily provided and programmed Available now	None to weak Weak to moderate Strong Very strong
Other factors that impact the market for development	Local planning documents Socioeconomic and ROW reports generated as part of the highway project evaluation Assessment data, MLS, local real estate reports Interviews with brokers, developers	Weak market for development Weak to moderate market Strong market Very strong market	None to very weak Weak to moderate Strong Very strong
Public policy	Local planning documents Interviews with local officials, local planners, reps of neighborhood or interest groups, state agency planners	Strong policy, strong record of policy enforcement and implementation Weak policy, weak enforcement No policy, weak enforcement	None to very weak Moderate to strong Very strong

Source: ECONorthwest

Note: Table assumes that the proposed transportation improvement improves accessibility. If not, then the potential for land-use change is either insignificant, or could be in the opposite direction (e.g., decreases in land values from the no-build alternative could cause land-use changes). If all other measures are "strong" and the accessibility measure is "weak", the indirect land-use impacts are likely to be less.

The proposed transportation improvement could be implicitly presumed in the local comprehensive plan if, for example, land uses are assumed to substantially build out even though the current highway capacity could not support that level of development at a reasonable level of mobility. If the buildout assumption holds, then the build alternative is possibly accounted for in the plan (assuming the plan reflects the market) and the no-build alternative needs to be generated based on what the market would provide in the study area without the improvement and its higher accessibility levels. If the local comprehensive plan does not show land uses substantially built out, then the build forecast likely does not include the proposed improvement and the effects of the build alternative need to be forecasted. See Step 6 for a more detailed discussion of the issue.

The reality of local land-use planning is that few if any plans are explicit about the assumptions they made regarding future transportation improvements. Most of them probably did not explicitly address whether highway capacity and increasing highway congestion would cause growth forecasts, in the aggregate or by sub-area, to be different from what the coordinated county allocation of state forecasts predicts. Thus, the kind of detailed analysis suggested in the previous paragraph (e.g., that the comprehensive plan explicitly considers the impacts of the project) implicitly assumes that plans are better than they are, and maybe better than they can be.

Probably the best an analyst can do is review the plan to make a judgment about whether the plan made any adjustments to land use designations or densities based on expected constraints on highway capacity. In most cases, the answer will be "no," which means that (1) implicitly, the plan assumed that any transportation problems would not become great enough to keep planned land-use types and densities from being achieved, (2) therefore, the proposed improvement, if it is now deemed necessary to accommodate forecasted growth, is implicitly part of the planned land-use forecast, and (3) *not* building the improvement would mean that the analyst would need to forecast the no-build land use pattern (in contrast to the typical thinking of focusing efforts on constructing a build forecast).

Though less important than changes to the planned land use, the analyst could also address whether the transportation improvement enabled the development envisioned in the 20-year plan to occur faster than the plan envisioned (e.g., annexations, UGB expansions, and rezonings occur sooner than anticipated) or than service providers could efficiently accommodate.

Step 8c: Describe Policies That Could Mitigate Those Effects

The previous steps assume *existing* policies and implementation history. For example, a city's policies and land use actions over the last 10 years may show a propensity to up-zone land in response to property owner requests. An analyst would have to consider these actions and note that, in view of past actions, indirect land-use impacts in response to the proposed transportation improvement may be more likely. But the past does not dictate the future. City councils and voter preferences change. It may be that a city is willing to adopt an access management ordinance or a new specific-area plan to guide the development around the new improvement. If so, then the indirect land use effects—especially those measured as inconsistencies with local plans—may be zero.

If the analysis of indirect land use effects identifies probable adverse impacts (e.g., high potential for plan or zone changes, increases in property value, increases in the rate of development.), the EIS will typically describe a set of proposed measures to mitigate the adverse impact.

Land-use mitigation typically occurs through local jurisdiction action. In some instances, however, land-use mitigation for the project could include, through outright purchase or other means, measures to control (or prevent) the development of land adjoining the facility.

In summary, the analysis of indirect land-use impacts must identify both beneficial and adverse impacts. If the analysis identifies adverse impacts, the analyst should work with local staff to identify appropriate mitigation measures. Some measures may require local review and adoption.

Summary of Step 8

1. Assess the potential for land-use change by analyzing changes in accessibility, changes in property value, expected growth, the relationship between land supply and demand, availability of public services, market factors, and public policy.
2. Complete the matrix shown in **Table 3** using the data collected in Step 1.
3. Using the matrix make a preliminary determination of the timing and extent of indirect land-use impacts. The determination may include both beneficial and adverse impacts. A meeting with local staff may be helpful in this task.
4. If adverse impacts exist, develop a set of proposed mitigation measures. Some mitigation measures may require local review and approval. Working with local staff is important in this step.

Step 9: Prepare a Final Report

Steps 1 through 8 describe the data and analysis that must be done to make an estimate of indirect land-use effects: however, those steps are not identical to the sections of a report on indirect land-use effects. The results, and documentation of the data and analysis that supports them, must be written in a memorandum or more formal document. Our recommendations for the organization of that report are as follows:

I. INTRODUCTION

PURPOSE OF THIS REPORT

PROJECT DESCRIPTION

IMPACTS EVALUATED

METHODS USED IN THIS REPORT

All this information can be derived from the planning judgment section of this report. Give a reference to the larger report for full citations of literature review, case studies, and estimates of impacts.

II. FRAMEWORK FOR EVALUATION

WHAT ARE INDIRECT LAND USE IMPACTS

HOW ARE INDIRECT LAND USE IMPACTS TYPICALLY MEASURED

Discussion of evaluation presented above, including that the evaluation has two parts: (1) How likely is it that a transportation project will be followed by some noticeable change in the land use that would not have occurred in the absence of the project or sooner than anticipated? (2) If such changes did occur, would they be consistent with the comprehensive plan?

Use **Table 3** from above, showing key variables.

III. EXISTING AND FORECASTED CONDITIONS

Steps 2 through 7 above. Data collection tied to key variables in **Table 3**.

IV. ASSESSMENT OF INDIRECT LAND USE IMPACTS

A summary assessment along the lines described in Step 8.

4.4.1.7 Additional Information

The approach just described has several strengths. It is logical, consistent with theory and federal requirements, scaleable (i.e., it can incorporate in many of its steps the more extensive and sophisticated methods described later in this report), and defensible. It is, compared to other methods (especially "black-box" modeling methods), relatively easy to explain to non-technicians (policymakers and the public). It is transparent: the assumptions are clear and open for debate. It can be relatively inexpensive and quick.

Its biggest weaknesses mirror its strengths. It can be done poorly because it can be done inexpensively, quickly, and based on planning judgment.

When transportation projects are big, significant, and controversial, and when schedule and funding allow, the ideal is to use the framework for the analysis described in this section, and augment the analysis with methods described in the following sections.

4.4.2 Collaborative Judgment

4.4.2.1 Overview

This family of approaches to land use forecasting for indirect land use effects differs from the previous one, planning judgment, in its emphasis on group processes, diverse inputs and outreach. The most common form of this approach for indirect land use effects work, the Delphi panel, has by now been used widely to forecast land use change in response to transportation improvements as part of *project level* analysis.

Extensive guidance on the technique is provided in *The Use of Expert Panels in Analyzing Transportation and Land Use Alternatives,* prepared as part of NCHRP Project 8-36, Task 04 (Seskin et al. 2002), and in *Use of Expert Panels in Developing Land Use Forecasts* (FHWA 2002). After reading this chapter, the analyst who believes that Delphi panels are an appropriate way to address indirect land use effects in their own context, should read these relatively brief reports in their entirety. We quote liberally from the Seskin NCHRP report but also go beyond it to suggest best practices and provide more specific guidance.

The standard way of implementing the expert panel has been via a Delphi panel (sometimes called an ELU or Expert Land Use panel which may, however, imply a less structured process). The Delphi panel or process produces some level of convergence on indirect land use effects through iterative responses by experts on the panel to each others' *individual* and *anonymous* analyses and comments. When described this way, it should be clear that this is a very structured, even artificial process, very different than getting knowledgeable people around a table to think aloud about guidance on a particular problem. ELUs are a politically appealing option because they appear to reconcile the judgment of diverse experts and have the appearance of wisdom and fairness. They can be fairly rapidly convened and do not typically require exhaustive data collection and analysis given the panelists' expertise.

There is now some limited work assessing the efficacy and accuracy of such panels, and their use in combination or comparison with other techniques. In this section, we will focus on what lessons have been learned in applying the Delphi technique and on guidance for best practices.

In the former section on planning judgment, we dwelt on the messiness inherent in drilling down through the assumptions made by planners in their initial comprehensive plans or transportation plans. We know that these may often represent the *without the project* base line conditions, but that is not always clear or the case. Because the practice of comprehensive planning is evolving and becoming more sophisticated in its use of GIS data and tools, because of the increasingly specific requirements of more state-level planning law (Georgia, Tennessee, New Jersey and North Carolina are but some of the latest entrants in the state-specified world of planning guidance) and because of the spread of travel models into MPOs and even local governments, drilling down into prior plans will confront planners with a new array of techniques used by local planners beyond the currency of today and yesterday. The analyst, therefore, needs to know what to look for in drilling down, so that the typical fault lines in assumptions and newer methodologies are laid bare.

4.4.2.2 Best Practices for Expert Land Use Panels/Delphi Processes

Overview

In an expert panel process:

> …selected experts provide their assessment of likely future outcomes by responding to several rounds of questions. An expert panel can be used as a primary analysis method or in conjunction with other tools, and is a cost-effective technique that can be applied in a variety of settings to produce reliable results. Expert panels combine an understanding of the theory of urban development, empirical knowledge of transportation/land use relationships, and detailed understanding of local conditions. They are not a replacement for quantitative data, but rather integrate data with the perceptions, intuition, and judgment of people familiar with the study area (Seskin et al. 2002).

We collapse the ELU and Delphi titles here but, to repeat a point made earlier, most Delphi processes are not conducted as group sessions when the opinions or analysis work is actually being done. There are often presentations to the panel and ensuing discussion but the preservation of anonymity has the critical value of removing force of personality, muting group dynamics, and reducing gaming of outcomes and agenda-setting from the interaction. In fact, as the case studies in NCHRP 8-36 suggest (and our own experience validates), where the process is treated as a discussion group, it can more readily break down.

Panels can work with different levels of technical input and support, ranging from purely written comments and opinions to carefully described and supported numerical results. In much the same way that pure, unsupported planning judgment is unacceptable practice, pure opinion without supporting argument and references to data is also unacceptable in a Delphi process. The key questions revolve around how much of what kind of data and analysis to provide. While NCHRP 8-36 provides some guidance here, we augment this in this section. Similarly, while NCHRP 8-36 states that the ELU can be used in conjunction with other tools, it does not provide guidance beyond this. We introduce this consideration as we walk through the steps of the Delphi process below and, most explicitly, in the case studies in Sections 4.4.3 – 4.4.6.

Applicability

NCHRP 8-36 states that while the largest and most complicated transportation investment decisions will likely require formal modeling, expert panels, in contrast, are likely to be useful when:

- It is important to include significant local knowledge about individual property owners, particular land parcels, local zoning, and real estate conditions.
- A holistic approach is needed, which can consider all aspects of urban systems. Formal models and other quantitative techniques can only partially represent the development dynamics at work.
- Conflicting societal values are present that need to be identified and accounted for.
- Politicians and/or the general public tend to view staff-generated findings with skepticism.
- The impacted area is relatively small and includes a single or few transportation projects. Expert panels are particularly suited to assess impacts in very localized areas, as is often the case with transit improvements

We would add to the above list that a short timeframe (say, less than 10 years) for projections lend themselves more readily to a panel than a long timeframe (say, 20 years). We would also argue that the first three bullets above apply, or ought to, in most contexts. Indeed the second bullet suggests that since formal models do not fully capture development dynamics, ELUs can fill this gap, which argues for their consistent use as a parallel check on many modeled processes. We agree with this idea, particularly when local conditions have sufficiently atypical characteristics that will be missed by models. Examples include highly growth managed environments that will not follow conventional market dictates or where models are partial and exclude important policy or physical constraints or in complex, mature urban areas where factors other than accessibility will drive land use change. In short, it seems that ELUs should be more used than they are. Of note, then, is where NCHRP 8-36 suggests expert panels would be *less* useful:

- The proposed projects have been well publicized and the affected area has too few people to have objective local panelists (i.e., everyone has formed an opinion).
- The affected area includes numerous proposed transportation projects. In this case, economies of scale are likely to be realized with the development of formal models.
- The transportation alternatives are so similar to each other that panelists cannot make significant distinctions between them.
- The affected area is so large that no panelist knows the entire area well (Seskin et al. 2002).

We do not think that the last bullet should preclude an ELU that has expertise in regional issues if that is the scale of the project. However in that case, since no one individual may have overarching knowledge, objective information from travel models is particularly useful to inform the process, for example. We would add to the above list that, where the indirect land use effects appear to be massive or occur over a long timeframe, ELUs may be a necessary *but not sufficient way* of forecasting impacts because the systemwide impacts of the improvement elude intuitive grasp and modeling may be the best way to identify or suggest these.

4.4.2.3 Resources and Inputs

While generally less time –and- data-consumptive than modeling processes, the extent of data and information required is obviously a function of the project and study area. For relatively complex issues, NCHRP 8-36 suggests the following type of material:

- Key policies: information on development policies that the panel should take into consideration (note that the panel must to be told how to weigh existing policies, as discussed in the section on the panel's charge).
- Land use: data that describes residential uses; developable land; key employment sites; and, vacancy rates and sales of office, commercial, and industrial space. In particular, data that captures the change over time (e.g. a 10 to 20 year period) and not just a current snapshot will be most useful.
- Transportation: data that describes the origins and destinations of travelers, measures of capacity, major transportation routes, and transit systems. Again, data that describes the change over time is best. Also, look for data describing significant changes in the trip characteristics (mode, purpose, length) over time.
- Socio-economic data: data describing the mix of skills, jobs, and incomes of the persons living in the study area, over time.
- Development constraints: environmental and man-made constraints (sewer, water, wetlands) that affect the location of development.

While they overlap with them some, we would add to the above list information on the 7 variables contributing to changes in local development patterns, as described in the planning judgment section. In particular, changes in accessibility brought about by the project must be quantified to the degree possible.

4.4.2.4 Step-by-Step

In this section we follow the sequence of six steps set out in NCHRP 8-36. We use their headings and subheadings, add some of our own, and extract what we believe to be their most normative and directed advice on Best Practices. Under Caveats in the next subsection we interject (into some steps) new information, research or insights that extend the approach, particularly in its use with other approaches.

Step 1: Know the Big Picture

The first step to successful use of collaborative judgment is to have a full understanding of how the panel's work will fit within the broader analysis. To this end, when beginning the collaboration process, clearly articulate the specific objectives that the panel will and will not address so that everyone has the same expectation. Also, be sure to identify the end use of the panel's analysis: if it is to be used as part of an EIS, this will help determine format and level of detail and interface with the EIS developers. Lastly, define roles and responsibilities: neutral facilitators will usually have more credibility than agency staff in managing the process. Stakeholders in the project can usefully form an oversight committee for panel composition, process format and briefing materials but should have no hand in producing the panel results.

Step 2: Design the Panel Process

A well conceived process is absolutely critical to getting meaningful results from a collaborative judgment exercise. A key first step is to identify the analysis parameters: the study area may be defined by the panel or be provided by the project team/oversight committee. One should always disentangle the study area from the impact area, which will often be much smaller. The study area should be large enough to logically bound the panel's work but not so big as to force analysis of a lot of extraneous material. Oftentimes TAZs will be the basic unit of analysis and these will need to be aggregated into larger subareas if a panel is not to be overwhelmed by detail. Since land use impacts lag transportation projects, a default timeframe of 10 years is safe. Beyond this timeframe models become more necessary as local experts, particularly developers, may be uncomfortable with longer range projections.

Next, clearly define the panel's "charge": for example, will they be asked for specific numerical estimates or order of magnitude estimates (high/medium/low)? Both the questions to be answered and how they are to be answered must be written out. Will they be survey questions, written statements, or numeric allocations with rationale? Panelists should be told how to treat current comprehensive plans or zoning or policies – they should not be taken as sacrosanct, preferably or typically, and the longer the timeframe the more changeable they are likely to be.

After this, identify and specify parallel technical efforts or methods which the panel will use or comment upon. While NCHRP 8-36 mentions the use of panels in conjunction with other techniques, it does not detail this idea. It is important for the agency and oversight committee to think through the costs, benefits and timing of such parallel work. The case studies discussed in Section 4.4.4.5 highlight both the benefits and pitfalls of such checks and balances to a pure Delphi approach.

Be sure to also specify the process format. While feedback from the panelists to each other did not show much change in individuals' second round in the case studies reviewed in NCHRP 8-36, it did serve to identify errors and increase understanding. Providing the rationale with the numbers increases convergence potential. While one or more panel meetings up front can help foster understanding, especially with complex projects, they add time and cost and open up the possibility of lobbying. Public attendance or press attendance at such meetings should be avoided, if possible, so as to minimize grandstanding and maximize open discussion. Panelists' names should never be attached to their responses – anonymity improves the credibility of results and reduces the "gaming" of outcomes. Usually two iterations suffice for most processes.

Lastly, plan the overall schedule: more project complexity, more panelists and more meetings increase the schedule. Be aware that the time to analyze results is often underestimated: make sure you have a realistic schedule and a firm commitment from panelists to it and to the work involved.

Step 3: Create the Panel

Panels need both generalists and specialists: true stakeholders belong on an oversight committee rather than an expert panel. An expert panel should comprise solid expertise not overly locked into one perspective – it is analogous to a jury. Experts for the panel may come from academia, real estate, land use or policy planners, economists, informed laypersons and so on, in balance with the technical demands of their charge. Panel sizes can be small for a written analysis of issues (6 - 10 people say). If numerical or statistical work is also needed, a larger panel is called for (10 – 15, say). Compensating the panelists is desirable – it increases commitment and can attract the experts.

Step 4: Final Preparations

Some final preparations before actually undertaking a collaborative judgment exercise include identifying, developing and preparing panel information. Obviously the amount of information prepared in advance for the panel varies by the complexity (and controversy) of the issues being analyzed. In the Resources and Inputs subsection above we listed the items from NCHRP 8-36 and added ones we thought important, paying special attention to providing information on *accessibility*. The case study on the Inter-County Connector (ICC) in Section 4.4.4.5 highlights both the importance of this information as well as the relative rigor of allocation models which use accessibility and other measures. Particularly where numerous stakeholders are involved and controversy surrounds the project, the accuracy of and buy-in to the data provided must be assured and vetted with an oversight committee or comparable agency/stakeholder group.

It is also a good idea to test run the process prior to the actual exercise: panel questions, surveys and directions must be pilot-tested with people outside the project team to ensure clarity. Panel meetings and exercises, if planned, should be thoroughly rehearsed beforehand for clarity, consistency and timing: so should any presentations to the panel, particularly from multiple sources whose data and information may be contradictory or duplicative.

Step 5: Manage the Process

Once the process has started, vigilant management is necessary to ensure the panel stays focused and produced useful results. First, clarify to the panel resource limitations and project goals/panel mission up front: it is important to make it clear to the panel at the outset what the resource capacity of the staff is to generate more information and analysis so as to set expectations. Panel disagreements, the case studies suggest, occur over project goals and the panel's charge, rather than process design or results. It is essential to discuss the goals and charge up front and get agreement on these, a good reason to convene the panel at least once.

Often overlooked yet fundamental is to know when to end. When the panelists' responses do not change from the previous rounds and are stable (defined as marginal change of less than 15%), even if there is not much convergence, consensus is unlikely. In the case studies reported, two rounds were sufficient to reach stability. While always desirable, consensus is not always achievable: the group's consent that the report is accurate and the outcome represents the best that was possible will have to suffice. This reflects the difficulty of the prediction for the particular project and it is thus especially important to capture the panelists' reasoning behind their numbers. Other techniques may then be invoked if convergence is needed.

When analyzing the results from a numerical exercise, calculate differences as well as similarities: simply averaging responses to produce an answer is generally too blunt a reporting method and is especially inappropriate under circumstances of wide divergence. More nuanced reporting is required. The average is problematic because it is so affected by outliers but the median does not acknowledge the extremes at all. Longview, Texas, panels (discussed in Seskin et al. 2002) use a blended measure to capture both characteristics:

$$(\text{Mean} + \text{Median})/2$$

In addition to measures of central tendency like the above, the coefficient of variation (CV) is also recommended. CV, the standard deviation divided by the mean, measures dispersion proportional to the mean, whereas the standard deviation is expressed in absolute terms. NCHRP 8-36 recommends the following set of rules:

$0 \leq CV \leq 0.5$	Good degree of consensus; no need for an additional round
$0.5 \leq CV \leq 0.8$	Less than the satisfactory degree of consensus; possible need for an additional round (assuming stability not reached) or alternative approach.
$CV \geq 0.8$	Poor degree of consensus; definite need for an additional round (assuming stability not reached) or alternative approach.

[CV = Coefficient of Variation, or: standard deviation / mean]

Step 6: Document the Results

Put simply, tell it like it is: whoever writes the report must avoid "spin" or bias. The draft report must be reviewed by the panel in an open way that supports the credibility of the work. An editor selecting from a mass of panelist emails, for example, must take pains to attribute any changes or nuances in redrafts so that agency or stakeholder influence cannot be imputed. A final panel meeting can be helpful in establishing how much, for example, the report will emphasize variation rather than blending.

4.4.2.5 Additional Information

Information on change in accessibility is essential for a productive outcome. One of the few studies comparing Delphi outcomes to modeled outcomes (from a 4-step travel demand model) concludes that

> …subsequent panels be fed accessibility data early in the process to inform their intuitive judgments, and that simple land use allocation models be considered as a complement to expert opinion (Ewing and Kuzmyak 2005).

The evidence from this evaluation highlights how very different were the judgments of panelists with and without model-derived land use forecasting information. Those with this data proposed much higher indirect land use effects than those without. This study also, however, demonstrates the importance of minimum standards for such allocation models (see Case Study in Section 4.4.4.5). This study goes on to recommend that larger MPOs develop integrated transportation/land use models to address induced travel and indirect land use effects, rather than rely on conventional 4-step models to provide accessibility information. More information on how this can be done is included in the 4 –step Travel Model section of this Chapter.

Another one of these rare comparative studies, in fact, contrasts a Trend-Delphi method with results from an integrated transportation – land use model (Condor and Lawton 2001). Case Study 2 in Section 4.4.6.4, presents its findings which suggest that 4-step models without feedback loops on land use underestimate significantly the indirect land use effects of transportation improvements, a position corroborated by Rodier (2004) in her comparison of the output of several such models to induced travel and, to a more limited extent, to indirect land use effects.

4.4.3 Elasticities and Induced Travel

4.4.3.1 Overview

Research consistently shows that expanding infrastructure capacity in congested corridors increases travel demand, to varying degrees. As previously discussed, acknowledging and accounting for the phenomenon of induced travel is essential to understanding and measuring possible indirect land-use effects. A simple conceptual diagram of these relationships was shown in **Figure 3** in Section 4.3. Recall that indirect land use effects are only one source of induced travel and to accurately measure those land use effects one must net out the other sources of induced travel, otherwise one might overestimate the accessibility benefits (and consequently the indirect land use effects) of the improvement.

The biggest traffic-inducing effects occur along highly congested corridors of rapidly growing regions. Few travel forecasting models, however, account for induced travel. Instead, some metropolitan areas have turned to the post-processing of travel model outputs to impute induced travel effects. This is often done by borrowing elasticity estimates (representing proportional change in demand [e.g., VMT] as a function of proportional changes in capacity [e.g., lane miles]) from secondary sources and pivoting off of initial travel-demand estimates to make adjustments that account for traffic-generating effects of expanding capacity. One such post-processor is FHWA's SMITE spreadsheet tool that borrows elasticities from other metropolitan areas to provide a first-cut estimate of generated traffic. This tool, however, relies on results from a limited set of studies mainly drawn from several decades ago, some of which have been critiqued in more recent reviews (Noland and Lem 2002; Cervero, "Induced", 2002). Below, a post-processing approach to adjusting travel-demand forecasts to reflect indirect induced traffic and growth effects based on more recent research is outlined.

4.4.3.2 Best Practices in Elasticities and Induced Travel

A "Second Best" Alternative: Post-Processing Travel Demand Estimates

This approach adjusts the outputs of the standard 4-step travel demand model to try to capture indirect land use effects (or induced growth). For readers unfamiliar with such models, Section 4.4.5.2 covers the basics of how they work.

In a review of four-step modeling and induced travel, DeCorla-Souza and Cohen (1999) concluded that some elements of induced travel that can be captured in conventional models are: increased travel distance (in trip distribution); increased shares of low-occupancy vehicles (in mode choice); and shifts to improved road facilities (in traffic assignments). Capturing induced travel in the four-step model thus requires feedback loops and the ability to equilibrate output results between sequential steps. Marshall and Grady (2005) recently applied the method of successive averages to Austin, Texas's travel model to account for induced travel feedback within the four-step travel-model framework. For example, a weighted average of travel times (across times of day) was fed back to the trip distribution step to adjust spatial flow estimates.

Many smaller MPOs, however, do not have the time or resources to automatically account for indirect travel demand within their four-step models. Instead, they must rely upon experiences elsewhere to adjust initial travel-demand estimates – i.e., they must post-process travel model outputs. This might involve making adjustments to future link volume assignments by using elasticities that pivot off of initial estimates. For example, assigned link volumes might be adjusted upwards to account for the traffic-generating effects of adding four traffic lanes using a pivot-point formula such as:

$$\text{Link Volume}_A = \text{Link Volume}_B * \{[\text{elasticity} * [(\text{capacity}_A/\text{capacity}_B)-1]] +1\} \quad (1)$$

where the subscripts "A" denotes "after" values (accounting for induced demand effects), "B" denotes "before" values (prior to adjustment). In this example, induced demand is expressed as a function of capacity expansion. Alternately, it could be expressed in relation to travel speeds or some other indicator of performance. Equation 1 reflects pivot-point estimates using *point elasticities*, such as estimated by log-linear equations. Should arc elasticities be available, the appropriate pivot-point equation is:

$$\text{Link Volume}_A = \text{Link Volume}_B\ [(\text{capacity}_A/\text{capacity}_B)^{\text{Elasticity}}] \quad (2)$$

While re-specifying and re-estimating four-step models along the lines suggested by DeCorla-Souza and Cohen (1999) would be a preferred approach to capture indirect land use effects, in light of the significant expenses and time commitments involved in substantially modifying large-scale forecasting models, post-processing should be considered a "second best" alternative. (note that re-estimating four-step models is discussed in depth in Section 4.4.5.3 of this Chapter).

A Better Alternative: Meta-Analysis of Induced Demand Elasticities for Post-Processing Adjustments

<u>Overview of the Approach/Method</u>

Estimates of induced demand effects imported from a single metropolitan area have questionable transferability. The phenomenon of induced demand is so complex and relationships between capacity expansion and shifts in travel behavior and land-use patterns are so unique, drawing insights from multiple settings is less prone to transferability problems. This can be done by using "meta-analysis" summaries of elasticity estimates—i.e., arithmetic averages from multiple empirical studies.

Tables 4 and 5 summarize induced demand elasticities estimated by various researchers over the past sixty years. **Table 4** summarizes studies where induced demand (expressed as percentage increases in traffic) is estimated at a fine grain – for specific facility improvements. This is normally done by comparing observed traffic counts along an expanded road to what would have been expected had the project never been built (using techniques like multiple regression and matched pairs). **Table 5** summarizes elasticity estimates drawn from area studies and simulations – often expressing changes in VMT at an aggregate level, such as counties, as a function of corridor-level road improvements (using simulations, econometric measures and other time-series techniques). Some authors argue that results from areawide studies are preferable since they reflect the spillover and network effects of road expansion – i.e., capacity expansions on one link can influence volumes on connecting links (DeCorla-Souza 2000).

Table 4: Summary of Facility-Specific Studies of Induced Travel Demand

Study	Setting	Data	Method	Facility Type	Variables: Demand	Variables: Supply	% Growth Attributable to Induced Travel: ST	IT	LT
Jorgensen (1947)	NY-CO	TS	GC	New parkway	ADT	New facility	25-30		
Lynch (1955)	ME	TS	GC	Turnpike	ADT	New facility			30
Mortimer (1955)	Chicago, IL	TS	GC	Expressway	ADT	New facility		3-33	
Frye (1964a)	Chicago, IL	TS	MP	Expressway	ADT	New facility			11[a]
Frye (1964b)	Chicago, IL	TS	MP	Expressway	ADT	New facility			7[a]
Holder, Stover (1972)	TX	TS	GC	Highways	ADT	New facility	0-21[a]		
Pells (1989)	London, UK	TS	MP	Highways	ADT	Widening			27[a]
Pells (1989)	London, UK	TS	MP	Highways	ADT	Widening		25	56
Pells (1989)	London, UK	TS	MP	Highways	ADT	Upgrade			80
Pells (1989)	London, UK	TS	MP	Expressway	ADT	New facility		77[a]	
Pells (1989)	London, UK	TS	MP	Tunnel	ADT	New facility			89[a]
Hansen et al (1993)	CA	TS/CS	GC/Reg	Highways	ADT	Widenings	--[b]	--[b]	--[b]
Kroes et al. (1996)	Amsterdam, NL	TS	MP	Tunnel	ADT	New facility		4.5	
Luk, Chung (1997)	Melbourne, AU	TS	MP	Freeway link	ADT	New facility	0		
Mokhtarian, et al. (2000)	CA	TS/CS	MP	Highways	ADT	Widenings	0	0	

Key:
TS = Time Series
CS = Cross-section
GC = Growth Comparison
MP = Matched Pairs
Reg = Regression
ADT = Average Daily Traffic
ST = Short-Term (< 1 year)
IT = Intermediate Term (1-5 years)
LT = Long Term (> 5 years)

Notes:
[a] Thought to include significant amounts of diverted trips
[b] Presented as elasticities: 0.2-0.3 for short and intermediate term; 0.3 to 0.6 for the long term

The studies listed in the two tables are drawn from many global metropolitan settings based on time series as well as cross-sectional data. The tables reveal elasticities have been estimated in many different contexts – in terms of type of road facilities (e.g., surface highways; expressways) and type of capacity expansion (e.g., new facilities, widenings, upgrades). Moreover, some (often older) studies express demand in terms of average daily traffic (ADT) while others (generally more recent) studies express demand in terms of VMT. In addition, the tables express percent changes in traffic attributable to induced traffic (**Table 4**) and induced-demand elasticities (**Table 5**) in short, intermediate, and long terms. For more details, see Cervero's 2002 study in *Journal of Planning Literature* entitled, "Induced Travel Demand: Research Design, Empirical Evidence, and Policy Directions."

Table 5: Summary of Area Studies and Simulations with Elasticity Estimates Based on Proxy Supply-Side Measures of Benefit

				Variables		Elasticity Estimates	
Study	Setting	Data	Method	Demand	Supply	Short-Term	Long-Term
Kassoff, Gendell (1972)	US urban areas	CS	GA	VMT/capita	Capacity Index	<0.58	--
Koppelman (1972)	20 U.S. cities	CS	Reg: OLS	VMT	Lane-miles	0.13	--
Payne-Maxie et al. (1980)	54 U.S. metro areas	CS	Reg: OLS	VMT/capita	Lane-miles	0.22	--
Hansen et al. (1993)	30 CA urban counties	TC/CS	Reg: OLS, DL, FE	VMT	Lane-miles	0.46-0.50	--
Hansen et al. (1993)	CA metro areas	TC/CS	Reg: OLS, DL, FE	VMT	Lane-miles	0.54-0.61	--
Hansen, Huang (1997)	32 CA urban counties	TC/CS	Reg: AR/DL, FE	VMT	Lane-miles	0.30	0.68
Hansen, Huang (1997)	CA metro areas	TS/CS	Reg: AR/DL, FE	VMT	Lane-miles	0.50	0.94
Noland, Cowart (2000)	70 U.S. metro areas	TS/CS	Reg: IV, DL, FE	VMT/capita	Lane-miles/capita	0.66	0.81-1.00
Fulton et al. (2000)	220 counties: MD, NC,	TS/CS	Reg: IV, DL, FE	VMT	Lane-miles	.3-.6 (OLS)	0.47-.89
Fulton et al. (2000)	VA, DC	TS/CS	Reg: IV, AR	VMT	Lane-miles	.13-.43 (AR)	--
Strathman et al. (2000)	48 U.S. urban areas	CS	Reg: IV	VMT/HH	Lane-miles/capita	0.29	--
Cervero, Hansen (2001)	34 CA counties	TS	Reg: 2SLS, DL, FE	VMT	Lane-miles	0.56	.78-.84
Cervero (2003)	24 CA corridors	TS/CS	Reg: OLS, 2SLS	VMT	Lane-miles, Speeds	0.10	0.39

Key:

TS = Time Series

CS = Cross-section

GA = Graphic Analysis

Reg = Regression

OLS = Ordinary Least Squares

DL = Distributed Lag

FE = Fixed Effects

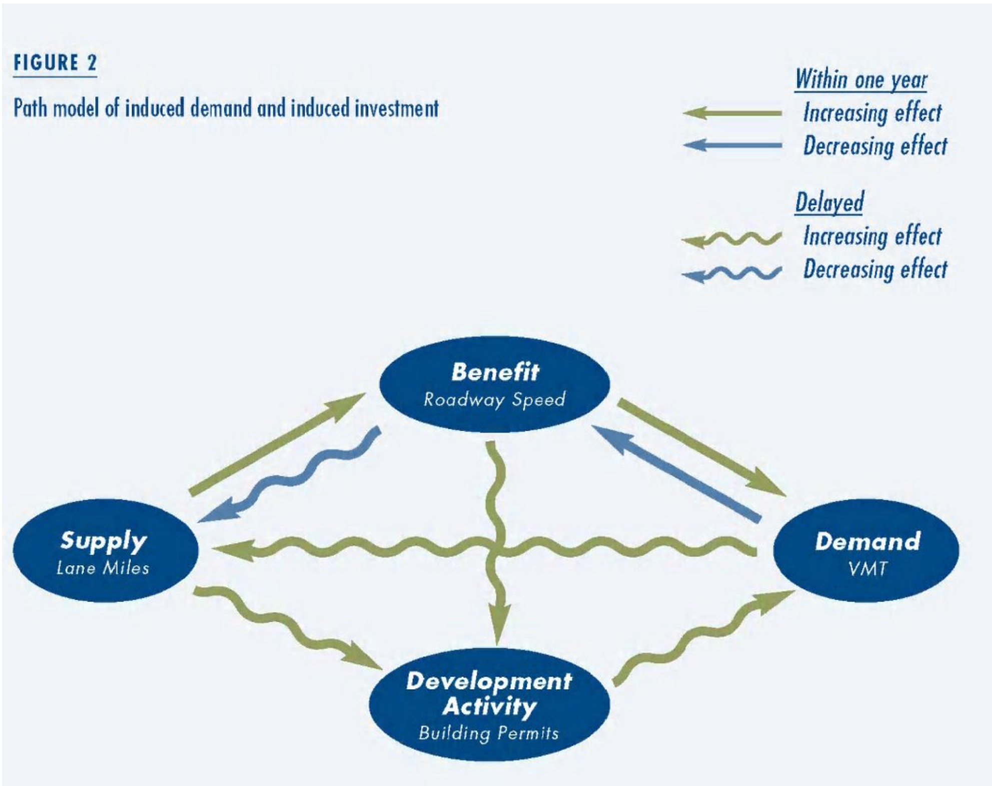
AR = Auto-Regressive OLS

IV = Instrument Variables

2SLS = Two-stage IV estimation

Recent research in California has advanced our understanding of how the indirect effects of road expansion get expressed in terms of shorter-term behavioral shifts in travel (e.g., by route and mode) and longer-term structural shifts in land use (i.e., indirect land use effects). Cervero (2003) examined 24 California freeway expansion projects (no new facilities were analyzed) across fifteen years using a path-model framework, as reflected in **Figure 5**, to sort out "induced demand", "induced growth" (indirect land use effects), and "induced investment" effects. Recorded traffic increases along expanded freeways were explained in terms of both faster speeds and land-use shifts. Because less than half of the recorded speed increases were statistically attributable to road improvements, a fairly modest long-term induced-demand elasticity of 0.39 was recorded. The longitudinal effects of rising VMT on roadway investments were of a similar order of magnitude. Even though the gains in traffic attributable to capacity expansion were moderate over the intermediate-to-long term, road capacity still got substantially depleted, mainly to factors like overall population and employment growth, demographic "megatrends" (like increased travel by women and increased car ownership), and behavioral shifts such as reversion to peak hour travel and reduced car pool and transit usage, etc...[6]

Figure 5: Path Model Framework for Tracing Induced Travel and Indirect Land Use Effects

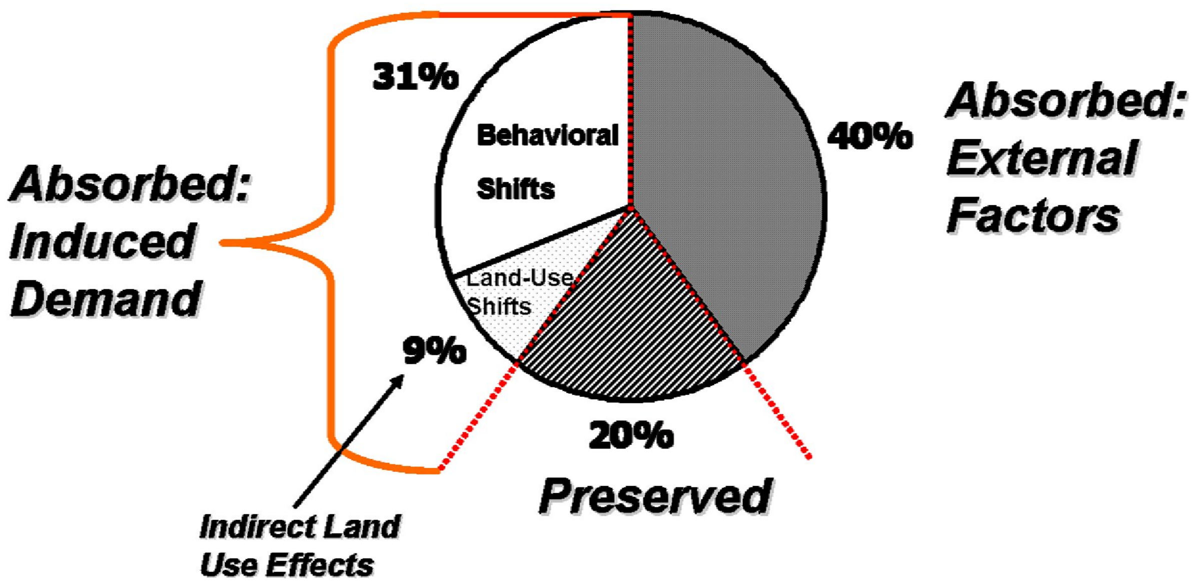


Source: (Cervero 2004)

The path analysis study by Cervero allowed road capacity increases among the 24 California study corridors to be apportioned into that which was "preserved" (i.e., representing a net benefit in travel speeds) and that which was "consumed" (i.e., through induced traffic and indirect land use effects). And the "consumed" portion was further broken into the capacity benefits that were depleted through shifts in travel (e.g., by route, mode, and time-of-day) and land-use changes (Cervero 2004). **Figure 6** shows that over a six to eight year period following freeway expansion, around 20 percent of added capacity is "preserved" and around 80 percent gets "consumed" or depleted. Half of this "capacity consumption" is due to external factors, like growing population and income. The other half is due to the induced-demand effects, mostly higher speeds and secondarily increased building activities (i.e., indirect land use effects).

[6] See "Road Expansion, Urban Growth, and Induced Travel: A Path Analysis" by Cervero (2003) for a more detailed discussion on sources of induced travel.

Figure 6: What Happens to Road Capacity Additions? Apportionments to that "Preserved" and "Consumed" by Induced Demand and Induced Growth



Source: (Cervero 2004)

What is the range of land use shifts around the 9% shown in **Figure 6**? This important question cannot be readily derived from the data behind the pie chart but it can be inferred. As noted, the issue at hand is that the pie chart apportionments, as a generalization of what was happening among the study corridors, was developed from the path model partitioning direct and indirect effects. As with all path models, this was based on beta weights -- i.e., standardized regression coefficients. Thus the means were 0 and the standard deviations were 1 for all coefficients -- including the land-use apportionments. The way these apportionments were estimated simply does not lend itself to any standard deviation or variance interpretation.

One can, however, infer the standard deviation from the original model of induced demand. The standard error on the coefficient of building activities (of 0.107, lagged over 2 years) was 0.055, or 0.51 of the coefficient. (The ratio was similar for 3-year lags). This gives a general order of magnitude of how much the elasticity varied across the sample (assuming it is normally distributed). Thus for the pie chart, one might reasonably infer that the 9% apportionment for land-use influences has a standard deviation of 4.5% -- i.e., 67% of the sampling distribution of land-use effects lies between 4.5% and 13.5%. And that 95% of the sampling distribution of land use effects lies between 0% and 18%. This range can be used to bracket the potential shift in land uses due to transportation improvements in a top-down sense.

This approach will represent the *potential* amount of induced travel. The analyst must still decide on a *likely* figure by assessing the factors in planning judgment**.** Note that the empirical research on elasticities is based on improvements to existing facilities. New highways in attractive greenfields with significant accessibility benefits could have greater percentage impacts than those quoted in this report, but we have identified no reliable research on this context.

Applicability

A meta-analysis summary of the studies listed in **Tables 4 and 5** reveals substantial variations according to the scale of analysis and methodological approach. **Table 6** summarizes the meta-analysis results. In the case of facility-specific studies from the past 20 years that relied mainly upon matched-pair comparisons, the percent of traffic growth attributable to induced demand takes on the following (unweighted) mean values: short term = 0 percent; intermediate term = 26.5 percent (standard deviation = 35 percent); long term = 63 percent (standard deviation = 28 percent).

Area studies that have used lane-miles as a proxy of road-conferred benefits have generally produced results suggesting greater impacts, as revealed by elasticities in **Table 6**. A meta-analysis calculation of post-1980 area studies that have presented elasticities based on proxy (lane-mile) estimates of benefits (drawn from **Table 5**, excluding disaggregate analyses) produced the following (unweighted) mean elasticities estimates: short term = 0.40 (standard deviation = 0.18); long term = 0.73 (standard deviation = 0.20). In comparison to facility-specific studies, not only are impacts more significant at the area scale of analysis, results are also more similar, with lower standard deviations (relative to means—i.e., lower coefficients of variation). Even when accounting for the fact that roads lag behind and respond to VMT growth, recorded induced demand effects remain strong.

Table 6: Meta-Analysis Summary of Induced Demand Elasticities[1]

	Facility Specific Studies	Areawide Studies
Short-Term	0	0.40
Medium-Term	0.265	NA
Long-Term	0.630	0.73

[1] Elasticities represent proportional change in demand (e.g., VMT) as a function of proportional changes in capacity (e.g., lane miles), controlling for other factors. Elasticities for facility-specific studies are imputed from percentage change estimates. *Source*: (Cervero, "Induced" 2002)

Some recent studies on proposed road improvements have borrowed from the meta-analysis summary by Cervero (2002) to estimate induced demand. This was the case with the proposed Inter-County Connector improvement proposed for Montgomery County, Maryland (Ewing 2006). In the absence of local evidence on induced demand, the study relied on the average data shown in **Table 6**.

By way of example, a simple "post processing" to account for induced demand impacts using the meta-analysis results from **Table 6** might work as follows. Say a travel estimate for a particular link 30 years from now whose capacity is being expanded by 25% is 10,000 ADT. Equation 1 could be used to adjust this ADT estimate to account for induced demand. (Since the values in **Table 6** mainly represent "point elasticity", equation 1 would generally be the appropriate post-processing formula.) Using the long-term elasticity value from areawide studies from **Table 6** (of 0.73), then the adjusted ADT estimate that accounts for indirect land use effects is:

$$10{,}000 * \{[(.73)*(1.25 - 1)]+1\} = 11{,}825 \qquad (3)$$

(Using the arc-elasticity pivot-point equation 2, the estimate is nearly identical – 11,769.) Thus, in the absence of local information, the best empirical evidence borrowed from the experiences elsewhere is that expanding road capacity by 25% would have an indirect effect of increasing traffic by around 12% above assigned link-volume forecast, accounting for induced traffic and indirect land use effects – i.e., 1,825 more average daily vehicle trips. Borrowing from California's experience, one could impute that 77.5% of this indirect effect (i.e., 31/40 from **Figure 6**) is due to indirect induced traffic (i.e., route, mode, and time-of-day travel shifts) and 22.5% is due to indirect land use effects (i.e., land-use shifts) – or in our example, 1,414 more vehicle trips due to induced traffic (1,825*.775) and 41 more vehicle trips due to induced land use effects (1,825*.225). These 41 vehicle trips, in this simple example, must be converted by the indirect land use effects analyst into the land use category expected to occur based on the overall analysis done for the project. If induced residential growth is anticipated, then 4 new SFD units (10trips/day = 40 trips) should be assigned and located. Of course, the challenge of a heuristic approach like this is it requires estimates of the spatial extent of the impacts. Quite likely, the induced demand effects of expanding capacity would be felt beyond a single link. Estimating the spatial extent of impacts might best be handled through some expert-judgment approach like a Delphi panel and/or an allocation model.

4.4.3.3 Resources and Inputs

Both primary and secondary inputs are typically relied upon in post-processing travel forecasts. The primary inputs are the travel forecasts produced by four-step models, specifically traffic assignments on network links. Forecasts based on assumed upgraded networks can be expected to account for route redistributions of travel but not new latent trips. To account for such indirect effects, secondary source information on elasticities must often be turned to, such as shown in Tables 4 through 6. If local data are available, elasticity estimates can be directly estimated to reflect local conditions. However, unless these estimates reflect the specific conditions of an improved corridor – e.g., in terms of congestion levels, traffic mixes, and availability of alternative routes – it might be preferable to borrow experiences from other places with road conditions that are more representative of any specific project of interest.

4.4.4 Allocation Models

4.4.4.1 Overview

Other sections of this report, including the one on planning judgment, describe the general steps in any evaluation of the effects of transportation on land use and development. Allocation models fit into several of the analytical steps in the middle. In particular, they are tools used to (1) allocate aggregate (e.g., regional or county) forecasts of population and employment to the smaller geographies typically necessary to evaluate the land-development impacts of a specific transportation project, and (2) convert those forecasts to an amount of land development, by type (e.g., residential, commercial). Consistent with the general steps already described, land allocation models have to be able to provide and justify at least two allocations: one *without* the transportation improvement, and one *with* the improvement.

The professional literature does not provide a single, definition of what an allocation model is. Klosterman (2005) defines planning support systems (PSS), which certainly would include allocation models, but other tools as well. Some of the better definitions include:

1. Tools whose purpose is "either projection to some point in the future or estimation of impacts from some form of development (Brail 2006)."
2. The "constellation of digital techniques (such as GIS) which were emerging to support the planning process (Batty 2003; Harris 1989)"
3. An "information framework that integrates the full range of current (and future) information technologies useful for planning (Klosterman 2005)."
4. A "wide diversity of geo-technology tools that have been developed to support public or private planning processes (or parts thereof) at any defined spatial scale and within any specific planning context (Geertman and Stillwell 2003)."

An underlying assumption of all planning support systems is that greater access to relevant information will lead to the consideration of more alternative scenarios, resulting in a better informed public debate (Geertman and Stillwell 2003). Point "1"above regarding purpose is broad but apposite for allocation models: they make projections and estimate impacts.

For our purposes here, we make a distinction between a population and employment *forecast*, and an *allocation.* We assume that forecasts for larger areas have been done, and can serve as control totals for allocations. For example, a city may have a technically sound and politically accepted *forecast* that it will grow by 200,000 people and 100,000 jobs in 20 years. To evaluate a specific transportation project, it must have *allocations* of people and jobs to smaller areas (e.g., transportation analysis zones, TAZs), both with and without the project.

Allocation means disaggregation, and disaggregation means detail. Long run modeling of average annual growth in mature metropolitan areas can be wrong about almost everything in particular but still prove approximately right in the aggregate: population and employment growth will average 1.0% to 1.5% over the long run. But if detail is required, problems multiply. The timing of the growth is affected by business cycles and local and federal policy: growth might be negative for several years, and then jump to over 4% for a few years. Similarly, the location of that growth in a metropolitan area is affected by myriad market and policy forces that make the type and density of development by location difficult to forecast. Yet predicting the location of growth at a neighborhood scale (hundreds of zones in a typical metropolitan transportation model) is what allocation models are called on to do.

Allocation models range from simple to complex. The simplest models are based on spreadsheets driven by inputs about expected changes in variables like population and employment. Many use Geographic Information Systems (GIS) technology to conduct some spatial analysis or display the results of the allocation.

These models require the planner to make assumptions about the future. These assumptions include the amount of population growth, density of development, improvements to transportation system, and so on. Though we discussed "planning judgment" earlier, the reality is that all analysis of land-use impacts requires planning judgment: the question is really about how much data and analysis is going to be assembled to inform that judgment and how automated the process will be.

Metropolitan areas are required to have MPOs and to do long-range transportation plans. Almost all MPOs have transportation models that require population and employment estimates by TAZ as inputs. So, one way or another, MPOs already have methods for allocating control forecasts of population and employment to smaller geographies. The methods for making those allocations range from planning judgment, to ad hoc models, to modeling packages, to integrated transportation modeling suites that include allocation models (e.g., DRAM / EMPAL – see Section 4.4.6.2). This section addresses the techniques in the middle: ad hoc and off-the-shelf allocation models. One way to draw a fuzzy line between the models described in this family and those described in later families is that the models here are *rule-based* while the models described later are *equation-based.* That distinction is not perfect (clearly the formulas in spreadsheet rules start to look like equations and can be written to solve equations simultaneously), but it does imply the notion of a simple, transparent, and relatively fixed allocation rule that contrasts with a black-box model of equations. Furthermore, models described in this section are all much less detailed in their assessment of transportation than typical four-step transportation modeling software.

4.4.4.2 Best Practices for Allocation Models

Overview of the Method

This section starts from the assumption that a jurisdiction (city, metropolitan area, region) has a technically sound and politically accepted forecast of long-run (20 to 50 years) change in population and employment. We refer to those forecasts as *regional control totals.* An allocation model must distribute those control totals to sub-areas (e.g., TAZs) subject to the constraint that the sum of the distribution must equal the control total. That is the primary function of the allocation model.

Issues raised in earlier sections of this report are immediately evident. We have already discussed them; we simply list some of the main ones here as a reminder:

- Implicit in most long-run population forecasts are assumptions about the future being like the past, including that future transportation systems will continue to provide service at about the same level. That raises the question for an analyst: Is the project that I am evaluating already assumed to exist as part of that forecast, or is it adding capacity beyond what was implicitly presumed in that forecast?

- That question becomes more critical the finer the grain of the geography being evaluated: i.e., as the forecasts get allocated to subareas.
- An allocation of population and employment to sub-areas must deal fundamentally with the interaction between land use and transportation that this report addresses. If there is little demand for development in a sub-area, little ability to provide public facilities and services to facilitate the development, or policy restrictions that constrain the development, one would expect to allocate proportionately less population and employment to that sub-area (other things being equal). In short, the conditions of land use, markets, and policy affect the amount of growth that gets allocated to an area, and the allocations are what drive the forecast of land-use change. An analyst has to pay attention to the potentially circular logic of cause and effect that may get built into the allocations.

The allocations of future population and employment to sub-areas (we use TAZs, the common modeling sub-areas, as a proxy for the term "sub-areas" in the rest of this section) are the primary drivers of estimates of changes in land use and development. Residents (population) and economic activity (as measured by employment) need built space. Thus, a second part of an allocation model is often one that converts population growth into housing units by type (with further sub-allocations to lot size, tenure, and, possibly, price) and employment growth into square footage by type (with further sub-allocations to acreage based on floor-to-area ratios).

Applicability

Given their purposes, allocation models apply to both the system planning and project evaluation modes. One can use them to allocate region-wide population, households, and employment in response to a range of factors including transportation. One can also use them to reallocate population, households, and employment in response to one specific transportation facility.

It is paradoxical that, given the current state of the practice, a jurisdiction will probably spend less time building its own model than it will learning and adapting existing model packages. That will change as the existing models get refined and simplified. But for now, a small jurisdiction (less than 50,000 population) or a rural one with limited staff is more likely to supplement pure planning judgment with a simple, spreadsheet allocation model than with a packaged model. Even larger MPOs are probably more likely to build a spreadsheet allocation model (a more complicated one, to be sure) than to purchase and adapt an existing model.

MPOs and larger cities with a long-run goal of improving modeling and evaluation capabilities on several fronts should, however, consider the use of existing modeling software: it may be more thoroughly researched (with better theoretical underpinnings and parameter specification); more flexible; more capable of doing other, related analysis; and more cost-effective.

4.4.4.3 Resources and Inputs

The assessment of resources and inputs is implied in the assessment above of applicability. Ad hoc models, if simple, are the least expensive. If very simple, they can be little more than an accounting sheet and display package for some of the key assumptions underlying what is primarily analysis by planning judgment. They can be implemented with no more than word-processing and spreadsheet software. They are scalable: the same steps that we outline below for creating such models can expand a single-tab spreadsheet into one with multiple tabs, linked relationships, and risk analysis built in. As noted above, and described more in the steps below, a jurisdiction must evaluate whether to use an existing model (publicly available or for purchase from a private vendor) or build its own.

4.4.4.4 Step-by-Step

Step 1: Evaluate Needs and Resources

The steps here are mainly covered by the previous discussion. The main point is that a jurisdiction should answer the following questions:

- Do we need <u>any</u> allocation model, or can we just rely on simpler methods? This is, in concept, a benefit-cost question about:
    - The level of analysis needed (a function of the expected size of the impact of the project, which is a function of its size, type, and design; the amount of controversy or likelihood of extended public debate; and state and federal requirements, for example, for an Environmental Impact Statement)
    - The cost of different levels of analysis, and the resources available to cover those costs. See **Table 2** in Section 4.3 for guidance on these points.
- If we do need to go beyond simpler methods such as planner or collaborative judgment, how far beyond should we go (again, an evaluation of benefits and costs)?
    - Build our own allocation model (simple or complex)?
    - Acquire an allocation model?
    - Go beyond rule-based allocation models to more complex, equation-based models (described in later sections of this guidebook under integrated transportation-land use models)

The next two steps talk about the first two of these options, starting with the second: you should decide whether to acquire an existing allocation model before you start building your own.

Step 2: Decide Whether to Acquire an Existing Allocation Model

There are many existing, rule-based, spreadsheet models that include elements of what we describe as an allocation model. We cannot cover all of them, and it would be inappropriate for this report to make a definitive recommendation on any one. Thus, this section provides examples of the kinds of existing models (in alphabetical order) that are available so that jurisdictions have a place to start in their own evaluation. Much of the text comes directly from web sites that describe the models.

Land Use Evolution and Impact Assessment Model (LEAM)

The Land-Use Evolution and impact Assessment Model (LEAM) is a planning support system designed to show land-use changes as a function of changes in economic, ecological, and social systems. Developed at the University of Illinois with funding from the National Science Foundation, LEAM uses people that have substantive knowledge of a particular system to develop and test separate models of the system (an expert system). These models then are run simultaneously in each grid cell of a set of raster-based GIS maps to form the main framework of the model.

LEAM begins with land-use transformation drivers, which describe probabilities of the forces (typically human) that contribute to urban land-use decisions. Thus, LEAM has the ability to test 'what-if' policy and investment scenarios on a spatial field. The model creates spatially specific data at a fine resolution (30x30 meters) for each scenario, and the visual images are analyzed for their implications including: environmental (water quality, habitat fragmentation, etc.), social (traffic congestion, infrastructure needs, etc.), and economic (jobs, economic development, etc.). Sustainable indices based on the derived impacts can then be developed to feed back into the model drivers.

LEAM uses both national data sets (land cover, census, transportation networks, slope, geography, environmental data [lakes, forests, protected open space]) and local data sets (parks, retail centers, schools, subdivisions, cultural centers, important natural areas, etc.) as inputs to the model. Variables and data relating to relevant local scenarios and the environmental impact assessment sub-models (e.g. habitat, water, and energy) are gathered after engagement meetings to determine local priorities.

The final products of LEAM model runs are analyses of a series of scenarios, presented as GIS maps or movies that show the transformation of the subject landscape as a product of change in model inputs, along with related and relevant tables, graphs, and maps that help explain the outcomes and their implementations.

LEAM has been successfully coupled with complex transportation models so that it could be used to show both direct and what this report refers to as indirect land use effects. One could add new links, roads, interchanges, or access to the transportation system and observe their effects on land-use, or change the way the transportation driver assigns weights to the importance of proximity to transportation to probabilities of land-use change.

Land Use Scenario DevelopeR (LUSDR)

The Land Use Scenario DevelopeR (LUSDR) was developed by the Oregon Department of Transportation to create a model with a simple structure and manageable data requirements for forecasting location decisions of household and employment developments. The model simulates households and employment establishments, packages residents into residential developments, allocates employment to economic sectors and groups them into business developments, allocates these residential and business developments to locations (using an iterative process that identifies candidate zones based on land availability and plan compatibility), and reconciles land supply and demand in each of various zones based on a bidding process. LUSDR allows for uncertainty and risk by employing micro-simulation techniques, detailed zone geography, and requiring that the model be run many times to simulate dynamic, behaviorally-based processes.

LUSDR uses information from Census files, employment and household base year estimates by TAZ, travel times and paths from regional travel demand models, Public Use Microsample (PUMS) household and person files, GIS layers (tax assessment data, building polygons, comprehensive plan designations, urban reserve, and regional transportation plans), and the 5-year subdivision approval inventory. LUSDR produces allocation scenarios based on population and employment inputs.

There is not much documentation and little application of this model. We note it here because it addresses, in concept, the issues of population, employment, and land use allocation.

PlanMaster

According to Facet Decision Systems' website (www.facet.com), PlanMaster is web-based software designed to allow the development of sophisticated models that illustrate behavior based on the inputs and assumptions used in the scenario. Users develop scenario planning models from pre-built components, and then customize them to fit local conditions. The customized models illustrate interactions between land use, transportation, economic development, and environmental decision factors. Its purported benefits:

- It allows a creative look at possibilities that would be discarded in a paper-based planning process. With a model, creating and evaluating a new scenario takes minutes instead of weeks of effort. Allocation models are custom-built within it that can include proximity to transportation facilities or accessibility measures.
- It is custom-built to show the community's specific issues, opportunities, risks and alternatives. Every community is unique, with its own resources, opportunities, and constraints. It models alternatives so that choices are more clear and defensible.
- Planners and decision makers get "big picture" understanding of the risks facing them, which allows them to develop contingency plans with confidence knowing all the details have been included.
- Paper plans are out-of-date as soon as they are printed. A Scenario Model is a "living document". Every external event or step in the implementation process can be added to the Scenario Model so it always shows the current status of the Community and its plans.

- A scenario model becomes a key implementation tool. It can be used to evaluate the potential impacts of individual projects to see how well they meet the community's goals. It also becomes an excellent tool for reporting progress against the Comprehensive Plan's milestones.

The "Growth and Impact Models" is the component of PlanMaster that models the effect of growth on a region over a period of time. It produces maps that illustrate the different results of each scenario to help stakeholders understand the effect of varying decisions and assumptions.

Spreadsheet Model for Induced Travel Estimation (SMITE)

The Spreadsheet Model for Induced Travel Estimation (SMITE) was developed by the Federal Highway Administration (FHWA) to predict the amount of vehicle traffic induced by a highway improvement, and its effects on consumer welfare and vehicle emissions. SMITE is a simple, Lotus 123 spread sheet model that takes into account new travel that may be induced by highway expansion over and above that which is simply diverted from other regional highways. For more information, see www.fhwa.dot.gov/steam/smite.htm.

SMITE does not appear to be designed to allocate regional population and employment: like other transportation models it appears to take those allocations as given and then calculates, at the margin, induced VMT and the value of that VMT (presumably based on estimates of consumer surplus based on rough estimates of a travel demand curve). Consistent with the definitions we use in this report, SMITE is focused on induced *travel*, not induced *land development*, though the two are clearly related. It also does not distinguish short term from long effects and indirect land use effects, research shows, accumulate over time. As noted earlier, SMITE also relies on evidence drawn from a limited set of studies, most conducted several decades ago, and thus might not be as relevant as meta-analysis summaries (as presented earlier in **Table 6**) for some current-day projects.

The SMITE model requires information about the transportation improvement under consideration, including length, increase in capacity, average daily traffic levels, hourly capacity, etc. The product of SMITE is an analysis of the stream of benefits over the lifetime of the investment, both for induced travelers as well as for pre-existing travelers, based on a benefit-cost analysis. See further comments on SMITE in Section 4.4.3.1.

TELUS/TELUM

TELUS National is a computerized information-management and decision-support system designed specifically for metropolitan planning organizations and state departments of transportation. Development of the initial version of TELUS (1996-1998) was a cooperative venture among the Institute for Transportation of the New Jersey Institute of Technology (NJIT), the Center for Urban Policy Research (CUPR) of Rutgers University, and the North Jersey Transportation Planning Authority (NJTPA). With funding from TEA-21 the TELUS passed through several cycles of revisions to ensure that the version to be distributed nationally would meet the widely varying needs of all MPOs and SDOTs across the nation. These revisions are included in TELUS National Version 3.0, which is now available.

TELUS does many things related to managing project evaluation, selection, and monitoring that are not relevant to the topics in this report. But it also contains economic and land-use components. Its land-use model will project the location of new residential and nonresidential development based upon changes in the transportation network as a result of TIP projects. This model is available as TELUM Version 4.0.

TELUM is a derivative of the METROPILUS model (based on ITLUP, and containing DRAM and EMPAL, models described in Section 4.4.6.2) developed by Dr. Stephen Putman. Its manual claims it is a self contained, novice-friendly land-use modeling system designed to project the location of new residential and nonresidential development based upon analysis of (1) prior and existing residential and nonresidential development, (2) the location of transportation improvement(s), and (3) overall congestion in the system. TELUM forecasts the location and amount of household and employment growth for up to 30 years.

TELUM uses economic and land use models to produce long-term forecasts of population and employment spatial patterns in a designated planning area. Based on user's inputs, TELUM uses current and prior residential, employment, and land use data to forecast their future levels by analysis zone, employment sector, household income group, and land use type. The model's web site states that it can be used for policy evaluation: policy changes on the demand side, in terms of urban design and land use control, as well as the policies acting on the supply side in terms of implementing various kinds of transportation improvements. These transportation improvements can include highway projects, transit projects, or combinations thereof, as well as measures to promote more efficient utilization of existing facilities. The model allows users to set constraints on the allocations based on other physical and policy variables. The GIS module embedded in TELUM allows users to view, print, and perform geographic analysis of zonal land use, demographic, and employment data entered by the user or forecasted by the model.

The software is available for free (www.telus-national.org) and runs on a PC with ArcView. It assumes that users have access to independent travel demand models and trip assignment package (e.g. EMME2, MINUTP, TRANPLAN, TRANSCAD, UTPS, etc.). The congested network travel times and/or costs produced as output from these packages may then be used as inputs to subsequent time period forecasts from TELUM.

Urban Land Use Allocation Model (ULAM)

The Urban Land Use Allocation Model (ULAM) is an extension of ArcView GIS software to help traffic planners forecast future travel conditions. ULAM was developed in Florida by Transportation Planning Services, Inc. ULAM is a land-use planning tool designed for a variety of planning applications, including allocation of future growth.

ULAM can be used to create and evaluate land-use scenarios such as comparing compact development patterns versus urban sprawl patterns. This is accomplished by changing assumptions, such as land-use densities or the amount of vacant land, within specified areas to create different scenarios of development density.

ULAM also models the impact on the transportation network for different scenarios. The impacts of changes in the transportation network on future land development patterns are reflected in the ULAM Real Estate Market Index. The model ranks each traffic zone for different types of development based upon travel time and accessibility to major land use activity centers and based upon socio-economic conditions within a given travel time around each traffic zone. As the transportation network is changed, the travel time on the network changes, which changes the ranking of each traffic zone for different types of development. For example, if a new expressway is added to the network the travel time between various traffic zones decreases, giving particular zones a higher ranking for most types of development. In addition, the market area (based upon travel time) has increased (the area defined by a specific drive time), so traffic zones in that area are more desirable for retail and other types of new development.

What If? Planning Support System.

According to the company's website (http://www.what-if-pss.com/), *What if?* is a GIS-based system that can be used to explore alternate futures for a community and prepare long-term land use, population, housing and employment projections for enumeration districts, political jurisdictions, and user-defined areas such as school districts, and traffic analysis zones. *What if?* PSS was developed jointly by LDR International, Inc., Data Chromatics, Inc., and Community Analysis and Planning Systems, Inc.

As its name suggests, *What if?* allows public officials and private citizens to simulate what would happen if public policy choices are made and assumptions about the future prove to be true. Policy choices that can be considered in the model include: (1) the expansion of public infrastructure; (2) the implementation of farmland or open space protection policies, and (3) the adoption of land use plans, zoning ordinances, and other growth controls. Assumptions that can be considered in the model include future population and employment trends and development densities. *What if?* has been designed to be used by non-technical people and in public settings, allowing currently available GIS information to be used to support community dialogue and collaborative decision-making.

What if? can be used for several types of allocations and estimates. It can allocate population, households, housing units, and employment by various geographies, including TAZs. It can allocate projected land-use demands to different locations based on their relative suitability for these uses and on public policies for guiding future growth. It can extrapolate from residential demand to estimate needs for open space and recreational land.

Summary

The synopses above provide a sense of the kinds of existing models available, and of amount of work it would take to evaluate them all in the context of a single transportation project. Several of the models are obviously quite different. As described by their promotional material, *What if?* is probably closest to what we have described in this section as an allocation model: a spreadsheet based model that can allocate population and employment to TAZs based in part on various land and infrastructure characteristics, and that can convert those allocations into measures of land development. But the model does not explicitly model how land changes in response to more transportation capacity. TELUM could be a good choice for MPOs, especially ones that already have it, or would consider acquiring TELUS for its broader capabilities with project evaluation and monitoring. PlanMaster is a broader-based model for scenario development and evaluation: in that sense it may incorporate some of the allocation model functions, but it goes beyond them.

Our conclusion is that existing models are probably not for relatively small jurisdictions looking to evaluate the impacts of a single project. They are for bigger jurisdictions, with a long-run perspective, and with the responsibility for evaluating many different future projects.

Step 3: Develop an Ad Hoc Allocation Model

Assume that a jurisdiction has (1) the desire and resources to supplement planner and collaborative judgment with additional data and analysis, (2) decided not to acquire and adapt an existing rule-based model to its local circumstances, and (3) decided to create an ad hoc allocation model. What steps would it take?

A logical way to develop a simple ad hoc model is to start with a listing of key forces: forces that encourage or hinder development. The previous section on planning judgment provides a good start; text and articles on urban economics and real estate development can go farther (see O'Sullivan 2006 or Moore and Thorsnes 2007 for example). The basic drivers are relatively clear and are incorporated into most existing and ad hoc allocation models. Land is more likely to develop or redevelop if it is:

- High-priced. To a large extent, this variable subsumes all that follow. Land is high-priced because households and businesses think its characteristics make it valuable.
- Close to other development (aka, a gravity model). Land close to urban land is more likely to develop than land farther away, other things being equal. The reasons are primarily access and agglomerative economies (clustering).
- Close to major highways. A better measure, if available, is some weighted travel time to important destinations, which is also called an accessibility index and can be derived from the gravity model formulae in the four-step model.
- Supplied with public facilities and services that are readily available, low cost, and high quality. Sewer lines and treatment capacity are key. Often overlooked by planners, but not by homebuyers, is the quality of the school system, which in hedonic pricing studies (i.e. where the independent variables are related to quality), is always one of the key predictors of land value.
- Vacant. If a TAZ has no vacant land, and if all the development is relatively new or otherwise of high value, getting yet more development will be more difficult.
- Unconstrained by other public policy. There are many good reasons for public policies that constrain development (health, safety, welfare). But those policies constrain growth. Alternatively, some public policies (e.g., urban renewal districts, enterprise zones) may encourage growth.

At the risk of over-simplifying, most allocation models take regional demand as a given (regional growth in population and employment—the control totals) and then look at primarily supply-side characteristics to decide where in the region the demand will go. Thus, we start with supply-side characteristics. Some of these steps are the same as or similar to the steps in the planning judgment chapter.

We will refer to steps 3.1 to 3.4 that follow as "the base case" allocation. Our point is consistent with the one made in the section on planning judgment: (1) any estimate of the land-use effects attributable to a transportation improvement requires a comparison of the expected development *without* the improvement to the expected development *with* the improvement, and (2) one must be clear about whether the base case already includes the transportation improvement being evaluated, or not.

Step 3.1: Determine the Supply of Buildable Land

The purpose of an inventory of buildable land is to document how much land is available for residential and non-residential development and to allow jurisdictions to estimate the "holding capacity" or the amount of residential development and employment that can be accommodated on the buildable land. Buildable land is usually defined as vacant land that is not constrained by natural or policy conditions to such an extent that its development would be illegal or prohibitively expensive.

A buildable land inventory can be simple or sophisticated, depending on the resources of the jurisdiction. A simple buildable lands inventory relies on local knowledge and fieldwork to complete the inventory. The data necessary for a simple buildable lands inventory includes comprehensive plan and zoning maps, assessor parcel maps, aerial photos (if available), and field analysis. A sophisticated buildable lands inventory uses these data, as well as GIS technology, to build a database of information about land uses. In brief, the steps in conducting a simple buildable lands inventory are:

1. Identify vacant and partially vacant parcels. The buildable lands inventory should identify vacant lots with no significant improvement or partially vacant lots that have some development but also have visible vacant areas. Where an analyst has access to a GIS parcel database which is connected to a Property Assessment database then partially vacant or "underdeveloped" parcels can be determined by identifying those parcels where, say, the land is worth more than the improvements or the improvement is less than 25% of its allowed zoning maximum.
2. Identify development constraints. Identification of development constraints occurs through document research, fieldwork, and/or aerial photo interpretation. Development constraints can include existing development or natural features such as steep slopes, wetlands, floodplains, etc.
3. Identify mixed-use and redevelopment potential. This step is primarily important for employment land but may also be applicable to residential land. Mixed-use opportunities may include combinations such as industrial and commercial uses in close proximity or commercial, retail, and residential uses in the same building.

   Redevelopment potential deals primarily with parcels with developed structures that are likely to be rehabilitated or demolished and new buildings constructed in their place. Not all, or even a majority of parcels that meet these criteria for redevelopment potential should be assumed to redevelop during the planning period.

Once mixed-use and redevelopment opportunities are identified, the results of Steps 1 and 2 should be adjusted to account for unique local circumstances that impact development potential.

4. Estimate development capacity. The final step in the buildable lands inventory analysis is to estimate the amount of employment or residential development that can be accommodated on the buildable land. This step requires estimates of density, expressed, for example, as employees per acre or dwelling units per acre.

   Considerations for estimating the capacity of employment land include:

   - The percent of employment that will require no new land, such as people who may work from their home like construction contractors or telecommuters.
   - The amount of employment that will be accommodated in existing development, as companies add employees without adding new space.
   - The amount of employment that will be accommodated on redeveloped land, such as an existing building that is renovated or torn down and replaced with a new building. Redevelopment of land generally increases employment density on the land.
   - Vacancy rates, especially for commercial and retail space
   - Density of employees, expressed in employees per acre or a floor area ratio.

   Considerations for estimating the capacity of residential lands include:

   - The mix of housing, such as single-family detached houses, mobile homes, or multifamily housing.
   - The density of housing, which is closely related to the mix of housing. Multifamily housing is likely to be denser (with more dwellings per acre) than single-family detached houses. If local data is unavailable, Nelson (2004) provides useful default values for densities by housing type.
   - Vacancy rates
   - The number of people living in group quarters, such a nursing homes, college dorms, or prisons. Since these people do not consume standard housing units, they are typically backed out of the population forecast for the purpose of estimating housing need.
   - Household size and household composition, which have changed with demographic shifts over the last several decades. Household sizes have decreased on average and household composition has shifted away from traditional families (married couple, with one or more children at home) to a greater variety of relationships between people living in a household. Where areas are subject to immigration, these trends might not hold.
   - Income and poverty status, which affect the characteristics of housing (type, size, and quality) a household can afford.

Other land needs for public or semi-public uses should also be considered. These uses include religious uses, schools, public buildings, parks, infrastructure, and other uses.

Step 3.2: Allocate Population and Population Growth to Sub-Areas

Demand for land will be driven by growth in employment and population. See Section 4.4.1 on planning judgment for a general discussion of forecasting employment and population growth. Allocations of employment and population to sub-areas like TAZs require an assessment and judgment about how demand and supply factors are matching. Throughout this section on allocation models we have said that one first allocates population and employment to a TAZ, and then converts that growth to measures of land development. The steps in this section are structured that way.

But as a practical matter, *the allocation of population and employment probably has to happen at the same time as the evaluation of the implications of that growth for land consumption*. How much population and employment growth will occur is in part a function of the ability of land supply to accommodate that growth at reasonable prices. To compare land demand to land availability, one must have some notion of how much land the potential allocations of population and employment growth to a TAZ are likely to consume. We address that analysis in Step 3.3.

For now, to keep it simpler, we note some of the other things that an allocation of population and employment to a TAZ should consider:

- Community development potential. The types of firms that a jurisdiction is likely to attract or have expand will depend on factors affecting the comparative advantage of the jurisdiction. These factors include: location relative to markets; availability of transportation infrastructure; capacity of public facilities, such as wastewater and drinking water; access to necessary support services; availability and quality of labor; access to educational and training programs; and public policy, such as taxes or economic development policies.
- Types of employment. Employment can be separated based on the characteristics of the land required or the expected density of employment. One way to classify land use by employment and typical industries is:
    - Commercial: Retail Trade.
    - Office: Finance/Insurance/Real Estate and Services.
    - Industrial: Agricultural (other than farming)/Forest/Fishing, Mining, Construction, Manufacturing, Transportation, Utilities, and Wholesale Trade.
    - Public: Federal, State, and Local Government.

  These groupings are not as distinct as they appear because there is substantial overlap between types of employment and land needs. For instance, commercial and retail employment generally have similar land requirements and may co-locate in a shopping center or office park.

Ultimately the types of buildings and employment densities matter more than the land use type for calculating land need. For instance, professional services (office) and local government (public) will work in office buildings. These considerations are addressed in Step 3.3.

- Supply of land in the TAZ. The amount of vacant and partially vacant land available in the TAZ will affect the amount of population and employment that can be allocated to the TAZ. The capacity of the land for development will be influenced by assumptions about development density and the types of buildings (i.e., single-family residences, office space, or heavy industry).
- Supply of land compared to demand for land. Step 3.1 gives some notion of supply. The regional control totals for population and employment growth are an indirect measure of the demand for land. The supply of vacant land in the TAZ and its development capacity will influence the amount of development that can occur in the TAZ.
- Prior growth trends. Knowledge of the 10-year history of development at the TAZ level is a valuable ingredient in specifying future allocation. Caution must be exercised here, however: allocation models should not keep allocating the same land use to the TAZs because of the pre-existing use without any checks and balances on reasonableness.

If allocating to all TAZs, the sum of the allocations should equal the regional control total. If allocating just to a subset of TAZs of interest in the analysis, the percent of development allocated should "seem reasonable." There are typically hundreds of TAZs in a metropolitan area: getting even 1% of the regional growth will be a lot for any single TAZ.

The factors to include in an allocation model should, of course, reflect local realities as derived from the above considerations. Nevertheless, the following are general guidelines or cautions on the factors to include in an allocation model.

- The importance of *accessibility* in any spreadsheet weighting system should be allowed to vary by land use (e.g. less for residential SFD; more for class A office space and regional retail - see sample spreadsheet in Table 1 in **Appendix D**)
- The importance of accessibility should be allowed to vary by the degree of maturity of the land use/transportation system (less in more mature contexts and in super-hot land markets where every available parcel might develop)
- Simple models can work. Allocation models that use only the available development capacity of the TAZ, its current mix of residential/non-residential uses and its 10 year history of development plus an accessibility measure, can provide good results
- Allocation models should have the capability to exclude specific factors from being considered in the allocation model (e.g. no conversion of prime agricultural areas)
- The sequence of allocation of land uses is very critical – the best (highest scoring TAZs, say) lands , if allocated first to given uses, fall out of consideration for other uses and very different land use patterns result; the logic for the allocation sequence may vary by context and should be explicit in model documentation

- It often helps to allocate first to large chunks of land (aggregates of TAZs), where assignments can be intuitively gauged for reasonableness, before allocating to smaller TAZs.
- Allocation models, since they try to replicate market behavior, are complicated by the existence of growth management systems. They have difficulty mimicking growth management phenomena like deflection; where models are developed in such contexts, the tool must be open to exogenously imposed constraints that reflect these patterns. A Delphi-type panel (see Section 4.4.2) can be used to identify these constraints.
- Existing zoning or the existing Comprehensive Plan must be included if they are durable and stable guides; if not, they are not essential ingredients and can be a post-processing consideration.

An example of a comprehensive Allocation model, which includes the rules of allocation and the controlling spreadsheets, is presented in **Appendix D**. This example uses fairly basic measures of accessibility (proximity to interchanges, frontage on major roads, VMT on roads) but has an otherwise nuanced series of rules.

<u>Step 3.3: Determine Site Requirements</u>

Residential and employment uses have different building characteristics and site requirements. If the TAZ does not have land that meets the site requirements for a certain use, then that growth for that use should probably not be assigned to the TAZ. For instance, if the TAZ lacks large, flat parcels, then it would not be wise to assume that that a large industrial employer will move to or expand in the TAZ. Typical site requirements for residential development include:

- Infrastructure. Residential development at urban levels requires access to infrastructure, such as potable water, sanitary sewer, stormwater sewer, electricity, and telecommunications.
- Transportation. Residential development requires access to roads. Although residents want access to large roads, such as state highways or interstate highways, most people prefer not to live adjacent to these types of roads. Other types of transportation that may be important for residential development include: pedestrian and bicycle infrastructure, air transportation, and transit.
- Parcel size. Residential development can vary from infill development of a single dwelling unit to a subdivision of 100 acres or more. Availability of a range of parcel sizes is important to residential development.
- Topography. Residential development can occur on flat sites or hillsides and slopes. The topography will have an effect on the type of residential development likely to occur. For instance, developers of large subdivisions generally prefer flat sites. In addition, development on hillsides is likely to be less dense than development on flat sites.

Site requirements for employment land depend on the type of employment locating on the land. The required site and building characteristics for industries likely to locate or expand in a jurisdiction can be inferred from regional and local employment trends. Some typical site needs for employment uses include:

- Parcel size. The parcel size will vary by the type of industry: large lot industrial sites (50+ acre parcels); campus research and development (R&D) and smaller manufacturing sites (20 to 40 acre parcels); smaller light industrial/office sites (5 to 20 acre parcels); and, speculative space within office/flex and mixed-use developments. **Table 7** summarizes the lot sizes needed for some types of firms.
- Parcel configuration and parking. Industrial users are attracted to sites that offer adequate flexibility in site circulation and building layout. Sites must also provide adequate parking, vehicular circulation and open space. Parking ratios of 1.5 to 2.5 spaces per 1,000 square feet are typical design requirements. In general, rectangular sites are preferred with parcel width of at least 200 feet and length that is at least two times the width for build-to-suit sites. Parcel width of at least 400 feet is desired for flex/business park developments.
- Land use buffers. Industrial areas have operational characteristics that do not blend as well with residential land uses as they do with office and mixed-use areas. As industrial use intensifies (e.g., heavy manufacturing) so to does the importance of buffering to mitigate impacts of noise, odors, traffic, and 24/7 operations. Adequate buffers may consist of vegetation, landscaped swales, roadways, and public use parks/recreation areas. Depending upon the industrial use and site topography, site buffers range from approximately 50 to 100 feet. Selected commercial office, retail, lodging and mixed-use (e.g., apartments or office over retail) activities are becoming acceptable adjacent uses to light industrial areas.

Table 7: Typical Lot Size Requirements for Selected Types of Industries

Industry	Lot Size (acres)	Site Needs
Printing & Publishing	5 - 10	
Stone, Clay & Glass	10 - 20	Flat
Fabricated Metals	10 - 20	Flat
Industrial Machinery	10 - 20	Flat
Electronics - Fab Plants	50 - 100	Suitable soil
Electronics - Other	10 - 30	
Transportation Equipment	10 - 30	Flat
Trucking & Warehousing	varies	
Wholesale Trade	varies	
Non-Depository Institutions	1 - 5	
Business Services	1 - 5	
Health Services	1 - 10	
Engineering & Management	1 - 5	

Source: ECONorthwest, 2001

- Flat sites. Flat topography (slopes with grades below 10%) is needed for manufacturing firms, particularly large electronic fabrication plants and on sites of over 10 acres for fabricated metals and industrial machinery manufacturing facilities.
- Soil type. Soils stability and ground vibration are fairly important considerations for special high-precision manufacturing processes, such as assembling 800 megahertz or higher-speed microchips.
- Building density. Today's industrial buildings are designed to accommodate materials shipments, goods storage, manufacturing processes, and administrative and customer-support functions. In addition to solid foundations to accommodate the weights of fork lifts moving heavy goods as well as machinery, interior ceiling heights of 18 to 28 feet are expected for manufacturing facilities. Even higher ceiling heights (of up to 45 feet) are expected for warehousing facilities. The ratio of building floor area to site area (FAR) typically ranges from 0.35 for industrial/flex buildings to 0.25 for low density suburban office buildings or 0.5 for more urban office buildings. Building depth for industrial and flex buildings is often 100 to 120 feet, while width varies significantly.
- Transportation. Many businesses are heavily dependent on surface transportation for efficient movement of goods, commodities, and workers. Proximity to air transportation is also key for high technology manufacturing industries, particularly those in the Electronic and Electric Equipment and Industrial Machinery industries. Access to transit is most important to industries with the greatest number of jobs and consumer activity.
- Potable water. Potable water needs range from domestic levels to 300 thousand gallons per day. Significantly higher levels of water demand are associated with selected industries, such as food processing and silicon-chip fabrication plants. The demand for water for fire suppression also varies.
- Sanitary sewer. Like potable water, sanitary sewer needs range from domestic levels to thousands of gallons per day.
- Power requirements. Electricity power requirements range from redundant 115 kilovolt amps (kva) to 230 kva. Average daily power demand generally ranges from approximately 5,000 kilowatt hours (kwh) for small business service operations to 30,000 kwh for large manufacturing operations. The highest power requirements are associated with industries such as metal and electronic fabrication.
- Fiber optics and telephone. Most if not all industries expect access to high-speed Internet communications. The amount of communication capacity necessary will vary depending on the type of business and their use of the Internet.

<u>Step 3.4: Convert Population and Employment to Land Use</u>

This step of the modeling is primarily a comparison of the information in Steps 3.1, 3.2, and 3.3 to get to a final estimate of land use for the base case. Converting population to residential land use involves multiple assumptions about (1) number of new residents, (2) expected number of people in group quarters, (3) the housing mix, (4) household size by type of housing, and (5) vacancy rates by type of housing. The population allocation will determine the number of new residents. The assumptions for remaining characteristics can be made based on Census data. **Table 8** shows an example summary of these assumptions. These assumptions can be tracked and manipulated in a spreadsheet allocation model.

The assumptions in **Table 8** can be used to estimate the number of new dwelling units needed for the planning period. The steps in this estimate include:

- Calculate the persons in households by subtracting the change in people in group quarters from change in new residents.
- Calculate the number of single-family dwelling units (DU) needed based on:
    - Multiply the share of single-family DU by persons in households to determine the number of persons in single-family DU;
    - Divide the number of persons in single family DU by the household size of single family DU to determine the new occupied single family DU; and
    - Multiply the vacancy rate by the occupied single-family DU to determine the total new single-family DU needed.
- Repeat the steps above (using the assumptions about multifamily housing) to determine the total number of multifamily DU needed.
- Add the total number of single-family DU and multifamily DU to get the total new dwelling units

Table 8 shows an example estimate of new dwelling units.

Table 8: Summary of Assumptions for New Residential Development

Assumption	Value
New persons, 2000-2020	13,567
New persons in group quarters, 2000-2020	310
Housing Mix	
Single-family	78%
Multiple family	22%
Household size	
Single-family	2.66
Multiple family	2.10
Weighted average household size	2.54
Vacancy rate	
Single-family	2.5%
Multiple family	5.0%

Source: ECONorthwest, 2001

Converting the allocation of employment to employment land use involves estimating (1) the distribution of employment by type, as described in Step 3.2 based on current and/or historic employment trends, and (2) several characteristics of employment development by type of employment: (a) share of total employment growth that requires no non-residential built space or land, (b) share of employment growth that will take place on existing developed land, (c) the vacancy rate, (d) employees per acre, and (e) square foot floor area per employee, (f) implied floor area ratio (FAR), (g) share of employment growth on redeveloped land, and (h) employment density increase on the redeveloped land. **Table 9** shows an example summary of these assumptions.

To calculate the land needs by employment type based on the characteristics in **Table 7**, an allocation model would need to:

- Calculate the amount of employment growth by land use type. Multiply the share of each employment type by the total employment allocation.
- Calculate the amount of employment growth that requires no non-residential build space or land. Multiply the share of employment that requires no non-residential build space or land by the total employment growth for each land use type.
- Calculate the amount of employment growth on existing developed land. Multiply the share of employment growth on existing developed land by the total employment growth for each land use type.
- Calculate the amount of employment growth on redeveloped land. Multiply the share of employment growth on redeveloped land by the total employment growth for each land use type.
- Calculate the amount of employment that requires vacant non-residential land. Subtract the amounts in A through D from the total employment for each land use type.

Table 10 shows an example of the output of an allocation model for the distribution of employment growth by type of land use.

The last step in the allocation model is to calculate the amount of vacant land and new built space needed by land use type. Typical steps:

- Determine acres of vacant non-residential land. Divide employment growth that will require new space (the last column of **Table 11**) by the assumption about employees per acre in **Table 10** for each land use type, with an adjustment for vacancy.
- Determine square feet of new building space. Multiply employment growth that will require new space (the last column of **Table 11**) by the square feet per employee assumption in **Table 10** for each land use type, with an adjustment for vacancy. **Table 12** shows the results

Table 9: Estimate of New Dwelling Units

Variable	Value
Change in persons, 2000-2020	13,567
-Change in persons in group quarters	310
=Persons in households	13,257
Single-family dwelling units	
Percent single-family DU	78%
Persons in single-family households	10,846
÷Persons per occupied single family DU	2.66
New occupied single-family DU	4,071
Vacancy rate	2.5%
Total new single-family DU	4,175
Multiple family dwelling units	
Percent multiple family DU	22%
Persons in multiple-family households	2,411
÷Persons per occupied multiple family DU	2.10
New occupied multiple-family DU	1,148
Vacancy rate	5.0%
New multiple family DU	1,209
Totals	
=Total new occupied dwelling units	5,219
Aggregate household size (persons/occupied DU)	2.54
+ Vacant dwelling units	165
=Total new dwelling units	5,384
Dwelling units needed annually 2000-2020	269

Source: ECONorthwest, 2001

Table 10: Assumptions for Non-Residential Land Demand

	Land Use Type			
Assumption	**Commercial**	**Office**	**Industrial**	**Public**
% of total emp growth that requires no non-res built space or land	5%	5%	5%	1%
% of emp growth on existing developed land	5%	5%	7%	7%
Vacancy rate	5%	5%	5%	5%
Emp/ acre	22.0	22.0	11.0	35.0
Sq. ft. floor area/ emp	350	350	650	400
Implied Floor Area Ratio (FAR)	0.18	0.18	0.16	0.32
Redeveloped Land				
% emp growth on redev. land	5%	5%	5%	5%
Relative density increase (emp/acre, area/emp)	50%	50%	50%	50%

Source: ECONorthwest, 2001

Table 11: Distribution of Employment Growth by Type of Land Use

Land Use Type	Total emp growth	Requires no non-res built space or land	On existing developed land	On redev. land	Requires vacant non-res land
Commercial	2,179	109	109	109	1,852
Office	2,092	105	105	105	1,777
Industrial	2,212	111	155	111	1,835
Public	778	8	54	39	677
Total	7,261	333	423	364	6,141

Source: ECONorthwest, 2001

Table 12: Vacant Land and New Built Space Need by Land Use Type

Land Use Type	Acres vacant non-res of land		Sq. Ft. of new building space	
Commercial	88.6	24%	682,316	24%
Office	85.0	23%	654,684	23%
Industrial	175.6	48%	1,255,526	44%
Public	20.4	6%	285,053	10%
Total	369.6	100%	2,877,579	100%

Source: ECONorthwest, 2001

Step 3.5: Repeat Steps 3.1 Through 3.4 With the Transportation Change Included

As noted in the section on *planning judgment*, an analyst must make a determination of whether the transportation improvement under consideration is already included in the population and forecasts (implicitly) or whether it is adding new capacity. Without that determination, no amount of data and modeling is of any value since the analyst does not know whether to add the induced development to the base case or subtract it.

4.4.4.5 Additional Information

Off-the-shelf allocation models did not exist ten years ago. The allocation models that did exist were not very adaptable. Allocation models are likely to become more accessible, adaptable, easier to use, and less expensive. In the future it may make sense for planners to use an existing allocation model, rather than developing an ad hoc model. For now, however, existing models are probably not for relatively small jurisdictions looking to evaluate the impacts of a single project. They are for bigger jurisdictions, with a long-run perspective, and with the responsibility for evaluating many different future projects. Planners may not use the models for the following reasons: a low awareness of the models and their potential uses, limited experience with the systems, and limited interest in using the systems (Klosterman 2005). The dependence of many of the off-the-shelf models on GIS creates a barrier to using some of these models (Geertman and Stillwell 2003).

Case Study: Comparing Forecasting Methods, Expert Land Use Panel vs. Simple Land Use Model

This is a particularly noteworthy study because it is one of the very few that compares a Delphi panel outcome with a simple land use allocation model outcome for the same project - a very controversial 18 mile highway (the Inter County Connector) connecting two radial corridors. The study was conducted in a region (Baltimore/Washington) and County (Montgomery Co, MD) noted for its very strong growth management history and sophisticated planning culture.

The paper, however, raises more questions than it answers about both the limitations of the Delphi process (e.g. wildly divergent projections by the panel were simply averaged in the end) and the value of a very basic allocation model (driven almost entirely by accessibility measures and allocation zone size). While the land use outcomes (jobs and households) of the two processes were strikingly different (much less regional change in Delphi), one cannot resolve these differences because of the serious limitations of the model itself.

The model, developed and executed very rapidly during the Delphi process so as to influence its findings, used only two variables: gravity model-derived *accessibility measures* and TAZ *size* to drive allocations. For Montgomery County only, zone development capacity was added, based on the current zoning, and was used to somewhat constrain allocations. No other zonal data was used.

Perhaps in less mature metropolitan regions that are less regulated and less highly differentiated (socio-economically, racially, land values, school quality etc.) and that are more obviously governed by market forces (i.e. where unconstrained zoning and job access primacy can be construed as givens) a very simple model like this is useful. The paper's inclination "…to advise MPOs to fully develop integrated land use and transportation models for regions as large and complex as Baltimore-Washington" is well taken. But even here, readers should be cautioned that the massive expense and effort associated with such models does not guarantee that the models will address indirect land use effects, as work by Rodier (2004) shows. We take up this matter in detail in Section 4.4.6.

In the ICC context, where data and modeling sophistication abound, the time and resource constraints of the process selected rendered this bold, midstream attempt to clarify indirect land use effects moot. Unquestionably accessibility data to panelists would have helped but it is essential that modeling efforts be a worthy counterbalance to Delphi panels.

4.4.5 Four-Step Travel Demand Forecasting Models With Heuristic Land Use Allocations

4.4.5.1 Overview

The *de facto* standard for forecasting future transportation demand in metropolitan areas of the U.S. is the so-called "four-step" process. The term "four-step process" continues to be widely used and has become synonymous with travel demand forecasting. The four-step process has endured widespread support and institutional legitimacy from decades of use by public agencies that control transportation purse strings. Many large metropolitan areas, like Metro Portland and the San Francisco Bay Area, have added additional steps to the process to account for the effects of smart-growth practices on non-motorized transportation (e.g., walk trips) and peak-spreading (e.g., through mixed-land uses). However, these add-ons generally do not improve or refine the ability to forecast indirect land use effects. No methods have been operationalized to date to account for the growth-shifting effects of traffic congestion or new road investments within the framework of the traditional four-step model. The dynamic models discussed in the next section do this by using traffic assignment outputs to adjust initial land-use allocation inputs. For the most part, network-assigned traffic forecasts remain the "bottom line" results of four-step modeling.

Four-step models have difficulty accounting for induced travel. Consequently, if prescreening and planning judgment lead an analyst to believe there is a strong likelihood of indirect land use effects and a four-step model is available, then it should be assessed for its potential to account for induced travel. Without this increment of induced travel in the model, indirect land use effects will be understated. Before we deal with how to assess the ability of a four-step model to deal with induced travel, the reader must understand the basics of the standard four step model.

4.4.5.2 The Basics of the Four–Step Model

The four-step process is in essence a series of independent submodels linked so that outputs from one step provide inputs to subsequent ones: results of *trip generation* models (that estimate numbers of trips produced by and attracted to zones, by purpose) feed into *trip distribution* models (that estimate origin-destination flows between zones) which then feed into *mode-choice* models (that apportion estimated flows between competing modes) which in turn feed into *travel assignment* models (that load forecasted trips onto computer-generated networks of major streets and transit lines).

The four-step process is widely used to inform and prioritize investment decisions within the transportation planning process. However, it was never meant to estimate the travel impacts of neighborhood-scale projects or development near transit stations. Because TAZs, which can be as large as census tracts in size, are their primary units of analysis, four-step models treat land-use futures at meso- and macro- geographic scales: corridors, sub-regions, metropolitan areas, and states. Their resolution tends to be too gross to pick up fine-grained design and land-use mix features of neighborhood-scale initiatives like New Urbanism and Transit Oriented Developments (TODs). For this reason, various post-processing techniques have evolved in recent years, including those that aim to account for indirect effects like induced travel and emissions impacts. To understand these techniques it is first necessary to understand the basics of the 4-step process.

Conventional four-step travel models break down demand into distinct sequential components wherein the end-product is estimates of traffic on highway networks and transit systems. For the most part, because regionwide (and thus mostly out-of-neighborhood) travel demand is forecasted, only motorized trips are typically modeled. Guiding the formulation and specification of models are economic theories of consumer choice, rooted in the principle that individuals choose among options so as to maximize personal benefit, or what economists call *utility*.

Initially, models are *estimated* in a base year using inputs from household-based travel diaries, adjusted census tabulations, and specialized surveys (such as for goods movement). Estimated models are then *validated* by comparing baseline estimates to actual volumes. Often, models are *calibrated* by making adjustments to parameterized coefficients to improve model performance. Once an acceptable level of accuracy is achieved for the base year, the models are then used for *forecasting* future travel demand. For more in-depth discussions of the conventional four-step model, see Meyer and Miller (2001).

Trip Generation

Trip generation models are used to predict the trip ends generated by a household, a business, or a zone. Origins are mostly treated as the point where trips are "produced" and destinations are the places to which trips are "attracted" to. Trip productions are usually the home, or residential, end whereas attractions are the non-residential end. Metropolitan Planning Organizations (MPOs) typically use regression equations or cross-tabulated trip rates to estimate numbers of trips per household as functions of such socio-economic variables as household size, income, and auto ownership. At the TAZ level, predictor variables normally include total population, employment, and the means of socio-demographic variables (like vehicles per household). The population and employment input numbers reflect land-use assumptions, determined by planners at a TAZ level, and remain fixed throughout the modeling process.

Trip Distribution

The task of a trip distribution model is to "link up" trip productions and attractions from the trip generation phase so as to estimate future travel flows. Usually, a gravity model is used to spatially distribute trips based on the scale, or "drawing power", of competing zones and inversely related to some function of travel time between zones. Gravity models reflect the fact that people perceive travel times differently for different trip purposes. Travelers generally will not invest large amounts of time for convenience shopping thus the "friction factor" for this purpose is large; in contrast, out of necessity many travelers are less sensitive to the time commitments of a commute trip. In the forecast of travel flows under smart-growth scenarios, trip distribution models have faltered most in the handling of intrazonal, or "within-zone", travel, something that post-processing adjustments aim to remedy (Cervero 2006).

Mode Choice

Future travel flows are next apportioned among competing modes – based on attributes of both the trip-makers (e.g., income and automobile ownership) and those of the modes themselves (e.g., travel times, costs, reliability). Almost universally, this is accomplished through the use of disaggregate, random utility models, in particular multinomial logit models. Traditionally, mode-choice models have predicted that travelers will choose options that maximize utility, or benefit, based on features of trip interchanges (e.g., travel times) as opposed to trip ends (e.g., quality of walking environment). In light of smart-growth objectives, some regions have begun to imbed variables like "pedestrian environment factors" as explicit predictors of mode choice (such as metropolitan Portland's widely cited LUTRAQ model).

Traffic Assignment

The final step of the four-step process involves the assignment of predicted modal flows between each origin-destination pair to actual routes – automobile trips onto highway networks and rail/bus trips onto transit networks. Historically, assignments have been based on the principle of user equilibrium – each user chooses a route to minimize travel time and that no user can reduce travel time by unilaterally changing routes. Some large MPOs have sought to refine traffic assignment by dynamically equilibrating between route choice behavior and overall network performance. Among the dynamic software packages to emerge in recent years are DYNASMART, PARAMICS, and TRANSIMS.

Historically, the chief deficiency of four-step models -- from an indirect-impact perspective – has been the usual absence of feedback loops between travel assignment and land-use allocations. A "feedback loop" is a connection between traffic assignment and initial land-use allocations that fuel the entire four-step forecasting process. Specifically, as travel times slow down because of heavy traffic loads, this diminishes accessibility along congested corridors for a future forecast date. This information on accessibility thus needs to be considered in making land-use allocations since, after all, accessibility is a key determinant of where future growth will occur. Ideally traffic assignment and land-use allocations needs to inform each other in a dynamic way.

Critics charge that failure to account for the traffic-assignment/land-use allocation feedback loop perpetuates car-based planning (Johnston 2004). Assigning large volumes of traffic to crowded corridors, theory suggests, will re-direct future growth to less congested corridors or close to urban centers and transit stations as travelers seek to avoid delays. Yet future population and employment is rarely re-allocated to greenfields, transit station areas or urban infill sites in response to worsening highway conditions. Nor are their efforts to account for the tendency of households and employers to co-locate so as to moderate the effects of congestion. The next section in this chapter specifically focuses on integrated transportation-land use models and their capacity to capture indirect land use effects of transportation facility improvements.

4.4.5.3 Best Practices in Travel Demand Model-Based Methods for Indirect Land Use Effects

There must be traffic congestion – existing or predicted – to spawn induced travel and land-use shifts following road expansion. Perceptions of traffic congestion vary considerably by urban setting and metropolitan size (Downs 2002). In big metropolitan areas, a change in conditions from a Level of Service (LOS) E (roughly 90% of capacity) to LOS D or better might be perceived to yield a significant improvement in flow conditions, thus triggering behavior shifts in travel and prodding some to make new trips. In a small to medium-size metropolitan area, an improvement from LOS D to C or better might be needed for induced demand and land-use shifts to reveal themselves (and in the latter case, over a number of years).

One way to begin to account for possible indirect land use effects of proposed road expansions is to compare assigned traffic volumes on links and levels of congestion within TAZs (e.g., average VMT/VHT) for two scenarios: one with a proposed road improvement and the other without (i.e. the counterfactual). The same initial allocations of future-year population and employment would be used in each forecast. Thus, the initial land-use assumptions would cycle through the four-step modeling process, resulting in different traffic load assignments and congestion levels for the two scenarios – presumably, the one involving road enhancements would have less congestion along particular corridors and affected TAZs.

How might one use this information to adjust initial land-use allocations? One possibility is simply to recalculate employment accessibility levels under each scenario and use the results to spatially allocate future population, for each scenario. Similarly, revised population accessibility forecasts could be used to re-allocate future employment. Because these two variables are endogenous (i.e., co-dependent), these adjustments would need to be done until some degree of convergence was reached. Essentially, this is what the dynamic models attempt to do as part of an integrated modeling package. However, for areas without truly integrated transportation and land-use models, the ability to link traffic assignment outputs and land-use allocation inputs in a mechanical, more heuristic fashion is certainly feasible – at least as a "second best" approach. There are no published or documented examples of this in the literature.

An even simpler approach would be to isolate TAZs that reap the biggest gains in accessibility from expanding link capacities and to judgmentally reallocate future population and employment to those zones. Logically, the growth would be shifted from the nearest TAZs whose network links do not experience travel-time reductions. Although such an approach might provide a reasonable order-of-magnitude adjustment in land-use allocations, it presupposes that the spatial extent of the benefits of road enhancements can be delineated and the benefiting TAZs under the "with" versus "without" scenarios can be identified. In truth, the impacts of a major road improvement reverberate throughout a network, influencing travel times on connecting links as well as distributor roads. Moreover, future traffic might also shift from other routes, reducing congestion on those links and make them also potentially attractive settings for future growth. Indeed, the judgmental approach outlined above amounts to a mechanical means of imputing accessibility changes and reflecting upon these changes in land-use re-allocations.

When it comes to using judgment to adjust initial land-use allocations, a better approach might be a marriage of traffic assignment output and expert judgment methods (like Delphi) to make land-use readjustments. Visual representations of estimated traffic loads under the "with" and “without” scenarios might be used, such as with TransCAD “theme symbol” plots of assigned linked traffic volumes and their average speeds.

Through a Delphi approach, experts could judgmentally reassign population and employment based on the “with” improvements scenario to account for the congestion-reducing and redistributive effects of road expansion. In this example, the result might be an upward adjustment of assumed baseline population and employment numbers for TAZs in central and western Berkeley to reflect faster travel and thus increased accessibility along the corridor. Through a panel of experts sharing each other’s land-use reallocations, and perhaps the rationales behind these reallocations, we would expect that over several information-sharing iterations, this would lead to some convergence of opinion on how land uses and traffic flows would adjust. In a sense, expert opinion takes the place of manual recalculations in linking traffic assignment outputs with land-use allocation inputs.

What such a marriage of traffic-assignment outputs and Delphi-based land-use inputs does not do, however, is cycle through multiple iterations of network assignments and land-use reallocations. Such a process would likely show that redistributing population and employment to the TAZs that reap the largest increases in operating speed will generate new trips that will erode some of these benefits. Consequently, making a single readjustment in land-use allocations based on traffic assignment outputs amounts to a partial equilibrium approach. Without full equilibrium adjustments, the results of such judgmental approaches are necessarily “second best”.

4.4.5.4 Resources and Inputs

The other necessary inputs to make judgmental adjustments in land-use allocations from traffic assignment outputs, beyond travel models themselves, include the availability of knowledgeable experts, whether in-house professionals or an external Delphi panel. A panel of experts need not be assembled in a single place, however. With video-conference tools now readily available (e.g., ADOBE’s Connect Professional software), it is possible to remotely conduct a real-time Delphi review. Also, as outlined above, GIS representation of traffic assignment outputs, such as those produced by commercially available packages like TransCAD and Cube, can be useful in visually sorting out which neighborhoods are likely to experience the largest increases in nearby traffic congestion (and thus become candidates for re-assigning future population and employment growth).

4.4.5.5 Additional Information

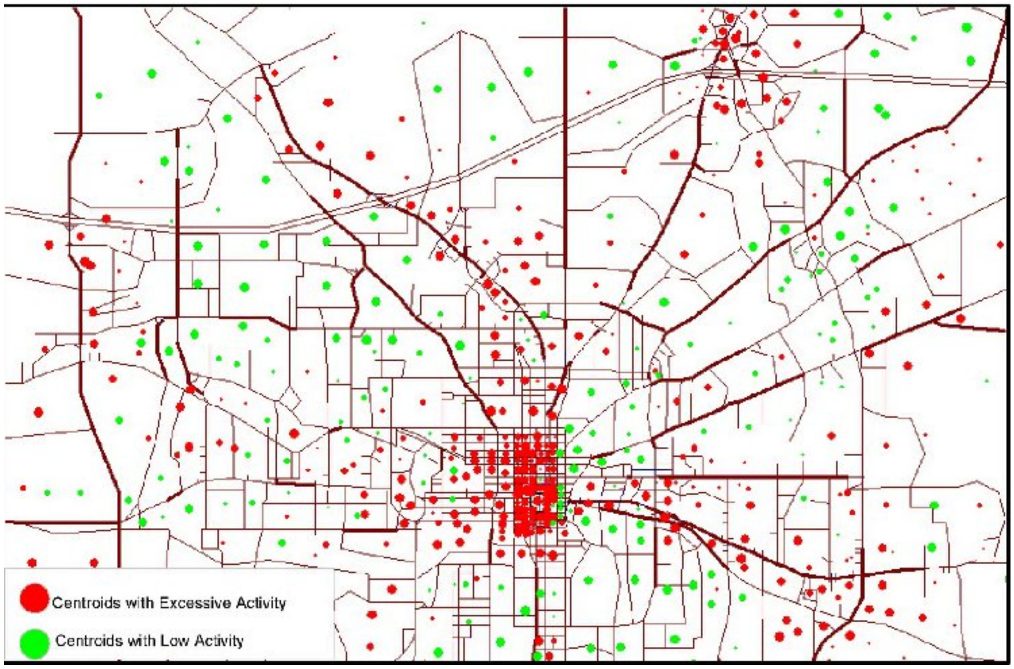
Alba and Beimborn have developed another approach for “mechanically” accounting for indirect land-use effects within the framework of the traditional four-step model (Alba and Beimborn 2004). This method takes given traffic link volumes on a network and works backwards to find the population and employment distributions – more specifically, trip origins and destinations – that best produce the reported volumes. Alba and Beimborn refer to this as achieving “land-use/transportation balance.” ”The idea is to solve the traffic forecasting process backwards to determine the levels of land use activity that results in levels of traffic that balance street capacities within an acceptable level of service. An optimization process is used to find a land-use pattern that is also consistent with our understanding of travel behavior".

The optimization method for balancing traffic and land-use activity is the Fratar Biproportional origin-destination table refinement method. While Alba and Beimborn portray this as a method to achieve a balance in traffic level-of-service and urban activities, this approach could very well be used to analyze the source of any assigned traffic loads, including imbalanced (i.e., highly congested) ones. Working backwards from traffic assignments to the origin-destination tables that are informed by land-use allocations and trip generation analysis, one could find a population-employment distribution that most likely gave rise to the assigned traffic estimates.

Alba and Beimborn applied this approach using the QRSII four-step software package for the Tallahassee, Florida MPO to identify TAZs with "excessive activity" and "low activity" for baseline assumptions of both population (i.e., trip origins) and employment (i.e., trip destinations). **Figure 7** flags the centroids of TAZs for which, based on acceptable link volume-to-capacity ratios, there are either excessive activities (i.e., too much population and employment) or relatively low amounts (i.e., too little population and employment). A further refinement is to stratify the results by trip origins (reflecting population distributions) and trip destinations (reflecting employment distributions). **Figure 8**, for example, presents clusters of TAZs, or sub-areas, specifically, districts 1 through 6, with relatively high levels of trip origins (i.e., households). The figure also shows that district 7 has relatively low trip origin volumes given the optimal link volume-to-capacity ratios in traffic assignment outputs. Achieving "land use/transportation balance" requires reallocating some *pro-rata* of households out of districts 1 through 6 and into district 7. This, of course, is only one side of the land-use allocation coin. The other side is represented by **Figure 9** which shows the pattern of "excessive" versus "low" destinations, or employment concentrations, for the centroids of Tallahassee's TAZs. Following the same logic, one would reassign employment from TAZs in the over-allocated district 8 (red dots) to the under-allocated district 9 (green dots).

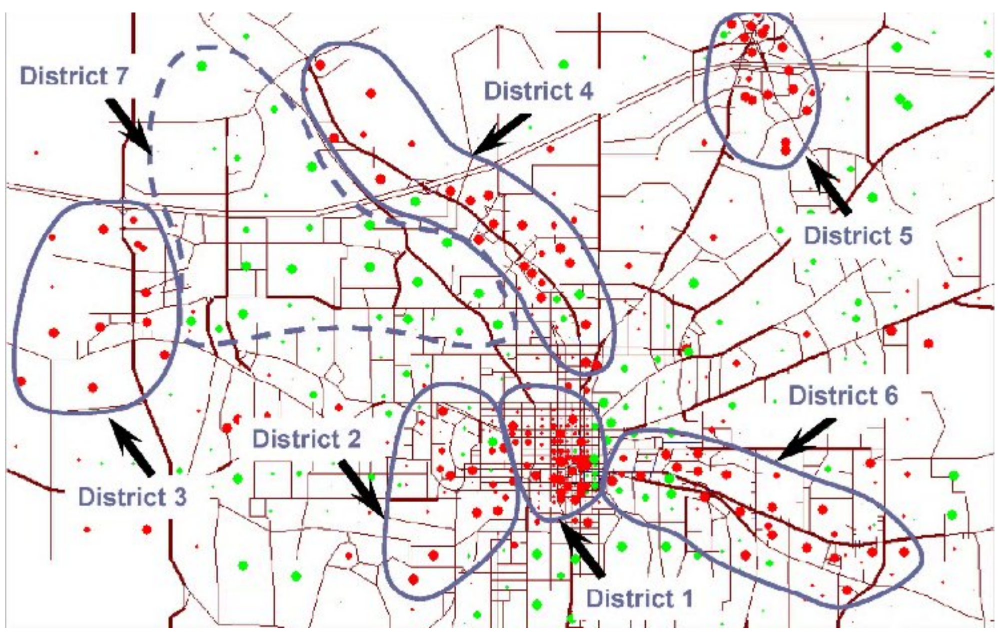
While Alba and Beimborn's approach has appeal as a way to account for indirect land use effects within the context of four-step modeling, it is not truly dynamic. This method fails to recognize that reallocating population and employment among districts, creates changes in link traffic volumes and V/C ratios. One could thus go through another round of backcasting to make further adjustments in population and employment allocations until some acceptable threshold of change in traffic performance is met. Nevertheless, to make this approach dynamic would be cumbersome and very time consuming. For this reason, using automated and integrated transportation-land use modeling approaches remains a first-best approach to using four-step model outputs to reallocate land-use.

Figure 7: TAZ Centroids with Either Excessive (Red/Dark) or Low (Green/Light) Land-Use Activities Based on Link Volume-to-Capacity Ratios in the Traffic Assignment State: Tallahassee, FL



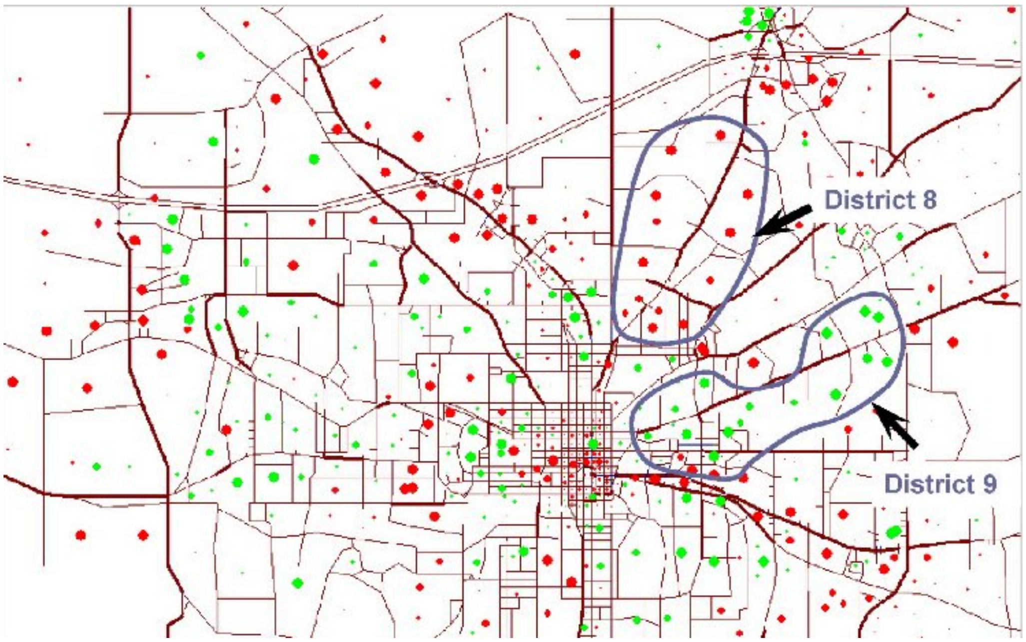
Source: (Alba and Beimborn 2004)

Figure 8: Sub-areas with Excessive (Red/Dark) or Low (Green/Light) Trip Origins, or Population Allocations, Based on Traffic Assignment Outputs: Tallahassee, FL



Source: (Alba and Beimborn, 2004)

Figure 9: Sub-areas with Excessive (Red/Dark) or Low (Green/Light) Trip Destinations, or Employment Allocations, Based on Traffic Assignment Outputs: Tallahassee, FL



Source: (Alba and Beimborn 2004)

4.4.6 Integrated Transportation-Land Use Models

4.4.6.1 Overview

Transportation and land-use integration is widely considered an essential element of smart-growth planning. Beyond the contemporary rhetoric of smart-growth planning, however, is a fairly long history of developing forecasting tools aimed at predicting the effects of pursuing such policies as transit-oriented development (TOD) and traditional neighborhood designs (TND)on land-use patterns and travel demand.

The models are "integrated models" because they explicitly account for the co-dependence between transportation and land-use systems Moreover, they are the most reliable and valid platform for quantitatively capturing the indirect growth effects of transportation investments. Michael Wegener's (1994) comprehensive survey of integrated models offers a good summary of their modeling concepts and methodological approaches.

The logic of integrated transportation-land use models is that land use and transportation are co-dependent and need to be treated as such in the mathematics of travel-demand forecasting. Built environments influence travel demand and at the same time travel conditions influence the locations, intensities, and degrees of mixing among employment and residential activities – i.e., built environments. The indirect nature of impacts is generally treated through multiple iterations between land-use allocations and network assignments of traffic with the ultimate aim of converging on a stable solution. Sometimes referred to as dynamic modeling, most integrated models seek an end-state equilibrium between population and employment distributions and forecasted traffic at some pre-defined future time (FHWA 2001).

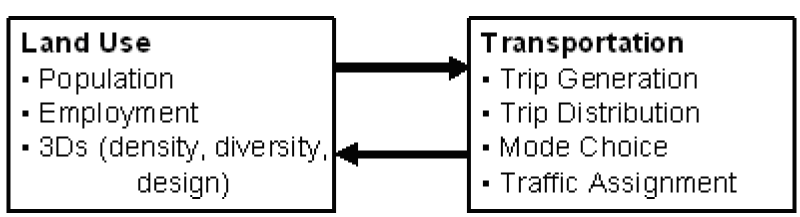
In all integrated models, the urban region is a set of discrete subareas or zones; typically traffic analysis zones (TAZs). Time is usually subdivided into discrete periods of between one and five years. Technically, integrated models are recursive simulation or semi-dynamic models. Although they model the development of an area or city over time, within one simulation period they are in fact cross-sectional. Most integrated models consist of several interlinked submodels that are processed sequentially or iteratively one or several times during a simulation period.

To varying degrees, all integrated transportation and land-use models are data intensive. Some, such as MEPLAN and TRANUS, borrow data from such secondary sources, as national input-output matrices and modify them by regional location quotients to generate regional input-output matrices. All rely on some degree of exogenous input assumptions (e.g., aggregate future population and employment growth for the region, future median household incomes). Because of their complex mathematical structures, maximum-likelihood techniques are almost universally used to estimate the coefficients and parameters of integrated models.

Figure 10 presents the logic of integrated models. Historically, population and employment apportionments at the TAZ level are inputted into transportation models, typically with population serving as inputs to home-based trip production estimates and employment serving as inputs for home-based trip attraction estimates of the *Trip Generation* step. Recently, growing interest in smart-growth planning has led to informing transportation-demand modeling with other elements of "land use" environments, notably the "3Ds" of the built environment – density, diversity, and design (Cervero and Kockelman 1997). Specifically, these finer-grained metrics of neighborhood characteristics have helped to refine not only trip generation estimates (Ewing 1996), but also trip distribution and mode choice (Cervero, "Built" 2002).

With land-use inputs cycling through the four-step model, the end-state of transportation demand models, notably traffic assignment (typically on highway networks), became an input into land-use allocations under the logic of integrated models. Over the years a series of data-intensive and mathematically complex modeling structures has sought to dynamically capture the co-dependence of land use and transportation as reflected in **Figure 10**.

Figure 10: Logic of Integrated Models



The common element, indeed the "glue", that holds the integrated model together is "accessibility". Mathematically, accessibility lies at the core of allocating population and employment in land-use models. Because accessibility embodies measures of travel time, it gets expressed in the trip distribution, mode-choice, and traffic assignment portions of the four-step model. Without the ability to measure and embed accessibility in both land-use allocations and in travel-demand forecasting, integrated models could not be operationalized and solved.

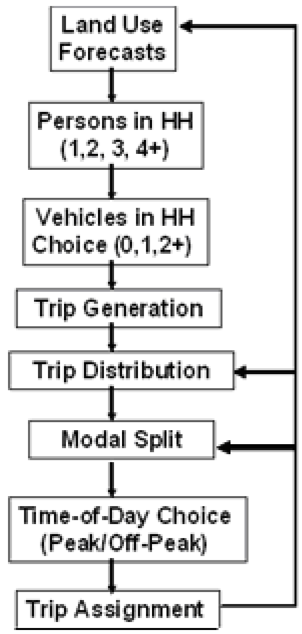
For most integrated models, it is the traffic assignment step that triggers the iterative process of land-use reallocations followed by travel-demand adjustments in trip generation and subsequent forecasting refinements. Typically, capacity-constrained algorithms reassign traffic until flows on all links stabilize and the total travel costs for a network are minimized. Early experiences with these approaches revealed large swings in traffic assignments among links from iteration to iteration, resulting in the development of more stable user equilibrium criteria based on nonlinear optimization procedures. Once stable solutions are reached, new travel-time estimates on an "existing plus committed" (E+C) transportation network are derived and then fed into the accessibility-based measures of land-use allocations, setting the iterative, two-way series of integrated land-use and transportation forecasts into motion.

4.4.6.2 Best Practices in Integrated Transportation-Land Use Models

Figure 11 expands the previous figure to depict the primary steps within the travel-demand forecasting process where feedback occurs following the initial traffic assignment. A more advanced seven-step transportation modeling structure is shown, such as the one the Metropolitan Transportation Commission (MTC) uses in the San Francisco Bay Area as part of the BAYCAST model. As indicated in the figure, MTC's BAYCAST framework adjusts the travel-time inputs to the accessibility measures used in land-use allocation models. If, for instance, forecasted traffic volumes and congestion levels in a sub-area are much higher than initially assumed in land-use allocation models, second-round land-use allocations will withdraw growth from impacted areas and reassign it elsewhere. Similarly, travel times are key inputs into computing friction factors in standard transportation gravity models in the trip distribution step. All else being equal, the spatial distribution of forecasted trips are over-allocated (in the initial trip distribution estimates) to zones suffering high congestion levels. Metropolitan areas that have been particularly keen about weighing the travel-demand impacts of land-use scenarios, such as Sacramento and Portland, routinely refine trip distribution estimates by including a feedback loop that re-distributes trips away from congested corridors following traffic assignment (Rodier et al. 2002).

The effects of congestion at the traffic assignment phase also get expressed in subsequent mode-choice estimates. This is because travel-time differentials between competing modes are core predictors in all utility expressions of discrete choice modeling, thus subsequent iterations of the mode-choice step reflect the impacts of traffic congestion. The mathematics of solving the combined "location-distribution-assignment" models are complex, made possible by nonlinear mathematical programs and modern computer advances.

Figure 11: Feedback Between Initial Trip Assignment and Subsequent Land Use and Travel Demand Forecasts in Integrated Models



Integrated transportation and land-use models, like DRAM/EMPAL and its successors, are largely "equilibrium" models in that they do not dynamically estimate travel-demand and land-use outcomes over time but rather produce end-state estimates based on equilibrating between the land-use allocation models and transportation demand forecasting models over multiple iterations for some defined target date. This amounts to a static-recursive approach to multiyear forecasting – i.e., cross-sectional representations of urban systems are moved forward through a series of discrete time intervals. The integrated models are governed by optimization techniques that ensure the respective model outputs converge toward a stable and complementary solution.

A detailed review of integrated urban models, prepared under the Transit Cooperative Research Program, is available from Miller et al. (1998).

Applicability

Integrated models offer the most robust platform for tracing induced traffic and growth effects from capacity expansion. Metropolitan areas like Portland, Oregon, Sacramento, and Washington, D.C. have relied on integrated models to capture such indirect effects, with varying degrees of success. Because of the significant amount of resources – travel and land-use data, technical expertise, software and support – needed to build, operate, and maintain integrated models, they generally have potential applicability only to regional planning organizations of large metropolitan areas of at least a million inhabitants. Smaller areas are best advised to rely on simpler methods, including those based on expert judgment.

Overview of Integrated Transportation-Land Use Models Available

DRAM/EMPAL/ITLUP

The most widely adopted integrated transportation/land-use modeling framework which many subsequent models built upon is DRAM/EMPAL, developed by Stephen Putman (1991). DRAM (Disaggregated Residential Allocation Model) and EMPAL (Employment Allocation Model) are the front-end land-use allocation components that feed into trip generation. Both are spatial-interaction models built around gravity-based measures of accessibility. When tied to the four-step model, the software package became known as ITLUP, for Integrated Transportation Land Use Package. ITLUP has been the most commercially successful and widely applied integrated modeling platform in the U.S. to date. Details on model specification and provisions for tying land-use and transportation forecasts are discussed below.

Like most operational land-use models, DRAM/EMPAL traces its beginnings to Lowry's (1964) "Model of Metropolis" for the city of Pittsburgh. In his comprehensive review of "Operational Urban Models", Wegener (1994, p. 19) described ITLUP as "a recursive adaptation of the Lowry modeling framework" and "one of the few success stories in urban modeling". For more details on this approach, see **Appendix E**.

Over the past three decades, some of the larger, more progressive metropolitan transportation planning organizations in the U.S. adopted the DRAM/EMPAL approach to land-use allocation. In most instances the models were married to modified four-step travel models to produce "quasi-dynamic" integrated models. The combined package became known as ITLUP (Integrated Transportation Land Use Package). Besides the Puget Sound region and metropolitan Portland, U.S. regions that have tested various forms of ITLUP models include the San Francisco Bay Area (Association of Bay Area Governments and the Metropolitan Transportation Commission), Metropolitan Washington Council of Governments, metropolitan Houston, and metropolitan Philadelphia.

According to Johnston (2004) since first coming on the scene in the 1970s, ITLUP has been adopted by about two dozen MPOs in the United States. In each case where ITLUP was introduced, local transportation planners modified their versions of the four-step transportation models to accommodate DRAM/EMPAL inputs to the trip-generation phase and traffic-assignment results as inputs to DRAM/EMPAL and at minimum trip-distribution estimates. Problems in achieving reasonably stable estimates of network-link travel times in the traffic assignment phase proved to be the Achilles heel in equilibrating between land-use and transportation models. Furthermore, growing concerns over the poor track record of such models in accounting for indirect land use effects and induced travel led to the introduction of newer generation models that sought to overcome these shortcomings.

Subsequent to release and commercialization of the ITLUP package, a series of alternative integrated models emerged. For the most part, these models followed a similar, yet more sophisticated, econometric framework for forecasting urban activities and travel demand. They sought to improve upon the ITLUP framework by introducing a more disaggregate (person-level) model structure and by more directly accounting for the effects of price signals on land-market and travel-choice behaviors. While specification improvements led to more logical and elegant model structures, problems with data-intensiveness and estimation complexity persisted and limited their application in practice. For the most part, later-generation integrated models have been principally employed by academics and scholars to test various policy scenarios such as the impacts of urban containment policies and road pricing.

Other integrated models like MEPLAN and TRANUS simultaneously estimate travel demand and location in spatial-interaction models, in which activities are implicitly located as destination of trips. Similar to ITLUP, TRANUS and MEPLAN apply a multi-path assignment to disperse future trips along networks. Because of their use of input-output methods, TRANUS and MEPLAN incorporate industries and households as consuming and producing sectors giving rise to goods movement travel.

MEPLAN

Worldwide, the most widely adopted integrated model, hands down, is MEPLAN, developed by Marcel Echenique (see Echenique et al. 1990). MEPLAN has been applied in more than 50 urban regions worldwide, mostly outside of the U.S. Because MEPLAN requires floorspace lease value data and floorspace consumption data, its usage in the U.S. has been limited to a handful of metropolitan areas that maintain fairly sophisticated, parcel-level databases of regional land uses.

Built on a generalization of multiregional input-output techniques, MEPLAN represents land markets with endogenous prices. In the land markets, production, consumption, and location decisions by activities are influenced by both money-price and generalized-cost (disutility) signals. The floorspace for retail activities, for example, is mediated by equilibrium prices set through market supply and demand. In the travel models, mode- and route-selection decisions are influenced by travel disutilities, including monetary costs and time delays. Land-use activities are allocated to geographic zones using discrete-choice (logit) models, with the attractiveness of zones based on the costs of inputs to the producing activity (including transportation costs), location-specific disutilities, and the costs of transporting production outputs to consuming activities (i.e., households and businesses).

The link between land-use activities and travel demand occurs "quasi-dynamically" in MEPLAN. Economic interactions among land-use activities in different TAZs are used to generate origin-destination matrices of different types of trips (e.g., home-based work trips for labor producers [i.e.households], and consumers, [i.e. employers]) within travel models. Matrices are loaded to a multimodal network with capacity restraints using nested logit forms of mode and route choice. The resulting network times and costs influence transport costs, which influence the attractiveness of zones and the locations of activities.

Under MEPLAN, the land market model runs first, followed by the transportation market model (i.e., travel-demand model). The transportation costs in one period are fed into the land-market model in the next period, thereby introducing lags in the location response to transport costs. Running MEPLAN involves simultaneously solving sub-models via a sequence of nested iterations. Hunt and Simmonds (1993) describes the solution process as a series of "chains" in prices and costs that run opposite to the "chains" in demand, beginning whenever a market price is determined by a constraint on supply and resulting in the prices for factors being exported. Sequentially, land use is influenced by the pattern of uses in the prior period and by previous transport accessibilities. Transport is influenced by previous infrastructure and present activity patterns arising from land use. Once the system of land prices and trades has settled down to represent a single point in time, recursion moves the system from one equilibrated point to another – what amounts to a cross-section static-recursive system supplemented by judicious use of lagged effects between sets of variables.

POLIS

Another genre of integrated models relies upon mathematical programming to optimize future allocations of travel and urban growth. One such example is POLIS (Projective Optimization Land Use Information System), a sophisticated mathematical programming formulation of the accessibility-based Lowry land-use allocation model (and its derivatives, like DRAM/EMPAL) based on random utility and incorporating the locations of basic employment (Prastacos 1986).

Developed by the Association of Bay Area Governments (ABAG) for the San Francisco region, POLIS represents a single mathematical program that seeks to maximize jointly the locational surplus associated with multimodal travel to work, retail, and local service sector travel, and jointly, the agglomeration benefits accruing to basic-sector employers. A joint objective function incorporates two spatial entropy terms, two travel cost terms, and a term which adjusts the zonal distribution of basic employment within the region. This distribution is maximized subject to various constraints (such as consistency between the amount of residential and industrial land available in each zone). Zonal totals for households and jobs are reconciled with county-wide sector totals as well as spatial tools to reflect the spatial agglomeration economies of basic-sector activity at the macro-spatial level.

Within POLIS, two transportation modes are modeled, termed private and public, based on estimated work and retail travel choices. Missing from the framework, however, is any form of detailed, congestion-sensitive network routing submodel. There were some discussions about linking POLIS (as a land-use input) to the region's multi-stage travel-demand models (like BAYCAST), however as often the case with models estimated by two different groups, incompatibilities between the two platforms proved too difficult to overcome. Because of large oscillations between land-use and travel-demand estimates from initial integration attempts, this effort was set aside.

One issue surrounding optimization approaches like POLIS is the appropriateness of jointly solving for both travel activity patterns and urban activity allocations. There remains some debate as to whether forcing a joint optimal solution is a valid objective for simulation given the instability inherent in, and many factors conditioning, urban growth and change.

UrbanSim

Developed under the Oregon Transportation Land Use Model Integration Project (TLUMIP), UrbanSim was designed to address the policy analysis requirements of metropolitan growth management, with a particular emphasis on land use and transportation interactions. The model, developed by Paul Waddell from the University of Washington, departs from the aggregate approach of spatial-interaction models like ITLUP that rely on cross-sectional equilibrium, instead relying on disaggregate change over small time intervals (Waddell 2002). UrbanSim explicitly represents the demand for real estate at each location and the actors and choice processes that influence urban development and land prices. It also uses an open source code that allows others to extend and refine the model. Past reviews (Miller et al. 1998; Dowling et al., 2000) have identified UrbanSim as more closely replicating transportation and land-use interactions than any large-scale integrated model available in the marketplace.

UrbanSim is actually a system of urban simulation models. Individual models represent: accessibility (by auto ownership levels), economic and demographic transition, household and employment mobility and location, real estimate development, and land prices. Using data inputs from the census transportation planning package, business establishments, and assessor parcel files, UrbanSim models land-use changes, represented by floorspace, for small geographic areas (e.g., 150m by 150m cells). Development decisions are represented using discrete choice techniques. Reuse of buildings and redevelopment of parcels are explicitly accounted for.

The link between UrbanSim and travel-demand models is bidirectional: accessibility levels from travel models are inputs to discrete choice estimates of development which then feed back into travel models. UrbanSim also incorporates local accessibility measures allowing the potential for walk trips as part of intrazonal travel to be captured. To date, UrbanSim has been applied in Oregon, the Salt Lake City region, and metropolitan Honolulu.

Other Integrated Models

Other models beyond the ones reviewed above have been developed and empirically applied to capture the joint influences of transportation and land use. These include: AMERSFOORT (Netherlands and U.K.); Boyce (Chicago); Calutas (Japan); Catlas/Metrosim (Chicago); Dortmund (Germany); Kim (Chicago); LILT (UK); MASTER (UK); OSAKA (Japan); PSCOG (Washington state); TRANSLOC (Sweden); TOPAZ (Australia); Hamilton (Canada); and Tranus (Venezuela, similar to MEPLAN in its structure).

Researchers have explored the degree to which integrated models developed with different data sets in different cities have potential transferability. Of particular note is the work of ISGLUTI (the International Study Group of Land Use Transport Interaction, initiated by researchers from the U.K. Transport and Road Research Laboratory [TRRL]). Between 1980 and 1991 TRRL conducted the largest ever comparative evaluation of large-scale urban models to investigate the degree to which models estimated and calibrated in particular metropolitan areas could be applied in other metropolitan areas with reasonably accurate results. Cross-applications of models were attempted in cities like Balboa, Spain, Leeds, U.K., and Dortmund, Germany.

The ISGLUTI study found sufficient similarity across nine integrated models to carry out a set of common tests. The tests examined the effects on travel choices and land-use arrangements associated with population changes, land-use restrictions, employment location policies, travel-cost assumptions, and timing of transportation system investments. In weighing the experiences of these cross-platform modeling exercises, Mackett (1993) concluded that integrated models are particularly helpful at analyzing congestion-reduction or energy-reduction strategies.

Activity-Based Microsimulation Models

Interest has recently shifted to modeling travel as a direct function of peoples' activity patterns. These models rely on the generation of random incidences of travel, using Monte Carlo technique and pre-specified probability distributions. A series of independent traveler responses are generated to create detailed representations of multitrip travel activity patterns. Summing over all of these individually simulated travel patterns provides aggregate flow estimates.

The best known microsimulation package in the urban transportation field is TRANSIMS, a modeling effort funded by the Federal Highway Administration. While most Monte Carlo-based microsimulations aim to generate travel-flow estimates, some (like the Dortmund model developed by Wegener) simulate intraregional migration of households as a search process on the regional housing market (Wegener 1982). Microsimulation models are usually "activity-based" in that they do not model travel *per se* but rather daily activities (i.e., the need to reach out-of-home destinations). Their focus is on modeling multi-leg trip tours. For the most part, activities – i.e., land uses -- are treated as static inputs to tour-based modeling.

The MASTER model, developed in the U.K.by Mackett (1991) is one example of an integrated land use-transportation model based on microsimulation. MASTER uses Monte Carlo methods to simulate the decision processes of individuals and their households over time. A comparison of MASTER with a more traditional zonal-level simulation model, LILT, revealed the microsimulation approach produced plausible and interpretative results (Mackett 1990).

As discussed below, metropolitan Sacramento is the one region that is earnestly seeking to link the advantages of macro-scale economic forecasting, as embodied in MEPLAN, and microsimulation. There, analysts are linking tour-based travel models involving microsimulation of individual tours of synthetic households, a microsimulation-based land development model, and a spatial input-output model of the regional economy.

While not truly "micro" in scale, another set of non-conventional modeling approaches to simulation of land-use change and transportation systems are cellular automata models. These models begin with an array or lattice of cells. Based on a set of transition rules and attributes of neighboring cells, each cell can be changed to another state in a subsequent stage. Transition rules govern the state of randomly placed cells depending upon the configuration of neighborhoods. Assumed land-use changes can be modeled using discrete-choice techniques like multinomial logit (such as with the California Urban Futures model). Simulated changes can be replicated over time to create a history of land-use sequencing. Cellular automata models work from the bottom-up, beginning with micro-level units and ending with macro-level aggregates. While the influences of transportation systems can indirectly be accounted for through discrete-choice estimates of land-use change (e.g., such as by including accessibility indicators as predictors), it would be a stretch to label cellular automata models as "integrated", thus they have limited application for tracing indirect effects, such as induced travel demand or indirect land use effects.

4.4.6.3 Resources and Inputs

Beyond the integrated model software platforms themselves, there must be the in-house technical capacity to operate, monitor, and upgrade sophisticated quantitative models. Integrated models rely upon fairly comprehensive land-use data disaggregated at small geographic levels, such as individual parcels and block groups. Activity-based models, in particular, require a fine-grain resolution of land-use data. To the degree that land-use variables (like mixed-use indices and urban-design metrics) are used as predictors of travel demand, spatial data needs to be all the more disaggregated to reduce the potential of an ecological fallacy. And because most contemporary travel models embody a utility-choice framework, a substantial number of travel-diary records are needed to estimate, calibrate, and apply forecast models. For the most part, only large MPOs with significant in-house resources are able to meet such significant data-input and resource demands.

4.4.6.4 Additional Information

It is generally accepted that integrated models do a better job than conventional four-step travel-demand forecasting models in accounting for indirect effects like induced demand. Various case studies (Sacramento, CA, Chittenden, VT, and Salt Lake City, UT) have assessed the ability of travel-demand and land-use models to represent the induced travel effects of expanding highway capacity. Most studies have employed sensitivity analyses that "turn on and off" various model components to isolate their relative contributions in explaining induced travel (Rodier 2004). Results suggest that when travel times are fed back into land-use models and/or trip distribution steps, models generally represent induced travel within the range documented by the empirical literature. Failure to account for induced travel in integrated models, however, can overstate the congestion-relief benefits of proposed highway projects – by over 200 percent in some cases.

In the case of Sacramento (see Case Study below), for instance, the MEPLAN model's estimate of VMT elasticity as a function of lane-mile expansion was 0.8 – i.e., a doubling of roadway capacity increased VMT by 80 percent, all else being equal. This is fairly similar in magnitude to the meta-analysis summary of long-term induced demand in **Table 6**. The region's travel-demand model, SACMET, which does not have a feedback loop between traffic assignment and land-use allocations, produced a more modest VMT/lane-mile elasticity of 0.23. In addition, sensitivity tests indicated that changing origin-destination patterns resulting from highway investments (enabled by full feedback from traffic assignment to trip distribution) accounted for almost all of the SACMET model's representation of induced travel. These Sacramento findings suggest that continued refinements of integrated transportation/land-use models provide considerable promise for accounting for indirect land use effects in scenario-testing of transportation investment options.

Case Study 1: Scenario Testing of Smart Growth Policies in Sacramento, California

The Sacramento region has taken on the mantle of America's "test bed" for tracing joint land-use and transportation models. A series of studies conducted in the Sacramento region over the past decade may offer the most useful insights into how integrated models function in estimating the indirect land use effects of transportation investments and how well various formulations of integrated models forecast the impacts of such smart-growth scenarios as creating Urban Growth Boundaries (UGB) and congestion pricing. To date, the following integrated model structures have been used to test transportation and land-use futures in greater Sacramento: MEPLAN (Rodier et al. 2002), TRANUS (Johnston and de la Barra 2000), DRAM/EMPAL, and the region's enhanced conventional travel model – SACMET (Johnston and Rodier 1999). Experiences with MEPLAN and SACMET are reviewed below.

MEPLAN

MEPLAN was first operationalized in the U.S. in the Sacramento region (Abraham and Hunt 1999). Model parameters were imported from previously estimated travel-demand models for the region.

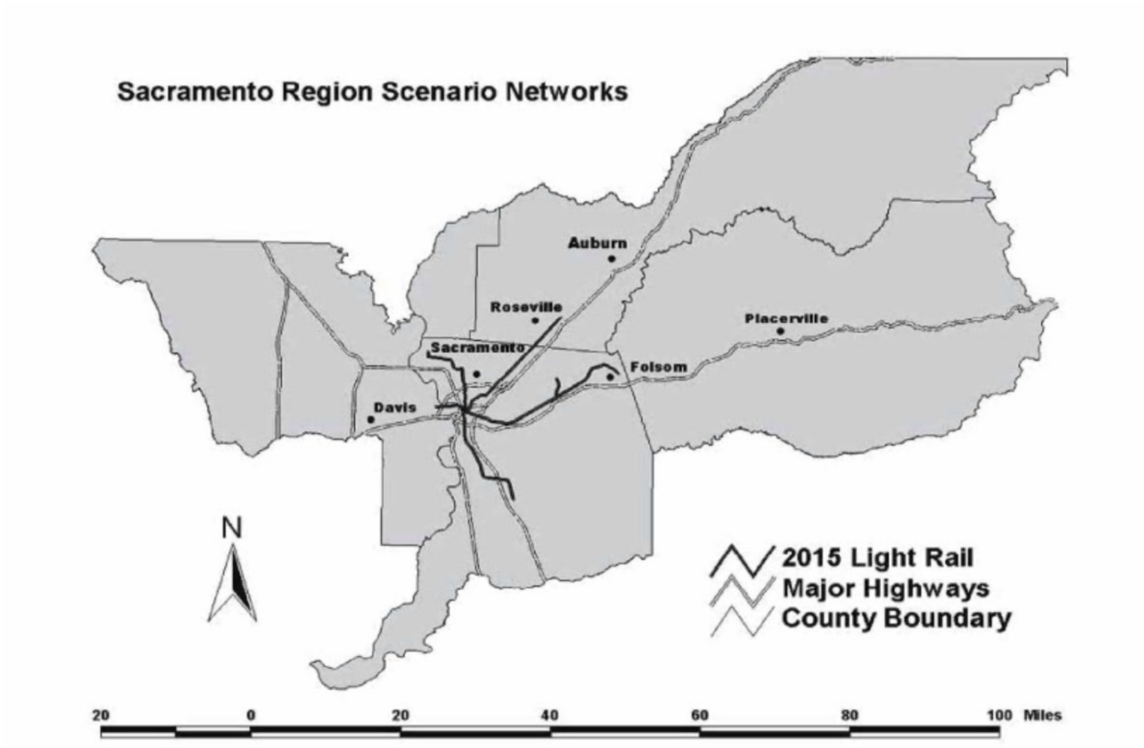
Figure 12 shows year-2015 transportation networks assumed under various scenarios that were tested using MEPLAN. Under a beltway scenario, MEPLAN allocated considerably more industrial growth to the metropolitan fringes relative to a base-case scenario. For a light-rail expansion scenario, MEPLAN predicted the dispersion of employment away from the central business district matched by residential gains in the CBD. Under a TOD scenario with land subsidies, MEPLAN estimated there would be clustering of both businesses and households in rail-served zones matched by a sizeable increase in both rail and bus modal shares. Adding steep parking surcharges to the TOD scenario accentuated these patterns.

Because of its market-clearing features, MEPLAN proved to be hyper-sensitive to price signals in allocating future land uses. Cross-movement of different industry and household types was pronounced in all scenarios. Follow-up scenario-tests involving various model enhancements of MEPLAN reached similar conclusions (Rodier et al. 2002).

MEPLAN and emission post-processor model outputs revealed the following:

- **New highway capacity projects induce travel demand (VMT increases) and increase emissions.** HOV and beltway projects increased development on the periphery (relative to base-case scenarios), contributing to relatively large increases in VMT (5% and 10%, respectively) and emissions (1% and 8%, respectively, for NOx).
- **Transit investments combined with TOD and pricing policies significantly reduce VMT and emissions.** For example, congestion pricing combined with light-rail expansion and urban infill assumptions were forecasted to reduce NOx emission by 7% to 29%. Moreover, these strategies were estimated to provide larger congestion-relief benefits than scenarios involving significant amounts of road expansion.

Figure 12: Sacramento Region Scenario Networks



Source: (Rodier et al. 2002)

<u>SACMET</u>

Another example of integrated model-testing in California's state capital and its surroundings involved using the 1996 Sacramento travel-demand model (SACMET). While SACMET does not feedback between land-use and travel forecasts, it does feedback within the multi-stage travel models, accounting for: trip lengthening in trip distribution; automobile ownership impacts on trip generation; joint destination-mode choice model for work trips; non-motorized mode choice; and time-of-day sensitive traffic assignment. In this sense, it captures indirect induced travel effects (as opposed to indirect land use effects). While DRAM/EMPAL was developed for the Sacramento region in prior years, for purposes of scenario-testing, SACMET treated land use as a unidirectional exogenous input. Still, the model explicitly accounts for changes in travel time on destination, mode, and route choice, change in transit accessibility on auto ownership (as input to trip generation), and effects of "walk-ability" and "bike-ability" on mode choice. SACMET's mode choice sub-model represents a relatively wide range of choices including drive-alone, shared-ride, transit, walk, and bike models. Its geographic detail is quite fine, roughly between block-level and census tract-level zones.

Similar to MEPLAN, the analysis of future Sacramento land-use scenarios found road pricing combined with LRT expansion and TOD yielded the largest reductions in VMT and emissions (Johnston and Rodier 1999). HOV, on the other hand, was estimated to increase VMT. Applying the compensating variation formula (see Small and Rosen 1981) to choice models enabled the scenarios tested under SACMET to be gauged in terms of their consumer surplus impacts by income groups. The pricing-plus-TOD/LRT scenario was also found to yield the highest welfare gains. Stratifying the results by income class revealed those from the lowest tier categories gain the most from transit expansion and TOD scenarios.

Cross-Model Comparisons

Comparisons of smart-growth scenario-testing in the Sacramento Region reveal the following among different integrated modeling platforms. Each approach offers particular advantages and limitations. MEPLAN is an integrated model, based on market-clearing principles. Accordingly, land-use adjustments and thus travel-demand and emission forecasts are highly sensitive to price signals. SACMET, on the other hand, embodies smart-growth variables (e.g., walkability indices) and forecasts at a more refined, neighborhood scale. Only SACMET can reflect the shifts from motorized modes to walking and cycling through upgrading sidewalk networks and inter-mixing land-uses at a neighborhood scale. As noted, however, SACMET accounts for indirect induced travel impacts but not indirect land use effects.

A comprehensive comparison of forecasts generated by three different integrated model platforms (MEPLAN, TRANUS, DRAM/EMPAL) with SACMET revealed substantial differences in model forecasting results, owing to different levels of spatial aggregation, equation specifications, and calibration approaches (Hunt et al. 2001). Without an endogenous land-use component, the SACMET model predicted larger VMT increases (and accordingly emissions releases) than the other models. Because the other models cannot reflect the impacts of streetscape and urban-design improvements on travel, model comparisons could not be made. However only SACMET is capable of shifting non-work travel to non-motorized modes in response to neighborhood-scale design enhancements.

New Directions for the Sacramento Region

Not content to rest on its laurels, the Sacramento region has embarked on a long-term model design initiative to update its land use-transportation forecasting models (Abraham et al. 2004). The reformed model is to have two main components. Household-based travel demand will be estimated through a tour-based transportation model with microsimulation of households. A synthesis of businesses and firms will be used to forecast goods and services movement (i.e. trucks and commercial vehicles). Regional growth analysis will be based on an aggregate, spatial input-output (I/O) model, which will allocate economic activity to locations in the region. A land development model will be used for determining location and extent of land use changes through the forecasting process. Taken together, the spatial I/O model and the land development model will be referred to as the land use model.

The integration of the land use and travel models will be accomplished by using accessibility and level of service (LOS) data from the travel model as inputs to the land use model. The land use model, in turn, will generate the household and employment data that will be used in the travel model. In application, the forecasting process is "path dependent." That is, it steps through time in "slices" of two to five years, with the results of the current time slice providing the basis for the next time slice. This is in contrast to "end state" forecasts, which forecast a horizon year only, but ignore the incremental transitions that take place in getting to the horizon year.

A parallel but different effort is also underway that will facilitate impact evaluation of land-use scenario testing in the Sacramento region (Johnston and Garry 2003). The aim is to combine urban economic models with GIS-based models for real-time scenario generation and evaluation, paving the way for a fully participatory planning process involving citizen review and commentary. Urban land-use allocation models being tested include the more spatially aggregate PECAS and the finer grained Oregon2 integrated model. The aim is to eventually model land use and travel at the very small cells (30 meters squared) and potentially even household level. Air emissions impacts will be calculated from California emission models like EMFAC. Additionally, the California Energy Commission data sets on energy consumption by land use will be combined with energy data on vehicle fuels to estimate energy and greenhouse gas emissions impacts. The ultimate integrated model seeks to implement the best model package recommended by Miller et al. (1998) in the TCRP H-12 review.

Case Study 2: Integrated Models Contrasted with "Trend-Delphi" Methods, The Portland Metro Results (Conder and Lawton 2001)

Like the above study and the ICC study in Section 4.4.4.5, this Portland area study is another rarity: a comparison of two approaches to the same land use forecasting project that incorporates transportation facility influences. Unlike the ICC case (which is a discrete project-level example of projecting indirect land use effects on jobs and households) but like the SACMET example, this is a systems planning mode study that compares the outcomes of two methods for the Portland Metro region. Land use allocation outcomes and travel patterns from the traditional trends- and experts- and local review MPO forecasting process are contrasted with outcomes from using econometric, residential and non-residential land use models tied into a 4-step travel demand model. The same travel model is used in both cases.

The land use models, which are integrated with the travel model (together called Metroscope), include information on prices and costs, land capacity, supply and demand and accessibility indices. They are obviously fairly fully specified and the result of substantial data collection and analysis that requires significant expertise.

The two methods produce very different land use allocation and travel behavior results. The traditional methods produce illogical and problematic outcomes (e.g. commuters continuing to engage in 4 hour delay commutes to comply with fixed land patterns) vs. Metroscope outcomes (e.g. land use allocation responding to growing congestion by decentralizing jobs and improving two-way flows). Congestion and the long term need for transportation investments appear to be overstated when the land use model is not linked to the travel demand model. Where human and financial resources permit, these results are a compelling example of the benefits of an integrated or coupled modeling approach over traditional methods.

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5.0 CONCLUSIONS AND RECOMMENDATIONS

Intended to function as a guidebook for forecasting indirect land use impacts of transportation projects, this Report does not quite fit the standard NCHRP format for a conclusions and recommendations chapter. Our conclusions about current guidance and our recommendations regarding various approaches are embedded in the many pages of Chapter 4. Rather than repeat or summarize that information, we use this Chapter 5 for a brief discussion about the limits of the guidance provided in this report and of some useful directions for future research.

Consistent with other recent surveys (e.g., the 2005 Executive Order 13274), our research finds that the practice of indirect land use effects analysis is variable in its techniques, detail, and rigor. Guidebooks such as NCHRP 466 offer comprehensive process guidance on indirect land use effects overall, and include useful checklists, definitions, and examples. There is little, however, that provides specific and directed guidance on the difficult and thorny issue of forecasting indirect land use effects.

The guidance available does not yet cope with all the details of this inherently complex question. While our report may move this guidance a step further, it stops well short of a plug-and–play manual. This is not surprising. The profession has learned much about the nature of transportation-land use interactions over the past decade and understands the directions of many causal variables. Yet, we still have trouble with the magnitudes of these variables and their interactive effects. Nevertheless, even here there is now enough useful knowledge accumulated to allow some specification of best practices. But if "best" means "most likely to predict the future," it may also mean "most demanding of data, staff time, and budget." Consequently, we also considered "second-best" practices--ones that are not as robust as the integrated models we examined but that might still get to approximate answers more quickly and cheaply. Our meta-analysis of elasticities, for example, produces rules of thumb for better informed practice. Using several approaches in combination or as checks on the limits of another method is the preferred approach for much of this work.

As controversy and lawsuits over indirect land use effects draw more resources into this area of practice, the pressure to consider indirect land use effects at the regional and local *planning* stage will increase. This will promote an integrated view of land use and transportation planning when transportation investments and priorities are initially considered and recommended as part of a more comprehensive effort such as an MPO's long-range transportation plan or a jurisdiction's comprehensive land-use plan. The *ex-post facto* analysis associated with project-specific impact assessments for EIS and NEPA investigations reveals wide gaps in the rigor of such upfront planning. Were such planning better informed, the need for and complexity of exhaustive project level analysis would be much reduced. Accordingly, while this report has focused on the project evaluation mode, we hope that its prescriptions will also inform the upfront system planning mode. Our discussion of four step and travel models, allocation models, or integrated models can be so applied.

The state-of-the practice would benefit from the following research and advances in current practice:

- **Comparative studies.** Studies that compare the forecasted land use outcomes of projects generated via different approaches with the actual outcomes are of great value. The report was able to find and cite only a handful of these, but they shed much light on where techniques are trustworthy and where they need much improvement.

- **More agile Integrated Transportation-Land Use models.** While we have commented on the complexity of such models, we are also aware of work to make them simpler and quicker to apply. Advances in their agility and reductions in their data-demands will make models like UrbanSim and its cousins more approachable.

- **A broader base of empirical work.** Modeling work should be balanced by empirical research. Much of the current work addresses expansions to existing highways. This allows easier before/after analysis than for new facilities. However, well-controlled studies of indirect land use effects that address both *improvements to existing* highways as well as *new* highways in rural through urban contexts will greatly enhance our understanding of project/land use change elasticities.

- **Expand the inventory of elasticity estimates**. Empirical research on the effects of capacity increases on travel demand in the near term and land-use shifts over the longer term is drawn from a limited set of studies capturing a limited set of operating environments. More evidence is needed on the sensitivity to travel demand and land-use activities to capacity expansion by city size, land-use mixes, density levels, and types of facilities.

- **When might better accessibility increase net regional growth?** The current consensus holds that adding accessibility in one part of the region merely shifts it from where it may otherwise have occurred. For most indirect land use effects work these phenomena occur outside the study area and are not part of the analysis. Yet numerous projects are justified by their ability to increase regional welfare. A clearer resolution of the scales and conditions under which net regional land-use gains (economic development gains being the real target here) may occur in response to transportation investments will also be of great value.

- **How complex do allocation models need to be?** Numerous allocation tools are used around the country. Many are home-grown methods devised by MPOs or local agencies. They vary from the very simple to the very complex. Meta-studies of formal, commercially available as well as more informal allocation models will help determine the minimum variables needed to produce credible results and will significantly advance the state of the practice.

- **Getting more out of four step models.** Because these models are so widely available, these tools should routinely be used to provide accessibility change data for indirect land use effects work. Easing this interface to improve the model's ability to work with off-line, exogenous allocation models will help improve the ease of executing this kind of a manually- managed feedback loop to identify indirect land use effects.