APPENDIX A

GUIDEBOOK SUMMARIES

The following appendix contains summaries of the guidance documents reviewed for this report including an assessment of their strengths and limitations.

NCHRP REPORT 466: DESKTOP REFERENCE FOR ESTIMATING THE INDIRECT EFFECTS OF PROPOSED TRANSPORTATION PROJECTS
By: The Louis Berger Group, Inc. for NCHRP (2002)

This reference book provides a thorough overview of how to conduct cumulative and indirect effects analyses. An eight step comprehensive framework is given that walks analysts through the entire process of analyzing cumulative and indirect effects; from initial scoping and prescreening straight through to mitigation. Overall, the framework is presented in a high level of detail and comes complete with checklists, forms, and flowcharts to assist with the decision making process. A long list of tools, both quantitative and qualitative, for estimating indirect land use effects is provided and the advantages and disadvantages of most tools are stated. The tools are explained concisely but one would need to consult the references given to be able to actually use the tools.

The strength of this document is its thoroughness and completeness. It considers a wide variety of tools and provides extremely detailed explanations for the rest of the framework. The report also suggests ways that the tools can be combined to produce even more robust analyses of possible indirect effects.

One limitation of the document is that it may go into too much detail on rather intuitive things (e.g. documenting notable features) while not providing enough detail on the more complicated things such as the tools. Also, another limitation of the document is that little guidance is provided on tool selection. The document also fails to emphasize that land use plans and forecasts might actually include an assumption that the infrastructure improvements would be built thereby making these items more representative of the build scenario rather than the no-build scenario; a very important distinction.

A GUIDEBOOK FOR EVALUATING THE INDIRECT LAND USE AND GROWTH IMPACTS OF HIGHWAY IMPROVEMENTS
By: ECONorthwest and Portland State University for the Oregon Department of Transportation (2001)

This report was written for analysts at the Oregon Department of Transportation to help them better and more consistently analyze the indirect land use effects of transportation projects to ensure compliance with federal and state laws. The report provides a well-explained eight step framework for considering the indirect effects of transportation projects and includes an example applying the framework to a hypothetical real-world case study. Of special interest are six in-depth empirical studies and 20 growth trend analyses documenting the indirect effects that
occurred at various project sites. The results of these studies helped inform the framework and the development of the factor analysis tool in Table 3.2.

A key strength of this report is its keen observations. A particularly noteworthy observation is that population and employment estimates in addition to land use plans often include the transportation improvement in their assumptions. Failure to recognize this could lead to confusion between the build and no-build forecasts. Another strength of this report is Table 3.2 which provides a concise one-page summary of the variables (and relevant ranges of important values) that most strongly impact indirect land uses.

However, this document also has some limitations. In particular, the report recommends the use of only one qualitative tool for assessing the indirect land use effects (an assessment of the variables listed in Table 3.2 by the project’s land use analyst) and fails to mention the many other more sophisticated tools that are available. Someone who reads only this report will have a narrow view of what tools can be used for this type of analysis. In addition, the report provides little guidance on how to weigh the relative importance of each of the variables in Table 3.2 given different situations.

GUIDANCE FOR PREPARERS OF GROWTH-RELATED, INDIRECT IMPACT ANALYSES
By: Caltrans (2006)

The purpose of California’s online guidance material is to, “help practitioners identify whether a growth-related impact analysis is needed for a proposed transportation project” and, if so, to, “help practitioners prepare an analysis that is sound and well documented.” The document states that the information provided is tailored to fit a California context.

California’s guidance begins with a detailed clarification of the definition of indirect land use effects. There is also a discussion of transportation’s role in land use changes. In fact, much of the early part of the document tends to be more theoretical in order to give the practitioner a good background on the subject. Overall, there is also a more resource-focused approach in this guidance than in other guidance documents. The guidance explicitly calls for translating the growth impacts into impacts on resources and even goes as far as to say that growth in and of itself is not an issue but that it must have an impact on a resource to be considered problematic. Also, a link to an example in which the analytical framework is applied to a hypothetical case is included on the document’s webpage.

The appendix of the report contains a summary of many land use forecasting methods. Five general categories of methods are specified: qualitative methods; transportation forecast based methods; geographic information systems (GIS) based methods; integrated land use and transportation models; and regression analysis, econometric forecasting, and models. A useful summary of strengths and limitations for each general category is included. The report stresses that the general category of regression analyses, econometric forecasting, and models should not be used since these methods are more geared toward assessing regional impacts of actions, rather than the more localized impacts in relation to an individual transportation improvement.

California’s document clearly articulates the definitions and theoretical foundations of indirect land use effects of transportation projects in a very concise manner. The document also
provides extensive information on prescreening projects and on estimating what types and levels of indirect effects one might encounter in different types of areas and with different types of projects.

**LAND USE IN ENVIRONMENTAL DOCUMENTS—INDIRECT AND CUMULATIVE EFFECTS ANALYSIS FOR PROJECT-INDUCED LAND DEVELOPMENT, TECHNICAL REFERENCE GUIDANCE DOCUMENT**

By: Wisconsin Department of Transportation (1996)

This guidebook provides state highway department employees with a detailed description of the entire indirect effects analysis. The document focuses both on indirect land use and cumulative effects: an approach that could lead to more confusion between indirect and cumulative effects than in formats where the two analyses are separated. The document manages to provide strong words of caution on what tools not to use (modeling and comparisons) and the drawbacks of some of the tools (e.g. trend extrapolation).

One of the biggest strengths of this report is its detailed description of how to define the study area. A number of techniques are provided and these are put in a matrix with different types of transportation projects so that the user can see what techniques are most appropriate for any given project context. A good overview of land use type definitions, types of plans, and other planning related terms is also provided which may be of great value to analysts. The guidebook also provides a good description of the land use panel method for analyzing indirect effects.

The guidebook states that direct comparisons with other projections should not be used as a tool for analyzing land use change. It is stated that no two projects are exactly alike and that the analyst should try and apply general knowledge to each unique circumstance rather than draw direct comparisons. While this is a valid point, it discourages the use of more sophisticated controlled comparison techniques which could be insightful.

**SECONDARY AND CUMULATIVE EFFECTS ANALYSIS GUIDELINES FOR ENVIRONMENTAL IMPACT STATEMENTS AND ENVIRONMENTAL ASSESSMENTS**

By: Maryland State Highway Administration (2000)

This relatively small booklet provides concise instructions on how Maryland State Highway Administration workers and contractors are to assess the indirect and cumulative effects of their projects. Like the Wisconsin guidance, the format of combined indirect and cumulative effects guidance could lead to confusion between the analyses. Though short, the entire process of how to conduct the analyses is covered; from determining the study area to analyzing the indirect effects on a resource. The description of how to determine a study area is fairly robust, however the tools provided for forecasting land use are somewhat simplistic.

Essentially, the booklet recommends looking at existing plans and traffic forecasts for the area and conducting interviews of knowledgeable local land use professionals and, from this, creating an informed opinion on what the results of the project might be. Then, the future land
use map is to be overlayed with resource maps to understand what resources might be impacted. Little explanation is given on how to determine the likelihood of land use changes.

Also, the booklet encourages limiting the analysis to using, “existing readily available data” and strongly discourages the use of land use modeling or other land use prediction tools. Limiting oneself to readily available data may go against the guidance given by the FHWA in “Questions and Answers Regarding the Consideration of Indirect and Cumulative Impacts in the NEPA Process (FHWA 2007).” When dealing with incomplete information, the FHWA document states that, “If the incomplete information relevant to reasonably foreseeable significant adverse impacts is essential to a reasoned choice among alternatives and the overall costs of obtaining it are not exorbitant, the agency shall include the information in the environmental impact statement.” The Maryland report, by focusing on the use of only existing data, seems to discourage obtaining new data as the FHWA says is needed if costs allow.

ENVIRONMENTAL PROCEDURES MANUAL—REVISION 2004-1, SECTION 480: SECONDARY AND CUMULATIVE IMPACTS
By: Washington State Department of Transportation (2006)

Washington’s guidance on secondary and cumulative impacts is limited and consists of a small section of a much larger environmental guidance document. The indirect effects guidance is essentially a bulleted list of information on applicable policies to tell why these issues are relevant, their definitions, and how to find out more information. No tools are described, instead analysts are referred to the Oregon guidebook and documents put out by FHWA and CEQ. In addition, little synthesis comparing these different sources is provided. Various flow chart graphics from outside sources are included to show how to analyze secondary impacts but there is little to no explanation of them.

ENVIRONMENTAL PROCESS MANUAL (DRAFT), SECTION 2200: SECONDARY AND CUMULATIVE IMPACTS
By: Idaho Transportation Department (2003)

Idaho’s guidance document on indirect effects, like Washington’s, is essentially a compendium of information taken from other sources and put into one document. The FHWA’s “Questions and Answers Regarding the Consideration of Indirect and Cumulative Impacts in the NEPA Process” is taken in its entirety and denoted as an exhibit within the document. Unlike Washington, Idaho also adds a section of FAQs to their report which provides some insights into how to consider indirect effects. However, to add to the confusion of the documents, the FAQs are answered as if they are meant for consumption more for the general public than by analysts (e.g. telling how the Idaho Transportation Department does analyses, not describing how it should be done) and brings up terms and concepts that are not described well elsewhere in the document. Overall, this report is somewhat confusing, feeling as if a set of information has been assembled with little synthesis, and generally lacks the detailed information an analyst would need to conduct a thorough analysis.
REFERENCES

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<tr>
<td><strong>Step 1</strong></td>
<td>Initial scoping (define study area)</td>
<td>Prescreen the project for addressing indirect / cumulative impacts</td>
<td>Do scoping of potential indirect effects</td>
<td>Understand data needs and resources that will be impacted</td>
<td>Understand existing conditions and trends</td>
<td>Make the first cut (pre-screening)</td>
<td>Define project study area</td>
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<td><strong>Step 2</strong></td>
<td>Identify study area directions and goals</td>
<td>Define study area boundaries</td>
<td>Define study area</td>
<td>Define study area</td>
<td>Establish policy assumptions</td>
<td>Delineate the study area</td>
<td>Analyze existing land development patterns and trends</td>
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<td><strong>Step 3</strong></td>
<td>Inventory notable features</td>
<td>Identify study area directions and goals</td>
<td>Get agreement on the basic demand drivers (pop. and employment forecasts)</td>
<td>Establish a time frame for the analysis</td>
<td>Measure the transportation outcomes with and without the project</td>
<td>Review previous project information and decide on the approach / level of effort needed for the analysis</td>
<td>Analyze the extent of land use planning and regulation</td>
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<td><strong>Step 4</strong></td>
<td>Identify impact-causing activities of the proposed action and alternatives</td>
<td>Inventory notable features</td>
<td>Gather land use and transportation data for the study area</td>
<td>Collect data</td>
<td>Estimate total study area population with and without the project</td>
<td>Identify the potential for growth for each alternative</td>
<td>Understand the type of project</td>
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<tr>
<td><strong>Step 5</strong></td>
<td>Identify potentially significant indirect effects for analysis</td>
<td>Identify impact-causing activities of the proposed action and alternatives</td>
<td>Gather data about public policy in the study area</td>
<td>Identify local regulations</td>
<td>Inventory land with development potential</td>
<td>Assess the growth-related effects of each alternative to resources of concern</td>
<td>Assess the potential for project induced land development</td>
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<tr>
<td><strong>Step 6</strong></td>
<td>Analyze indirect effects</td>
<td>Identify potential indirect / cumulative effects for analysis</td>
<td>Describe development patterns without the improvement</td>
<td>Map resources and land uses</td>
<td>Estimate how the project will change the location and types of development in the study area</td>
<td>Consider additional opportunities to avoid and minimize growth-related impacts</td>
<td>Assess potential consequences to the human environment</td>
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<td><strong>Step 7</strong></td>
<td>Evaluate analysis results (noting uncertainties)</td>
<td>Analyze indirect / cumulative effects</td>
<td>Summarize other relevant impacts of project</td>
<td>Apply land use forecasting tools</td>
<td>Compare the results of the analysis for all alternatives</td>
<td>Discuss tools to manage land development</td>
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<td><strong>Step 8</strong></td>
<td>Assess consequences, develop appropriate mitigation strategies</td>
<td>Evaluate analysis results (noting uncertainties)</td>
<td>Address increased potential for land use change</td>
<td>Analyze results of land use forecasting tools</td>
<td>Document the process and findings of the analysis</td>
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<td><strong>Step 9</strong></td>
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<td>Assess consequences, develop appropriate mitigation strategies</td>
<td>Address consistency of potential land use changes with the plan</td>
<td>Write summary of secondary impacts</td>
<td></td>
<td>Devise and conduct a mitigation strategy</td>
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<td><strong>Step 10</strong></td>
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<td>Describe policies that could mitigate those impacts</td>
<td>Mitigate impacts</td>
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<td><strong>Step 11</strong></td>
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<td>Do final report</td>
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<tr>
<td><strong>Comments</strong></td>
<td>More of a resource focused approach than other methods: extensive analysis of the resources that could be impacted is called for</td>
<td>Same as NCHRP 466 except the scoping and definition of the study area are broken into 2 separate steps</td>
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<td>Does not discuss setting up a study area.</td>
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APPENDIX C

SURVEY QUESTIONS FOR INDIRECT LAND USE EFFECTS ANALYSTS

This appendix contains the actual questions and background information that were provided to the practitioners interviewed for this report.

ABOUT THE PROJECT

This interview is part of a Parsons Brinckerhoff study for NCHRP looking at forecasting indirect land use impacts of transportation projects. You have been selected for an interview because of your broad experience in working on transportation / land use projects. The objectives of this study are to, “(1) review, evaluate, and summarize available guidance for transportation project build/no-build land use forecasts; (2) to identify best land use forecasting practices; and (3) to develop recommended land use forecasting methodologies based on best practices.” Your input fits most directly within part 2 above but will be invaluable for helping inform the latter stages of this project as well. While forming your answers, please note that in this context indirect land use impacts refer to investigating actual changes in land uses rather than on the separate but closely related issue of induced demand on a transportation network as a result of urban growth stemming from an improvement. That said we wish to thank you again for your participation and valuable input!

1. General background

   a. Please summarize what you see as your three most important projects on this topic:

      Project name:
      Year completed:
      Brief description:
      Treatment of indirect land-use impacts (including type of forecasting)
      Funding for indirect effects (state amount allocated and level of adequacy):

      Project name:
      Year completed:
      Brief description:
      Treatment of indirect land-use impacts (including type of forecasting)
      Funding for indirect effects (state amount allocated and level of adequacy):

      Project name:
      Year completed:
      Brief description:
      Treatment of indirect land-use impacts (including type of forecasting)
Funding for indirect effects (state amount allocated and level of adequacy):

b. Overall, how many transportation-related land use forecasting projects have you worked on and for how long have you done these types of projects?

c. Please give us an overview of the specific training you have had on this topic (e.g. from guidebooks, training sessions, etc…)

   Training name:
   Year completed:
   Brief description:

   Training name:
   Year completed:
   Brief description:

   Training name:
   Year completed:
   Brief description:

d. Overall, based on your experience, do you think that indirect impact projects are adequately funded?

e. Do you integrate the indirect and cumulative impacts section of the EIS with the economic impacts section?

2. Prescreening

   a. How do you prescreen projects to determine whether a detailed analysis of indirect effects is even needed?

   b. How do you prescreen projects to determine which land use forecasting method to use in a particular context?

   c. Does your prescreening precede the budgeting process?

3. Analytical process

   a. Do you have an explicit predetermined set of steps that you apply to each analysis (e.g. as in the guidance documents)? If so, what are they?

   b. How do you determine the study area size for your analysis?

   c. How do you determine the time period to use for your analysis?

   d. Once indirect effects have been identified, do you translate the impacts into environmental measures (e.g. potential storm water runoff changes) so as to assess their environmental significance? If so, what environmental measures do you
use? If not, how do you make the connection between the indirect effects and their effects on the environment?

e. In your projects, were you given fixed control totals for population and employment forecasts for the study area or were you able to add growth based on the facility’s impact?

4. Attention to details

a. Do you check to determine if plans and forecasts used in your analyses contain assumptions that the transportation improvement would be built and, if so, how do you treat these assumptions so that a clean baseline no-build estimate is obtained?

b. Do you consider the existing or planned provision of services such as sewer and water when assessing the likelihood of development associated with a transportation project?

c. When conducting your analyses, do you consider the history of whether jurisdictions have stuck to their plans and zoning in the face of development pressure?

5. Opinion questions

a. In your opinion, what is the most defensible methodology for estimating land use impacts?

b. Are there any land use forecasting techniques your organization refuses to use (e.g. models, panels, etc…)? Why?

c. What do you believe state transportation departments’ roles should be regarding mitigation of indirect land use impacts?
APPENDIX D

ALLOCATION PROCEDURE FOR NEW DEVELOPMENT IN GWINNETT COUNTY, GEORGIA
By: Facet Decision Systems Inc., for PB PlaceMaking, March 2007

INTRODUCTION

This document describes the algorithms used to allocate land use, households and income-generating buildings for further analysis in fiscal, transportation, and facilities planning. Specific attention is paid in this write-up to the role of transportation factors in the procedure. The algorithms described in this document have not yet been calibrated, so it is anticipated that there will be revisions to this document. The gross system uses a series of algorithms to allocate land use to each parcel in the county, and then aggregates these parcels to the TAZ (Traffic Area Zone) level. While the allocation at the parcel level is “hypothetical”, this inaccuracy should be minimized when averaged over the larger TAZ area. Note that since we are doing two time steps, this methodology will be done twice, once with 2005 as the starting conditions, and once with the intermediate time step (either 2015 or 2020) as the starting conditions. This will reduce the effects of allocation order somewhat and lead to a more consistent distribution of the various land use conversions.

ALLOCATION OVERVIEW

The allocation algorithm takes place in several overall phases, each of which is described in more detail below.

• Parcel Analysis
• Parcel Allocation
• Component Allocation

PARCEL ANALYSIS

Each parcel is “scored” using a combination of factors that determine how attractive each parcel is to given development types. The factors are listed in Table 1 where the columns are the land uses and the rows are the factors that have been considered.

The development types consist of 8 “commercial” development types and 5 “residential” types:

Commercial

• CR (Commercial retail)
• OP (Office Professional)
• IP (Institutional)
• LI (Light Industry)
• HI (Heavy Industry)
• PRC (Parks and Rec)
• TCU (Telecom and Utilities)
• MU (Mixed Use)

Residential

• EST (Estate)
• SF (Single Family)
• TH (Townhouse)
• MDR/HDR (med or high density residential)
• UHDR (Ultra high density with 25+ household per acre)

THE ROLE OF ACCESSIBILITY IN THE SCORING OF PARCELS

There are a number of land use types whose attractiveness score is heavily influenced by accessibility and traffic volumes.

Commercial Retail

The land usage most affected by transportation is commercial retail, which (in our current model) is allocated entirely based on a proxy for traffic counts, so that the most "attractive" commercial locations are those with the most traffic, especially those that are in close proximity to highway interchanges.

Mixed Use / Office Professional

Mixed use is allocated only in the areas defined by Gwinnett County as being in a "Major Activity Center", and these centers are all located in immediate proximity to highway access. Office professional is affected by its proximity to highway interchanges, so both show tendencies to "clump" around highway interchanges.

Residential

Most classes of residential have a driver that increases their attractiveness for development based on proximity to highways. While this is a smaller factor than the size of the parcel (large parcels are significantly more attractive for developers than scattered smaller parcels) it is still an important factor, and meant that we changed the allocation order so that commercial retail was allocated before residential, to ensure that commercial retail was not "crowded out" by allo-
cation of residential land use. This change in allocation order allowed us to use a simple proximity-based utility model while preserving the observed tendency of retail and office buildings to cluster around major streets, with residential developments close to (but not on) these thoroughfares.

**Industrial**

In our original allocation model we observed that industrial parcels were widely scattered. To counteract this, we added a secondary influence on industrial allocation that was based on proximity to major roads. Because industrial properties are allocated last, they are only allocated on "leftover" parcels, so we see a clustering of industrial parcels in relatively undeveloped areas near highways. It is important to note that parcels zoned industrial have high conversion penalties for land use conversion, so industrial zoning tends to stop these parcels from converting to other land uses.

Once the raw score of each parcel is applied (in a range of 0.0 to 1.0) there are a number of modifiers applied to the raw score, specifically exclusions, redevelopment penalties and conversion difficulty.

**Exclusions**

Some parcels are entirely inappropriate for certain types of development, whether due to their physical (such as a farm on a parcel which is nothing but bedrock) or policy (historic sites are not available for office development) nature. As a result, a large (generally -10.0) modifier is added to these parcels to ensure that they are not developed for a given use. An absolute threshold will be set to ensure that “unsuitable” parcels are not developed (this is generally at 0.0, but this is another threshold value that will need to be calibrated, the threshold will certainly be “high” enough that “excluded” parcels cannot be used.) These exclusion rules are summarized in Table 2.

**Redevelopment Penalties**

It is generally easier and less expensive to do “greenfield” development than redevelopment. To model this, any parcel that has existing structures built has a negative modifier (generally -0.2 to -0.4) applied to all other land uses to reflect the fact that this parcel is likely to retain its current land use (and structures). We may apply a “partial redevelopment” penalty to areas that are currently underdeveloped or in need of redevelopment, so that these areas are less attractive than an identical “greenfield” parcel, but more attractive than other parcels that would need redevelopment.
**Conversion Difficulty**

Table 3 defines the conversion difficulty of changing from one land use to another. This difficulty is assessed as a penalty in the score, and may be dependent on the level of policy control exercised (e.g. a penalty range of 0.1 to 0.5 for “no policy control” to a range of 0.4 to 2.0 for “strong policy control”)

**PARCEL ALLOCATION**

Once the parcels have been scored, parcels are allocated in priority order. This priority order may change by scenario (based on the amount of policy intervention) The current “market based” allocation order is:

- Ultra High Density Residential (UHDR)
- Estate Residential (EST)
- Institutional (IP)
- Parks and Recreation (PRC)
- Telecom and Utilities (TCU)
- Office Professional (OP)
- Mixed Use in Major Activity Centres (MUR)
- Mixed Use in other areas (MU) Commercial Retail (CR)
- High Density Residential (HDR)
- TownHouse (TH)
- Single Family Residential (SF)
- Light Industrial (LI)
- Heavy Industrial (HI)

Note that the first five categories are added to the model as planning department overlays, so they are effectively “set” at the beginning of a given scenario: the only reason to assign a priority order is to resolve conflicts in case the same parcel is accidentally allocated twice.

The actual priority order is critically important. The following example of an apparent inconsistency in the ordering illustrates the difference between “priority allocation” and what is often called “best use” allocation. In general, residential is more profitable than commercial retail, but residential construction can readily use small (sub-acre) parcels while commercial retail is generally only possible on larger parcels. If we allocate residential before commercial retail, then residential is likely to “-fill” all of the parcels available for commercial retail. By making commercial retail a higher allocation priority than residential, we place the more constrained construction first, and then “fill in” with residential, despite the fact that actual development patterns are generally exactly the opposite.

Once a given allocation is assigned then there are three “paths” for determining what is on the parcel:

- If the parcel has changed types or is new development, then the contents of the parcel will be built out (LDR at 3 units/acre, commercial at appropriate floor area ratios and densities)
• If the parcel has not changed types and the current construction is above a threshold value (probably 2/3s of maximum density) then the parcel will keep its current contents.

• If the parcel has not changed types, and is below the threshold, then the parcel will be “rebuilt” up to capacity. Whether this is new construction, or an addition to existing structure(s) is irrelevant to the operation of the model.

OVERFLOW ALLOCATION

Because we are allocating at the sub-county area level, we are likely to run into situations where a given subarea does not contain sufficient developable (non-excluded) parcels. In this case we will need to note that there is an excess of a given type and allocate it at the county level before proceeding with the next priority allocation.
### Table 1: Ranking of Different Factors for Each Land Use Type

The higher the number is, the more important the factor is to the land use.

<table>
<thead>
<tr>
<th>Planning Dept Overlay (areas are designated for land use based on policy) - This overrides any other factors.</th>
<th>Commercial Retail (CR)</th>
<th>Office Professional (OP)</th>
<th>Institutional Public (IP)</th>
<th>Light Industrial (LI)</th>
<th>Heavy Industrial (HI)</th>
<th>Parks, Recreation, and Conservation (PRC)</th>
<th>Transportation, Communications, and Utilities (TCU)</th>
<th>Mixed use in Major Activity Centers (MUR)</th>
<th>Mixed use - other areas (MU)</th>
<th>Estate (EST)</th>
<th>Single Family (SF)</th>
<th>Townhouses (TH)</th>
<th>High Density Residential (HDR)</th>
<th>Ultra-high Density Residential (UHDR)</th>
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<tr>
<td>Cluster of similar use</td>
<td>1</td>
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<td>2</td>
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<td>Proximity to Hwy Interchange</td>
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<td>Proximity to Principal Arterials</td>
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Table 2: Exclusion Rules

Exclusions that apply to the land use types.
If the land use is excluded for a parcel, then that parcel can never convert into that land use.
This is to capture knowledge about developments that can likely not happen or about factors that preclude use (such as a very small parcel will never be turned into a warehouse).
False means exclude those set of parcels for that land use.

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<th>HDR</th>
<th>UHDR</th>
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</table>
Table 3: Conversion Difficulty

The table shows the conversion difficulty for land use conversions from one type to the other. There are five levels of difficulty ranging from very easy to very difficult:

- Very Difficult - 5
- Difficult - 4
- Normal - 3
- Easy - 2
- Very Easy - 1

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<th>Townhouse</th>
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</tbody>
</table>
APPENDIX E

MATHEMATICAL STRUCTURE OF DRAM/EMPAL AND ITLUP

The mathematical structure of DRAM/EMPAL as described by Putman (1991) is summarized in this appendix. The integrated portions of the model structure are highlighted.

INITIAL LAND USE ALLOCATIONS

Consistent with urban economic theory and as embodied in the original Lowry Models of land-use allocation, the integrated forecasting of future population and employment starts with “basic” employment as the drivers of regional growth. Export-oriented basic jobs are estimated based on external forecasts and located according to site characteristics and subjective inputs. EMPAL’s structure for spatially allocating basic employment is as follows:

\[ E_{m,j,t} = \lambda^m Q_j + (1-\lambda^m)E_{m,j,t-1}, \]

where:

\[ Q_j = \frac{\sum_i N_{i,t} \prod_{j}^m \alpha_i^m c_{i,j,t} \exp (\beta_i^m c_{i,j,t})}{\sum_k E_{m,k,t-1} \prod_{k}^m \alpha_k^m c_{i,k,t} \exp (\beta_k^m c_{i,k,t})} \]

where:

- \( N_{i,t} \) = Number of Employed Residents residing in zone i at time t (converted to households in DRAM),
- \( E_{m,j,t} \) = Number of Employees of type m working in zone j at time t,
- \( c_{i,j,t} \) = travel time (or cost) from zone i to j at time t
- \( L_j \) = Land area of zone j
- \( \alpha^m, \beta^m, \gamma^m, \delta^m \) = empirically estimated parameters for type-m employment

EMPAL thus allocates employment of type m to zone j at time-point t as a function of employment of the same time for a prior time point (t-1) and comparative accessibility of labor markets (i.e., employed residents) in the same employment time as well as a land-availability factor. As with most spatial interaction models, the denominator of equation 2 constitutes a “balancing term”, representing the inverse of a spatial accessibility index of the Hansen type.
Ignoring the mathematical structure of equations 1 and 2, a simpler notation is:

\[ E_t = f(E_{t-1}, N_t, c_t) \]  

(DRAM is the counterpart model to EMPAL, designed to spatially allocated households (i.e., employed residents), and essentially follows a similar mathematical structure:

\[ N_{h,i,t} = \sum_j E'_{j,t} Z^h_{i} , \]  

where:

\[ E'_{j,t} = \sum_l \alpha_{h,l} E_{l,j,t} , \]  

and

\[ Z^h_{i} = \left[ L^{q^h}_{v,i,t} X^{r^h}_{r,i,t} L^{s^h}_{r,i,t} \prod_v n^{h_i}_{h,d,t} c^{a^h}_{i,j,t} \right] [\sum_h L^{q^h}_{v,k,t} X^{r^h}_{r,k,t} L^{s^h}_{r,k,t} \prod_v n^{h_i}_{h,k,t} c^{a^h}_{k,j,t} ]^{-1} \]  

Thus similar to EMPAL, DRAM relies on a gravity-model structure to apportion land development, in the case of DRAM, among household types. As with EMPAL, DRAM can be expressed in shorthand notation as:

\[ N_t = f(E_t, L_t, N_t, c_t) \]  

In practice, however, to circumvent the identification problem of simultaneous equations 3 and 7, lagged-endogenous specifications have been used to solve the systems of equations, converting equation 7 to:

\[ N_t = f(E_t, L_{t-1}, N_{t-1}, c_{t-1}) \]
The co-dependent nature of employment and residential location is reflected by the contemporaneous nature of locating both Employment \((E_t)\) in equation 3 and Households \((N_t)\) in equation 7. First, EMPAL allocates employment across TAZs in forecast period \((t)\) using prior period \((t-1)\) accessibility, population, and employment totals. DRAM next forecasts future allocation of households using prior period \((t-1)\) locational accessibilities but also using the forecast period \((t)\) distribution of zonal employment. A sub-model, called LANCON, translates employment and household growth to land consumption estimates. DRAM also contains the system’s trip distribution models, converting housing allocation probabilities into vehicle trips using region-specific vehicle utilization rates. Home-to-work trip matrices are then split into private and public vehicular modes using a multinomial logit model, and private-car trips are allocated to the highway network using capacity-constrained traffic assignments. Travel cost changes are fed back into DRAM/EMPAL, which in turn – and subject to suitable physical capacity or other constraints on zonal-level land use – generates new spatial interaction matrices resulting from revised accessibility measures.

Modified versions of DRAM/EMPAL have also linked with conventional travel-forecasting models, yielding the ITLUP models. Perhaps the most celebrated example of “stylizing” ITLUP to local conditions is the LUTRAQ (Land Use-Transportation-Air Quality) model, developed through the 1000 Friends of Oregon to test light-rail TOD scenarios as an alternative to a proposed western bypass in Portland. The Puget Sound Council of Governments similarly used DRAM/EMPAL and their local travel model to test land-use scenarios in an “integrated” fashion (Murakami and Watterson 1992). There, basic employment was first distributed. Then a baseline set of travel costs were produced for the 2020 forecast year based on the local travel model followed by a run of DRAM and EMPAL. Next, scenario-specific transportation system improvements were assumed for 2020, DRAM and EMPAL were re-run, producing inputs for a second-round of forecasts from the travel model. Prior to inputs into the travel model, DRAM and EMPAL iteratively sought a stable solution (in effective locating trip origins and destinations) through nonlinear mathematical programming. In the Puget Sound models, scenario-specific results were later compared to the 2020 baseline model runs. Thus, a series of 2020 scenarios were generated within a single feedback loop. Particular attention was given to the environmental repercussions of future land-use/transportation arrangements based on region-wide mobile source emission estimates.

Subsequent updates of the population-employment allocation structure of ITLUP has led to various refinements, such as multiplicative attractiveness functions of residential allocation based on more than proximity to job opportunities – e.g., quality of infrastructure, zoning and regulatory constraints, socio-demographic factors such as neighborhood quality. As with all large-scale modeling, however, the introduction of more realistic assumptions added complexity to models, necessitating not only more hard-to-measure explanatory inputs (and thus increasing the risks of error propagation) but also complicating the ability to estimate stable and reliable parameter coefficients.
REFERENCES
