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TECHNICAL SUPPORT CONTRACT

Land Use Forecasting Case Studies:

A Synthesis and Summary

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A. OVERVIEW AND INTRODUCTION

I) SCOPE OF WORK

This set of case studies constitutes the synthesis and summary of Task Order #4, FHWA contract #DTFH61-95-C-00168. Work on the Task Order has involved the following:

Task 1: Methodology

This task included the development of a set of goals and objectives for case study research on the state of the practice in metropolitan land use forecasting, and a preparation of a series of questions used by the researchers in conducting the case studies.

Task 2: Site Selection

Work on this task included identification of a preliminary list of metropolitan areas that exhibit a range of best practice techniques in metropolitan land use forecasting, a review of the relevant characteristics of each, and the recommendation of metropolitan areas for case study development. The researchers were aided in the development of a preliminary list by discussions with technical peers and by the results of a survey sent to all MPOs. The final selection of case studies occurred in 1998.

Task 3: Case Study Development

This task involved gathering information and preparing case studies for each of the metropolitan areas.

Task 4: Final Report

Work on this task has included the assembly of reports from Tasks 1 through 3 into a final report which documents both the process and the findings of all research conducted and the development of this Synthesis and Summary Report.

II) INTRODUCTION TO THIS REPORT

Land use forecasting is one of the first steps in the travel demand forecasting process as it is practiced in the United States. These forecasts are particularly important for the planning of urban infrastructure, such as the highway system and public transportation network. Infrastructure plans for public facilities such as streets, water, and sewers may also be based on the outputs produced during the land use forecasting process. Although the land use forecasting models reviewed in this report are primarily associated with the transportation planning process, this type of forecasting also has important potential applications in urban infrastructure planning, private investment planning, and site selection.

Both ISTEA and TEA-21 recognized the importance of land use forecasting as a key part of the transportation planning process. Accordingly, the FHWA has supported efforts to review and improve the state of the practice for both land use forecasting and transportation planning. These efforts include numerous studies undertaken as part of the Transportation Model Improvement Project (TMIP), local and state government research efforts, and independent evaluations of the various aspects of the land use and transportation modeling processes, such as the case studies undertaken for this report.

The land use modeling process is primarily a local government process. The main players are city, county, and state governments, citizens, and other local interest groups. Land use models normally are developed for a single metropolitan area and operated within the Metropolitan Planning Organization (MPO) transportation planning framework. The population and employment forecasts produced in this process provide a general framework within which local governments fashion policies to guide growth in a metropolitan area. In some states, there are official state population and employment forecasts that must be used or at least considered in the MPO planning process, but in others, the population and employment forecasts are generated locally and are not required to conform to state forecasts.

This report provides a synthesis and summary of five case studies of existing land use forecasting models currently in use by MPOs. The models were chosen because they represent the range of best practices in land use forecasting as currently undertaken in the United States.

The next section of this report contains a summary of each of the five case studies. Following this, we discuss the case study material by focusing on six key questions.

B. SUMMARIES OF THE LAND USE MODELING CASE STUDIES

Portland, Oregon: Metro[1]

The Portland, Oregon, metropolitan area provides a rich policy context for a land use forecasting case study, in addition to an innovative set of forecasting techniques. Portland Metro is the only elected regional government in the United States. The fast pace of growth in Portland and the array of growth management policies initiated by the State of Oregon make Portland a particularly interesting site for a case study. The State of Oregon has initiated policies within the state land use planning program and the Oregon Transportation Plan and other policy initiatives which link land use and transportation planning, imposes strict urban growth boundaries on urban development at the edges of its metropolitan areas, and attempts to make Oregon cities denser and more oriented to pedestrians and transit.

The technical approaches used for land use forecasting at Portland Metro include a test application of the DRAM/EMPAL models, the in-house Spatial Allocation Model (SAM), and a more recent in-house Real Estate Location Model (RELM). All of these models use population and employment forecasts developed by Metro in conjunction with local governments. The SAM model is a modified Lowry gravity model that operates in an incremental fashion to allocate new development to the existing vacant land supply. The allocations are made within a 100-zone allocation matrix. A third generation land use forecasting model, RELM, is undergoing development. The econometric model has been used to evaluate various growth management policies and their impact on the housing market in the region.

Data from the regional GIS is the foundation for the allocation of the land use forecasts. Regional housing, employment, and vacant land by land use type area are all assigned to a matrix of ¼-acre grid cells. This process allows the data to be analyzed more uniformly and increases the flexibility in aggregation for alternative studies. The technical sophistication of the travel demand and land use forecasting procedures, and are highly disaggregate data, were the basis for selecting Portland as the site for a TRANSIMS[2] application.

[1] For more information see http://www.metro-region.org

[2] The **TRansportation ANalysis SIMulation System** (TRANSIMS) is a set of new transportation and air quality analysis and forecasting procedures developed as part of the Travel Model Improvement Program by the U.S. Department of Transportation, the Environmental Protection Agency, and the Department of Energy.

Seattle, Washington: PSRC[3]

Seattle, like Portland, is experiencing rapid population and economic growth and must balance this within a growth management framework. The State of Washington Growth Management Act of 1990 requires that jurisdictions establish urban growth areas and create comprehensive plans that are consistent with the region's long range plan. Beyond these contextual similarities, however, other aspects of these agencies, and the approaches taken to produce land use forecasts, are quite different.

The political structure of the Puget Sound Regional Council (PSRC) is more similar to MPOs across the nation than to Portland Metro, since it lacks Metro's status of a regionally elected government with taxing and policy authority. PSRC is responsible for preparing long-term land use forecasts for use in metropolitan transportation planning. These forecasts are based on population and employment projections provided to PSRC by the State Office of Economic Analysis.

PSRC was one of the earliest users of the DRAM/EMPAL models, initially working with Stephen H. Putman in their application, and later making some independent innovations in the structure and application of the models that distinguish it from later versions of the models distributed by Stephen H. Putman. The innovations made in the use of this model, including the agency's efforts to cope with a wide range of policy questions, makes Seattle an interesting case study with substantial relevance to other MPOs.

The most notable of these changes is that the models were restructured to operate on 10-year steps, in a quasi-dynamic fashion. In addition to the changes to the model structure, PSRC is one of very few MPOs to iterate between the land use and travel models, as well as within the travel models, to feed back congested travel times. Emme/2 is used for the travel forecasting models. PSRC uses an allocation process to disaggregate the land use forecasts to traffic analysis zones, using constraints required by the Growth Management Act. Finally, a technical and political process ensures that thorough review and political support are generated for each forecast update.

San Diego, California: SANDAG[4]

San Diego is another large and rapidly growing metropolitan area. As such it provides a benchmark case study within the California planning and policy context, and as a fast growing sunbelt city, San Diego also has particular relevance to other sunbelt cities.

The land use forecasting methods at the San Diego Association of Governments (SANDAG) represent a hybridization of several techniques, including a heavily modified EMPAL model and the Projective Land Use Model (PLUM) residential model, which

[3] For more information see http://www.psrc.org

[4] For more information see http:/www.sandag.cog.ca.us

incorporate multiple constraints, randomized reallocation, and account for development projects 'in the pipeline.' Land consumption is accounted for in a SANDAG model by the name of Sophisticated Allocation Process (SOAP), which allocates forecasts to approximately 26,000 blocks. The procedure also relies heavily on GIS processing, using the Arc/Info GRID module, and incorporates municipal comprehensive plans as constraints.

The combination of technical approaches adopted by SANDAG and their integration provide a useful case study for other MPOs evaluating ways to combine technical approaches in innovative ways. SANDAG's heavy use of GIS is likely to be increasingly reflected in the procedures of other MPOs around the nation. SANDAG staff have also been exceptionally attentive to analyzing forecasting errors, which is an undervalued aspect of the practice of forecasting. The heavy reliance of SANDAG on the comprehensive plans of their constituent jurisdictions also makes this a particularly interesting case study.

Dallas, Texas: NCTCOG[5]

The Dallas - Ft. Worth metropolitan area presents an opportunity for analyzing the use of sophisticated data collection and data processing techniques. The regional planning agency for the area, North Central Texas Council of Governments (NCTCOG) is exemplary in its use of the most advanced technology to keep up with data requirements of its model.

NCTCOG makes use of DRAM/EMPAL to produce its land use and socioeconomic forecasts. These are then disaggregated and become an input to the agency's transportation model system, which is currently being upgraded to a new package. The agency's intent is to have a fully integrated land use and transportation model forecasting system within the next two years. The combination of state-of-the-art data gathering and processing with their sophisticated model system was the reason for including this region for one of the case studies.

Longview, Texas: Longview

The Longview Texas Metropolitan Planning Organization (MPO) in east Texas was one of the first MPOs in Texas to utilize a GIS system in the 1980s. In 1992, Longview undertook a second major innovation in the land use forecasting process when it used the Delphi Process to forecast the location of population and employment growth. This project was conducted in conjunction with the Texas Transportation Institute (TTI) at Texas A & M University.

The spatial allocation of the forecasted population and employment growth is a critical input to any transportation model. The quantitative land use forecast models reviewed in

[5] For more information see http://www.nctcog.dst.tx.us

the other case studies in this report attempt to forecast future land use – population and employment – using highly quantitative models. These processes are data-intensive and formula-driven.

The Delphi Process approaches forecasts differently. It uses the local knowledge of a broad cross-section of people to build a consensus forecast. According to the City staff, growth in the Longview area has occurred in the locations forecasted by the 1992 Delphi Process. As the Longview MPO undertook its second use of the Delphi process in 1998 and 1999, the researchers took advantage of the opportunity to observe and describe that process firsthand, and added Longview to the land use forecasting model case studies.

C. SYNTHESIS OF LAND USE FORECASTING CASE STUDIES

This synthesis looks at the similarities and differences between land use forecasting techniques in five metropolitan areas. In particular, we focus on the following six questions:

1. What policy capabilities can each address?
2. To what extent is the public involved in the forecasting process?
3. What is the horizon year for the forecast?
4. How much staff time is required to run and maintain the models and/or conduct the process?
5. How are the models linked to GIS?
6. What are the data requirements for each modeling procedure?

Land use forecasting models use four classes of data as the foundation for the forecasting process, as noted below. There is a substantial body of research that has documented and quantified the relationships between these variables and the generation/attraction of traffic and travel in an urban area. The four data classes are:

- Land supply and density of development;
- Socio-economic distributions of population;
- Distribution of employment by industry type; and,
- General measures of accessibility in urban areas.

TCRP Report 48[6] recently looked at the state of integrated land use and transportation models. The authors reached the conclusion that the state of the practice for integrated land use and transportation models would be improved through the use of case studies of the various aspects of model development and implementation. The same can be said for land use forecasting models themselves.

This report is a starting point for such an effort. We review the work of MPOs on the refinement and evolution of their land use forecasting models and techniques. With these general comments in mind, we now turn to the six questions considered in this synthesis.

[6] Eric Miller, David Kriger, and John Douglas Hunt, *Integrated Urban Models for Simulation of Transit and Land Use Policies: Guidelines for Implementation and Use*, Transportation Research Board, Washington DC, 1999.

I) WHAT POLICY CAPABILITIES CAN EACH TECHNIQUE ADDRESS?

Land use forecasting models were developed to provide input to transportation planning models and have a solid institutional history of performing this task. The advent of formal land use forecasting models have their roots in research conducted in the fields of geography, economics, and transportation in the 1950s and 1960s. This work analyzed and described the nature of the relationships between land use and travel, beginning with the expression of simple relationships such as trip generation rates by land use type. The use of computers and the development of the four-step transportation models strengthened the connection between the empirical land use forecasting models and transportation planning and allowed the development of the relatively complex transportation models that are presently in use by MPOs to forecast future traffic flows.

Travel demand models use the output of the land use forecasting model, that is – the detailed distribution of population and employment by small geographic area – which then drive the estimation of travel demand and network travel volumes. The outcome of this process is used to answer questions regarding the capital expenditures that will be required to meet the future needs of the transportation system. As practiced today, the models are used primarily in the context of the future needs of the highway and arterial network. However, other policy questions, transportation and non-transportation alike, could theoretically be answered using these models. Below, we discuss four such policy areas.

Costs of Transportation

The outputs of the land use models are used as an input in travel models for estimating facility demand. This, in turn, is used to estimate the cost of facility construction necessary to meet the forecasted demand. This process could be extended to provide the basis for the estimation of the full costs of transportation, assuming that model outputs include mode split estimates. There are constraints that limit the ability to generate detailed transit information, which we discuss below, and obstacles in generating different scenarios (a useful companion to full-cost estimation), also discussed below.

Nonetheless, the application of quantitative land use forecasting models could help to further the state-of-the-art in full-cost estimation. Consensus-based models, such as the Delphi process, are less applicable to this type of analysis, given the highly quantitative nature of a full-cost analysis.

Transit Feasibility

Quantitative land use models such as those reviewed for this study can be used in conjunction with travel models to generate mode split estimates. Transit networks are modeled just as highway networks are.

One impediment, however, is that the land use model's forecasting zones are usually quite large and many of the urban form factors that influence transit ridership occur within relatively small-scale areas. The traditional planning area for an LRT station, for example, is an area of about one-quarter mile around an individual station, which can be smaller than a model forecast zone. Thus, the output of land use models would need to be disaggregated to the finer-grained corridor level required for a feasibility analysis. Portland has started effort to increase number of its model zones and to decrease their size.

As in full-cost estimation, the more quantitative models are more useful for this type of application than consensus-based models such as the Delphi.

Scenario Testing

Another set of possible uses of land use model forecasting models includes the fiscal analysis of alternative urban forms, the cost of different land development patterns, and the analysis of regional growth patterns, including issues such as carrying capacity of a watershed or airshed. This type of analysis, which occurs on an infrequent basis, is more likely to occur if it can use the results of existing procedure such as a formal land use forecasting model.

Despite the level of effort required to create alternative land use scenarios, there are several examples in the last ten years of the use of land use forecasting models in scenario testing. The LUTRAQ Project[7] in Oregon developed land use and transportation scenarios that were used to analyze transportation alternatives to the construction of a bypass freeway outside the Portland urban area. This analysis contributed to the decision to not build the bypass freeway.

The US 301 Study Task Force in Maryland developed a complex set of land use and transportation scenarios to model future growth in the areas west of Washington DC. This study modeled eight combinations of the transportation and land use scenarios and used the results to recommend a series of transportation and land use changes in the MPO's areas along US 301. As a result of this study the 1996 Task Force Report recommended a number of projects and institutional changes that could be used to address the transportation land use issues along the US 301 Corridor. The US 301 Policy Oversight Committee[8] is working with state and local officials to implement many of the recommended changes.

[7] LUTRAQ – Land Use, Transportation , Air Quality Connection Project. Between 1991 and 1997 this project produce eleven reports on alternative land use and transportation patterns in response to a proposed bypass freeway in Washington County Oregon. For more information see http:/www.friends.org

[8] For more information on US 301 Policy Oversight Committee see http://www.mdot.state.md.us

Metro in Portland carried out alternative growth scenario testing as part of its 2040 Growth Concept planning. Using the initial distribution of households and employment from its Spatial Allocation Model (SAM) as a base case, Metro staff adjusted the distributions in accordance with three different growth scenarios,[9] each of which were reviewed by local jurisdictions. The results of this manual allocation were then fed back into the transportation model to capture the differences in transportation networks.

Although Metro carried out scenario testing, its process was done by hand – a very long and tedious process. Doing a scenario analysis with such a model requires changing the underlying equations that drive the allocations of households and employment. The equations used in empirical land use models are based to one extent or another on the Lowry gravity model and represent distributions which are observed "on the ground." Scenario testing requires altering the coefficients of these equations, which in turn requires a theoretical basis for doing so. As the theoretical basis for altering the distribution of households based on measures other than travel impedance is improved, it will be possible to expand the applicability of land use forecasting models. Ongoing work for the State of Oregon furnishes examples of new approaches to land use forecasting.[10]

In contrast, the Delphi process is quite responsive to these types of scenario analyses. This process relies on the cognitive abilities of its panel rather than empirically specified relationships between variables and so lends itself well to the consideration of different policy scenarios.

Facilities and Services Planning

Perhaps because the organizations that perform transportation planning are rarely responsible for other types of urban infrastructure planning, the formal land use models of MPOs are seldom used directly in other types of infrastructure planning. However, it is possible that land use forecasting models could be adapted for use by other forms of urban infrastructure modeling, including the following:

- Water demand forecasting and system design;
- Sewer capacity forecasting and system design;
- Stormwater runoff forecasting and system design; and,
- Power/gas usage forecasting.

All of these types of infrastructure planning need to have basic information on the size and location of areas of future population and employment. In some cases, the level of detail

[9] The three growth scenarios were "Grow Out," a semi-trend scenario; "Grow Up," which held Portland's Urban Growth Boundary constant and allocated all growth within it; and "Grow Elsewhere," which allocated some of the growth to satellite communities.

[10] For more information, see http://urbansim.org.

available from a land use model exceeds the data requirements of the traditional facilities model process. For example, a water system planning project may only need to know the number of people forecast for an area and not the details of household income. This would be the case if the water planning process did not assume that there is any difference in water consumption based on income level or that any such difference in water consumption was more than offset by the requirement of providing adequate fire flow capacity. In either case, the model output could be a useful tool in forecasting the demand for urban infrastructure.

It may also be possible to extend land use forecasting models by borrowing techniques and approaches from the development of integrated models that has been underway for some time now. Although the leading land use models have focused on urban transportation data, addressing issues such as land price, housing price, and other urban economic issues would expand the range of policy options that a land use forecasting model could address. Urban geography may provide a valuable source of future innovation in land use forecasting models. Enriching the land use modeling process by using information from non-transportation fields of research would also expand the range of policy analysis options that a land use forecasting model could address.

II) TO WHAT EXTENT IS THE PUBLIC INVOLVED IN THE FORECASTING PROCESS?

Land use forecasting is a highly technical process that is less conducive to wide public involvement than are other planning activities. That the process is not very accessible to the public is not by intent but rather due to the nature of technical modeling. However, there are a number of professionals outside of the modeling process and a number of citizens who will understand both the process and the results if they are given the opportunity to review them. The challenge for local governments is to provide enough opportunities for public review and involvement, along with the contextual information that will facilitate the public's understanding.

In general, the land use forecasting process involves minimal public outreach, and most involvement comes at the end of the process when the public is given an opportunity to review the results of the modeling process. Instances in which land use allocations are controversial (e.g., allocating large population increases to presently rural areas) are most likely to generate public interest and call for more public involvement.

Table 1, below, shows the types of individuals involved in different stages of the process. We have broken the process down into its technical phase, during which the models are run and reviewed internally, and its external review stage, which takes place following the technical work. In most, but not all, cases the public is most involved during this second stage, as we discuss below.

Table 1: Public Involvement

		Persons involved in:	
City, State, & MPO	**Land Use Model**	**Technical Work**	**External Review**
Portland, OR: Metro	In-house Spatial Allocation Model (SAM)	Initial allocation made by MPO staff, subsequent allocation to smaller-areas by local jurisdiction planners Special interest groups and citizens representatives have role in technical work.	Local jurisdictions and the state reviews Open houses held for public input
Seattle, WA: PSRC	DRAM/EMPAL	MPO staff and technical advisory committee	Local jurisdiction and state reviews Public review
San Diego, CA: SANDAG	EMPAL (heavily modified), PLUM, and SOAP	Produced by MPO staff and presented to Regional Growth Management Technical Committee	Local jurisdictions and state reviews Public review
Dallas, TX: NCTCOG	DRAM/EMPAL	Subcommittee of the Regional Transportation Committee	Local jurisdictions and state reviews Public review
Longview, TX: Longview	Delphi Process	Growth Allocation Committee is comprised of local business and agencies	Local jurisdictions and state reviews Public review

In Dallas, San Diego, and Seattle, the public is given an opportunity to comment on the results of the forecasting process, usually toward the end, and it is involved in the adoption process as well. This level of public involvement is fairly typical for a technical modeling process.

In Portland, the technical phase is carried out by the Metro staff which presents its draft work to the Metropolitan Technical Advisory Committee (MTAC). This board includes one citizen representative from each of the three counties comprising the MPO. The board also includes positions specifically reserved for public special interest groups such as land use watchdog and environmental organizations, school districts, and affordable housing advocates. The citizen representatives and the reserved positions for special interest groups provide a direct link for public input much earlier in the forecasting process and to a greater extent than most other MPOs.

Longview has a process that is most intensive in terms of public involvement. Here, a Delphi Process is used in which the actual allocations are carried by the Growth Allocation

Committee, comprised of local business leaders, citizens representatives, and professionals. In this case, the citizens have a direct role in the growth allocation process from the beginning. In this type of model, it is also easier to involve the public because the methods are more diverse and intuitive than are the heavily quantitative models, which rely heavily on complex mathematical formulae.

While the level of public involvement is partially a function of the type of process used and the institutional norms of the MPO (some, like Portland, have a tradition of greater public involvement in regional issues), it will also be determined in part by the size of the MPO. That is, the larger the region, the more extensive will be the data requirements and the more complex will be the modeling process. Finally, the process is also impacted by an MPO's place in the regional governance structure. Metro is the only directly-elected MPO, giving it an added incentive to be responsive to the public. The other MPOs function as inter-governmental advisory bodies.

Would greater public involvement improve the process? The answer to that question is unclear. The highly technical nature of the modeling and forecasting implies that a substantial commitment is required for educating participating members of the public as well as a commitment to staying with a lengthy process. However the formal inclusion of citizens early in the forecasting process would certainly help reduce any criticism of the process or its outcomes.

III) WHAT IS THE HORIZON YEAR FOR THE FORECAST?

Federal transportation planning rules require that MPOs use at least a 20-year planning horizon in their transportation planning program. However, many MPOs exceed this in order to provide themselves adequate time to conduct periodic updates of their population and employment projections. That is, a 25-year forecast horizon allows MPO plans to stay within the federal requirements while providing the time needed to produce updates every five years. However, the choice of the horizon year also has important policy implications.

Table 2 shows the planning horizons used by each of the five case study areas.

Table 2: The Planning Horizon

City, State, & MPO	Land Use Model	Horizon Year
Portland, OR: Metro	In-house Spatial Allocation Model (SAM)	20 + year
Seattle, WA: PSRC	DRAM/EMPAL	30 year
San Diego, CA: SANDAG	EMPAL (heavily modified), PLUM, and SOAP	20 + years[1]
Dallas, TX: NCTCOG	DRAM/EMPAL	25 year
Longview, TX: Longview	Delphi Process	25 year

[1] SANDAG has the goal of adopting a new forecast every two years. However, this goal has been hard to meet due to the time that it takes to have the MPO board ratify the forecast.

NCTCOG, Longview, and the PSRC all plan for a 25-year horizon or more. The other two case study areas use a 20-year horizon.

In addition to its federally required transportation planning functions, Metro also handles regional land use planning within the Oregon land use planning framework. The dual responsibilities constrain its ability to chose a longer horizon time. Although always required to carry out land use planning with a 20-year horizon, the 1995 amendment of ORS-197.296[11] six years ago strengthened the legal requirements behind the 20-year rule by mandating that a 20-year supply of residential land be maintained. Because of the linkages between land use and transportation planning, it is not feasible for Metro to carry out transportation planning with the less restrictive 25-year horizon because it would conflict with the 20-year horizon under which it must forecast land use.

SANDAG currently faces a different set of policy conflicts with its horizon year. The most recent forecasts indicate that San Diego cannot accommodate projected growth beyond the year 2015 (two years short of its twenty-year goal) because there is not enough land to meet the forecast level of development at the densities allowed by the local comprehensive plans (which SANDAG cannot alter). SANDAG has developed an interim solution to this problem by making limited changes to the allowable densities in some areas, but a long-term solution will need to be found. This illustrates how the choice of a horizon year can impact the ability to carry out the required forecasts. A year that is too far out may lead to more growth than the constraints of local policy will accommodate.

IV) HOW MUCH STAFF TIME IS REQUIRED TO RUN AND MAINTAIN THE MODELS AND/OR CONDUCT THE PROCESS?

Although a substantial amount of staff time is necessary to collect and maintain the data needed to run the highly quantitative models, an exact accounting is difficult to estimate for several reasons. Foremost among these is that, while all of the models make use of data that is maintained in the local GIS system, this maintenance is not always counted by the MPOs, or is not counted in the same fashion, as part of the cost of maintaining the land use model. Another cause of uncertainty stems from the processing of employment data, which is the single largest data set that the empirical models process. Taken from ES-202 files,[12] these files require substantial processing on an annual basis to accurately assign all covered employment within a metropolitan area to their proper locations. To do so, they must first be assigned to the parcel level, a substantial task due to the

[11] Oregon Revised Statutes Chapter 197 – Comprehensive Land Use Planning Coordination, Section 296 – Sufficient Supply of Buildable Land within an Urban Growth Boundary.

[12] The ES-202 files come from unemployment insurance records maintained by each state's Employment Department.

inconsistencies in employer reporting. The parcels are then aggregated to the relatively coarse land use zone level.[13]

Given these uncertainties, the estimates of staff time are shown in Table 3, below.

[13] Employment sector data is discussed more thoroughly in the final section.

Table 3: Staff Time for Model Runs

City, State, & MPO	Land Use Model	Annual Total Staff Time to Collect/Maintain Model Data	Time to Make One Model Run or Allocation
Portland, OR: Metro	In-house Spatial Allocation Model (SAM)	~ 850 hours	~ 400 hours
Seattle, WA: PSRC	DRAM/EMPAL	Not available	Not available
San Diego, CA: SANDAG	EMPAL (heavily modified), PLUM, and SOAP	~ 7,000 hours	~ 176 hours
Dallas, TX: NCTCOG	DRAM/EMPAL	~ 6,800 to 8,500 hours	~ 80 hours
Longview, TX: Longview	Delphi Process	~ 420 hours	~ 1,200 hours

The table above indicates rather large disparities between time estimates. As noted previously, it is difficult to obtain estimates that can be compared across models, due to differences in accounting for GIS data maintenance and differences in the treatment of the large employment sector files.

The estimates for Metro and Longview are for one model run only. However, the estimates are less certain for the other three, which may include ongoing maintenance of GIS and other data. Also, Metro's estimates do not include the effort required to process the employment files, while the PSRC, SANDAG, and NCTCOG have staff permanently assigned to the maintenance of social economic data required for the forecasting process. SANDAG, in particular, puts significant effort into the maintenance of approximately 700 socio-economic variables, data which runs back to 1950.

Note that Longview's Delphi process requires a more modest commitment in terms of staff resources to support the model, but that it requires the most staff time for the process itself. This is in part because data is maintained as part of ongoing GIS systems, but the long process time also stems from the amount of staff time needed to set up and run the growth allocation committee meetings and process the results.

V) HOW ARE THE MODELS LINKED TO GIS?

All of the land use forecasting models use data that is derived from GIS systems, which keep substantial portions of their data at the parcel or address level. As such, GIS data exists in a very disaggregate state when compared to the aggregate data used by a land use forecasting model. For example, the Portland-area GIS system contains data on just under 600,000 parcels. Its land use forecasting model, by comparison, operates with 100 zones covering the same area as the GIS. In the travel model, this data is allocated to 1,260 traffic analysis zones which cover the same area.

Table 4, below, shows the levels of geography used by the land use forecasting models and the number of traffic zones to which data is allocated in the modeling process.

Table 4: GIS and Modeling Geography

City, State, & MPO	Underlying Geography in the GIS System (Approximate number of units)	Number of Land Use Model Zones
Portland, OR: Metro	Census Tracts (328) Census block groups (1111) and parcels	100
Seattle, WA: PSRC	Census tracts (574) Census block groups (2407)	219
San Diego, CA: SANDAG	Geographic reference areas, based on Census tracts (443), Census block groups (1655)other community planning areas, and parcels.	204
Dallas, TX: NCTCOG	Census tracts (898) Census Block Groups (3759)	191
Longview, TX: Longview	Census tracts (22) and parcels	6 Districts with35 sub-areas

The second column in Table 4 indicates the geography that underlies the GIS of each MPO. All of them are based on Census Bureau divisions, such as block groups or tracts. The second column also provides an estimate of the total number of units, or zones, in which the GIS data exists. SANDAG maintains an elaborate GIS database, whose most disaggregate data level is a polygon layer that contains the Master Geographic Reference Areas, of which there are 25,915. These areas are the result of overlaying the region's census blocks, tracts, city boundaries, zip codes, and so on. The third column, which shows the number of zones in the land use model, indicates the extent to which GIS data must be aggregated. Metro has the advantage of having its GIS and modeling processes handled by same division within the agency, providing excellent internal coordination.

The aggregation process is unique for each modeling system. Although it is possible to develop an automated process for this task, it is not carried out often enough to justify the programming effort that would be required to do so. Instead, aggregation from the parcel level to the land use modeling zone level is done manually within GIS. Establishing better links to the regional GIS would reduce the time and cost of data collection and aggregation.

VI) WHAT ARE THE DATA REQUIREMENTS FOR EACH MODELING PROCEDURE?

Extensive amounts of data are required for the quantitative models. The acquisition, maintenance, and calibration of data represents the largest personnel cost for each MPO. Even for the Delphi, the acquisition of good data is not a trivial cost. This section

describes the data requirements for each model. Because these are so extensive, we have broken them down into five different data types:

- Population and employment control totals
- Housing unit/household data
- Employment data
- Land supply data
- Travel model data

Population and Employment Control Totals

Each modeling process begins with the estimation of a regional population and employment forecast. This important first step sets the boundaries for all of the forecasting work that follows. The MPOs derive their control totals in several different ways as shown in Table 5, below.

Table 5: Economic and Population Control Totals.

MPO	Land Use Model	Population and Employment Forecast Source
Portland, OR: Metro	In-house Spatial Allocation Model (SAM)	Generates its own forecasts which are reviewed by an expert panel
Seattle, WA: PSRC	DRAM/EMPAL	Does its own forecast using economic base theory
San Diego, CA: SANDAG	EMPAL (heavily modified), PLUM, and SOAP	Carries out its own forecasts using a very large time-series database of 700 variables dating back to 1950
Dallas, TX: NCTCOG	DRAM/EMPAL	Required to use official state-level forecasts
Longview, TX: Longview	Delphi Process	Required to use official state-level forecasts

PSRC, SANDAG, and Metro each produce their own economic forecasts using regional economic models that are exogenous to the modeling process to establish their own control totals for population (or households) and employment which are used by the land use forecasting models.

SANDAG and PSRC have a long history of running sophisticated economic models. The PSRC model is structured by economic base theory and uses an econometric model that solves for 116 equations simultaneously. In the future however, PSRC will need to use a state forecast generated by the Office of Finance, a change brought about by the state's

Growth Management Act. PSRC is preparing to undertake another round of economic forecasting and it is unclear how they will balance their forecasts with the official forecast used in the land use planning process. SANDAG has an extensive economic dataset that contains 700 variables and is used to run a series of regression-based coefficients that are developed for use in the local econometric forecasting model.

Metro, which previously based its economic forecast on data from other regional economic forecasts (i.e., from the Northwest Power Planning Council, the Bureau of Economic Analysis, or WEFA), now uses an in-house model. The State of Oregon has recently begun to produce an official state population and employment forecast for use by its state agencies. Local governments are not presently required to use this forecast in their land use planning process nor for transportation planning. However, a recent court case determined that local governments have to consider the state forecasts, and, if they chose not to use them, they must provide legal finding that supports and explains why the state forecasts are incorrect. This decision can be expected to have an impact on the economic forecasting process used by Metro.

Dallas and Longview are required to begin their forecasting process with the official population forecast obtained from State Comptrollers Office. A limited amount of local adjustment to this forecast is allowed.

The use of official or state-wide forecasts is a growing trend in transportation planning. This type of coordinated forecasts avoids the problems associated with each jurisdiction making independent forecasts that in the aggregate are unreasonable.

Housing Unit/Household Data

Household data by income category is a key input into a transportation planning model. All of the models used by the five MPOs use this data to estimate trip generation rates. Table 6, below, describes the types of housing unit and/or household data that each MPO uses.

Table 6: Household Variables

MPO	Housing Units	Other Housing Unit Variables	Total # of Households	Number of Income Categories	Other Household Variables
Portland, OR: Metro	No	No	Yes	4	Number of multi- and single-family households
Seattle, WA: PSRC	No	No	Yes	4	Number of multi- and single-family households, average household size
San Diego, CA: SANDAG	Yes	No	Yes	7	Number of occupied units - i.e., vacancy
Dallas, TX: NCTCOG	No	No	Yes	4	None
Longview, TX:	Yes	Building	Yes	1	Average household size

Longview		permits, building demolition		(Median household income)	

The quantitative models forecast land use using the number of households as a surrogate for population. That is, households are considered to be mobile and are not directly linked to the existing housing stock. In addition, these models do not do a good job of addressing the specifics of household location decisions and the fact that some portion of the total households remain at their current location during a model run iteration while others are more mobile. However, the abstraction of the urban residential housing market allows the model to function in the aggregate and to avoid a series of housing-related issues including vacancy rates, type, location, and condition of housing supply and life-cycle stage of household residents.[14] Note that this "abstraction" problem is much less likely to occur with the Delphi Process, as the expert panel can be assumed to take the built environment into account in its analysis.

Longview and SANDAG also use data on the number of housing units in their modeling process. Longview tracks this information as background data for review by the Growth Allocation Committee in order to show where development has occurred and where building demolitions have exceeded new construction (resulting in declining populations in some portions of the area). SANDAG is the only MPO that tracks vacancies, using housing unit data in conjunction with land use data, in order to determine the number of vacant buildings by zone.

Income is included because the number of trips per household, auto ownership, and mode split are directly related to the income level of the household. The number of income categories used is determined by the structure of the model. Increasing the number of categories provides a finer-grained analysis of the effect of income on trip-making activities.

Employment Data

Employment data is a key part of any transportation planning model because employment is one of the key trip attractors. Journey-to-work trips account for a large percentage of the total number of trips made by household on a daily basis. Journey-to-work trips are also import because they are a major component of travel to the PM peak hour travel. Retail employment is also modeled because it is a surrogate for the location of retail business and, as such, a primarily destination for home-base shopping trips.

Employment data by establishment is available through state employment departments from the covered employment data files (the ES-202 files which were previously

[14] The abstraction of residential decisions also reduces the model's applicability for a variety of urban and housing planning applications.

discussed). This was the primary data source for Metro, SANDAG, PSRC, and NCTCOG. Longview obtained data from a commercial database that provides employment by establishment data.

Table 7, below, lists the sub-sectors modeled by each MPO.

Table 7: Employment Data

MPO	Employment Sub-Sectors
Portland, OR: Metro	Basic Retail Service
Seattle, WA: PSRC	Manufacturing Retail Service Government WTCU (Wholesale, Transportation, Communication, and Utilities)
San Diego, CA: SANDAG	Manufacturing Wholesale Retail FIRE Service Government TCU (Transportation, Communication, and Utilities)
Dallas, TX: NCTCOG	Manufacturing Retail FIRE Service Government WTCP (Wholesale, Transportation, Communication, and Utilities)
Longview, TX: Longview	Basic Retail Service

The table above indicates the varying levels of employment sub-sectors that each of the MPOs model. SANDAG classifies the employment data into eight categories – the most complex data classification scheme used by the five MPOs reviewed in this study. It also provides the most detailed employment forecasts. At the other end of the scale, Portland and Longview use only three employment categories in the forecasting process. Simply stated, the more employment categories used, the more finer-grained an analysis can be undertaken for each category. Metro uses such a coarse breakdown largely because it places a greater emphasis on land use and household variables.

As with households, employment is projected as an abstract economic variable, rather than as a variable that is tied to the built environment. Although SANDAG is an exception, none of the quantitative land use models address the various physical aspects of employment location, such as supply of building space or type. Thus, the link between projected employment and the space to house workers and businesses is not addressed and the assumption is made that if employment is forecast for an area, then the needed building infrastructure will be available. SANDAG includes one variable, the number of occupied employment units (i.e., vacancy) in order to make the link between employment level and building supply more explicit. In all cases, employment is constrained in a given

area based on the land supply that is available for development for employment. This is a policy-based constraint that in most cases is established by government planning and zoning regulations.

Land Supply Data

Land supply data fill a critical role in the land use forecasting model process. Land supply functions as both a constraint on future development and as the determining factor for the type of development in a particular zone or area. Importantly, it is through the land supply variables that the policy context is manifest within the land use models. That is, the specification of the amount of land that is available, for what use, and at which densities is a policy decision made at local and regional levels of government. Through the land supply variables, government policies are incorporated into land use models.

Table 8, below, shows the land supply variables used by each of the models.

Table 8: Land Supply Variables

MPO	Type of Land Supply Variables	How Land Supply is Constrained	Other Land Supply Variables
Portland, OR: Metro	▪ Acres of developed land ▪ Vacant developable land by type ▪ Percent land zoned residential	Maximum density by land use type	No
Seattle, WA: PSRC	Acres of developable land in zone (%)	Employees per unit (acre) of employment land	No
San Diego, CA: SANDAG	Total buildable land area by type	Maximum density by land use type	▪ Redevelopment potential ▪ Amount of residential land consumed for employment.
Dallas, TX: NCTCOG	▪ Land supply by type ▪ Vacant acres of residential land ▪ Vacant acres of commercial land ▪ Total acres of residential land	▪ Land supply by density ▪ Vacant land by density	▪ Priority for development ▪ Density of future development
Longview, TX: Longview	Land supply by type	Land supply by density	No

Four of the five procedures reviewed – Metro, SANDAG, NCTCOG, and Longview – explicitly include the amount of land (in acres) by type of use (residential or employment) in their models. PSRC uses the amount of developable land by type measured as a percentage of the total amount available in a zone.

Only SANDAG explicitly addresses redevelopment in its modeling process. That it is missing in the other models may be related to a lack of consensus on an appropriate process for modeling the redevelopment process. Nonetheless, neglecting the role of redevelopment reduces the effectiveness of those models.

The use of land supply as a constraint introduces a "geographic inertia" into the modeling process. In this case, geographic inertia can be defined as the fact that once an area is developed with a particular land use pattern – parcelization, types of uses, transportation system, etc. – the existing built environment changes very slowly. Relatively rapid change in the development pattern occurs primarily on vacant land and once that land has developed, the developed pattern resists effort to change it. None of the models measure change in the existing built environment over time because they do not do a good job of capturing the built environment in the first place. Yet such a longitudinal assessment of change in the existing developed areas is necessary to provide an accurate picture of growth in an urban area.

It can be argued that the effect of the use of land supply as the major constraint on the model process is to have the model produce a "plancast" rather than a forecast. That is to say, the model forecasts a land use pattern that mimics public policy at the local level and, as such, is subject to shifts in local policy. This is especially true if there are model zones in which there are large amounts of vacant land but little growth is projected because the zoning or plan policies do not allow development to occur. An example of such a case would be a rural area outside a city that has been designated for agricultural use and where there are strict policy limits that restrict new development, i.e., the model assumes that there is no available land for development. From a purely analytical standpoint, there is nothing inherently good or bad in such a policy limitation, but its impact on the model forecast needs to be acknowledged.

Travel Model Data

The four quantitative models all use aggregate measures of travel time or accessibility that are derived from the travel models as an input for land use forecasting. Generally, this data is from a previous time period, usually 5 or 10 years before the period being modeled, which simulates the effects that network supply and congestion have on development. This data therefore represents a type of feedback loop from the travel model. The travel model feedback is intended to simulate the impact that development has on the travel network and that the travel network consequently has on development.

Table 9, below, shows the travel time and accessibility measures used by each MPO.

Table 9: Travel Model Data

MPO	Travel Time Measures	Accessibility Measures
Portland, OR: Metro	Sum of travel time	▪ Access to employment ▪ Access to housing by income level ▪ Total employment access
Seattle, WA: PSRC	Travel impedance (time & cost) between zones	Accessibility index
San Diego, CA: SANDAG	Travel impedance (time & cost) between zones	None
Dallas, TX: NCTCOG	Trip length and travel time	None
Longview, TX: Longview	None	None

The quantitative models have the benefit of a transportation model that provides an indication of access, and knowing how this influences land use decisionmaking can help with population and employment allocations. Longview does not use travel model data in this process. Instead, a Delphi does this on an intuitive, knowledge-based basis. This information is incorporated into the individual assessments of the potential changes that are assessed as part of the Delphi process.

With one exception, the travel time/accessibility measure is used from the start of the travel period and is not updated during the process. By not accounting for the fact that travel times increase as more households/employment are added to a zone, the models are not able to decrease the attractiveness of the zone. The Spatial Allocation Model used by Metro in Portland comes much closer to providing a feedback loop, using multiple iterations between the land use and travel models.

D. CONCLUSION

This document has summarized and synthesized information about five land use forecasting models, which were reviewed in detail in a companion report for FHWA by the same authors, *Land Use Forecasting Case Studies* (December 1998). The models were chosen because they represent the range of best practices in land use forecasting as currently undertaken in the United States.

Metro, PSRC, NCTCOG, and SANDAG represent varied approaches in the application of four highly quantitative models. Both PSRC, with its strong economic model and SANDAG, with its rich dataset, place a strong emphasis on the economic side of modeling, incorporating a wide range of variables and basing forecasts in strong economic theory. Metro has pushed the state-of-the-art in developing cutting edge in-house models. Its Spatial Allocation Model comes much closer to providing a feedback loop between the land use and travel models than any of the others. It has also been innovative in its involvement of citizen representatives and special interest groups in the technical phase of

forecasting. NCTCOG is the largest of the MPOs, covering such a large area with so many jurisdictions that it is analogous to modeling for a small state.

Longview's use of the Delphi process provides an interesting contrast to the quantitative models. It appears to be a viable alternative to the empirical modeling process for small and medium-sized MPOs, particularly those that do not have the capability or resources to run the formal empirical models. We note, however, that the Delphi should not be considered just by those MPOs with expertise and resource constraints, as the Delphi can be successfully used to answer questions which the quantitative and mechanistic models cannot, such as the analysis of different scenarios and consideration of the built environment. However, it is not clear if the Delphi process could be made to function effectively for a large MPO. Assessing this question would require additional research.

Although the models discussed in this synthesis and summary have performed well at forecasting future land use and transportation patterns, there is still room for improvement in the forecasting process, in model design and specification, and the use data from GIS systems. To be more widely used, the land use forecasting models should evolve by doing the following:

- Establishing better links to the regional GIS to reduce the time and cost of data collection and aggregation
- Expanding the number of forecasting zones so that finer-grained forecasts can be readily developed
- Incorporating direct links to the built environment in order to better account for changes in housing stock and employment space over time