# Final
# Land Use and Transport Modeling Design Report

*prepared for*
Sacramento Area
Council of Governments

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# 1 Executive Summary

This project's purpose is to design the next generation travel demand forecasting models, which will be used for regional travel forecasting by SACOG. As part of this effort SACOG is reviewing its land use forecasting process and evaluating an integrated land use and travel forecasting model.

The design effort included three phases. First was ***user needs assessment***. Through workshops and focus groups in January and February, SACOG has reached out to all users of the current model in government agencies, consultant offices, and interested members of the community-at-large. The outreach generated a list of user needs that guided subsequent phases of the design.

The second phase was ***development and evaluation of alternatives***. Three options were developed by the design team, which varied in level of difficulty and the extent to which the user needs were addressed: The recommendation of the design team was to work aggressively over the next five years to fully implement the most basic option, called the "New Standards" option. This option meets many (but not all) of the user needs, and provides a platform on which to make other enhancements over time.

The final phase of the project is ***the model design***, which will be used by SACOG to guide its model development efforts over the next five years. The design team focused on the New Standards option, and prepared a detailed description of the model, identified key data requirements, and estimated the costs and time required to develop and implement the model.

This report provides a summary of the project, and a recommended design of SACOG's next generation of forecasting tools. The design is intended to guide SACOG's model development activities, resulting in a state-of-the-art set of regional land use and travel forecasting tools.

## 1.1 User Needs Assessment

For the purposes of the model design, comments from model users were summarized into a listing of eight categories.

- **Relevance to Current and Future Land Use and Transportation Policy Issues.** New models should allow for reasonable analysis and evaluation of key policy issues which the region is likely to face over the next 10 years (e.g. smart growth strategies, pricing, intelligent transportation systems, environmental justice, etc.) and effects of transportation infrastructure on travel behavior (e.g. induced or suppressed demand, peak spreading).
- **Supporting Specific Upcoming Planning Applications and Projects.** New models should anticipate major upcoming planning projects by SACOG and other agencies in the

region (regional plan updates, changes to air quality conformity process, project planning or funding initiatives, etc.).

- **Transparency of Inputs.** Key input assumptions should be explicit, and subject to public review.
- **Comprehensive in Scope.** The scope of the new models should be broadened to include more detail on key areas outside the formally-defined Sacramento region.
- **Credibility.** Emphasis should be placed on reasonableness checks, sensitivity testing, and validation of the new forecasting tools, to maximize understanding and confidence in the models.
- **Behavioral Accuracy.** The new models should be based on the best knowledge of travel behavior and land development.
- **Capability of Scenario Testing.** The new models should be designed to allow for straightforward, realistic testing of policy decisions.

### 1.2 Evaluation of Alternatives

Guided by the detailed listing of user needs, the design team developed three options for travel and land use forecasting models, and presented these options to model users at a Symposium held in April 2001. The evaluation consisted of ratings of the extent to which each option addresses user needs, and estimates of development cost and difficulty. The options are as follows:

- **New Standards Option**. This option is based on a simulation of personal travel, and an aggregate Spatial IO Module and land development model to forecast land use. While somewhat limited in the extent to which this option would address user needs, its advantages are that it relies almost wholly on existing software, requires minimal new data collection, and could be implemented in phases over the next three years.
- **Enhanced Option.** This option includes a more detailed simulation of travel, and would implement simulation for the land use model. These improvements would allow for much more dynamic modeling of land use and travel interactions, but would require new software development and data collection, and would also require additional time and funding to implement.
- **Advanced Option.** This option includes a fully integrated simulation of all significant travel and land use activities. These options would provide the most realistic representation of both travel and land use systems, and the most flexibility in meeting user needs. This option would require significant new software development, data collection and additional research, and would require more than five years to implement.

Although differentiated by their capabilities and costs, the three options had a number of common elements:

- ***Path-Dependent Forecasting Approach***. This means that forecasts are built up to a planning horizon year in fixed increments of one to three years. This approach captures timing issues related to infrastructure deployment.
- ***Simulation of Behavior***. Simulation is increasingly used in both land use and travel models, because it provides greater detail in policy-sensitive variables. This approach would replace the aggregate, zone-based models currently used by SACOG.
- ***Interactivity Between the Land Use and Travel Forecasts.*** Although it is widely accepted that land use development and transportation behavior are inextricably linked, traditional forecasting models treat them as separate phenomena. Many of the most commonly cited user needs depended on land use forecasting models which influenced travel models, and vice versa.
- ***Use of Geographic Information Systems***. In part because more detail was desired by many model users, and in part because geographic information systems (GIS) is increasingly becoming the preferred medium for data development, maintenance, storage, and exchange among many agencies all of the model options are based on GIS data.

Based on the evaluation and feedback from model users at the Symposium, the design team recommended that the final design be based on the New Standards option.

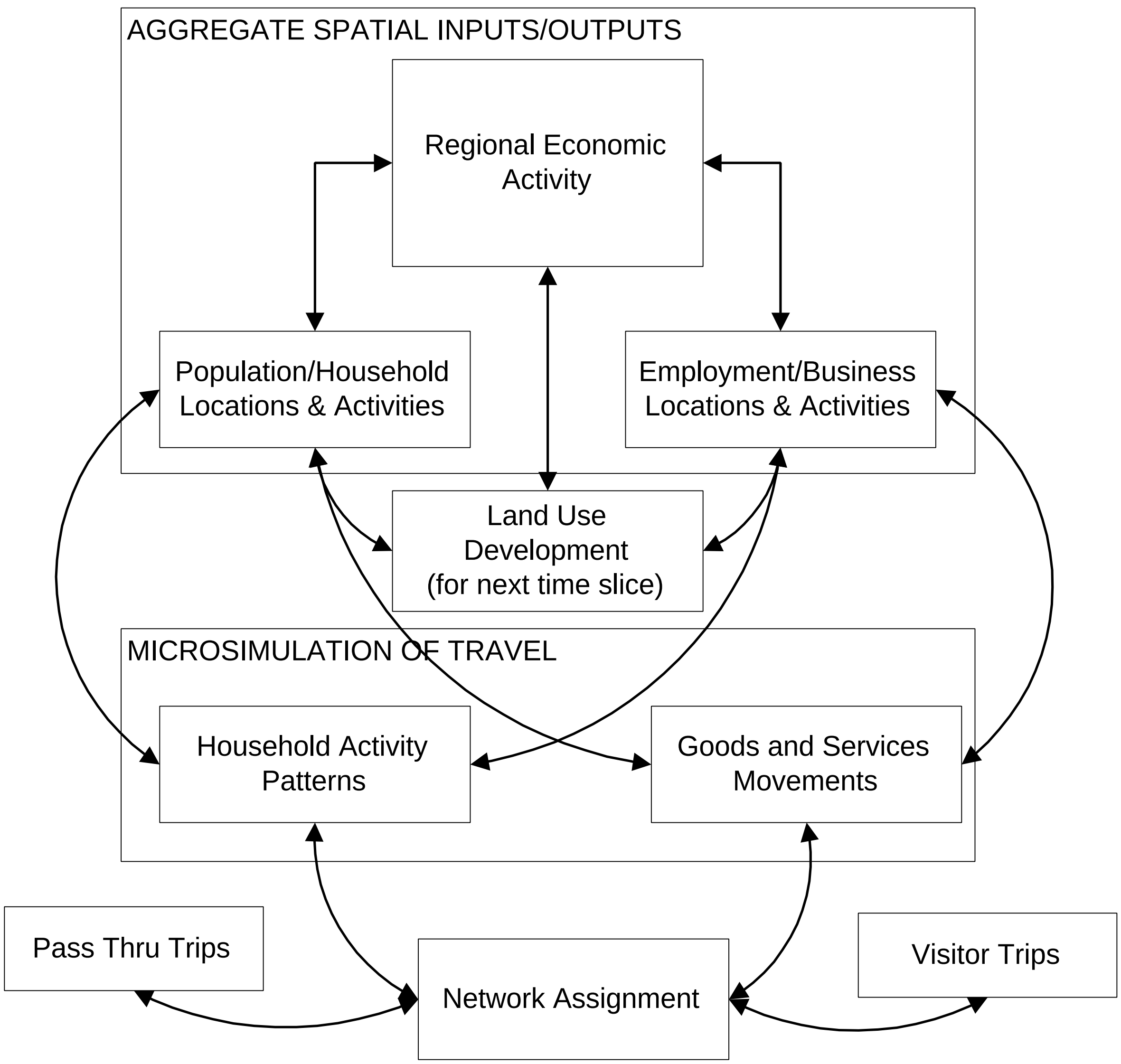
### 1.3 Model Design

The model design resulted in a detailed, element-by-element description of a set of integrated land use and travel models. The description included identification of resources needed to develop and test the models, general staffing requirements for maintaining and using the models over time, and potential enhancements that could be implemented in a modular fashion over time.

The basis modeling system can be broken into three connected parts: 1) a Day Activity Pattern Module, which will simulate both household and business travel behavior; 2) a Spatial IO Module, which would provide an allocation of economic activity throughout the region; and 3) a land development model which would simulate land use change.

These three components are connected in several ways. The Day Activity Pattern Module requires detailed input data, such as the location and composition of people and households, and the location and type of employment. This input data will be generated by the Spatial IO Module. At the same time, the allocation of economic activity in the region is sensitive to travel conditions and accessibility, which are strongly influenced by the transportation system (i.e. roads, transit, bike trails, etc.). The outputs of the Day Activity Pattern Module from one time period provide inputs for the Spatial IO Module in the subsequent time period. This interaction is mediated by the land development model. This overall modeling system is illustrated in Figure ES-1.

**Figure ES-1**
**New Standards Model Framework**




While it is too soon to provide detailed task-by-task cost estimates, budget-level estimates of what will be necessary to develop and implement the New Standards model over a three year period are summarized in Table ES-1. The range of cost is $750K-$1.25M over three years

If that level of budget is not available, cutbacks would be required in the detail or complexity of the models, or SACOG staff would have to undertake more of the data collection, model development and implementation.

**Table ES-1**
**Model Development Costs (Exclusive of SACOG staff costs)**

| Task | Year 1 | Year 2 | Year 3 | Total |
|---|---|---|---|---|
| Development of land use models | $100-150 | $150-200 | 0 | $250-350 |
| Development of travel models | 150-225 | 100-125 | 0 | 250-350 |
| Integration, testing, training, documentatic | 0 | 0 | $200-300 | 200-300 |
| Data collection | 50-150 | 0-100 | 0 | 50-250 |
| Total | $300-525 | $250-425 | $250-425 | $750-1,250 |

Not included in the development costs are added SACOG staff costs. Two full time staff would be necessary, one for creation and upkeep of the GIS databases and the definition of land use scenarios, and another for creation and upkeep of the network databases and the definition of network scenarios. It would be desirable to have a third person, with the main responsibility of running the model system and analyzing the output.

Some additional types of data will need to be compiled from existing sources:

- Floor space data
- Data for a multi-sector regional "make-use" input-output matrix.
- Data to describe inter-regional travel and attractions.

It is recommended that the model system be implemented in a phased manner over the next three years. In year one, the Day Activity Pattern Module and data collection efforts should begin. In year two, the remaining data collection tasked would be completed, and the land use models developed. Year three would be devoted to calibration, testing and validation of the model system. This schedule would result in a finished model system, ready for use in preparation of the 2005 Metropolitan Transportation Plan (MTP).

# 2 Overview of the Design Process

This project's purpose is to design the next generation travel demand forecasting models, which will be used for regional travel forecasting by SACOG. As part of that effort SACOG is reviewing its land use forecasting process and evaluating an integrated land use and travel forecasting model.

The design effort included three phases. First was ***user needs assessment***. Through workshops and focus groups in January and February 2001, SACOG has reached out to all users of the current model in government agencies, consultant offices, and interested members of the community-at-large, and prepared an inventory of the needs for travel and land use forecasting data, analytical tools, and results. This work has been summarized in a "User Needs Assessment" report.

The second phase was ***development and evaluation of alternatives***. This phase culminated with Symposium I on April 5, 2001. Three options were presented by the design team at Symposium I: a ***New Standards*** option, an ***Enhanced*** option, and an ***Advanced*** option. The recommendation of the design team was to work aggressively over the next three years to implement the New Standards option. This option meets many (but not all) of the user needs. Additionally, this option provides a platform on which to make enhancements to the overall modeling system over time. Symposium I materials have been summarized, and are available on the SACOG website.

The final phase of the project is ***the model design***, which will be used by SACOG to guide its model development efforts over the next three years. After Symposium I, the design team developed a detailed model design, based on the New Standards option. Additionally, likely development time, costs, and staffing for the models were estimated.

The draft model design was the subject of Symposium II, held on Monday, June 18, 2001.

This report provides a brief summary of the project, and a recommended design of SACOG's next generation of forecasting tools. The design is intended to guide SACOG's model development activities over the next three years, resulting in a state-of-the-art set of regional land use and travel forecasting tools.

## 2.1 User Needs Assessment

The first phase of the design process was taking an inventory of user needs. Three forums for discussing needs with model users[1] were organized. Users of both the travel demand model (SACMET) and the SACOG projections of population and employment were included in the

[1] "Model users" includes persons who actually use the models directly, and generate forecasts for their organizations, and persons who use outputs of the models for other purposes (e.g. emissions estimates).

forums. The user needs forums resulted in literally hundreds of specific comments on the current SACOG forecasting tools, desired capabilities of the next generation of tools, and limitations or characteristics to be avoided in developing the new tools. For the purposes of evaluating options, and for developing the final design, these comments were summarized into a listing of 40 more generalized user needs, split into eight categories. The eight user needs categories are described below.

- **Relevance to Current and Future Land Use and Transportation Policy Issues.** The should allow for reasonable analysis and evaluation of key policy issues which the region is likely to face over the next 10 years (e.g. smart growth stratedise, pricing, intelligent transportation systems, environmental justice, etc.). The effects of transportation infrastructure on travel behavior (e.g. induced or suppressed demand, peak spreading) should be captured.
- **Supporting Specific Upcoming Planning Applications and Projects.** The new models should anticipate major upcoming planning projects by SACOG and other agencies in the region. Phase-in of the new models should be sensitive to these projects. The needs of local agencies, which currently use SACMET or SACMET-derived data for locally-developed models, also need to be considered.
- **Transparency of Inputs.** Key input assumptions should be explicit, and subject to public review.
- **Comprehensive in Scope.** The scope of the forecasting tools should be broadened to include more detail on key areas outside the formally-defined Sacramento region, but clearly affecting travel to, from, and through the region.
- **Credibility.** Emphasis should be placed on reasonableness checks, sensitivity testing, and validation of the new forecasting tools, to maximize understanding and confidence in the models.
- **Behavioral Accuracy.** One criticism of four-step travel models, especially in conjunction with fixed land use forecasts, is that the models do not accurately reflect actual behavior by travelers, households, firms, and land developers. The new forecasting tools should be based on the best theories and models of behavior relevant to travel and land development.
- **Capability of Scenario Testing.** Since forecasting tools are intended to provide input to policy decisions, the tools should be designed to allow for straightforward, realistic testing of policy decisions.

Table 1 provides a listing of the user needs. More detail on the listing, and the specific comments and notes from the user input forum are reported separately.

| **Table 1**<br>**User Needs Inventory** |
|---|
| **A. Policy Relevant** |
| **Support the policy issues which the region is likely to face:** |
| 1. Smart Growth strategies |
| 2. Pricing policies (e.g. toll roads, HOT lanes and parking) |
| 3. ITS strategies (e.g. travel information, operations improvements, etc.) |
| 4. "Non-traditional" transit modes (community-serving transit, BRT) |
| 5. Environmental justice and social equity issues |
| **Capture important "secondary effects" of transportation projects and growth:** |
| 6. Effects of transportation projects on land development |
| 7. "Induced" or "suppressed" demand |
| 8. Peak spreading or changing times of travel |
| 9. The secondary effects of the built environment (i.e. urban design, density, mixed use, etc.) on travel behavior should be included in the model. |
| 10. The secondary effects of the transportation projects (i.e. roadway width, presence/absence of sidewalks, inclusion/exclusion of bike lanes, etc.) on travel behavior should be included in the model. |
| **B. Significant Upcoming Model Applications** |
| **Upcoming model applications using SACOG forecasting tools:** |
| 1. "New Starts" applications for Light Rail Transit |
| 2. Metropolitan Transportation Plan in 2005 |
| 3. State Implementation Plan in 2003 (air quality) |
| 4. Air Quality Conformity Test of Transportation Plans |
| **Local agencies/other model users applications:** |
| 5. EIR's/EIS's |
| 6. Traffic impact studies |
| 7. Specific/General Plans |
| **C. Flexible** |
| 1. Usable or adaptable for local and sub-regional studies by other agencies |
| 2. Fine level of detail, to allow for others to tailor it to their needs. |
| 3. Developed and maintained in a standardized, portable format. |
| **D. Transparent** |
| 1. Key input assumptions should be explicit, and subject to public review |

| **Table 1 (cont'd)**<br>**User Needs Inventory** |
|---|
| **E. Comprehensive** |
| 1. Inter-regional and even international travel should be represented in some form |
| 2. Special emphasis on inter-regional rail. |
| 3. Special emphasis on travel between the region and the Bay Area. |
| 4. Commercial vehicle and truck travel should be represented in some form. |
| 5. Airport ground access should be included in the model. |
| 6. The model should include some way of representing seasonal and recreational travel. |
| 7. Model input and forecast data should include specification of significant land development information (agricultural quality, environmentally sensitive lands, etc.) |
| **F. Credible** |
| 1. Validation—the model should predict known conditions |
| 2. Sensitivity tests—the model should provide reasonable results when key variables are changed |
| 3. Are the input assumptions (fuel costs, forecasts, etc.) reasonable? Do they cross-check with other known sources? |
| 4. Are known trends in demographics (aging, income, etc) reflected in forecasts? |
| 5. Key model output measures should be reasonable and understandable by non-technical persons |
| **G. Behaviorally Accurate** |
| 1. Model should correctly represent travel behavior by individuals, and include the major factors influencing travel behavior. |
| 2. Model input data should include key variables affecting travel behavior (income, number of workers, number of autos, school age children, retired, etc.) |
| 3. Non-motorized modes (bike, walk) and "substitutes for travel" (work-at-home, e-commerce, telecommute) should be represented in the model |
| 4. Forecast data for the model should be market-based, and represent developer and firm behavior, in addition to general plans and public land use policy. |
| 5. Model should represent travel as it actually occurs (i.e. mixing modes and purposes, occurring at different times of day, etc.) |
| **VIII. Scenario Testing** |
| 1. Forecasting tools should be able to generate and test multiple scenarios built around key variables and assumptions |
| 2. Forecasting tools should take account of general trends (e.g. e-commerce, telecommuting, etc.) in reasonable ways |

### 2.2 Evaluation of User Needs

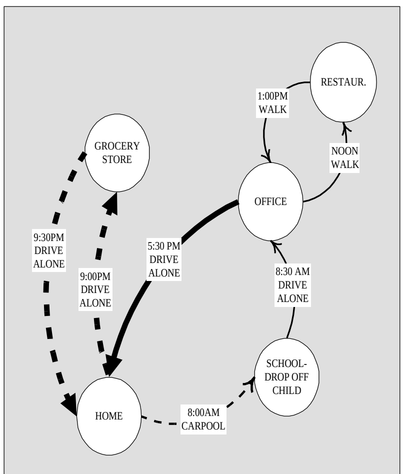
The user needs inventory was used in two ways in the design process. First, the needs themselves were reviewed by the design team to develop necessary ***model elements*** and ***functional requirements*** for the new forecasting tools. Second, the user needs were used as evaluation criteria for the major design options considered.

The current travel demand model used by SACOG is SACMET. SACMET is a good example of an intermediate four-step travel demand model. The model uses fixed land-use and development forecasts. In other words, the land use forecasts do not change with changes in the travel network. This characteristic limits the ability of the current model to deal with policy issues such as “Smart Growth”, which recognize the inter-dependence of land use development and provision of transportation infrastructure. Also, retaining fixed land use forecasts severely limits the ability to evaluate the “secondary effects” of transportation infrastructure (e.g. sprawl, induced travel, etc.). Because many users were interested specifically in these policy issues, the ability to link the land use forecasts reasonably with changes to the transportation infrastructure assumed in the forecasting models was a key functional requirement of the new forecasting tools.

SACMET is a “trip-based” model, which means that the model predicts trips from one zone to another in the model network. If estimated, calibrated and validated properly, this type of model can predict person and vehicle flows on major facilities reasonably. However, there are certain characteristics which limit the ability of trip models like SACMET to provide analysis of key transportation policies. Road pricing is good example of one such policy. When a toll is charged to use a roadway facility, a complex set of behavioral adjustments are made by users, all of which affect the transportation system as a whole. First, persons with different income levels and values of time respond differently to the tolls themselves. Persons with higher income or higher values of time are more likely to pay a toll in order to save time. To model these behavioral responses, the demographic characteristics of the persons making trips need to be tracked. Trip models are practically speaking unable to do this in an efficient or realistic way. For this reason, the ability to tie the demographic characteristics of travelers in the models was identified as a key functional requirement of the new forecasting tools.

Trip models “disintegrate” a person’s travel into independent, isolated trip segments. Figure 1 illustrates a typical worker’s travel over the course of one day, and the disintegration of that travel into trips for the purposes of modeling. Within the model, decisions made about the first trip of the day have no effect on the subsequent trips. For example, the mode of travel of the first trip (from home to drop off a child at school) is by car. It is very unlikely that the second trip (from school to workplace) would be made by any mode but by car, but in a trip model, each trip is treated in isolation, with choices of mode of travel and destination of trip detached from the other travel a person needs to do over the course of the day. Again using the road pricing example, a common behavioral response to peak period pricing would be to alter one’s daily activities to avoid traveling during the peak pricing periods. Because trip models disintegrate travel into independent trip segments, and because the time-of-travel is typically computed using fixed factors on zone-to-zone trips, none of this behavioral response to road pricing can be captured. The ability to capture a pattern of activity and travel over the course of a day at the person level was defined as a functional requirement of the new forecasting tools.

**Figure 1**
**Typical Day's Travel As Represented in Conventional Travel Demand Model**



Typical Day's Travel:
Working Adult, w/kids

| PURPOSE | Vehicle Trips Made | Transit Trips Made | Non-Motorized Trips Made | All Modes |
|---|---|---|---|---|
| Work | 1 | | | 1 |
| Shop | 2 | | | 2 |
| Home-Other | 1 | | | 1 |
| Work-Other | 1 | | 2 | 3 |
| ALL PURPOSES | 5 | | 2 | 7 |
| | | | | |
| | | | | |

Equity of transportation investments refers to the spread of the benefits and costs of investments over various demographic groups in a region. To the extent that the benefits and costs are spread evenly, equity is achieved. Increasingly, the equity of transportation investments is a concern of agencies which fund transportation projects. In fact, new Federal regulations will require some analysis of the equity of investments in regional transportation plans. As with road pricing, the ability to evaluate equity depends on models capable of tracking the demographic characteristics of persons traveling within a region. Because trip models focus on estimating travel flows from one zone to another, without reference to the persons actually making the trips, their ability to evaluate equity is extremely limited. The ability to track the benefits and costs of travel over various demographic groups was defined as a functional requirement of the new forecasting tools.

Table 2 lists the model components required to address the user needs.

**Table 2**
**Model Elements and User Needs**

| Element | Comments |
|---|---|
| ***Land Use Model*** | |
| Base Year Population | **Current Practice:** Track housing unit completions, apply vacancy rates. Tallied by SACOG minor zone. |
| | **To Address User Needs:** More detail on household structure (size, workers, lifecycle, etc.) and location. |
| Base Year Employment | **Current Practice:** Track job locations by SITUS address and SIC code. Tallied by SACOG minor zone. |
| | **To Address User Needs:** More detail on location. Ideally, more detail on employment types. |
| Shifts in Population Demographics Over Time | **Current Practice:** Allocate DOF population growth to minorzone. Rule-based cross-classifcation to persons, workers, income. |
| | **To Address User Needs:** Forecast detailed household characteristics based on known characteristics and trends. More geographic detail needed. |
| Shifts in Size/Structure of Economy Over Time | **Current Practice:** Based on current development trends and land use policy (general plans). Constrained by DOF population growth. |
| | **To Address User Needs:** Tied to changes in labour supply and the ability of the transportation and land-use system to serve the needs of various industries. |
| Labor Market -- Demand and Supply | **Current Practice:** Regional employment growth parallels (and constrained by) regional household growth. |
| | **To Address User Needs:** Changes in employment tied to employment conditions (wages, etc.) and available labor in region. |
| Household Relocation | **Current Practice:** Not addressed. |
| | **To Address User Needs:** Minimally, allocations of new households should be based on household and area characteristics, and on supply/demand by area. Ideally, "move" or "stay" decision for each household based on household characteristics. |
| Firm / Business Relocation | **Current Practice:** Not addressed. |
| | **To Address User Needs:** Minimally, aggregate allocation to zones, with floorspace prices adjusted to clear market. Ideally, "move" or "stay" decision based on firm characteristics. |
| Floorspace Prices | **Current Practice:** Not addressed. |
| | **To Address User Needs:** Equilibrium with floorspace demand by firms and households and area supplies. |
| Development of Floorspace | **Current Practice:** Implied development of acreage based on acres/job rates. |
| | **To Address User Needs:** Simulation of development probability by parcel or grid cell, with consideration of floorspace prices and vacancy. |
| Goods Movement/ Shipment Logistics | **Current Practice:** Simple truck model. |
| | **To Address User Needs:** Simulate shipment of goods at the firm/business level. Take account of industry characteristics. |

| **Table 2**<br>**Model Elements and User Needs** | |
|---|---|
| **Element** | **Comments** |
| *Travel Model* | |
| Auto ownership | **Current Practice:** Cross-sectional auto-ownership model. |
| | **To Address User Needs:** Enhance current model with more detailed household data, linkages to other parts of model. Ideally, include vehicle type in model. |
| Tour/<br>trip generation | **Current Practice:** Trip-based. Limited use of accessibility variables. |
| | **To Address User Needs:** Day pattern model with logsum feedback from lower models. Some accounting of household characteristics. |
| Destination choice | **Current Practice:** Trip-based destination choice, integrated with mode choice model. |
| | **To Address User Needs:** Tour-based destination choice, with intermediate stops. |
| Mode choice | **Current Practice:** Trip-based, with non-motorized modes. |
| | **To Address User Needs:** Tour-based mode choice, with mixed-mode tours. |
| Time of Travel | **Current Practice:** Fixed factors. |
| | **To Address User Needs:** Time choice model, sensitive to household characteristics and travel conditions. |
| Level of spatial detail | **Current Practice:** Zone-level for all. |
| | **To Address User Needs:** Some block-face level of detail needed (especially for non-motorized travel). |
| Network Simulation/Route Choice | **Current Practice:** Multi-class equilibrium for highway; shortest path AON for transit. Non-motorized not assigned. |
| | **To Address User Needs:** More classes needed, especially for transit. Ability to assign non-motorized trips. Ideally, network micro-simulation. |
| Application Framework | **Current Practice:** Zone-based enumeration by OD, mode, purpose, time of day. |
| | **To Address User Needs:** Person-based and firm based enumeration, to track demographic characteristics with travel. |
| External and Special Trips | **Current Practice:** Fixed matrices. |
| | **To Address User Needs:** Airport access model needed. Inter-regional travel keyed to growth in neighboring regions. |

### 2.3 Forecasting Options Considered

Using the model elements and functional requirements, three generic options for forecasting were defined. Each option included all of the model elements, and advanced the current practice toward the minimum functional requirements needed to meet the user needs. The options are as follows:

- **New Standards Option**. This option includes a Day Activity Pattern Module, implemented through micro-simulation of travel choices and a more traditional, zone-based trip assignment, for the travel model. The land use model would utilize an aggregate or zone-based approach, but would include a direct link to the travel model, and would be dynamic (i.e. stepping through time). The advantages of this option are that it relies almost wholly on existing software, requires minimal new data collection, and could be implemented in the next three years.
- **Enhanced Option.** This option includes a more detailed Day Activity Pattern Module. The land use model would include micro-simulation of household location decisions, and land development activity. These improvements would allow for much more dynamic modeling of land use and travel interactions. This option would require some new software development and data collection, and would also require additional time to implement.
- **Advanced Option.** This option includes a fully integrated micro-simulation of all significant travel and land use activities. This option would provide the most realistic representation of both travel and land use systems, and the most flexibility in meeting user needs. This option would require significant new software development, data collection and additional research, and would require at least five years to implement.

A more detailed description of the options is provided in the next chapter of the design document. A tabular description of the options is provided in Appendix A.

These options were presented at Symposium I in April 2001. The options were evaluated in terms of there potential to meet user needs and the resources likely to be required for implementation. In terms of user needs, each of the options would provide significant advancement in meeting the needs.

The New Standards option provides much greater capability for addressing key policy issues facing the region than the current tools. This capability is based on the integration of the land use and travel modeling, the more detailed and realistic representation of travel behavior, and on the application framework, which better reflects the way the region develops and the role of transportation infrastructure in that development. The Enhanced and Advanced options provide greater capability still, largely by shifting the land use/economic forecasting tools from an aggregate model framework to simulation.

All of the options provide greater behavior accuracy than the current tools. Each option is based on a simulation of travel behavior, which provides a much greater level of detail and better reflects actual choices people make in there daily activities and travel. While the New Standards option provides a much more accurate representation of the regional economy and land development, it is based on an aggregate, zone-level, input/output economic model, and is limited in its ability to represent some processes related to employer, firm, and land developer behavior. The Enhanced and Advanced options significantly improve the accuracy of these parts of the models.

On several categories of user needs, the options provide greater flexibility and forecasting capability, but at some cost. In terms of scenario testing, each option provides an array of policy variables, input data variables, and model output for testing policy scenarios. However, because of the application framework, which steps through time rather than leaping to an "end-state" horizon year, the process of developing a forecast would take more time and effort, especially initially when the tools are new to both SACOG staff and to local agency staff.

A more detailed and comprehensive presentation of the evaluation of the options against the user needs is presented in tabular form in Appendix B.

In terms of resources, likely to be required for each of the options, each would require a significant development effort, additional SACOG staff for maintaining and using the input data and running the models, and training for staff in local agencies which would use some or all parts of the models. Not surprisingly, the New Standards option would require the least in terms of new resources, and the Advanced option, the most.

- The New Standards option would require some additional software, but most of the key software required has already been developed by others and would only require acquisition and customization for use in Sacramento. The most critical new data requirement would be a survey of existing floorspace to develop the economic and land use development models. Staffing is difficult to estimate. Development costs are likely to be in the less than two million dollar range, and could be developed incrementally over the next three years. Additional time may be needed for testing and training.
- The Enhanced options would require some additional software, but as with the New Standards option, most of the software has been developed and used elsewhere. The amount of work required to customize the software for Sacramento would be greater than that for the New Standards option. In addition to the floorspace data, more detailed commodity price data would be needed, as well as a household panel survey (i.e. a survey over time) to develop some of the models of household relocation and change. Staffing level would be similar to the New Standards, and development costs would be higher. Model development time would probably be five years.

- The Advance option would require development of some new software, and significant new data beyond that required for the Enhanced option. SACOG staffing would not be significantly greater than for the New Standards or Enhanced options, but the development cost would be significantly greater. Also, due to the fact that this option would include some pioneering elements, the development costs and time would be somewhat uncertain.

A more detailed tabular presentation of the resources required for each option is provided in the Appendix C.

### 2.4 Conclusion

Based on the information and evaluation presented above, the recommendation of the design team was to proceed with detailed design work on the New Standards option. This recommendation was based on the significant improvement in forecasting capability that this option would provide, the relatively low risk in development, and the likelihood that the main development work could be accomplished over the next three years. The following chapters of this report provide the detailed design based on this option. The design deviates from the option in some regards, due to issues and opportunities which came up during the design process, but in the main, the design closely follows the option as defined in the second phase of the design process.

# 3 Brief Description of the Options

## 3.1 New Standards Model

The basic model is an Origin-Destination Matrix traffic assignment model, a tour based transportation demand model with microsimulation of individual travel by mode and time-of-day, an aggregate Spatial IO Module for allocating activity to locations, a developer model, and two procedures for synthesizing micro-level data from aggregate data.

Three levels of spatial detail are used. The land use allocation procedures work with a few hundred zones (Land Analysis Zones). The results of the land use model are then allocated to grid cells, to provide more detailed output regarding environmental impact and to allow more detailed input regarding developability, land use regulations and micro-level effects on location. The transport model uses the zones (LAZs), but could use links (or "link tributary areas") when more spatial detail is required. The quantities associated with each link would be based on an aggregation of the grid cell values and/or a disaggregation of the zonal values.

The land use model simulates the location of activities, households and firms. The amount of activity (population, employment and households) in each zone is simulated using an aggregate economic equilibrium framework in each year. Households are divided into several categories based on income and, perhaps, household size and age of householder. Employment is divided into categories based on industry. Quantities of these categories are allocated to zones in each year to fit into the available floorspace, considering aggregate travel conditions ("skims") from the previous year's transportation simulation.

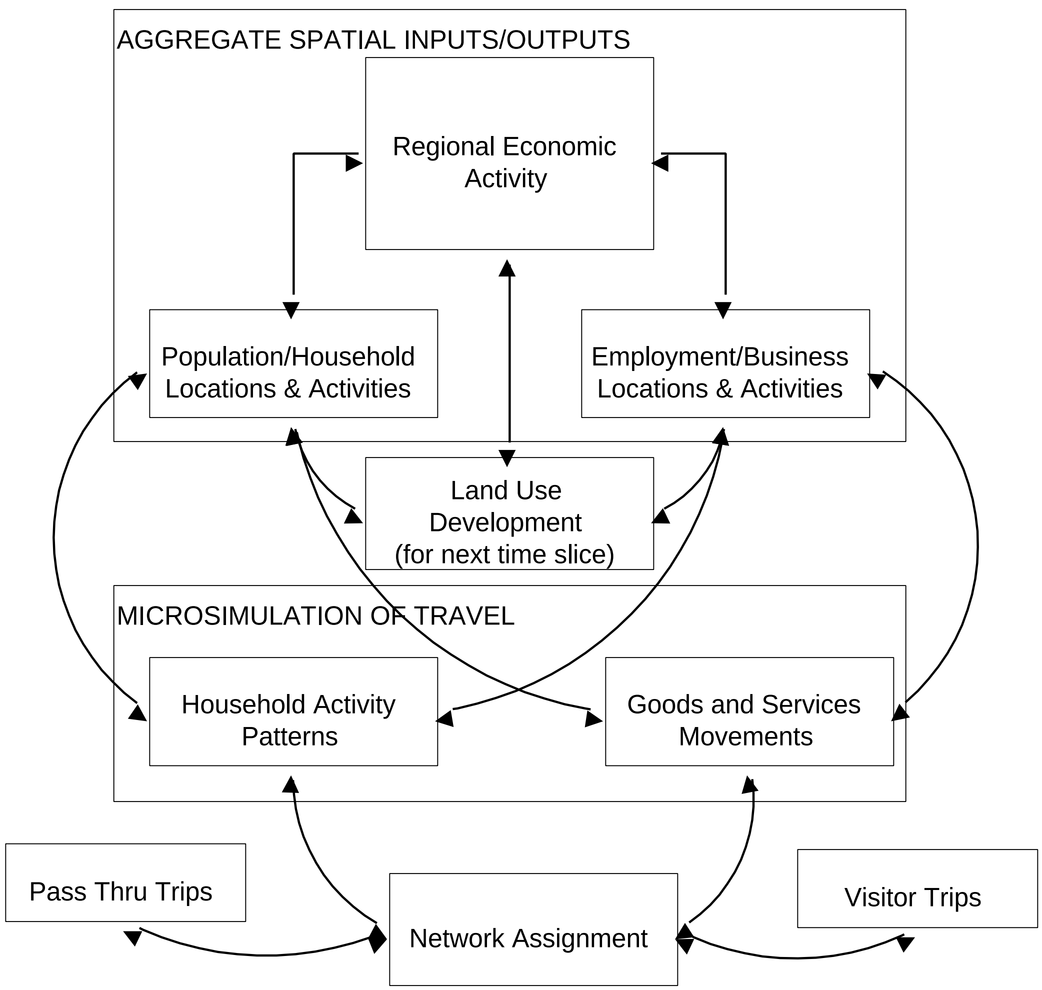
Between years, the amount of floorspace in each zone is updated based on a simulation of developer behavior. This simulation iterates through the grid cells, to take into account details of land properties and general plan inputs.

The aggregate quantities of household categories are used as inputs to an Iterative Proportional Fitting procedure (IPF), which generates households for the transportation model. Households from the census Public Use Micro Sample (PUMS) are sampled in each future year, so that various aggregate totals match the quantities forecast in the aggregate land use model. The aggregate quantities of employment by categories are used as attractors in the destination choice models.

Work and school location TAZ's for each household member are selected based on the economic "flows" of labor and education from the aggregate equilibrium model, and the number of vehicles in the household is predicted in light of the residential, work and school locations.

Travel for each individual in each household is simulated as the choice of a full day pattern of activities and trips. The pattern of trips is not directly influenced by the simulated choices of other household members. Household characteristics influence predicted pattern choice, as do measures of accessibility from the current time period (log-sum measures and other accessibility measures based on aggregate travel characteristics (skims) and land use measures).

**Figure 2**
**New Standards Model Framework**




After the day pattern is predicted, the departure and return time periods for each tour are selected based on a logit model of time-of-day combinations. Accessibility measures and/or logsums from lower levels can influence time-of-day choice.

Mode choice for work tours is based on a logit model of travel conditions to work in the selected time period. For other tours, mode choice is a simultaneous choice with the primary tour destination.

Intermediate stop locations are selected using a separate allocation process, with intermediate stop opportunities not feeding back to the primary destination and mode choice.

Application of these models is done using microsimulation with the entire sample of households (or a weighted subsample if there is a need to reduce run time). The simulated activity schedule includes a list of all trips for each person that can be aggregated in a variety of ways for policy analysis. Within the model system, they are aggregated into OD matrices, segmenting by purpose, mode, time-of-day, and perhaps key segmentation variables such as income. Traffic assignment is done with a standard capacity restrained iterative assignment algorithm, with several classes of traveler.

For goods and services transport, the quantities of industry in each zone is divided into businesses using a simple distribution of business sizes by industry. Trip generation rates are used to predict for-hire shipments, own-account shipments and employee tours for each business. Mode split takes into account accessibility by vehicle type. The resulting vehicle trips are loaded onto the network along with the person trips.

Examples of travel models applied in this way are models done for Portland METRO and San Francisco County.

### 3.2 Enhanced Model

The enhanced model has a more dynamic representation of the longer-term changes in the region. Households are not resynthesized in each time period from the aggregate quantities, but rather households are written out to a database at the end of each year. This population of households is read in at the beginning of the next year's simulation. The long-term choices of households are simulated using transitions models. These include births and deaths, people leaving one household to form (or join) another, choice to move (change residence), changes in work status, and transitions in household auto ownership.

Households can be categorized arbitrarily in various ways (by such variables as income potential, occupation, race, student status, lifecycle and ages, and preselected sensitivities to mode characteristics) so that longer term transitions in location and auto ownership can be completely consistent with the unique aspects of each household. In the basic model tour and trip-making can be influenced by these aspects of household behavior; in the enhanced model the location of households will be consistent with this tour and trip-making behavior, so that, for instance:

- Student households will tend to locate near education facilities,

- Households with skilled labor occupations will tend to locate near manufacturing and related jobs, and
- Environmental justice issues regarding race and income can be analyzed spatially.

The choice of job location is much more explicit in this enhanced model. Rather than allocating "flows" of labor between zones, household's choice of job is represented as a search process for unemployed people. The search process identifies a set of employment options for consideration. The full travel model is then run for each of these people in their hypothetical jobs, which establishes the full mode, vehicle and time-of-day possibilities for these jobs. These travel conditions by mode and time-of-day influence the attractiveness of each job. A nested logit model is used to simulate the choice from among these options and the additional alternative of remaining unemployed.

The set of available job options is updated each year based on the aggregate employment values in the Spatial IO Module. Each job option is assigned to a particular grid cell based on the land development types in each grid cell. Labor prices by labor category and zone are adjusted dynamically based on the percentage of job options chosen, so that both the demand for labor (i.e. number of offers) and the supply of labor (i.e. number of offers accepted) can respond appropriately.

The dynamic nature of this household transition model makes it necessary to simulate residential floorspace price changes dynamically as well, so that residential rent changes dynamically and residential vacancy rates are specifically represented.

On the transport side, a micro-simulation framework is used to stochastically predict a single day's sequence of tours and trips for each person in the synthetic population. The models themselves contain somewhat more detail than those in the basic version, including (a) more different activity purposes distinguished, (b) more logsum feedbacks between various models, (c) more explicit and integrated treatment of intermediate stops on tours, (d) more spatial detail for location choice and access to transit, and (e) explicit choices between sub-periods within the peak periods. The output level of detail from this implementation would support network micro-simulation, as well as aggregating up for use in more typical traffic assignment.

In the transport model, a "micro-assignment" procedure can also be explored, so that each trip can be loaded from an exact origin or destination, and can respect the unique characteristics and sensitivities of the person making the trip. A micro-assignment assigns each trip to the network individually, from an exact origin to an exact destination, using the most attractive path for a particular individual. Traffic assignment thus works at the link or blockface level – from an assignment perspective the number of potential origins and destinations is equal to the number of links in the network. The Micro-assignment results will not be integrated with the land-use model or with any log-sum feedback – it will be a post processor submodel to provide more accurate link volumes and emissions predictions in certain future years for which evaluation is to be performed.

Individual shipments of inter-industry goods and services are sampled from distributions to match aggregate total flows from the Spatial IO Module. Truck movements are simulated first independent of time of day (considering only whether the truck will be in the area on the model day) and then a traveling salesman algorithm is used to program the stops and times-of-day for trucks. Total shipping costs from this are fed back into the Spatial IO Module in the next time period.

The enhanced model can also be improved to provide better forecasts of emissions effects. A major improvement in this area would be to add models of vehicle type choice and vehicle usage. In addition to predicting how many vehicles each household owns, the system would predict the types of vehicles (compact, SUV, etc.), as well as which vehicle is used for each auto trip.

### 3.3 Advanced Model

The advanced model takes the concepts of the household demographic microsimulation and applies it to firms and other institutions. Thus, the decision of firms to relocate, open or close business establishments in particular locations will be microsimulated. Firms' labor purchases and goods and services supply are also dynamically simulated, giving a dynamic representation of the prices and quantities of labor and other goods and services. Thus all prices and markets are simulated as being in dynamic disequilibria, with prices changes occurring because of shortages or surpluses or changes in inventory.

The household and population model can be enhanced with specific models of the changes in income and occupation. "Job offers" can be based on the characteristics of specific synthetic firms, providing a more appropriate matching between people and their jobs. Household location choice models (in particular, the choice of whether to move) can be linked directly with the simulation of these other household transitions.

Household and firm location models can make use of "search" algorithms, to avoid the dependency on the zonal representation. Search algorithms can consider exact locations directly, instead of considering exact locations as a secondary decision to the zone location decision.

The developer model can be enhanced, so that land assembly issues are considered. The behavioural unit in the developer model will be one "Developer" instead of one "Unit of Land".

Goods and services movement is as in the Enhanced Model.

For personal transport, there are explicit models of household members traveling together, both in joint activity participation, and also for providing rides to and from activities, and of allocation of household vehicles to household members. Car ownership is now predicted using dynamic transactions models of vehicle ownership and type choice. Time-of-day choice models will use duration models to work on a more continuous level rather than using heuristically defined periods. The mode choice model and networks will include a specific representation of parking locations, prices, supply and demand, simulating parking usage across the day.

Other improvements which might be considered for an advanced version include:

- Transport supply – headways, signal timing, parking prices, parking supply
- Parking space allocation over the day
- Weekend vs. Weekday and Multi-day trips
- A detailed model of emissions
- Traffic network microsimulation as a post-processing step
- Traffic network microsimulation results fed back into trip making and land-use decisions

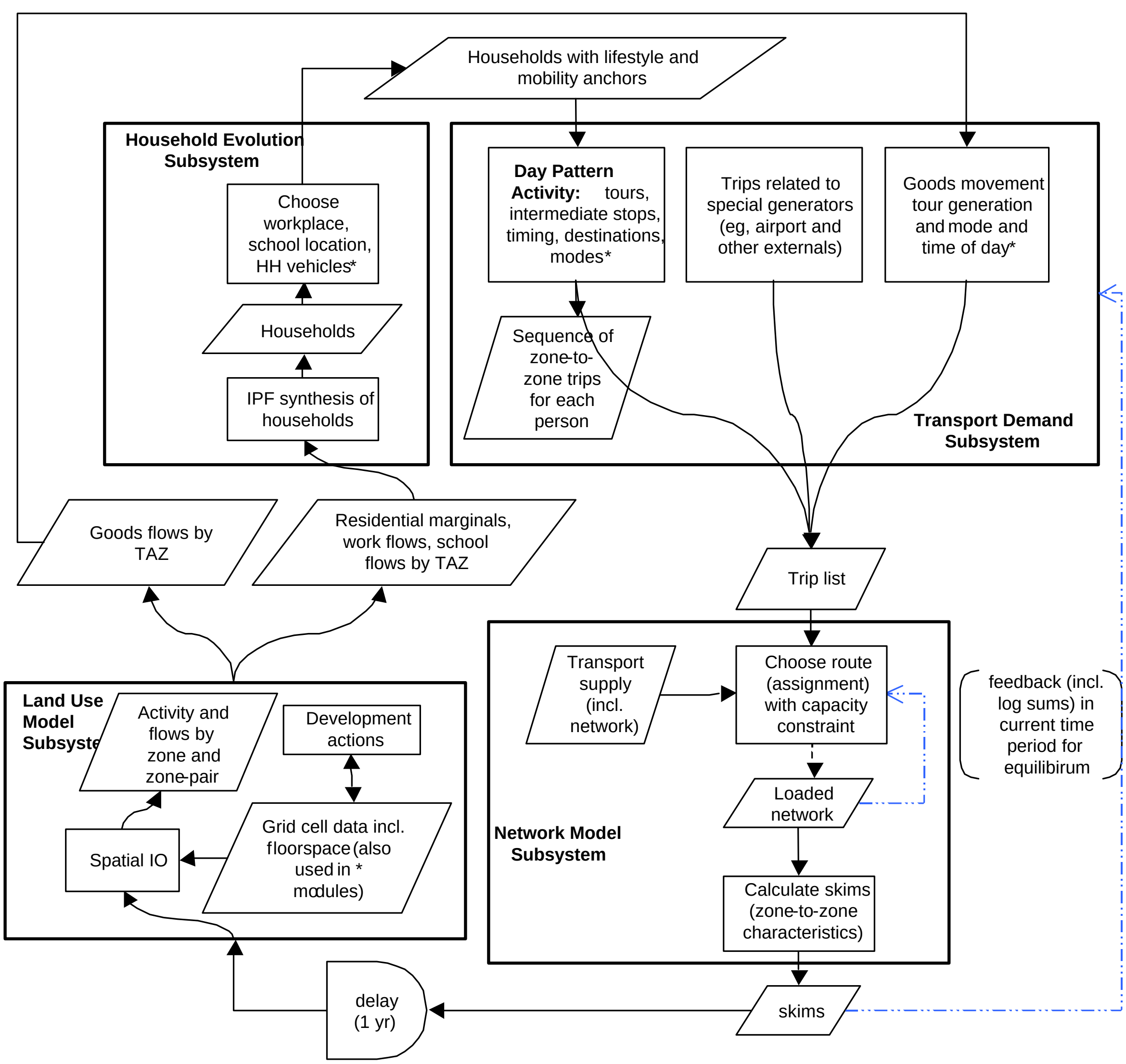
# 4 New Standards Model

This section provides a more detailed description of the model elements on the New Standards Model.

## 4.1 General Design Issues

For purposes of understanding and model development, it is helpful to view the model elements combined in subsystems. Figure 3 groups the elements into four subsystems, hiding some of the elements within those subsystems.

**Figure 3**
**New Standards Model Element Linkages**



The land-use model elements described below (Section 4.2) in the Land Use Model Subsystem. They are the spatial IO process that determines the interaction between different types of industry and population and the flow of commodities, and the developer model that predicts realistic changes in development type for each grid cell of land.

Most of the travel model elements described below (Section 4.3) are in the Transport Demand Subsystem. Within this subsystem is the box labeled ‘Choose activity schedule’, which includes all aspects of the generation, destination choice, mode choice and time-of-day elements described in separate sections below, except for work and school location choice. The other two model boxes within the Transport Demand Subsystem each have their own description section below. These three components can be developed separately.

The Household Evolution Subsystem includes the work and school location models, and the auto ownership models, described above, as well as the generation of the synthetic population. If the data precautions described below in the description of the work and school location models are adhered to, then this subsystem can be partially developed separately from the Transport Demand Subsystem. However, its development cannot be finalized until the activity schedule is completed, since it requires accessibility measures.

The Network Model Subsystem has its own descriptive section below. It can be developed separately.

#### *4.1.1 Calibration and Equilibration*

A "Bayesian sequential estimation procedure" will be followed to calibrate the models and ensure that they work together accurately. The submodels in the figures and individual relationships within the submodels will be calibrated separately from the overall modeling system. Statistical methods will be used as much as possible, where hypothesis are made as to the size and type of error and a likelihood function will be maximized, to establish parameter values that maximize the probability that the submodel would predict the behavior observed in various surveys and data collection exercises.

The entire model must also be calibrated. The model will be run and the model outputs compared with a selection of weighted observed data to provide a goodness-of-fit measure. Certain parameters will be adjusted, and the model re-run to determine the affect of changes in various parameters on the goodness-of-fit. This will provide information to a search procedure, that will search for values for a set of highest level parameters.

When the search has converged on a set of parameters the remaining lack-of-fit will be explored interactively using a weight sensitivity matrix. This may lead to small changes in the details of the model design and specification, so that the model can more accurately represent the Sacramento situation.

An important issue is that the model requires travel conditions ("skims") from a previous time period, yet there is no way to measure such travel conditions directly. A process we call "equilibration" will be used, where the situation in Sacramento is assumed to be relatively stable in the base year, and the model itself will be used to establish travel conditions, turning off the time delay in response to travel conditions and running the model repeatedly. To ensure that this process is accurate, observed vehicle counts and passenger counts will be used as a set of targets.

#### *4.1.2 System Architecture Design*

The entire system will be split into four parts for computing:

- A GIS platform and databases in ArcView or similar software, for viewing spatial outputs and manipulating geospatial inputs,
- A network model platform and databases, in TP+ or similar software, for performing equilibrium route choice and mode choice, and for viewing network outputs and manipulating network inputs,
- A suite of land use sub-models, as a suite of executable programs with a shell interface for running them in a consistent and traceable manner, and
- A suite of travel sub-models, implemented in a similar manner as the land use models, and possibly even under the same shell interface.

A set of conversion routines will be necessary for converting data to and from the formats required by the network model platform and the GIS platform. The various conversion routines will each be implemented within one of the four parts.

Some additional programs and utilities may also be required for specific tasks:

- Programs for pre-processing Census input and other common types of socio-economic input data files.
- Programs for post-processing the output for certain types of analysis such as equity analysis. These could be, for example, scripts for Oracle or another relational database program, which then writes out files that can be viewed spatially in a GIS.

### 4.2 Land Use Model Elements

This section describes the modules and procedures for simulating the arrangement of activity in space. It is useful to think of this as two separate processes: the process through which developers provide floorspace in the region, and the process through which activities locate within that floorspace and interact with each other.

In the New Standards model, there are three primary software modules: the Developer Module which models the development of floorspace in the grid-cells of land, the Spatial IO

Module which establishes the quantities of activities in each zone within the constraints of available floorspace, and the Population Synthesizer which takes the aggregate quantities from the Spatial IO Module and synthesizes a disaggregate population of households for travel microsimulation. The Developer Module and the Spatial IO Module represent the two behavioral processes; while the population synthesizer is simply a link between the aggregate representation of economic activity and the disaggregate representation of travel.

The elements are designed with a view to replacement: the Enhanced and Advanced versions of the model replace certain land use elements with more sophisticated and behaviorally realistic modules. The element categories below refer to behavioral processes and modeling tasks, not to the three modules.

### *4.2.1 Base Year Population*

#### *4.2.1.1 Approach, Background, Theory and Process*

The base year population is established by two modules, the Spatial IO Module and the Population Synthesizer.

The quantity of population in each zone by category in the base year is established by calibrating the Spatial IO Module. One set of targets for this calibration is the observed population by household category by zone from the Census Bureau. This procedure is described in more detail for employment location below. It should be possible to closely match the Census Bureau targets, although it may not be desirable to exactly match them.

The Population Synthesizer will take these quantities by category, and use the well-established Iterative Proportional Fitting (IPF) procedure to sample individual household records provided by the Census Bureau. The probability of each household record being sampled is based on the quantity of population in each zone by category (from the Spatial IO Module), and other average characteristics of the census tract (which are not represented in the Spatial IO Module.) Thus the population in the zone at the end of the procedure is made up of detailed household records, with the total population, total number of households, income distribution, household size distribution, etc. matching either the values reported from the census or the values from the Spatial IO Module calibrated to the census.

The households are generated for each zone in the population synthesizer. Exact grid cell home locations are assigned to each household by a two stage procedure – a logit model of housing type choice with size terms based on the quantity of each housing type in the zone, and a simple random allocation to grid cells containing the chosen housing type. The size terms in the dwelling type choice need to be updated after each assignment of a household to a grid cell, so that when the supply of one type of dwelling is exhausted remaining households will choose from among the remaining types.

The Spatial IO Module establishes the economic interactions of households in aggregate: primarily the supply of labor, the demand for residential floorspace, and the demand for education, retail goods and personal services. The aggregate quantities of residential floorspace consumption and the aggregate zone-pair flows of labor and goods and services are an input to the Household Evolution Module. In the initial development, the floorspace quantities will be used when assigning homes locations to individual households; but the travel model (below) is responsible for determining all destinations, including workplaces, school locations and shopping locations.

#### *4.2.1.2 Inputs*

The aggregate marginal distributions by census tract are from the Census Bureau's Summary Tape Files (STF). The individual household records are from the Census Bureau's PUMS. The type and quantity of residential floorspace in each grid cell comes from the land development module. The population by category by zone comes from the Spatial IO Module. The quantities of floorspace consumed, and the flows of labor, education, retail goods and personal services also come from the Spatial IO Module.

#### *4.2.1.3 Outputs*

A listing of household records, with the full information from the Census Public Use Microsample, and a detailed grid cell and housing type for each household's home location.

#### *4.2.1.4 Data Requirements - Estimation*

Household sample with dwelling type and zone. An indication of the number of dwellings of each type in each zone. Household expenditure functions and floorspace consumption functions for the Spatial IO Module. Household mobility/dwelling choice data is needed. A retrospective housing location/lifestyle-change survey could be an efficient use of data collection resources.

#### *4.2.1.5 Data Requirements - Running*

Fixed aggregate zonal characteristics. Census PUMS.

#### *4.2.1.6 Development Effort, Resources and Software*

The IPF procedure is fairly standard software. The choice of dwelling type requires a procedure to calculate size terms from the land development model and a procedure to update those size terms as households are assigned to grid cells. The choice of grid cell requires grouping grid cells, then selecting from a group, then updating the group. The Spatial IO Module is considered below, under employment location.

### *4.2.2 Base Year Employment*

#### *4.2.2.1 Approach, Background, Theory and Process*

Employment is modeled with an aggregate model of categories of employment. A Spatial IO Module is used (really a spatial "social accounting matrix", since households are included), with each category of activity consuming and producing 'commodities', which are categories of goods and services. The movement of commodities is the economic basis of the travel in the modeling system, and the travel conditions (distance, cost and time by mode and time-of-day) for the movement of commodities is how the transportation system influences the attractiveness of zones for different activity types.

For each zone, there are two logit allocation models for each commodity. The first is an allocation of the quantities purchased among the various 'exchanges' where they are sold by others. The second is an allocation of the quantities sold among the various 'exchanges' where they are bought by others. The utility of each alternative in these models is influenced by the price at the 'exchange', and the characteristics of transporting the commodity to or from the exchange by different modes and at different times-of-day. The composite utility calculations from these two logit models for each commodity are the transportation related input into the location choice model for categories of firms, industries and households. These are called the "Buying Utility" for the commodity in the zone, and the "Selling Utility" for the commodity in the zone.

Exchanges are location-specific markets for a commodity, where sellers sell commodities to buyers. Prices are established in exchanges by iteration so that the quantity bought equals the quantity sold – thus the spatial allocation procedure assumes a short-run market equilibrium in commodities. For simplicity and realism, commodities are assigned to be either purchased from the exchange in the zone they are consumed (e.g. for labor, where the labor is exchanged, and the price set, in the employment zone) or purchased in the exchange in the zone they are produced (e.g. for retail goods, where the goods are exchanged, and the price is set, at the retail establishment). Thus for each commodity in each zone, one of the logit allocation models (either the buying or the selling) consists of only one alternative.

Imports and exports occur at exchanges. The commodity import quantity and export quantity are given by functions, so that as prices rise more imports are attracted and as prices fall more exports are produced. The import and export functions tie the Sacramento economy to the economy of the rest of the world.

Different household types are considered as a category of activity, and labor provided by various occupation categories are considered commodities. Floorspace types are also considered commodities in that they are consumed by categories of activities, but the amount of floorspace available for consumption in each zone is fixed in any one time period (but adjusted between time periods by a separate land development module.) Floorspace must obviously be purchased from the exchange in the zone in which it is consumed.

The base year employment in each zone should match, at least approximately, aggregate observed values. This is accomplished by using observed values of employment by zones as 'targets' in an automatic calibration procedure, which adjusts alternative specific constants for each activity category in each zone. If the data describing the amount of floorspace of each type in each zone is consistent with the data describing the amount of employment of each type in each zone (and consistent with the representation of the amount of floorspace consumed per employee by industry) then the calibration procedure will be able to match the observed employment patterns exactly. An exact match with spatial employment data is not necessarily desirable, however, as it may mean a large mismatch with other target data, such as commodity price data. There will be certain data inconsistencies that need to be accounted for, and it may be that in some cases the best way to account for inconsistencies is to put less faith in the employment distribution data.

Floorspace is considered a commodity in this process, but only the demand for floorspace is represented. The supply of floorspace is simulated incrementally in the land development module described below.

The Spatial IO Module is an appropriate tool for understanding the relationship between the SACOG area and other nearby areas, such as the Bay Area. Thus the zones used by the Spatial IO Module will include a "collar" of zones outside the SACOG area.

#### *4.2.2.2 Inputs*

Social accounting matrix, in the form of a “Make” table and a “Use” table, with elasticity information, which incorporates household expenditure data, and floorspace use functions. Distribution of employment by zone from ES202 covered employment data. Imports and Exports of commodities.

#### *4.2.2.3 Outputs*

Amount of activity by type by zone. Buying utilities and selling utilities by commodity by zone. Overall benefit measures by activity type. Commodity prices by zone. Commodity flows by zone pair.

#### *4.2.2.4 Data Requirements - Estimation*

Input-output table as a “Make” table and a “Use” table, available for purchase from IMPLAN. Information or assumptions on elasticity of technical coefficients in IO table. Floorspace consumption rates. Labor force participation rates by household type and by occupation. Trip length distributions by commodity.

#### *4.2.2.5 Data Requirements - Running*

Make and use table, including floorspace and labor. Import and export functions.

#### *4.2.2.6 Development Effort, Resources and Software*

The generalized spatial IO using commodities and buying and selling utilities is available as open source software. The calibration procedure will require some development, but can build off of the software written by John Abraham for his PhD dissertation.

### 4.2.3 Shifts in Population Demographics

#### *4.2.3.1 Approach, Background, Theory and Process*

In the New Standards model, the Spatial IO Module described above establishes the quantities of households by zone and category in future years (see below under "Home Relocation"). The Spatial IO Module only cross-classifies households into a few categories, by income and by one or two other variables. The remaining aspects of demographic change need to be established by the population synthesizer and Household Evolution Module.

#### *4.2.3.2 Inputs*

Nation or state demographic projections

#### *4.2.3.3 Outputs*

Demographic projections by household category, for Spatial IO Module household categories, by zone.

### 4.2.4 Shifts in Size/Structure of the Economy

#### *4.2.4.1 Approach, Background, Theory and Process*

The changes in the economy are calculated in the Spatial IO Module. The Spatial IO Module responds to changes in the region-wide economic make up. In general, the elasticity of the make and use tables will allow the IO relationships to evolve without further input. It should be possible, however, to adjust the parameters of these relationships in each year.

#### *4.2.4.2 Inputs*

Quantity of each industrial category in each time period. Import functions and export functions by commodity by exchange. Any changes in production function or consumption function by industry. In general, there are two options for generating these forecasts. The California Center for the Continuing Study of the California Economy is one example of an independent research institute which provides long-range, county-level forecasts of economic growth by sector. These or similar forecasts could be used to estimate sectoral growth rates which could be applied to base year data. A second option is to generate forecasts to test locally-determined growth scenarios.

*4.2.4.3 Outputs*

The Spatial IO Module is run at each time period, so the data types output in any future time period is the same as in a calibration year time period: Amount of activity by type by zone. Buying utilities and selling utilities by commodity by zone. Overall benefit measures by activity type. Commodity prices by zone. Commodity flows by zone pair.

*4.2.4.4 Data Requirements - Estimation*

Need to establish: elasticity of technical coefficients, import-export functions

### 4.2.5 Labor Market Demand and Supply

*4.2.5.1 Approach, Background, Theory and Process*

Labor is modeled as a commodity in the Spatial IO Module. Thus, it is modeled as being in short-run equilibrium during any one-time period, with the price (i.e. average wage) adjusted to ensure demand matches supply. The production of labor categories by household categories is elastic with respect to price, so that households increase the supply of a type of labor as the price increases. The consumption of labor by categories of industry is also elastic.

Thus, there is no direct model of labor shortage or of unemployment, or of the ease or difficulty of finding a job or finding an employee, or of the time it takes for labor markets to respond to changes. In reality, average wage may not vary much from time to time and from place to place, but it may be easier to find jobs or employees at different places, and it different times. In the model, average wage will need to vary more as a surrogate for variation in the ease or difficulty of finding jobs or employees.

The travel portion of the model determines workplace and school location destination choice in the microsimulation of individual travel. The labor market model, on the other hand, is not a microsimulation model. In the base year, both models can be constrained to known aggregate employment totals during calibration. In the future years, however, the two models need not be constrained to each other. To conceptualize this future time-period difference between the Spatial IO Module and the travel destination model, the Spatial IO Module works in terms of "labor", while the transportation destination choice model works in terms of "jobs". The amount of labor produced by each job is fixed in the base year, but is allowed to change zone-by-zone in future years in response to changes in the zonal price of labor. A behavioral interpretation of this is that employers can coax more labor out of each employee by paying them a higher salary. Since the destination choice model uses salary as an attractor variable the two cannot diverge indefinitely.

*4.2.5.2 Inputs*

Functions for labor production by household categories, functions for labor consumption by industrial categories.

*4.2.5.3 Outputs*

Labor flows by zone pair, labor prices by exchange, for each labor category.

*4.2.5.4 Data Requirements - Estimation*

Need to establish: elasticity of technical coefficients, import- export functions. Labor prices and any other data on the ease or difficulty of finding work or employees.

### 4.2.6 Home Relocation

*4.2.6.1 Approach, Background, Theory and Process*

Quantities of household categories are allocated to each zone in each time period by the Spatial IO Module. The spatial pattern will change primarily because:

- the buying utilities and selling utilities for various commodities will change as the transportation system changes, affecting the accessibility for households
- the development model will change the spatial arrangement of suitable floorspace

To avoid large scale shifts between time periods, "inertia terms" will be included, which are proportional to the quantity of activity in the zone in the previous time period. The relative influence of the inertia terms can be used to calibrate population and employment shifts to time series data.

Shifts in primary demographics, such as age distribution and household size, will be an exogenous input.

The quantities of household categories allocated by the Spatial IO Module will be used to feed the population synthesis procedure, which will recreate individual households to match to total quantities.

*4.2.6.2 Inputs*

Inertia terms, calculated from the log of the previous distribution. Make and use tables for all industry and household categories, including floorspace consumption. Census PUMS. Zone by zone demographic variables from the cross-classification model.

*4.2.6.3 Outputs*

List of households for each zone.

*4.2.6.4 Data Requirements - Estimation*

Need to establish: inertia terms, based on historical time-series data (1990 to 2000 census.) Also, there is some potential to use expert opinion surveys.

### *4.2.7 Firm / Establishment Relocation*

*4.2.7.1 Approach, Background, Theory and Process*

Quantities of industrial activity are allocated to each zone in each time period by the Spatial IO Module. The spatial pattern will change primarily because:

- the buying utilities and selling utilities for various commodities will change as the transportation system changes, affecting the accessibility for industry
- the development model will change the spatial arrangement of suitable floorspace

To avoid large scale shifts between time periods, "inertia terms" will be included, which are proportional to the quantity of activity in the zone in the previous time period. The relative influence of the inertia terms can be used to calibrate population and employment shifts to time series data.

*4.2.7.2 Inputs*

Inertia terms, calculated from the log of the previous distribution. Make and use tables for all industry and household categories, including floorspace consumption.

*4.2.7.3 Outputs*

Quantity of industrial activity in each zone (e.g. employees by type by zone).

*4.2.7.4 Data Requirements - Estimation*

Inertia terms can be established from time series data on distributions of employment and population. If the new census data is available the model can be run from 1990 to 2000 and inertia terms adjusted to achieve a best fit between the observed 2000 distributions and the modeled 2000 distributions. Without new census data,

### *4.2.8 Floorspace Prices*

*4.2.8.1 Approach, Background, Theory and Process*

Floorspace is modeled as an aggregate quantity of space, not as individual units available to rent. There is no representation of floorspace "vacancy" in the New Standards model. All floorspace is consumed in each zone, with prices adjusted so that demand equals the supply that is fixed in any one time period.

Floorspace prices are thus critical to the short-run equilibrium treatment of floorspace. In reality, developers and landlords respond to vacancy rates, watching especially for any change in the patterns of tenants moving in and moving out. They then adjust their prices in a dynamic pattern, approximating but probably never achieving price equilibrium. In the equilibrium aggregate allocation treatment in the New Standards model there is no representation of vacancy rates, and no representation of dis-equilibrium. Thus, floorspace prices act as a surrogate for some other measures, and prices in the model need to have more variation between time and place than actual prices.

#### *4.2.8.2 Inputs*

Quantities of floorspace by type by zone from the developer module

#### *4.2.8.3 Outputs*

Price of floorspace by type by zone from the developer module

#### *4.2.8.4 Data Requirements - Estimation*

Some indication of demand elasticity for floorspace, and trade-offs among accessibility (buying and selling utility in the Spatial IO Module), quantity and price. A Stated Preference Survey may be appropriate.

### ***4.2.9 Development of Floorspace***

#### *4.2.9.1 Approach, Background, Theory and Process*

The Land Development Module is where the land use in the model is most sensitive to site-specific considerations, such as detailed zoning regulations, frontage, construction cost concerns (e.g. slopes) and environmental regulations. The Land Development Module also considers the age of buildings, so that the model can properly represent the tendency to redevelop or renovate in older neighborhoods. The Land Development Module provides the spatial detail for allocating households' home locations and industry locations within a TAZ, for use by the travel models.

The land in the region is divided into "grid cells". Zoning regulations, develop-ability, maps representing the age of dwellings and the type of development, environmental regulations, environmental impact, etc. can all be overlayed on top of the grid system, so that each grid cell has information regarding each of these dimensions.

A logit model of alternative development decisions needs to be established. The model will be two conditional choice models. The first is the choice of whether to demolish the current space, add to and renovate the existing space, leave the current space as is, or to redevelop the cell as a different type of space. The first model is conditional upon the current space type, and is influenced by the grid cell characteristics and the zonal average rent for the various space types. (If the current space type is "vacant" then the demolish alternative is not available, otherwise the model is the same.) A logit model will be used. Development of adjacent cells can also be used to influence or constrain development for a given cell.

The second conditional choice model is a model of how much space to supply, conditional upon the decision to develop or redevelop. The maximum amount of space is set by zoning regulations, and higher zonal average rents increase the probability of more space being developed. Since the grid cells are all the same size (at least within each zone) the quantity of space choice in this module is also a density of development choice.

It is important to note that the development module does not allocate development to zones, either in aggregate or through a choice of what grid cell to develop. Rather, the development module simulates a choice for each grid cell of whether to develop, redevelop, leave as is, or demolish. To constrain the module somewhat, the average floorspace prices in all zones also impacts the choice in each grid cell, so that grid cells are less likely to be redeveloped if more profitable opportunities lie elsewhere.

The defining characteristic of a grid cell is that it contains a single type of development and the full grid cell is subject to the same set of zoning regulations. The grid cell must be small enough so that the set of them provide an appropriate representation of built form and permitted development. The grid cells should also be able to represent the diversity of building age and density of land coverage. Since residential areas tend to be relatively homogeneous, the grid cells do not have to be as small as a residential lot. So the footprint of a typical commercial building (with it's associated parking) is a desirable size.

The grid cells must be considered as a synthesized disaggregation, akin to the individual households and individual trips. The simulation is not expected to accurately forecast the future use or development patterns of individual grid cells, any more than it is expected to accurately forecast the future behavior of actual households or the future trips of actual individuals. Since grid cells have a specific location, here is a very real danger that model users will interpret the model results for a single grid cell as a real forecast for that grid cell. It is important, therefore, to provide the user interface tools to report statistics on aggregate grid cells (either TAZ zones or other, more arbitrary, aggregations).

The Spatial IO Module requires the aggregate floorspace results by zone for the interior model areas. The Spatial IO Module also requires floorspace quantities for other zones, outside of the immediate SACOG area. A more approximate, aggregate, floorspace development model will be developed in these zones: probabilities will be calculated from the grid cell development equations, and the probabilities will be applied as shares (adopting the "law of large numbers") to a cross-classification of land by current and permitted development.

#### *4.2.9.2 Inputs*

Maps (masks) or overlays of: zoning regulations and other regulations affecting development (e.g. environmental regulations, large government landholder policies) in each time period; physical constraints on develop-ability (e.g. slopes); properties fronting arterials; and building stock age distributions.

For external zones in a ring outside of the SACOG area: a cross classification of land by current and permitted development.

#### *4.2.9.3 Outputs*

Age, quantity (density) and type of development for each grid cell. Aggregate quantities of floorspace types by zone.

#### *4.2.9.4 Data Requirements - Estimation*

Disaggregate data on development choices, and data on the development choices available but unchosen. The dataset should include a randomly selected set of parcels in the Sacramento Region. Development status for two points in time will be needed for each parcel. A portion (approximately 10 percent) of the parcels should actually have development activity across the two time periods. The sample could be generated by correlating historic permit activity with parcel-level land use data.

## 4.3 Travel model elements

### *4.3.1 Trip/Tour Generation*

#### *4.3.1.1 Approach, Background, Theory and Process*

The approach to travel generation is what most distinguishes activity-based approaches from alternative trip-based approaches. Instead of treating each trip as a separate behavioural unit, activity-based approaches take into account that some trips are chained together in tours so that more than one destination is visited between the time leaving and returning home. A decision about mode, location or departure time that affects one of those trips is likely to affect all other trips in the sequence as well. Using the “tour” as the main unit of behavior was introduced in the late 1970s in work by McFadden and Ben-Akiva and others, and was first widely applied in the Netherlands in the 1980’s.

Just as different trips made in a tour are interdependent to some degree, so are different tours made during the day. If a person stops to shop on the way home from work, it decreases the chance that the same person will need to go out again after getting home. The departure times for one tour will generally influence the departure times that are possible for any other tours made during the day. The day-pattern approach recommended here was first introduced in the work of Ben-Akiva and Bowman at MIT, and has recently been applied in work in both

Portland and San Francisco. It has the advantage of being a very practical extension of the existing trip-based and tour-based models using the approach of hierarchical discrete choice models. Thus, it overcomes many of the limitations of the trip-based approach, and is not as untested in theory and practice as some other new activity-based approaches, such as those applied in TRANSIMS and ALBATROSS.

We can see in Table 3 how the behavioral choice units change as we go from the conventional aggregate trip generation approach to the disaggregate day-pattern approach. Rather than treating the number of trips for each purpose as an independent choice, those trips derive from a multi-dimensional choice of the number of tours made during the day for each purpose and the number of intermediate stops made on those tours. Once the activity pattern is specified, the travel can be broken down into separate tours or trips for the prediction of destination choice, mode choice and departure times, keeping interdependence between separate tours only when necessary (e.g. in time of day, when it is necessary to know what time the person arrives home from the primary tour of the day in order to predict the soonest time they can leave again for any subsequent tours).

**Table 3**
**Alternative Trip Generation Approaches**

| **Approach** | **Predicted unit of behaviour** |
|---|---|
| Aggregate trip generation | The average number of trips per person-day for a specific trip purpose, origin zone and population segment. |
| Disaggregate trip frequency | The number of trips per day for a specific trip purpose for a specific person and household. |
| Disaggregate tour frequency and type | The number of tours per day for a specific tour purpose for a specific person and household.<br>The number of intermediate stops made on each half of each tour for that person/household. |
| Disaggregate day pattern choice | The purpose and type of the primary activity of the day for a specific person and household.<br>The number of secondary home-based tours made for each specific purpose for that person/household.<br>The number of work- and school-based tours made during the day for that person/household.<br>The number of intermediate stops made on each half of each tour for that person/household. |

An important design issue is the variety of activity purposes that are modeled separately. In the San Francisco model system, four different tour types were predicted: home-based work, home-based school, home-based other, and work-based. In the initial Portland models, work and school were combined as a separate purpose, but home-based other was split into maintenance and discretionary activities. Also, the primary activity of the day was predicted to be either at home or out of home. This is important for identifying people who work at home. In the more current Portland model system, work and school activities are predicted separately. Also, there is a sub-model that distributes maintenance tours into shopping, serve-passenger and personal business and other maintenance, plus another sub-model that distributes discretionary tours into meals, social visits and other discretionary.

For SACOG, we recommend an approach similar to the latest Portland models, using the disaggregate day pattern choice model structure distinguishing the purposes home-based work, home-based school, home-based discretionary, home-based maintenance and work-based, plus further sub-models to split the maintenance and discretionary tours into more detailed purpose categories for the lower level models. The reason for the sub-purposes is that they tend to show very different behaviour for destination choice, mode choice and time of day.

#### *4.3.1.2 Inputs*

The major inputs to the Day Activity Pattern Module are household and person characteristics. These will include at least:

- The number of people in the household in various age categories.
- Relationships among household members
- The number of workers in the household.
- The income of the household.
- The number of vehicles available to the household
- The location of the residence.
- The employment status and student status of the person.
- The location of the workplace, if employed.
- The location of the school, if a student.
- The age of the person.
- The gender of the person.
- Type of residence

Of these variables, household size by age group, number of workers, household income, location of the residence and age, gender and employment status of the person are controlled and generated directly in the synthetic sample generation process. Workplace location and school location are endogenous to the system, and will be predicted as higher level location choice models in the travel model system, constrained to match the results of the land use model or projections. Vehicle availability is endogenous to the system as a higher-level travel model.

Other household and person characteristics may also be useful in predicting activity pattern choice. These could include own or rent residence, residence tenure, race, occupation, disability status, and drivers' licence status, to name a few. Using those variables in forecasting, however, would suggest that their distributions perhaps should be predicted exogenously for each area and used to constrain the synthetic sample generation. Otherwise, we may wind up with inappropriate distributions within specific TAZ's. For that reason, it is unlikely that many of these additional variables would be used in the models.

The other key variables for predicting pattern choice are accessibility variables. These are key variables because they provide feedback from supply to demand through changing conditions on the travel networks. The most theoretically correct approach here is to use logsums (expected utility measures) from the lower level choice models, calculated for each person in light of their personal and household characteristics (thus, these can be called disaggregate logsums). For example, the composite utility of making a secondary shopping tour with an intermediate stop would be the logsum calculated up through the mode choice, destination choice, intermediate stop location choice and time of day choice models, across all possible modes, destinations and time periods. The use of disaggregate logsums requires a lot of computation and can increase model forecast turnaround time considerably. Simplifications can be made by using logsums for 'average' persons within each zone (these can be called aggregate logsums), by assuming most frequent outcomes in some of the lower levels (for example, assuming non-work tours occur during off-peak hours), or by ignoring some of the lower levels (such as intermediate stops). Each time a simplification is made, some realism of sensitivity to travel conditions and activity opportunities is lost, but computational requirements are reduced. In the Portland models, logsums were used, and all of the above types of simplifications were made in certain cases.

An even simpler approach was used in the San Francisco models. There, the network skims and land use variables were used together in GIS to create a wide variety of accessibility variables of the type:

- Number of total jobs accessible within 45 minutes by car in the AM peak
- Number of retail and service jobs accessible within 60 minutes by transit in the PM peak.
- With various modes, travel time boundaries and times of day.

These variables are fairly simple to generate and to use, but they are rather arbitrary and not very comprehensive across modes, locations and times of day. Logsum-type variables are more efficient carriers of information and are more theoretically correct. One of the key design decisions of the model system is designing a way to bring accessibility logsums into the activity pattern models while taking some judicious shortcuts that keep the run times within reason. Since the work location and school location are predicted before applying the pattern choice model, for those tour purposes the logsums only have to cover the mode choice and time of day models, and not the location models. For other tour purposes, peak travel and time of day shifting is not that common, so those logsums can be across modes and destinations while assuming a fixed time of day. Another reduction in computation time is achieved by ignoring the location of any intermediate stops, thus not having to apply the intermediate stop location choice models when calculating logsums.

In summary, for the initial implementation of the New Standards Model, we recommend following the same approach as in the Portland models to calculate accessibility variables for the pattern choice models:

- For work and school, an aggregate logsum across all available modes and times-of-day, given the residence and work locations.
- For other tour purposes, a logsum across all available destinations and modes, given the residence location, assuming a single time-of-day.
- For all tour purposes, various land use density variables such as the number of retail jobs within a quarter mile of the residence location, etc. These particularly help to explain the attractiveness of making intermediate stops during the tour.

#### *4.3.1.3 Outputs*

For each person, the model predicts the probability of various daylong activity patterns. When applied using a stochastic Monte Carlo approach, the model generates a set of predicted tours for each person-day. Each predicted tour has the following attributes:

- Home-based or work-based
- The tour priority in the day (primary or secondary)
- The activity purpose at the primary destination
- The number of intermediate stops on the way to the primary destination
- The number of intermediate stops on the way from the primary destination
- The activity purpose at each intermediate stop
- Log sum overall attractiveness measure

These are then inputs for the lower level models.

The model also predicts the activity purpose of the primary activity of the day in cases when that activity is undertaken at home and not on tour. For people who are predicted to stay home all day, this will be the only output from the model; there are no tours predicted. However, it is possible to predict that a person’s primary activity occurs at home, and that they conduct secondary tours for other activities.

#### *4.3.1.4 Data Requirements - Estimation*

Almost all of the data for estimation will come from the household travel survey. This data first needs to be processed to create tours and daylong activity patterns from the activity diary data. For SACOG, most of this processing has already been completed during preparation of the Survey Report.

The most significant task in creating the estimation data set is in generating logsums from the lower level models. This means that those models have to be estimated first, that all network level of service data to go into those models has to be ready, and that software has to be written to apply those models and calculate the logsums. All of that work needs to be done in any case; it just means that final versions of the highest-level models need to be estimated last.

#### *4.3.1.5 Data Requirements - Running*

The data for running the models is essentially the same as for estimation, except that the PUMS-based synthetic sample is used in place of the household travel survey data. The calculation of logsums is virtually the same in estimation and application.

#### *4.3.1.6 Development Effort, Resources and Software*

This will be one of the more resource-intensive parts of developing the travel models, because the activity pattern choice model can be fairly detailed and complex, and also because the calculation of the logsum accessibility variables is involved to first set up. The Portland and San Francisco models will provide a good starting point for both model specification and software design, so that will reduce the effort required somewhat.

#### *4.3.1.7 Software Design Issues*

The activity schedule model lends itself to multi-threading (simultaneous running on two or more machines in a network, in order to reduce elapsed run time), since in each iteration the calculations for each person are independent of the calculations for all other persons. Although multi-threading has not been implemented in Portland or San Francisco, this should be seriously considered in Sacramento. If multi-threading is selected, it may be possible to increase the realism of the logsums.

### *4.3.2 Destination Choice*

#### *4.3.2.1 Approach, Background, Theory and Process*

Destination/location choice models are the disaggregate equivalent of distribution models used in the four step process. The two main types of variables are attraction variables and impedance variables. Just as in distribution models, the attraction variables are based on zone-level land use variables, such as the number of households, students enrolled and people employed in various employment categories. A critical set of attraction variables, to link the destination choice to the urban land development model, are the grid cell floorspace quantity variables, and the associated floorspace price variables from the Spatial IO Module.

These are mainly in the form of "size variables", meaning that an absolute measure is used (e.g. the number of people employed), as opposed to a density measure (the number of people within a certain radius). Density variables can also be used as attraction variables, but their effect is measured over and above the influence of the size variables. Size variables are necessary because the zones are of varying sizes and represent aggregates with varying numbers of individual potential destinations. Discrete choice theory requires that size variables be used to account for that aggregation process.

In typical aggregate distribution models, and even in many disaggregate destination choice models, the impedance measure is simply some function of highway travel time. This specification has the weakness that changes in other variables such as transit times or parking costs will not influence the choice of destination. A more correct and useful approach is to use the composite expected utility across all modes as the main impedance measure. This is calculated as the logsum from the mode choice model evaluated conditional on each possible destination being chosen. Additional network level of service variables can be included in addition to the mode choice logsums. For example, some function of highway distance or time can be added to ensure that the model produces accurate trip length distributions. Such variables tend to be correlated to the mode choice logsums, however, so care must be taken in model estimation to ensure that the overall behavior of the model remains reasonable.

We recommend estimating and applying three different types of destination choice models. These types are described below, with references to the subsequent table that lists the input variables used in each type.

##### *4.3.2.1.1 Work and School Location Choice*

These models are estimated and applied for each worker and student in the sample, respectively. When these models predict locations, nothing is yet known about the person's activity pattern for the day. They can thus be thought of as longer-term models that will be an essential part of the land use model in future enhancements. Until then, the work and school location choice models will be constrained to be reasonably consistent with the zonal employment (by different categories of labor) as predicted by the Spatial IO Module.

In the base year calibration, workplace destination choice will be constrained, through calibration of zonal constants, to be consistent with the census place of work data. The Spatial IO Module is also constrained to this data, to provide a consistent relationship between workplace destination and labor in the base year. In future years the relationship between jobs (workplace location) and labor is allowed to diverge somewhat. (Over time the spatial wage data will serve to limit this divergence, since a mismatch in one year will lead to changes in wage the next year in the Spatial IO Module, which will influence the destination choice in the travel model).

Almost all of the information that is input to these models, (the household and person characteristics and the land use and network data) is exogenous from the perspective of the travel demand portion of the model system. The only endogenous information is in the form of logsums from the mode choice model, calculated for a "typical work tour" (AM peak to PM peak with no intermediate stops) to each possible work location.

Estimating these models requires that all work and school addresses from the person-level questionnaires be geocoded and processed, even if the person did not actually visit that address during the diary day. In both the Portland and San Francisco models this extra information was not available, and the model structure needed to be adjusted (Portland) or additional assumptions were made (San Francisco) in order to accommodate the work location model.

#### *4.3.2.1.2 Tour Primary Destination Choice*

This model is similar to the work and school location choice, but it is estimated and applied at the level of a specific tour, further down the model chain. The model predicts the location of the primary destination of the tour. This destination is specified as the one where the activity of the highest importance takes place. If two or more activities have the same importance level, the one with the longest duration of stay is designated as the primary destination. At this point, several additional pieces of endogenous information are available, including vehicle ownership, the tour's times of day and number of stops, and the usual work and school locations, if applicable. The destination choice models can use all of this information, particularly in calculating the logsums from the mode choice models. Vehicle availability is then known as are the times of day and the number of intermediate stops, all of which will be important variables in the mode choice utilities.

There can be a separate tour destination choice model for each tour purpose, for which tours are predicted separately. This will likely be work, school, shopping, serve passenger, other maintenance, social visit, meal, other discretionary, and work-based. Each model would use the logsum from the tour mode choice model for the corresponding tour purpose. For work and school, the destination need only be predicted if it is different from the usual work or school location respectively.

#### *4.3.2.1.3 Intermediate Stop LocationCchoice*

This third type of location choice model predicts the location of any stops along the tour other than the primary destination. The location of the primary destination is already known, so the impedance is measured from the tour origin to the stop and then on to the primary destination (or the other way around if the stop is on the way home). The main mode for the tour is also known, so the impedance variables can be mode-specific and logsums do not need to be used. Since the mode for an intermediate stop  modeled and it can be different than the tour mode, it would be more realistic to use a mode choice logsum from the intermediate stop mode choice model, instead of the tour-mode-based impedance, to explain intermediate stop location. Such a feature might improve the model system's realism in predicting response to neighborhood walk-ability improvements, given good input data of that type.  However, the procedure adds considerable run time and has not been implemented in Portland or San Francisco.  It can be considered as a possible future enhancement.

In the San Francisco models, all of the intermediate stops on a given tour were predicted independently, not knowing the predicted location of the other stops.  In Portland this was improved upon by designating a "primary stop" on any half-tour with more than one intermediate stop, the primary stop being the one with the greatest detour distance from the straight line between the tour origin and destination.  The model is then applied in stages, first predicting the location of the primary stop, and then predicting the location of any other stops along the half-tour conditional on the primary stop location.  For instance, if a secondary stop is made before the primary stop, then the impedance is measured from the tour origin to the secondary stop and on to the primary stop.

#### *4.3.2.1.4 Sampling of Alternatives*

A key feature in the approach for estimating and applying the location choice models is the sampling of a set of alternative locations for each observation.  This approach makes the computation feasible.  The choice set would be too large if all zones were included.  In the San Francisco models, stratified sampling was used, using uniform sampling probabilities within each stratum.  In Portland, importance sampling was used, with the probability of sampling each zone being a function of a size variable (the most suitable land use variable for each tour purpose) divided by an impedance measure (a function of the distance from the tour origin).  Importance sampling, as used in Portland, is more efficient, but requires a bit more computation and can give choice sets with varying numbers of unique alternatives.  Neither of these turned out to be a problem in Portland, so we recommend this approach is recommended for Sacramento.

#### *4.3.2.1.5 Zone Size and Number*

A key design decision for the location choice models (and also the mode choice models) is the spatial detail used in specifying zones.  In San Francisco we added detail by moving to smaller zones – from 129 zones in S.F. County to 755.  The zones were smaller, but the manner in which the data was defined and processed did not change considerably.  In Portland, by contrast, we moved from using a system of 1244 TAZs to a system of using about 10,000 network links.  Note that the level of service variables for car and transit were still taken from network skims at the 1244 TAZ level.  The only variables that were used at link level were the land use variables and very localized pedestrian impedance variables such as the walk access time to transit. This hybrid approach is efficient because it uses finer spatial detail where it really makes a difference and uses coarser TAZ-level detail for OD matrix variables where it does not make so much difference and would be prohibitive to process to store and the data. Such a hybrid approach is recommended for Sacramento, using TAZ's to provide auto and transit network skims, but using network links to define walk accessibility and land use measures.

*4.3.2.2 Inputs*

Table 4 summarizes the input variables, as described in the preceding section.

**Table 4**
**Input Variables for Key Travel Submodels**

| Variables | Work and School Locations | Tour primary destinations | Intermediate stops |
|---|---|---|---|
| Household and person characteristics | X | X | X |
| Home location | X | X | X |
| Usual work and school locations | | X | X |
| Vehicle ownership | | X | X |
| Tour origin | | X | X |
| Tour destination | | | X |
| Main mode for tour | | | X |
| Tour and stop times of day | | X | X |
| Tour priority and number of stops | | X | X |
| Land use variables | X | X | X |
| Logsum from mode choice models | X | X | |
| Other network-based level of service | X | X | X |

*4.3.2.3 Outputs*

These models predict the location of every out-of-home activity that is predicted in the Day Activity Pattern Module. The locations are predicted at a level of spatial detail smaller than TAZ's, such as link faces. It would also be possible to randomly assign each destination to a single grid cell (the smallest unit used in the Land Development Module) along the predicted link (proportional to some size measure for each grid cell).

*4.3.2.4 Data Requirements - Estimation*

The data required for estimation includes household, person and observed activity schedule data from the household travel survey, as well as land use data at the newly defined link level for the survey year and TAZ-to-TAZ level of service component estimates (e.g., in-vehicle time, transfer time, cost, etc) by mode and time period of day for the survey year.

*4.3.2.5 Data Requirements - Running*

As is the case for the other models, the main difference between estimation and application is that in application the synthetic sample is used in place of the household travel survey sample. It may be feasible to use larger samples of destinations in application than in estimation, depending on the run time. For microsimulation models across so many different people, however, it is not clear that using larger choice sets will improve the spatial spread or accuracy of the forecasts.

### *4.3.3 Mode Choice*

*4.3.3.1 Approach, Background, Theory and Process*

The mode choice modeling approach here is not substantially different than for trip-based models. The main difference is that we can have different mode choice models at the tour level and the trip level. At the tour level, the model predicts the "main tour mode" used to get from the tour origin to the primary destination and back. In defining the main tour mode, the following choice set is recommended:

- Car-to-transit
- Walk-to-transit
- Car-driver
- Car-passenger
- Bike
- Walk

A separate tour mode choice model will be estimated for each different tour purpose in the Day Activity Pattern Module. Note that for some of the non-work purposes there may not be enough transit observations to adequately estimate parameters for the transit modes. This would mean either (a) removing transit from the choice sets for those purposes, (b) constraining transit-specific parameters to be the same as they are for other purposes where there are more observations, or (c) pooling data to estimate for multiple purposes jointly, making non-transit parameters purpose-specific, while making some of the transit-specific parameters generic across purposes.

A second level of mode choice models is recommended to predict the mode for each trip along the tour. The trip mode will be constrained by the main tour mode, as shown in Table 5:

**Table 5**
**Tour Mode Designations**

| **Trip Mode** | **Tour Mode** | | | | | |
|---|---|---|---|---|---|---|
| | Car-to-transit | Walk-to-transit | Car-Driver | Car-Passenger | Bike | Walk |
| **Walk** | X | X | X | X | X | X |
| **Bike** | X | X | X | X | X | |
| **Car – SOV** | X | X | X | X | | |
| **Car - 2 occ.** | X | X | X | X | | |
| **Car – 3+occ.** | X | X | X | X | | |
| **Walk to bus** | X | X | | | | |
| **Walk to LRT** | X | X | | | | |
| **Car to bus** | X | | | | | |
| **Car to LRT** | X | | | | | |

The table above is just an initial example. Different rules may be determined upon further examination of the mode combinations actually observed in the data.

For transit submodes, it is not yet clear whether bus and LRT are competing modes in enough instances to make it worthwhile to include them separately in the trip mode choice model. Otherwise, the choice between bus and LRT would be determined by the network path-builder.

For car, the distinction between driver and passenger is important in a behavioral sense, and so is included in the tour mode choice. The distinction between single occupant, 2 occupant and 3+ occupant is more important in network assignment, so this is made in the trip mode choice model.
School bus may be another important mode to include in the choice set for school tours.

#### *4.3.3.2 Inputs*

For the tour mode choice models, the inputs are essentially the same as listed for the tour destination choice models above, except that we now also know the primary destination of the tour. The key input variables are the network level of service variables for the appropriate times of day from the tour origin to the primary destination and back. Variables associated with motorized components of a tour should be defined at the TAZ-to-TAZ level, and variables associated with non-motorized components should be defined at the more detailed (e.g., link) level. The variables should include:

TAZ-to-TAZ

- Road network distance
- SOV network travel time
- HOV network travel time
- Auto tolls
- Parking cost at the destination (hourly, daily, weekend day, and monthly)
- Walk-to-transit wait time
- Walk-to-transit in-vehicle time
- Walk-to-transit fare
- Walk-to-transit transfers
- Car-to-transit car access/egress time
- Car-to-transit wait time
- Car-to-transit/transit in-vehicle time

- Car-to-transit fare
- Car-to-transit transfers
- Car-to-transit walk access/egress time

More detailed level

- Walk-to-transit walk access/egress time (e.g., distance from link centroid to nearest transit stop on each trip end, translated into time assuming 3mph)
- Walk time (e.g., for TAZ-to-TAZ and intra-TAZ distances under 2 miles, use link (centroid)-to-link (centroid) distance, translated into time assuming 3mph)
- Bike time (e.g., for TAZ-to-TAZ and intra-TAZ distances under 2 miles, use link (centroid)-to-link (centroid) distance, translated into time assuming 12mph)

For the trip mode choice model, the level of service is only one way for the specific trip segment of the tour, using the origin, destination and departure time period for that specific trip. More variables may be needed than the list above, depending on which specific sub-modes are included in the choice sets.

For the tour mode choice model, for tours that have intermediate stops, an important input variable is the logsum from the intermediate stop location model, giving the expected utility across all possible stop locations when using a specific mode.

##### *4.3.3.3 Outputs*

This model predicts a mode for each tour and, ultimately, each trip predicted by the Day Activity Pattern Module.

##### *4.3.3.4 Data Requirements - Estimation*

Estimation will require highway and transit network skims of the above variables for each different time period that is distinguished in the time–of-day models. Logsums calculated from the intermediate stop location choice models will also be needed.

### *4.3.4 Time of Travel*

##### *4.3.4.1 Approach, Background, Theory and Process*

The approach that has been followed in both San Francisco and Portland is to jointly predict the departure period from the tour origin and the departure period from the tour primary destination. Five time periods are distinguished:

- Early morning
- AM peak

- Midday
- PM peak
- Evening

There are 25 possible combinations of these periods for a tour. If, however, we assume that no tour lasts overnight (e.g. everyone is home by 3 AM), then there remain only 15 relevant combinations that need to be included in the choice set. In practice, this assumption excludes very few cases from estimation, and many of those cases may be data errors in any case.

The time of day models are estimated and applied in 4 steps:

- The time period combination for the primary tour or activity of the day.
- The time period combination for any secondary tours in the day. These are constrained to occur either entirely before or entirely after the primary tour.
- The time period combination for any work-based subtours. These are constrained to occur entirely inside the time periods for the work tour.
- The departure time period from any intermediate stops visited during the tour. These are constrained to begin after the initial departure time for the half-tour.

There will be separate models for different tour purposes.

##### *4.3.4.2 Inputs*

The inputs for the time-of-day models are the same as for the Day Activity Pattern Module, plus we also have the outputs from that model in terms of all the tours and stops made during the day.

An important accessibility input is the expected utility of traveling for a given purpose in a given time period, calculated as the logsum from the destination choice and mode choice models across all possible destinations and modes.

##### *4.3.4.3 Outputs*

The predicted departure time period for every trip made during the day.

### 4.3.5 Route Choice

##### *4.3.5.1 Approach, Background, Theory and Process*

A number of different approaches are available to predict route choice and assign vehicles to specific road and transit links. For the initial versions of the New Standards model, we recommend using the same approach as is currently used for SACMET: equilibrium traffic assignment using TAZ-level origin-destination trip matrices. Although a new software package should be purchased to perform the assignment, the general approach is not different from what is currently done.

The travel model can produce forecasts with finer spatial detail than is used in TAZ-level aggregate traffic assignment. The forecasts are literally lists of simulated trips, with each trip end located to the grid cell level, or at least the network link level. Ideally, the traffic assignment method would use this level of detail, rather than first aggregating trips to zones. Although probably not part of the New Standards package, there are two ways that this can eventually be done. One is to use purpose-written assignment software, such as is being written for the ODOT project. This uses aggregate volume-delay curves in the same way as conventional traffic assignment, but it uses the full spatial detail of the trips so that traffic is spread to all network links. A second alternative would be to get software manufacturers such as CitiLabs or Caliper to change the code of their assignment packages to accept input in the form of lists of individual trips rather than O-D matrices. Note: All that might need to be done in this respect is for the software to accept sparse matrices, reading in a record for each O-D pair with non-zero trips. Further discussion with software vendors on this issue will be useful.

A third approach is to use more realistic network microsimulation instead of aggregate traffic assignment. This approach simulates each vehicle on the network, including turn movements, queuing, speed variations, etc. The output from the travel model in the form of lists of simulated trips is well suited to this type of network simulation. A number of software packages already exist for this type of simulation, including CORSIM, MITSIM, VISIM and others. These packages, however, are only feasible for use on sub-areas of the regional network. An alternative will be the TRANSIMS microsimulator, which will work for the entire regional network and will integrate car and transit traffic into the same microsimulation. Although the entire TRANSIMS package may not be feasible for use by SACOG for several years, it is likely that the TRANSIMS network microsimulation module will be useful in five years or less, soon after the New Standards model is completed.

#### *4.3.5.2 Inputs*

As mentioned above, the form of the inputs depend on the approach used. The most detailed network assignment and microsimulation approaches will use lists of simulated trips, using the mode, departure time and detailed origin and destination locations for each trip. For more conventional TAZ-level assignment, the simulated trips will first be aggregated to TAZ-level OD trip matrices. A separate matrix will be created and assigned for each time period/mode combination.

#### *4.3.5.3 Outputs*

The key output is the predicted traffic volume and speed for each road and transit link in the network for each time-of-day. These outputs can then be used to generate further output in the form of TAZ-level origin-destination level of service measures (skims) that are used as inputs for subsequent land use and travel forecasts.

With the most detailed types of network microsimulation it will also be possible to relate predicted travel times to individual simulated trips. This will give more accurate analyses for things such as equity analysis, particularly in seeing who is most affected by severe traffic congestion and delays. (Detailed network microsimulation has the advantage of predicting these delays in the correct places, while aggregate assignment methods often predict the longest delays upstream of the true bottlenecks.)

#### *4.3.5.4 Data Requirements - Estimation*

Key data for calibrating assignment results are observed network flows and speeds, typically from independent traffic counts. Other than such a calibration process, no true "estimation" is typically performed for network assignment or microsimulation. The parameters that are used in the software (e.g. volume-delay curves) tend to be based on past experience and calibration evidence rather than on site-specific model estimation.

#### *4.3.5.5 Data Requirements - Running*

The key data requirement is in the coding of the road and transit networks. If the ability to assign to the level of individual links and/or grid cells is desired, then all of these links need to be coded into the networks for the base year and any forecast years.

#### *4.3.5.6 Software Design Issues*

The recommended approach is to rely mainly on available packages such as TP+ or TransCAD for assignment and VISIM or TRANSIM for microsimulation. For more detailed spatial assignment, custom software is required, unless the vendors of the currently available packages can add such features to their packages over the next few years.

### *4.3.6 Auto Ownership*

#### *4.3.6.1 Approach, Background, Theory and Process*

For the New Standards model, a fairly basic approach for auto ownership is recommended: a cross-sectional model to predict the number of vehicles owned by each household. In the model hierarchy, this model fits between the land use and travel models. It is applied conditional on where each person in the household works and goes to school, but prior to knowing anything about their activity pattern for the particular travel day.

Although the best functional form of the model is a subject for empirical analysis, a "stop-repeat" model formulation is recommended. The model would first predict whether the household owns 0 or 1 vehicles. Then, conditional on owning 1 vehicle, the model would predict whether the household owns 1 or 2 vehicles, and so on. The alternatives to this type of formulation are a simple MNL model or else a nested model specification.

*4.3.6.2 Inputs*

The inputs are all characteristics of the household and its members, including where people work and go to school. In terms of accessibility, a number of different measures may be useful:

- Travel times and distances from home to work for all household workers;
- Travel times and distances from home to school for all household students;
- Logsums reflecting accessibility from the home zone for non-work purposes (across all modes, destinations and times-of-day)
- Logsums reflecting accessibility from the work zones for non-work purposes (across all modes and destinations during the midday)
- Other measures reflecting land use densities and parking around the home zone and work zones.

Note that in the initial version measures of vehicle technology such as car prices, fuel prices, fuel efficiency, fuel types, etc are not recommended. These will, however, be important inputs in enhanced versions when we estimate models to predict vehicle types and usage.

*4.3.6.3 Outputs*

The model will predict the number of vehicles owned by each household in the sample.

*4.3.6.4 Data Requirements - Estimation*

All data required for estimation is available in the household travel survey, with the exception of the accessibility measures which will need to be compiled by calculating logsums from other models.

*4.3.6.5 Data Requirements - Running*

The same as for estimation, except that PUMS data and endogenous predictions will be used in place of the household travel survey data.

*4.3.6.6 Development Effort, Resources and Software*

The software for estimation and application is relatively simple and is available from previous studies.

### 4.3.7 Shipment Logistics for Goods Movements and Freight

*4.3.7.1 Approach, Background, Theory and Process*

The intention of this module is to provide lists of the individual vehicle trips and person trips generated by business activities, including the following for each of these trips:

- Start time

- Origin link
- End time
- Destination link
- Tour mode and associated set of available trip modes.

These trips are then aggregated into flows and loaded to the travel networks together with the flows of trips from households.

The Spatial IO Module forecasts the amount of industry in each economic sector in each model zone, with the corresponding flows of commodities from the zone to all other zones. The goods movement procedure starts with the quantity of a one industry in one zone, and works its way through all the different industries in the zone before moving on to the next zone. It ends when all the zones have been considered.

For a given industry in a given zone, the quantity is divided into individual business establishments (BE) by sampling from an observed distribution of business establishment sizes. Trip generation rates (per unit of industry) for (1) person tours, (2) for-hire vehicle visits (including arrival and departure) and (3) own-account vehicle tours are then selected from a joint sampling distribution of rates that is a function of the industry, the accessibility and associated travel conditions, the related vehicle costs and the size of the BE. The development of this joint sampling distribution will involve the use of information from commodity flow surveys and special generator surveys.

The number of person tours from the BE is then determined by multiplying the person-tour rate by the size of the BE. Person tours are then handled in much the same way that work-based person tours are handled in the household trips module. (In fact they are some of the same trips – and they may indeed be handled solely and entirely in the household trips module as ‘work-based tours’, if appropriate.)

The number of for-hire vehicle visits at the BE is then determined (again, by multiplying the rate by the BE's size). Each of these visits is then assigned a mode (the type of vehicle making the visit). This is done using a logit model with utility functions that include accessibilities and vehicle costs. After all the visits at the BE have been considered, then the specific link for the BE is determined by first randomly selecting a grid cell from among the full set of such cells with appropriate space types in the zone containing the BE and then identifying the link that includes that cell in its ‘tributary area’. BEs in the transport sector, including trucking firms and depots, will be identified as locations where larger numbers of departures occur, some of which are special ‘initial departures’, along with larger numbers of arrivals occur.

The result is a vector of arrivals and departures by vehicle type at each link. A doubly-constrained gravity model is then applied for each vehicle type separately in order to join together vehicle departures and subsequent vehicle arrivals, with the restriction that the arrival cannot be at the same link as the departure for a given trip. (Future work beyond the New Standards model will consider alternative destination choice formulations for the linking of arrivals to departures that more directly take into account the results of the land use modules).

Each special ‘initial departure will then be assigned a specific departure time from an observed distribution, and then ‘chains’ of trips starting with these initial departures will be traced from the full set identified by the gravity model for the mode (vehicle type), with the timing of the arrival and departure for each subsequent visit determined from the network travel times and a further assigning of the time between arrival and departure from an observed distribution of such times for the sector. This is continued until all of the trips for the vehicle have been considered.

The number of own-account vehicle tours from the BE is then determined (again, by multiplying the rate by the BE size). Each of these tours is considered in turn. First the mode (type of vehicle) is selected for the tour. This is done using a logit model with utility functions that include accessibilities and vehicle costs. Then the number of stops and the zones containing these stops are both assigned to the tour using logit models with utility functions that include location accessibilities, travel conditions, the distribution of commodity flows determined in the land use module and a range of alternative specific constants related to the sector and assigned mode. An initial departure time for the vehicle from the BE is also assigned from an observed distribution, and the timing of the arrival and departure for each subsequent stop is determined from the network travel times and a further assigning of the time between arrival and departure from an observed distribution of such times for the sector. The specific link for the BE and for each subsequent stop is assigned by first randomly selecting a grid cell from among the full set of such cells with appropriate space types in the zone and then identifying the link that includes that cell in its ‘tributary area’.

#### *4.3.7.2 Inputs*

Location of industry from Spatial IO Module, accessibilities by mode by location.

#### *4.3.7.3 Outputs*

List of commercial trips

#### *4.3.7.4 Data Requirements - Estimation*

Region-wide business inventory; commodity flow survey.

### *4.3.8 External and special trips*

#### *4.3.8.1 Approach, Background, Theory and Process*

For the New Standards model, the approach for external trips will be essentially the same as is done now. The number of external trips entering and leaving the regional network at various points is estimated based on traffic counts and surveys, and these are input to a matrix estimation algorithm to get an OD matrix of external trips. These trips serve as an exogenous input in traffic assignment to generate “background” flows on the network.

We propose adding some detail to the treatment of external traffic to treat Solano County and the rest of the Bay Area differently from other externals. One option would be to include each of the 9 Bay Area counties as separate external zones (perhaps more than one zone for nearby Solano county). The same approach could be used for counties east of the Sacramento region along routes I-80 and 50, as far as Tahoe and the Nevada border. In the New Standard model, these new zones would not be used in the same travel models that are applied for study area households. They could, however, be used in simpler “pre-processor” models to allow some endogenous influence on the level and pattern of external traffic. An example would be an elasticity-type model that predicted the number of external trips from various counties as a function of county level population, demographic and economic forecasts or scenarios. If these external counties are treated explicitly in the input-output land use models (spatial economics), then that would be even better than using a simple elasticity-based model.

A simple inter-regional mode choice model could also be combined with this approach. For example, a model could be calibrated to split each county-to-county flow into travel by road and rail (and possibly air) depending on trends in traffic congestion and service alternatives for inter-regional travel.

The other type of personal travel that should be incorporated at some level is special types of trips within the region that are not well handled by the Day Activity Pattern Module approach. These types of trips include:

- Trips to and from the airport
- (Other) trips made by tourists and non-residents within the region
- Trips to and from major regional attractions.

In the New Standards model, we propose to explicitly model only the first of these trip types: trips to and from the airport. It is expected that a study will be commissioned to provide forecasts for a proposed light rail extension to the airport, and this study can provide both data and funding for creation of an airport access model within the next two years. This survey is likely to contain a mix of RP and SP data. The model will contain two components: (a) a generation/attraction component to predict the number of trips to and from the airport from each location, and (b) a mode choice component to predict the share of those trips to use private car, transit and taxi.

*4.3.8.2 Inputs*

As mentioned above, the inputs will be:

- County-level demographic and economic data and projections.
- Levels of service for inter-regional and airport-based transit.

*4.3.8.3 Outputs*

The outputs will be OD matrices of external trips and airport-based trips by mode. These outputs will be merged with the outputs of the Day Activity Pattern Module at the network assignment stage.

*4.3.8.4 Data Requirements - Estimation*

The main data required for calibration/estimation will be:

- External trip surveys and counts
- Airport access survey data

*4.3.8.5 Data Requirements - Running*

These are mainly the data mentioned as inputs above in 3.3.8.2.

*4.3.8.6 Development Effort, Resources and Software*

Purpose-designed software will be designed and run for these models. Since the models themselves will be relatively simple and independent, the software design and implementation should be less resource intensive than for other modules.

### 4.4 Module Linkages

Table 6 lists data linkages between modules in the overall forecasting system.

**Table 6**
**Data Interchanges**

| Data Element | Land Development | Spatial IO Equilibrium | Household Evolution/Transition | Household Travel | Business Travel | Network Assignment | Household Synthesizer | Demographic Shifts | Comment |
|---|---|---|---|---|---|---|---|---|---|
| | Forecast Module | | | | | | | | |
| **Land Use/Travel Model** | | | | | | | | | |
| Networks | | | | | | Use | | | Standard highway, transit networks; Software TBA. |
| Travel Attributes (Zone-to-Zone Skims) | | Use | | Use | Use | Produce | | | Standard highway, transit skims. |
| Travel Attributes (Linkface-to-Zone Data) | | | | | | Opt. Use | | | If linkface level assignment desired. |
| Population Distribution | | Produce | Use | | | | Use | Use | |
| Employment Distribution | | Produce | Use | | Use | | | | |
| Auto ownership distribution | | Use | Produce | Use | Use | | Use | | |
| Aggregate Economic `Flows` of Goods and Services (in $) | | Produce | | Use | Use | | Use | Use | Factors used to convert from $ to households, persons, jobs |
| Tour List (Personal Travel) | | | | Produce | | Use | | | |
| Tour List (Business Travel and Services Movement) | | | | | Produce | Use | | | |
| Tour List (Goods Movement) | | | | | Produce | Use | | | |
| Grid Cell Inventory of Building Space by Type | Update | Use | | Use | Use | | Use | | |
| Price of Building Space by TAZ | Use | Produce | | | | | | | |
| Grid Cell inventory of Zoning/Geography/Constraints | Use | | | | | | | | |
| Individual Synthetic Households | | | | Use | | | Produce | | |
| PUMS Household Records | | | | | | | Use | | |
| OD Matrices | | | | | | Produce | | | |
| IO Model "Make" and "Use" Tables (Industry by Commodity) | | Use | | | | | | | |
| Import/Export of Commodities (to/from Outside Region) | | Use | | | | | | | |
| Overall Benefit Measures | | Produce | | | | | | | |
| Price Signals for Goods, Labor and Other "Commodities". | | Produce | | | | | | Use | |
| Demographic Details by Zone | | | Produce | | | | | Produce | |

**Table 6**
**Data Interchanges**

| Data Element | Forecast Module: Land Development | Spatial IO Equilibrium | Household Evolution/Transition | Household Travel | Business Travel | Network Assignment | Household Synthesizer | Demographic Shifts | Comment |
|---|---|---|---|---|---|---|---|---|---|
| **Calibration and Estimation Data** | | | | | | | | | |
| Current Distribution of Employment/Population (Census, ES202) | | Use | | | | | | | |
| Traffic Counts | | | | | | Use | | | |
| Observed Travel Patterns (Household Survey) | | | | Use | Use | | Use | | Completed in 2000. |
| Observed household characteristics (Household Survey) | | Use | | | | | Use | | Completed in 2000. |
| Census PUMS | | | | | | | Use | | |
| Development History (e.g. Permits, Inventory in Two Time Periods) | Use | | | | | | | | |
| Building Values (Observed Lease Rates) | Use | Use | | | | | | | |
| Household Retrospective Survey on Transitions | | | | | | | Use | | Panel recruited from household survey respondents. |
| Floorspace Consumption Rates and Elasticities for Industry and Households) | | Use | | | | | | | |
| Population and Employment Distribution in a Second Time Period | | Use | | | | | | | |

# 5 Implementation Issues

## 5.1 Training

The main types of training needed will include:

- The concepts and structure behind the New Standards model
- Contents and maintenance of the GIS data base
- Contents and maintenance of the network data
- Defining and documenting new alternatives for analysis
- The mechanics and options involved in running the model for an alternative
- Various ways of processing and analyzing the model output.

The most efficient way of providing this training in the first instance will be for SACOG staff to be in place and working closely with the consulting team that is selected to build the model system. The procedures for maintaining, running, testing, analyzing and documenting the model system and its outputs will be a significant product of the model development effort, and it is recommended that SACOG be closely involved. After that, a more formal and tailored training process can be created for other staff at SACOG and client agencies.

## 5.2 Costs

While it is too soon to provide detailed task-by-task cost estimates, rough estimates of what will be necessary to develop and implement the New Standards model over a three-year period were estimated. The estimates are provided in Table 7. The total is in the range of $750K-$1.25M. Table 7 provides a rough breakdown of costs.

**Table 7**
**Model Development Costs (Exclusive of SACOG staff costs)**

| Task | Year 1 | Year 2 | Year 3 | Total |
|---|---|---|---|---|
| Development of land use models | $100-150 | $150-200 | 0 | $250-350 |
| Development of travel models | 150-225 | 100-125 | 0 | 250-350 |
| Integration, testing, training, documentatio | 0 | 0 | $200-300 | 200-300 |
| Data collection | 50-150 | 0-100 | 0 | 50-250 |
| Total | $300-525 | $250-425 | $200-300 | $750-1,250 |

To do the full range of what has been described above, the required budget would be near the upper end of the estimated range. If that level of budget is not available, cutbacks would have to be made in certain areas:

- Some loss of detail in the models, in terms of activity purposes, economic sectors, zone size, ability to assign trips below TAZ level, etc.
- Some loss of accuracy and consistency in terms of less complete behavioral linkage and feedback between all of the constituent models.
- More of the model system implementation, testing and documentation in the later stages would need to be done internally by SACOG staff.
- Less detailed treatment of inter-regional travel outside the SACOG region – i.e. to the Bay Area.

The budget estimate also rests on a few key assumptions:

- Data for and development of an airport access model will be funded by a separate project.
- Only an aggregate freight model will be developed. A more detailed microsimulation model of freight movements would require additional funds.
- Any other enhancements described for the Enhanced and Advanced versions would require additional budget.

In addition to the estimated budget will be internal SACOG staff costs. At least two full time staff will be necessary, one for creation and upkeep of the GIS databases and the definition of land use scenarios, and another for creation and upkeep of the network databases and the definition of network scenarios. It would be desirable to have a third person to have the main task of running the model system and analyzing the output, although some of this work could be contracted out to consultants also.

### 5.3 Data Availability and New Data Collection

The following data sources will need to be in place to develop the models:

- A GIS parcel database.
- Road and transit networks.
- Census counts and PUMS records.
- The household travel and activity survey.
- Road and transit cordon counts.
- Regional employment and school enrollment data.

Some additional types of data will need to be compiled from existing sources:

- Floor space data.

- Data for a multi-sector regional "make-use" input-output matrix.
- Data to describe inter-regional travel and attractions.

Finally, some additional data will need to be collected through surveys:

- Additional floor space data, such as through aerial surveys.
- Airport trip survey (paid for by a separate project).
- Freight cordon counts, and any additional traffic and passenger counts that prove to be needed.
- Freight shipper behavioral surveys (if needed, these would probably need to be funded through a separate project).

# 6 Next Steps

This section of the report is intended to identify generic tasks and phasing to advance toward full implementation of the New Standard model system within a three year time period. Obviously, the ability to meet this goal depends on funding, staffing levels at SACOG, and other priorities for SACOG staff. The phasing outlined here blocks some of the key data collection and model development tasks into short term (Year 1), middle term (Year 2) and long term (Year 3). As discussed in the previous section, it is assumed that two full time staff persons are dedicated to the implementation of the modeling systems in the short-to-middle term.

This phasing is intended to develop a finished model system to be used in preparation of the 2005 MTP. While integration and testing is intended to be contained within Year 3, it is likely that some testing and calibration will carry over into the preliminary MTP analysis.

## 6.1 Short Term Tasks

Two tasks should be initiated in Year One of the model implementation:

- ***Estimation and Application of the Day Activity Pattern Module.*** This module would functionally replace the household-based travel portion of the current SACMET model. The "module" is a linked set of choice models related to different elements of travel behavior. This task is suited for short term implementation for several reasons. The bulk of the data needed for model estimations is available in the 2000 Household Travel Survey. The module could be used on a "stand-alone" basis, as an upgrade to the four-step SACMET travel model, while data and model development proceeds on business travel models and on the land use/economic models.
- ***Collection of Floor Space Quantities.*** Detailed data on quantities and types of building floorspace is a required data source for estimation, calibration, and validation of the land development and economic models. While several sources exist for many of the other required input data, the quantity of floor space by type, broken down by parcel, is not available in usable from from any other source. For this reason, this data collection is merited in Year 1.
- ***Business Establishment Survey.*** The survey should be designed to elicit information about person tours from work, for hire vehicle deliveries/pick-ups, and "own account" pick-ups and deliveries. The survey could be patterned on a similar survey recently completed in Calgary.

## 6.2 Middle Term Tasks

Four data collection tasks could be initiated immediately, but would need to be completed by the end of Year Two.

- ***Collection/Synthesis of Floorspace Price Data.*** Price data is a surrogate indication of vacancy rates and other incentives to develop land in a particular area. Unfortunately, no comprehensive, current data source currently exists. Others have tried using the available, spotty data sources, plus a "Delphi" approach relying on local brokers, developers, and researchers to fill in gaps. Ideally, some current/base year and some historic data would be prepared for model estimation, calibration, and validation.
- ***Development of a "Grid Cell" System and Data Elements.*** The land development module is proposed to run on a "gridded" set of data, which would then be aggregated to zones for processing in the Spatial IO Module and travel modules. All of the floorspace inventory, and other variables affecting the location and quantity of land development (zoning, development status, environmental constraints, local accessibility information), will need to be split down the the same grid system. The UPLAN process can serve as a starting point for this task.
- ***Acquisition and Development of Data for Spatial IO Module.*** Development of the Spatial IO Module requires several sets of input data, specifically for the modeling region. ES202 is typically used to estimate quantities of employment by sector. IMPLAN or similar vendors can provide a "make-and-use" table for a fee. The other inputs required (IO technical coefficients, floorspace consumption rates, labor force participation rates, and commodity trip length distributions) all must be extracted from other data sources and prepared for the Sacramento region. All of the data sources related to employment need to be adjudicated with SACOG's employment monitoring data and household and population data by minor zone (or parcel). In this process, gaps in data coverage must be filled using the best sources available or professional judgement.
- ***Collection/Synthesis of Historical Development Data.*** Estimation of the land development model will require assembly of some historical permit data on development on a randomly selected sample of parcels. The development status of each parcel will need to be determined for at least two points in time for the estimation dataset.

Three significant model development tasks should be completed by the end of Year Two:

- ***Estimation and Application of the Spatial IO Economic Module.***
- ***Estimation and Application of the Land Development Module.***

While these tasks are theoretically separable, in practice, they should be treated as one work effort. All of the data collection synthesis tasks mentioned above would need to be in place for the estimations, along with GIS procedures for managing and displaying input and output data.

- ***Estimation and Application of the Business Travel Module.*** This module consists of models estimated from the survey of business establishments. It is intended to cover both work-based tours by employees, as well as freight travel generated by businesses. As part of the application of this model, the person-tour information from the business establishment survey will need to be adjudicated with the work-based tour information from the Day Activity Pattern Module.

### 6.3 Long Term Tasks

The major task proposed for Year Three is the integration of the Day Activity Pattern Module and the land development and spatial economic models. This task will include system architecture and some limited software development to efficiently run the modeling system as an integrated package. The task will also include extensive calibration and validation, and sensitivity tests to prove the entire system.

As mentioned above, it is likely that additional calibration and testing will carry over, as part of the preliminary work in the 2005 MTP.

### 6.4 Other Model System Enhancements

The phasing for the New Standards model as proposed above is aggressive, and will require a significant allocation of SACOG resources, both in staffing and funding. This section describes some specific enhancements that can be carried out to go from the system described as the New Standards Model to provide some of the features described under the Enhanced and Advanced Models. First, there are two general types of enhancements that are very important, but are not the subject of this chapter:

- For the land use model, going from the aggregate framework of the New Standards version to the disaggregate microsimulation framework of the Enhanced and Advanced versions is a fundamental shift.
- In the travel models, several improvements are proposed for the Enhanced and Advanced versions that involved subtle changes in the model specification and structure to improve the accessibility linkages between the various sub-models.

Both of those areas of enhancement, described in Section 2, will improve the technical and theoretical aspects of the model system, but will not change considerably the scope of the system in terms of the types of behavior modeled and the types of variables that can be considered. In this section, we focus on a few specific enhancements that can increase the scope of the New Standards modeling system, and also could be carried out as more or less separate sub-projects at any time during the model development process.

#### *6.4.1 Vehicle Type and Usage*

Urban transportation models typically consider all cars as equals. There is no distinction between the fuel consumption, driving characteristics and emissions rates of different types of vehicles. In reality, these distinctions could be important for the resulting forecasts. For example, any policy or exogenous shift that would cause people to shift from driving SUV's to driving more compact vehicles would have a major influence on fuel consumption, emissions and perhaps even traffic delays (i.e. compact cars take up less road space and effectively increase lane capacity).

The Sacramento household travel and activity survey collected data on the makes, models and vintages of all vehicles owned by each household, and also identified the vehicle used for each car trip. This data can be used to supplement the travel models in two ways:

- In addition to predicting how many vehicles each household owns, we can also estimate a model to predict the type of each vehicle owned, in terms of body type (subcompact, compact, midsize, luxury, pickup, van, SUV, sports car, etc.), origin (American, Asian, European), vintage (e.g. 1-3 years old, 4-6 years old, etc.) and perhaps even fuel type (gas, diesel, CNG, electric, hybrid, etc.). Such a model would be sensitive to forecasts of changes in vehicle technology and prices, as well as any policies to influence the technology and prices.
- Conditional on what types of vehicles are owned by a household, a vehicle allocation model can predict which vehicle is used for each trip. Such a model would tend to allocate SUV's, for instance, to trips made by parents with their children, while compact cars would more often be used for city driving and by people traveling alone.

A supplemental data source for these types of models is the California Energy Commission's statewide vehicle ownership survey. The latest wave of this survey is being carried out in 2001.

#### *6.4.2 Simulation of Freight Transport*

The New Standards model includes a fairly aggregate approach for modeling goods movements, corresponding to the aggregate spatial economic framework proposed to model land use. It would also be possible to undertake a more ambitious approach to simulate the goods movements of individual firms. Data collection for similar work is being undertaken in Calgary and perhaps other cities, and it would be possible to use this data for a model transferred to the Sacramento situation. This microsimulation approach for freight would work best if the land use model also works with the microsimulation of individual firms, as is proposed for the Enhanced and Advanced model systems. It would be possible, however, to apply a freight microsimuation model combined with the current New Standards land use model.

#### *6.4.3 Parking Supply and Demand*

Although parking cost and availability is a crucial behavioral factor in many cities, typical urban travel demand models are very poor at dealing with parking supply constraints. Although some researchers have come up with ways to include parking in network-based traffic models – essentially treating parking lots and spaces as separate links or terminal nodes with fixed capacity – this research has not made its way into regional models. One difficulty is that the type of parking available can vary a great deal from individual to individual.

Another is that cars occupy parking spaces for varying lengths of time, requiring a method than can keep track of how many vehicles are parked across the day. This approach would work best in combination with a network microsimulation framework.

### *6.4.4 Detailed Traffic Network Microsimulation*

Computer packages such as TRANSIMS, CORSIM, VISIM, etc. are available to perform detailed vehicle-by-vehicle microsimulation of the traffic network. Of those available, TRANSIMS appears to be the only one that will work at the regional level. It also seems to go the furthest in terms of its treatment of transit and parking. Although the full TRANSIMS framework has not yet been tested, the Microsimulation module does appear to be relatively well developed. It would be possible to use the activity lists forecast by the New Standards model as input to the TRANSIMS microsimulator, as a supplement to the type of information provided by standard traffic assignment. Some method of feedback would need to be developed between the two systems, analogous to the way that travel times from traffic assignment are fed back to the other demand models.

### *6.4.5 Detailed Pedestrian Microsimulation*

The New Standards model will predict walk and bike trips at a fairly detailed level of accuracy – at least to the link-face level and down to the grid or parcel level if necessary. These predictions could be used as input to a detailed simulation of pedestrian movements in sub-areas where such trips are most prevalent – i.e. in downtown Sacramento. It is likely that computer software already exists for performing such simulations, although we would need to investigate such simulation models and their properties in more detail before firmly recommending this enhancement.

### *6.4.6 Emissions Modeling*

As mentioned above, modeling vehicle type and usage could greatly improve the accuracy and policy responsiveness of emissions forecasts. Short of that, another improvement would be to keep track of hot starts and cold starts separately. Because we model a whole day's activities for each person, we have a good estimate of how long the person leaves his or her vehicle parked between activities. Thus, we can locate the emissions produced by cold starts separately from those produced by hot starts.

### *6.4.7 Inter-regional Travel*

The New Standards framework includes an aggregate treatment of travel to Bay Area counties and other surrounding Northern California counties, essentially treating each county as a separate "external" zone that is included in the spatial economic framework. There will be separate models of trip generation and mode choice to those regions. If this area of demand is of high interest or priority, then it would be possible to investigate ways to model interregional travel in more detail. At this point, we do not have any detailed recommendations as to how this would be done.

#### *6.4.8 Weekend and Seasonal Travel*

The New Standards model will predict travel for a "typical" weekday, reflecting weekdays at the time of year when the household survey data was collected and when traffic and passenger counts are taken. It would be possible to extrapolate these models to also predict travel in the weekends and for different times of year. One option would be to mount additional household and intercept surveys to observe travel during those periods. Short of that, the most efficient approach would be to use factoring of trips generated for various purposes to represent the relative change in the number of those trips between weekdays and weekends, and across seasons. The factoring would need to be based on evidence from other regions, as well as from traffic counts and whatever data is available in Sacramento. There may also need to be separate sub-models to account for types of non-resident trips that tend to occur seasonally or on weekends – including summer tourism and winter skiing.

# Appendix A: Definition of Model Options

# Definition of Forecasting Model Options

| Element | Options | Current | Options: New Standard | Options: Enhanced | Options: Advanced |
|---|---|---|---|---|---|
| **Land Use Model** | | | | | |
| Base year population | | | | | |
| | Track housing unit completions, apply vacancy rates. | x | | | |
| | Synthesized with Beckman procedure, resample PUMS to match aggregate zonal breakdown for income, household size, etc. Rule-based allocation to parcels/blockfaces | | x | x | |
| | Synthesized as above, "Partial Equilibrium" with travel preferences – households are in locations that are appropriate for them based on their randomly generated sensitivities and preferences | | | | x |
| Base year employment | | | | | |
| | Track job locations by situs address and SIC code. | x | | | |
| | Aggregate model of industrial activity, in categories of occupation and industry | | x | | |
| | Individual firm simulation, with specific characteristics for shipping, labour and customers. | | | x | |
| | Individual firm simulation as above, with "Partial Equilibrium" so that individual firms are in desirable locations given their randomly selected characteristics. | | | | x |
| Shifts in population demographics over time | | | | | |
| | Allocate DOF population to minorzone. Rule-based cross-classifcation to persons, workers, income. | x | | | |
| | Birth rates, death rates. Household dissolution and formation. | | x | | |
| | Advanced tracking of socioeconomics (race, income, occupation) | | | x | x |
| Shifts in size/structure of economy over time | | | | | |
| | Current development trends + land use policy, bounded by housing unit growth. | x | x | ? | |
| | Tied to changes in labour supply and the ability of the transportation and land-use system to serve the needs of various industries | | | ? | |
| | Firm formation and dissolution, firm relocation | | | | x |
| Labor market -- demand and supply | | | | | |
| | Regional employment parallels regional housing unit growth. | x | | | |
| | Zonal aggregate -- changes in employment conditions (salary, benefits, etc.) to match demand to supply in each zone | | x | | |
| | Model of occupation transition/skills upgrading based on labour market conditions; -- tied to individual households and impacting labour migration | | | x | x |
| Home relocation | | | | | |
| | N/A | x | | | |
| | Aggregate allocation of household categories to zones, with floorspace prices adjusted to clear market for residential space. Based on household categories (not individual household characteristics). Rule-based assignment to individual parcels/blockfaces re-performed in each time period | | x | | |
| | "Move" or "Stay" decision for each household based on household characteristics. Zone choice with rule-based assignment to parcels/blockfaces. External impacts (e.g. school quality, crime) on location choice | | | x | |
| | As above, but triggered by changes in household composition/jobs/income | | | | |
| | As above, but simulation of search procedure (in place of zone choice with rule-based assignment) | | | | x |

# Definition of Forecasting Model Options (continued)

| | | | Options | | |
|---|---|---|---|---|---|
| **Element** | **Options** | **Current** | **New Standard** | **Enhanced** | **Advanced** |
| Firm / establishment relocation | | | | | |
| | N/A | x | | | |
| | Aggregate allocation to zones, with floorspace prices adjusted to clear market. Based on categories. (Micro-level effects handled in development model.) | | x | | |
| | "Move" or "Stay" decision based on firm characteristics. Zonal choice with rule-based assignment to parcels/blockfaces re-performed in each time period | | | x | x |
| | As above, but simulation of search procedure (in place of zone choice with rule-based assignment) | | | | |
| Floorspace prices | | | | | |
| | N/A | x | | | |
| | In equilibrium with floorspace demand by firms and households | | x | | |
| | Price adjustments by land-owners simulated dynamically based on vacancy rate and cost function | | | x | x |
| Development of floorspace | | | | | |
| | Implied development of acreage based on jobs/acre (see attached tables) | x | | | |
| | Aggregate zonal development based on floorspace prices. Allocation to individual parcels based on simple rules. Re-development/demolition included. | | x | | |
| | Simulation of individual developer behaviour for parcels/gridcells/linkfaces; with consideration of zonal floorspace prices and vacancy rates | | | x | |
| | Simulation of individual developer behaviour as above, with consideration of neighbouring parcels and direct simulation of land assembly. Consideration of Developer Permit procedures beyond just permitted uses and development impact fees – e.g. bureaucratic delay and special relaxations. | | | | x |
| Shipment logistics | | | | | |
| | N/A | ? | | | |
| | Trip based goods movement, with intermodal assignment | | x | | |
| | Simulation of individual shipments, and allocation of shipments to trucks nearby. Time-of-day choice responsive to travel conditions. Mode choice (i.e. truck type). | | | x | x |

# Definition of Forecasting Model Options (continued)

| Element | Options | Current | New Standard | Enhanced | Advanced |
|---|---|---|---|---|---|
| **Travel Model** | | | | | |
| Auto ownership | | | | | |
| | Zone-based | x | | | |
| | Cross-sectional vehicle holdings model. No logsum linkages | | x | | |
| | Cross-sectional vehicle holdings model with logsum linkages | | | x | |
| | Dynamic vehicle transactions and type choice models, including logsums | | | | x |
| Tour/ trip generation | | | | | |
| | Trip-based. Limited use of accessibility variables | x | | | |
| | A simple day pattern model with a few tour purposes, no explicit household interactions, limited logsum feedback from lower level models | | x | | |
| | A more detailed day pattern model with more tour purposes and more logsum feedback from lower level models | | | x | |
| | A day pattern model with explicit interaction between choices made by various housheold members, more linkages to other models | | | | x |
| Destination choice | | | | | |
| | Trip-based destination choice, integrated with mode choice model | x | | | |
| | Work and school locations already known (above generation models). Tour-based destination choice integrated with tour-based mode choice Separate intermediate stop location model, but with no logsums to upper levels. | | x | | |
| | Same as "basic", but with logsums from intermediate stop location up to destination and mode choice models | | | x | x |
| Mode choice | | | | | |
| | Trip-based, with no non-motorized modes. | x | | | |
| | Tour-based, including non-motorized modes - no mixed-mode tours (except P&R) | | x | | |
| | Both tour- and trip-based, including non-motorized modes, mixed modes | | | x | |
| | Same as "enhanced", with explicit model of parking choice | | | | x |
| Time of day | | | | | |
| | Factoring for a few periods | x | | | |
| | Choice model for about 15 time period combinations. Limited logsum feedback from lower level models. Separate peak-spreading model within peaks | | x | x | |
| | Use of more time time periods, and both choice and duration models. More extensive logsum feedback. | | | | x |
| Level of spatial detail | | | | | |
| | All data at TAZ level | x | x | | |
| | LOS at TAZ level, land use at block-face level | | | x | x |
| Network simulation/ route choice | | | | | |
| | Assignment in MINUTP | x | | | |
| | Assignment in TP+ | | x | x | x |
| | Network micro-simulation | | | x | x |
| | Micro-assignment respecting individual characteristics | | | ? | x |
| Application framework | | | | | |
| | Zone-based enumeration, store by OD, mode, purpose, time of day | x | | | |
| | Person-based sample enumeration, full sample, simulate and store individual choices | | x | x | x |
| External and special trips | | | | | |
| | Fixed matrices | x | | | |
| | Airport access model.Inter-regional trips sensitive to growth in other areas. | | x | x | |
| | Airport access model Other regions included explicitly in location choices. | | | | x |

# Appendix B: Evaluation of Model Options and User Needs

# User Needs Evaluation of Forecasting Options

| User Need | Current Tools | Forecast Model Options: New Standard | Forecast Model Options: Enhanced | Forecast Model Options: Advanced | Comments |
|---|---|---|---|---|---|
| **Policy Relevant** | ○ | ◔ | ◒ | ◒ | |
| **Support the policy issues which the region is likely to face:** | | | | | |
| Smart Growth strategies | ○ | ◔ | ◒ | ● | Options including fine geographic detail, microsimulation of land use changes, and effects of mixed use, perform best (enhanced, advanced). |
| Pricing policies (e.g. toll roads, HOT lanes and parking) | ◔ | ◒ | ◒ | ● | All options improve signifcantly, because person/household data retained in trips/tours. |
| ITS strategies (e.g. travel information, operations improvements, etc.) | ○ | ◔ | ◔ | ◒ | Traveler information not captured; traffic management captured with micro-simulation of assignment (advanced only). Other improvements based on better market segmentation. |
| “Non-traditional” transit modes (community-serving transit, BRT) | ○ | ◔ | ◔ | ◔ | Software limitations make this difficult at regional level. A "proxy" approach, at best, is possible. |
| Environmental justice and social equity issues | ◔ | ◒ | ◒ | ● | Each option provides capabilities of tracking household and demographic data on trip makers to trips. |
| **Capture important “secondary effects” of transportation projects and growth:** | | | | | |
| Effects of transportation projects on land development | ○ | ◒ | ◒ | ● | Land use/travel model integration necessary. |
| “Induced” or “suppressed” demand | ◔ | ◒ | ◒ | ● | Time-of-travel choice, chaining of activities, land use dynamics needed to perform better. |
| Peak spreading or changing times of travel | ○ | ◒ | ◒ | ● | Time-of-travel choice or duration of activity model needed to perform better than current tools. |
| The secondary effects of the built environment (i.e. urban design, density, mixed use, etc.) on travel behavior should be included in the model. | ◔ | ◒ | ◒ | ● | Micro-simulation of land use and travel provides greatest capability (enhanced, advanced option). |
| The secondary effects of the transportation projects (i.e. roadway width, presence/absence of sidewalks, inclusion/exclusion of bike lanes, etc.) on travel behavior should be included in the model. | ○ | ◔ | ◔ | ◒ | Highly detailed network data and assignment needed to make more improvement. |
| **Significant Upcoming Model Applications** | ◒ | ◒ | ◒ | ● | |
| **Upcoming model applications using SACOG forecasting tools:** | | | | | |
| “New Starts” applications for LRT | ◔ | ◒ | ◒ | ● | All options include ground access to airport; advanced land use models can do a better job of land uses complementary to LRT service |
| MTP in 2005 | ◔ | ◒ | ◒ | ● | More advanced models are much more policy sensitive and faciliate a wider range of policy options in the MTP |
| SIP in 2003 | ◔ | ◒ | ◒ | ● | All options provide more time periods, with more detailed information on trips. |
| AQ conformity | ● | ● | ● | ● | All options will meet requirements (as do current tools). |
| **Local agencies/other model users applications:** | | | | | |
| EIR’s/EIS’s | ◒ | ◒ | ● | ● | All options capture joint effects of land use and travel changes. Tools/protocols for local users needed. |
| Traffic impact studies | ◒ | ◒ | ◒ | ◒ | Fine geographic (and network) detail provides better accuracy in representing projects. Tools/protocols for local users needed. |
| Specific/General Plans | ◒ | ◒ | ◒ | ● | Full effects of land use and travel changes captured, including mixed use. Tools/protocols for local users needed. |
| **Flexible** | ◒ | ◒ | ◒ | ◒ | |
| Usable or adaptable for local and sub-regional studies by other agencies | ◒ | ◒ | ◒ | ◒ | Finer geographic detail, "trip diary" output provide flexibility; model complexity makes it potentially more difficult to use. |
| Fine level of detail, to allow for others to tailor it to their needs. | ◔ | ◔ | ◒ | ◒ | Enhanced, advanced models contain more detail on zones and networks. |
| Developed and maintained in a standardized, portable format. | ◒ | ◒ | ◒ | ◒ | Data in standard format or GIS makes it more portable; custom software may reduce portability and standardization. |

● Fully addresses user need
◒ Partially addresses user need
◔ Minimally addresses user need
○ Does not address user need

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# User Needs Evaluation of Forecasting Options (cont.)

| User Need | Current Tools | Forecast Model Options: New Standard | Enhanced | Advanced | Comments |
|---|---|---|---|---|---|
| **Transparent** | ◔ | ◒ | ◒ | ◒ | |
| Key input assumptions should be explicit, and subject to public review | ◔ | ◒ | ◒ | ◒ | Activity/tour approach more intuitive, but models themselves more complex and potentially harder to understand. |
| **Comprehensive** | ○ | ◔ | ◒ | ◒ | |
| Inter-regional and even international travel should be represented in some form | ◔ | ◒ | ◒ | ◒ | Basic, enhanced provide exogenous inter-regional demand; advanced provides inter-regional demand model. |
| Special emphasis on inter-regional rail. | ○ | ◔ | ◔ | ◒ | As above |
| Special emphasis on travel between region and the Bay Area. | ○ | ◒ | ◒ | ◒ | As above. Limited network expansion to Solano County assumed. |
| Commercial vehicle and truck travel should be represented in some form. | ◔ | ◔ | ◒ | ◒ | Basic option as simple trip-based truck model. Enhanced, advanced include more dynamic input/output approach. |
| Airport ground access should be included in the model. | ○ | ◔ | ◒ | ◒ | Required for any airport LRT extension, usable for all options. |
| The model should include some way of representing seasonal and recreational travel. | ○ | ○ | ◔ | ◒ | More time periods and multi-day travel in the advanced model |
| Model input and forecast data should include specification of significant land development information (agricultural quality, environmentally sensitive lands, etc.) | ○ | ◔ | ◒ | ◒ | More data on land variables needed. Improved developer modules do a better job of considering the impact of local physical conditions |
| **Credible** | ◒ | ◒ | ◒ | ◒ | |
| Validation—the model should predict known conditions | ◒ | ◒ | ◒ | ◒ | More advanced options have more flexibility, but are also more difficult to validate because of data limitations |
| Sensitivity tests—the model should provide reasonable results when key variables are changed | ◒ | ◒ | ◒ | ● | More advanced options have more ways to respond to policy, and their mechanisms for responding to policy are more behavioural and believable |
| Are the input assumptions (fuel costs, forecasts, etc.) reasonable? Do they cross-check with other known sources? | ◒ | ◒ | ◒ | ◒ | More opportunity for inputing the "actual" numbers (rather than some composite surrogate) in the advanced models |
| Are known trends in demographics (aging, income, etc) reflected in forecasts? | ◔ | ◔ | ◒ | ◒ | All options provide greater detail in demographic forecasts, especially in household structure. |
| Key model output measures should be reasonable and understandable by non-technical persons | ◔ | ◒ | ◒ | ◒ | More detailed output for all options, but understandability depends on user familiarity and presentation. |
| **Behaviorally Accurate** | ◔ | ◒ | ◒ | ● | |
| Model should correctly represent travel behavior by individuals, and include the major factors influencing travel behavior. | ◔ | ◒ | ◒ | ● | More advanced options provide more sophistication and greater congruence with actual behavior and choices. |
| Model input data should include key variables affecting travel behavior (income, number of workers, number of autos, school age children, retired, etc.) | ◔ | ◒ | ◒ | ● | All options require more detailed input data, provide more detailed forecast data. |
| Non-motorized modes (bike, walk) and "substitutes for travel" (work-at-home, e-commercer, telecommute) should be represented in the model | ◔ | ◒ | ◒ | ● | Walk and bike included in basic option. Non-travel substitutes included in enhanced, advanced options. |
| Forecast data for the model should be market-based, and represent developer and firm behavior, in addition to general plans and public land use policy. | ◔ | ◔ | ◒ | ● | Enhanced, advanced options include developer behaviour models. |
| Model should represent travel as it actually occurs (i.e. mixing modes and purposes, occurring at different times of day, etc.) | ◔ | ◒ | ◒ | ● | All options based on tours or activities. More advanced options factor in both personal and household dynamics. |
| **Scenario Testing** | ◔ | ◒ | ◒ | ◒ | |
| Forecasting tools should be able to generate and test multiple scenarios built around key variables and assumptions | ◔ | ◒ | ◒ | ◒ | Key variables and assumptions are "levers" built directly into the advanced model, so they are much easier to change than in a less comprehensive framework' |
| Forecasting tools should take account of general trends (e.g. e-commerce, telecommuting, etc.) in reasonable ways | ○ | ◔ | ◔ | ◒ | Tricky in any model, but at least in the more advanced models we have more places to "fiddle" |

● Fully addresses user need
◒ Partially addresses user need
◔ Minimally addresses user need
○ Does not address user need

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# Appendix C: Resource Evaluation of Model Options

# Resource Evaluation of Forecasting Options

| | Forecast Model Options | | |
|---|---|---|---|
| **Resource** | **New Standard** | **Enhanced** | **Advanced** |
| **Software Development/Acquisition** | | | |
| Land Use Model | Some commercial software needed for land use/travel integration. Modification of SACOG's UPLAN for data preparation, management. | Modify software developed for ODOT statewide model. | Major enhancement of software developed for ODOT statewide model, plus develop software for some new elements. |
| Travel Model | Modify existing software (Portland, SF). Acquire commercial software for assignment. | Modify existing software (Portland, SF). Acquire commercial network microsimulation software. | Major enhancement of existing software (Portland, SF), and develop some new elements. Acquire commercial network microsimulation software. |
| Other | Link with Arcview needed | Link with arcview [4] | Link with arcview [4] |
| **Data Requirements** | | | |
| Land Use Model | Floorspace data by sector and land use zones needed. | Floorspace data same as "New Standard" but to smaller zones. Commodity price data needed. Panel survey for household change. | Need floorspace data for smaller zones (or parcels), plus commodity price data. Also, developer behavior survey |
| Travel Model | Airport ground access survey needed. | Same as "New Standard", but possibly finer zones. | Same as "Enhanced", but also nneed data on other issues- vehicle type choice and use, weekend travel, interregional travel. Additional stated-preference surveys. |
| Goods Movement | Truck cordon count, basic I/O table needed. | Same as "New Standard", but more detailed I/O data needed. | Same as enhanced, plus a shipper survey needed. |
| Other | | | |
| **Staffing Requirements** | | | |
| SACOG | Some new staff required. | Same as "New Standard", but staff will need training. | Same as "Enhanced", but staff will need training. |
| Other Model Users | Minimal orientation, training. | Minimal orientation, training. | Minimal orientation, training. |
| **Development Cost** | | | |
| Land Use Model | Medium | High | High, with some uncertainties |
| Travel Model | Medium | Medium | High, with some uncertainties |
| Other | Low | Low | Medim |
| **Development Timeframe** | **1-2 yrs** | **3-4 yrs** | **>4 yrs** |
| Land Use Model | Short | Middle | Uncertain |
| Travel Model | Short | Middle | Long |