*Preliminary Draft for Review*

# Proposed Design of a Second Generation Land Use-Transport Model for Oregon

## Transportation and Land Use Model Integration Program
## Task 1C

Prepared for

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This document describes the proposed architecture of the second generation land use-transport models for the Oregon DOT. The models and their supporting data are described at a fairly abstract level. The goal in producing this document is to outline for the project team and Peer Review Panel the overall modeling approach. This will facilitate discussions about the general framework, about which much discussion and constructive debate is anticipated. Once the group has reached agreement on the overall design of the modeling framework, the consultant team will turn to the production of detailed model specifications for the model, its supporting data, and the application framework in which it will be implemented.

The document describes the background of Oregon's Transportation and Land Use Model Integration Program (TLUMIP), focusing on the work completed to date. The project team has met several times to collaborate on the design of the second generation model. Some of the products of those sessions are presented. Finally, a high level model design is presented in outline format.

## 1. Background of the Program

In our proposal for the first generation model development work, submitted in March, 1996, we advanced the idea of a scalable and consistent framework for conducting land use and transport modeling for Oregon. We envisioned a disaggregate approach based upon discrete choice modeling concepts and random utility theory. The model was to be based in a geographic information system (GIS). It also was to be capable of handling varying spatial resolutions and extents, from parcel-level metropolitan models to aggregate and coarse statewide models of intercity movements. Our vision was an ambitious and heady one, and it remained largely intact until the first peer review panel meeting. What has since emerged has been shaped by the concerns and ideas shared in that meeting as well as the collective experience that the study team — the consultants, ODOT staff, the Peer Review Panel, and the Modeling Steering Group — have gained since.

Several key decisions emerged from that first peer review meeting. It was acknowledged that the proposed approach was theoretically pleasing and followed the advancement of large scale urban models towards a dynamic disequilibrium framework. But the proposed approach was also judged to carry significant risks for the Oregon DOT, as much of it was unproven. Several panelists assailed the project schedule, declaring it too short to complete the work outlined. In the end it was decided that we would pursue separate approaches for the metropolitan and statewide models. It was decided that the statewide model would be implemented within a proven existing modeling package, while the metropolitan model would represent original work as originally proposed. Several factors influenced these decisions. It was felt that the current crop of integrated land use-transport models could not handle the spatial resolution required by a metropolitan model, whereas experience abroad proved their success in regional modeling. It was also hoped that pursuing two different modeling approaches would double our experience base, allowing us to design a second generation model that incorporated the best of both approaches.

Our experience to date with both approaches has been mixed. A detailed critique of the first generation models has been prepared separately that addresses many of these issues. It is clear that the models are at least partially functional, capable of addressing the key policy and investment issues deemed important during the second TLUMIP Peer Review Panel meeting (December, 1996), summarized in Table 1. The prototype metropolitan model (UrbanSim) was successfully developed from scratch, and has undergone cross-sectional calibration in the Eugene-Springfield

*Table 1: Major analysis issues identified at the first Peer Review Panel Meeting*

| Issue | Spatial scale of relevance | | |
|---|---|---|---|
| | Statewide | Substate | Urban |
| Effect of land supply on land use and location decisions | ● | ● | ● |
| Effect of congestion on land use and location decisions | ❍ | ● | ● |
| Cumulative effects of retail location choice | | ❍ | ● |
| Effect of large commercial development on UGB periphery | ❍ | ● | ● |
| Effect of land supply on travel behavior | ● | ● | ● |
| Effect of highway capacity increases on travel behavior | ● | ● | ● |
| Effect of network connectivity on travel behavior | | ❍ | ● |
| Effect of parking supply on travel behavior | | ❍ | ● |
| Effect of urban form on mode choice | | ❍ | ● |
| Effect of rail investment on highway use | ● | ❍ | |
| Effect of changes in the demographic composition of Oregon | ● | ● | ❍ |

area. It is presently undergoing testing to determine its dynamic behavior using data from 1980 to 1995. The statewide model has likewise been successfully implemented in TRANUS, an integrated land use-transport modeling framework developed by De la Barra (1989, 1996). Our efforts to implement it at such a large scale have necessitated many changes to the software, some of which have only recently been completed. Both prototypes are operational and can be used for evaluation purposes. The statewide model is presently being used in a study of the I-5 corridor.

Several broad conclusions can be drawn from our first generation modeling work. Neither approach has proven superior to the other; each possesses unique and attractive qualities and features. Nor has either approach proven totally satisfying. Applying TRANUS in a statewide context has stretched both the software and its underlying theoretical framework to its absolute limit, but the resulting model is still too geographically coarse to be useful for many studies. Other shortcomings exist as well. The metropolitan model, operating at the land parcel level, more than overcomes the geographical scale limitations of the statewide model. However, the resulting data requirements are onerous and expensive to collect, and the business location model is not as robust as the household location model. Moreover, it has become abundantly clear that the TLUMIP program cannot financially sustain two separate model development streams, irrespective of the perceived value of such.

## 2. Second Generation Model Design Concepts

Against this backdrop, we began work on the second consultant contract (hereafter referred to as TLUMIP2). Based on our experience in the first contract, we proposed to consolidate further model development work into a single flexible framework. Several design concepts were outlined in the consultant proposal:

- An overall design heavily influenced by the original model design (a disaggregate approach based upon discrete choice modeling and random utility theory)

- Maintenance of consistency between the location choice and travel destination choice models
- A nested or hierarchical representation of economic activities and land use
- The ability to construct and implement synthetic models to substitute for behavioral ones
- The ability to apply the model in either an aggregate or disaggregate mode (dictated by scale and data dependencies), with the ability to accommodate varying qualities and extents of geographic coverages
- The use of a grid-based modeling backplane
- A single transportation network representation
- Expansion of the model to include rail passenger and freight modes of transport
- Development of the modeling platform using object-oriented programming using the Java language, with the resulting products placed in the public domain using the GNU general public license
- Inclusion of robust facilities for data visualization and scenario manipulation and comparison

Most of these concepts were proposed in the consultant proposal for the first contract, and have been either implemented within UrbanSim or realized through the use of TRANUS. Other concepts, such as those relating to grid-based model and synthetic models, have emerged as a result of our subsequent experiences.

An important first step in the second generation model design has been a critical review of the first generation models. It sought to condense the experience gained to date into a single document that could inform the oversight committees and advise the project team. We also embarked upon a test of the dynamic behavior of the UrbanSim model, an effort that has included attempts to calibrate the time series component of the model. Both of these provided important direction in the design of the second generation models.

Two brainstorming sessions have been held to facilitate the model design. These have been attended by the principal investigators from the consulting team and the ODOT project manager. Other team members attended the first session and made important contributions as well. The group reviewed the progress to date and the TLUMIP2 consultant proposal, and developed a goal statement for the TLUMIP2 work:

> Develop, test, and implement a coherent, robust, rational, and integrated model of land use, transport, economic, and environmental interactions, within the available budget and schedule constraints.

During the first session we identified eleven key design criteria which could shape model development. Different model designs could emerge depending on how much emphasis the designers placed on these criteria. Making them explicit required the group to acknowledge and rank them, and to remain cognizant of them during discussions about the second generation model. These concepts included:

- Behavioral fidelity
- Behavioral resolution: The level of representation can be fully disaggregate or aggregate

- Issue relevance: Is the modeling system useful for evaluating the type and extent of issues facing the users (principally ODOT staff, but potentially all transport planners in Oregon)?
- Policy responsiveness
- Spatial resolution
- Modularity and flexibility: How easily can model components be synthesized, tested, and replaced without disturbing the rest of the model?
- Data requirements: The level of data required and the cost of its collection and maintenance
- Calibration effort: How much work would be required to calibrate such a model?
- Integration with other models: The ability for the model to seamlessly integrate with other models used by the Department, especially several models used for evaluation (e.g., STEAM, HPMS, etc.)
- Scalability: The ability to use easily apply the model at varying levels of geographical and behavioral resolution

The group ranked these criteria and discussed the degree of concensus on them. Each person was asked to allocate 100 points to each of the criteria; those judged more important received more points than those less important. The individual and composite rankings are shown in Tables 2 and 3. Individual scores were tallied, and a composite score computed. Each person's deviation from the group score was the sum of the absolute differences (by criteria) of the individual score from the group average. This is shown in Table 2, with the columns sorted in order of increasing deviation from the group average. This presumes that the group average represents the ideal outcome. An alternative intepretation might be that the client's needs and expectations are paramount, and that the deviations from his score might be illuminating. This outcome is shown in Table 3.

A few generalizations can be gleaned from reviewing the rankings. The range of scores for most of the criteria was wide, almost always in the range of 10 to 20 points. The sole exception was for behavioral resolution, where the range was 5 points. The range was the largest (20 points) for issue relevance, policy responsiveness, and modularity/flexibility. These three criteria comprised two-thirds of the points assigned by Carl Batten, Pat Costinett, and Doug Hunt. The others assigned it between a third and one half of their points. One might interpret this finding by concluding that the useability of the finished model was paramount; all other concerns were subordinated to them. Those who assigned the lowest score of these three criteria (Bill Davidson, Rick Donnelly, and Bill Upton, each with 35 points) perhaps expressed their pragmatic concerns: the most pleasing of models would still be failures if they could not meet the remaining criteria (many of which revolve around the resources and schedule available). Interestingly, Davidson, Donnelly, and Upton assigned two to three times more points to criteria related to development issues (data requirements and calibration effort) than did Batten, Costinett, and Hunt. Keith Lawton and Paul Waddell consistently scored between these two subgroups.

Based on the average scores, the three most important criteria were policy responsiveness, issue relevance, and modularity/flexibility. This was due to the effect of three persons (Batten, Costinett, and Hunt) placing most of their points in these categories, while the others spread them more evenly across the range of criteria. The somewhat related issues of spatial resolution and

*Table 2: Ranked deviation from the average score*

| Criteria | Lawton | Upton | Batten | Davidson | Costinett | Waddell | Donnelly | Hunt | Total | Mean |
|---|---|---|---|---|---|---|---|---|---|---|
| Behavioral fidelity | 5 | 10 | 10 | 15 | 10 | 15 | 5 | 10 | 80 | 10 |
| Behavioral resolution | 5 | 5 | 5 | 10 | 10 | 10 | 5 | 5 | 55 | 6.875 |
| Issue relevance | 15 | 10 | 20 | 15 | 25 | 10 | 10 | 30 | 135 | 16.875 |
| Policy responsiveness | 20 | 15 | 20 | 15 | 25 | 15 | 10 | 30 | 150 | 18.75 |
| Spatial resolution | 5 | 10 | 5 | 10 | 0 | 10 | 5 | 3 | 48 | 6 |
| Modularity/flexibility | 10 | 10 | 25 | 5 | 15 | 15 | 15 | 7 | 102 | 12.75 |
| Data requirements | 15 | 15 | 10 | 10 | 7 | 5 | 20 | 5 | 87 | 10.875 |
| Calibration effort | 15 | 15 | 5 | 15 | 8 | 5 | 10 | 5 | 78 | 9.75 |
| Integration with other models | 10 | 5 | 0 | 5 | 0 | 10 | 10 | 5 | 45 | 5.625 |
| Scalability | 0 | 5 | 0 | 0 | 0 | 5 | 10 | 0 | 20 | 2.5 |
| Deviation | 30 | 31.75 | 33.25 | 34.75 | 39.5 | 42.5 | 47 | 48.75 | | |

*Table 3: Ranked deviation from the client's score*

| Criteria | Upton | Davidson | Lawton | Donnelly | Waddell | Batten | Costinett | Hunt | Total | Average |
|---|---|---|---|---|---|---|---|---|---|---|
| Behavioral fidelity | 10 | 15 | 5 | 5 | 15 | 10 | 10 | 10 | 80 | 10 |
| Behavioral resolution | 5 | 10 | 5 | 5 | 10 | 5 | 10 | 5 | 55 | 6.875 |
| Issue relevance | 10 | 15 | 15 | 10 | 10 | 20 | 25 | 30 | 135 | 16.875 |
| Policy responsiveness | 15 | 15 | 20 | 10 | 15 | 20 | 25 | 30 | 150 | 18.75 |
| Spatial resolution | 10 | 10 | 5 | 5 | 10 | 5 | 0 | 3 | 48 | 6 |
| Modularity/flexibility | 10 | 5 | 10 | 15 | 15 | 25 | 15 | 7 | 102 | 12.75 |
| Data requirements | 15 | 10 | 15 | 20 | 5 | 10 | 7 | 5 | 87 | 10.875 |
| Calibration effort | 15 | 15 | 15 | 10 | 5 | 5 | 8 | 5 | 78 | 9.75 |
| Integration with other models | 5 | 5 | 10 | 10 | 10 | 0 | 0 | 5 | 45 | 5.625 |
| Scalability | 5 | 0 | 0 | 10 | 5 | 0 | 0 | 0 | 20 | 2.5 |
| Deviation | 0 | 30 | 30 | 40 | 40 | 60 | 70 | 70 | | |

scalability scored the lowest, with 6 and 2.5 average points respectively. This was surprising, as a single framework was advanced as a practical necessity in the consultant proposal. It is interesting to again consider the client's perspective; he ranked policy responsiveness, data requirements, and calibration as his three most important criteria. One might argue that these findings illustrate a lack of concensus among the project team members. Our interpretation was not as glum; we attributed the variation to differences in backgrounds and roles rather than insurmountable philosophical differences. In any case, we used what we learned in this exercise to help decide between alternative modeling approaches.

During this time frame we also developed a five year TLUMIP plan. This was partially motivated by our collective realization that we could not accomplish all that we wanted to within the second generation contract. By this time we had completed our first brainstorming session and postulated that we would not be able to achieve some of the desired concepts described above within the TLUMIP2 contract. Several factors influenced our thoughts on this, from the risk involved to data limitations to schedule and resource constraints. Our preliminary five year plan is shown in Figure 1. Some of the notable elements include a second TLUMIP Symposium in the summer of 2000, a third consultant contract (TLUMIP3), and the design of models and data collection in TLUMIP2 that will anticipate both generations of model development. The desire to avoid a major redesign of the model between TLUMIP2 and TLUMIP3 (such as we are currently undertaking) guided us through the outline of the five year plan. Not illustrated in the plan is a goal to integrate some of the second and third generation work with Tracks E (land use modeling) and F (freight and logistics) of the USDOT's Travel Model Improvement Program (TMIP), leveraging both research and development programs in the process.

## 3. Conceptual Model Design

A generalized framework for carrying out integrated land use-transport modeling would ideally include several major behavioral components:

- Time and space,
- Transportation services and supply (networks),
- Model-wide economic activity levels,
- Model-wide demographic levels,
- Spatial distribution of economic activities,
- Spatial distribution of demographics,
- Development and alteration of space,
- Personal travel / household travel,
- Goods and services shipments,
- Business travel,
- Visitor travel, and
- Trips with at least one end external.

Each of these major components are presented in outline form in the sections that follow. The information flows among these model components are shown in Figure 2.

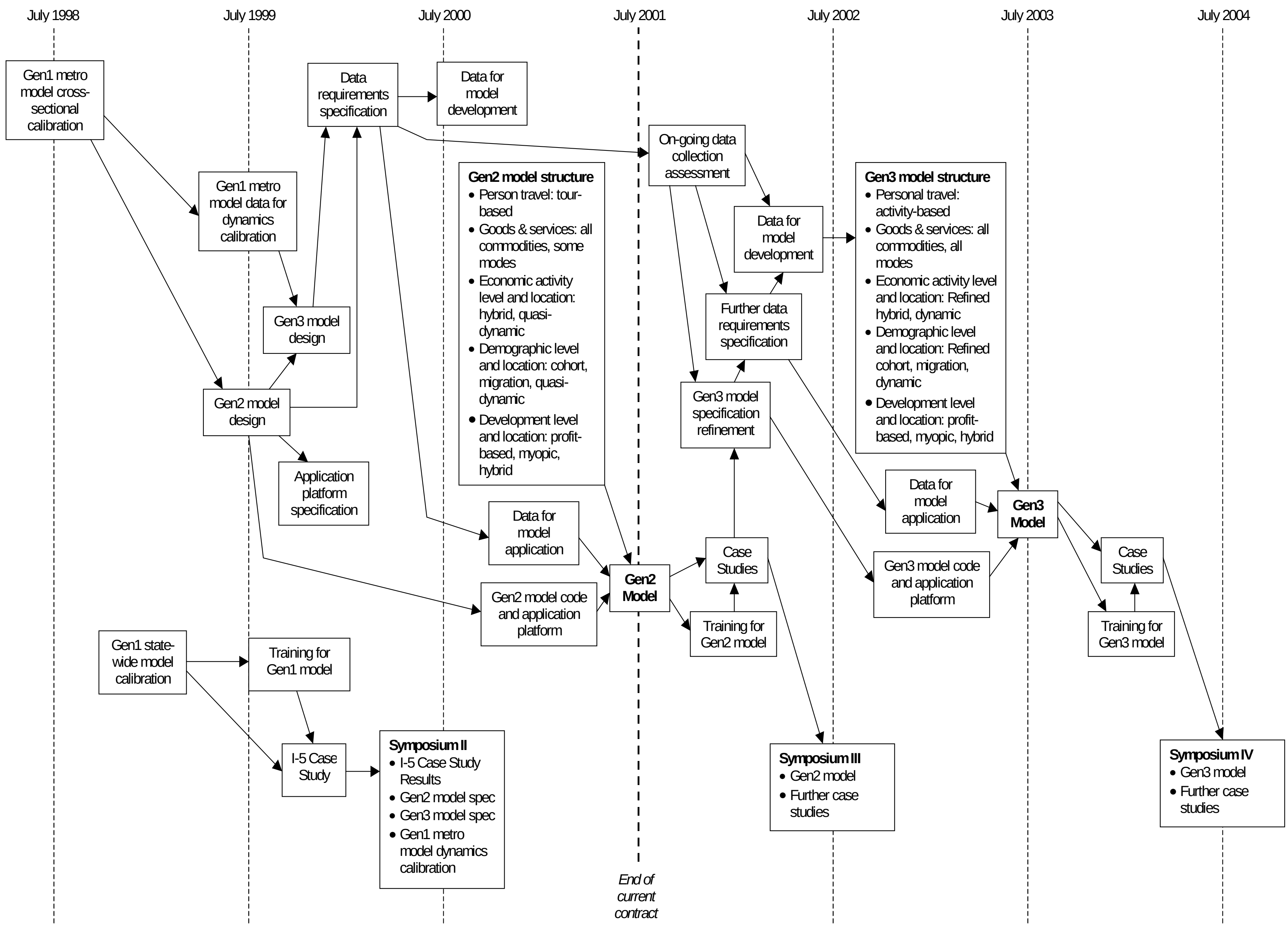


*Figure 1: TLUMIP five-year plan*

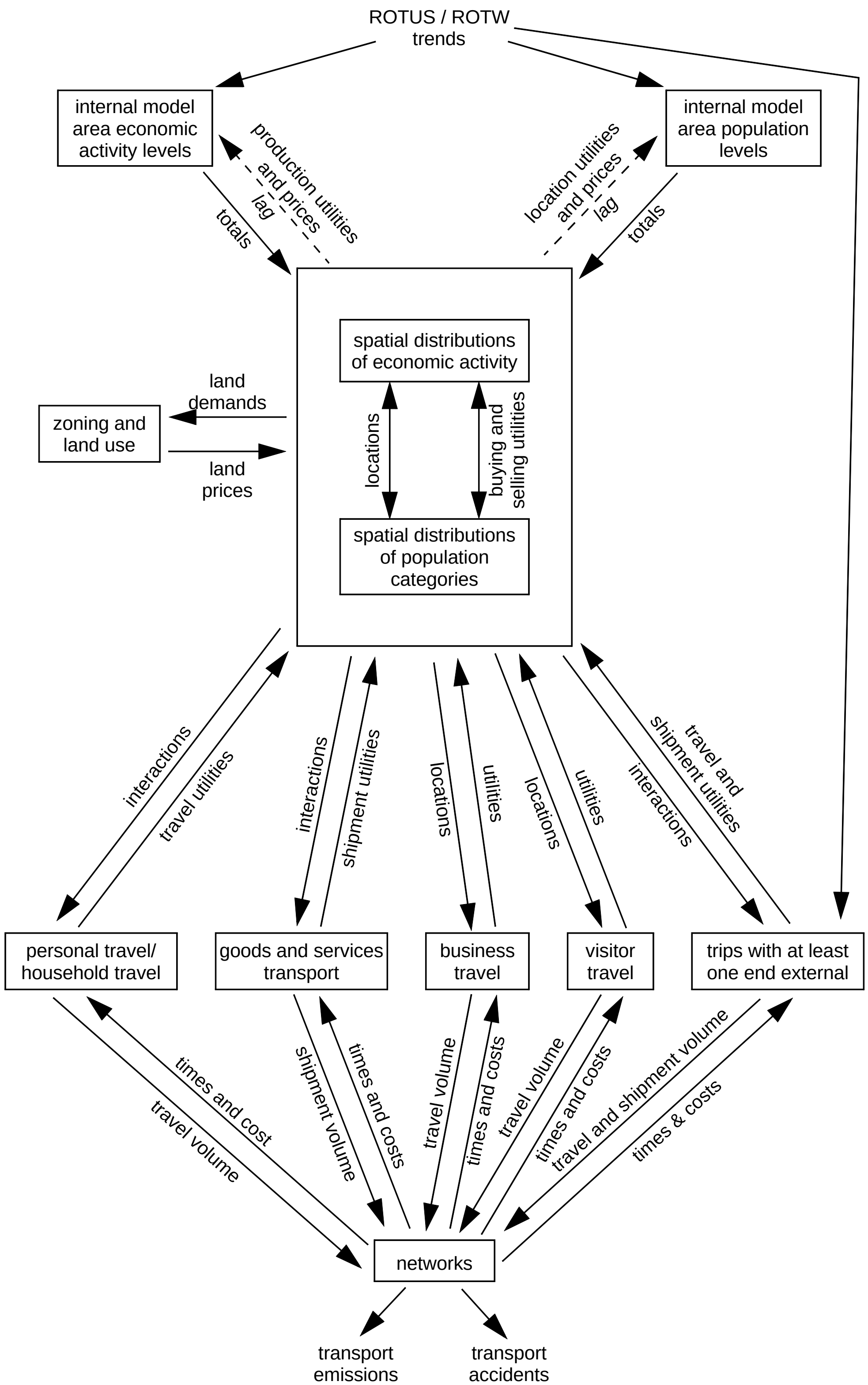


*Figure 2: Model components and their interactions*

## 4. Time and Space

4.1 The geographic area covered by the model includes more than just Oregon. All of Oregon and strips of land just beyond the borders of Oregon are represented at the greatest level of detail using 'internal' zones. Beyond this area, the rest of the United States and beyond to the rest of the World are represented at increasingly aggregate levels with increasing distance from Oregon using larger and larger 'external' zones.

4.2 The area covered by the internal zones, called the 'internal model area', includes:
- All of Oregon;
- A strip of Washington about 50 miles wide against the border with Oregon that includes Vancouver in the west and Tri-Cities in the east;
- A strip of Idaho about 50 miles wide against the border with Oregon that includes Boise; and
- A strip of California about 50 miles wide against the border with Oregon.

4.3 The internal zones:
- Act as locations of space, production, consumption and exchange;
- Are largely based on census tracts;
- Nest into counties;
- Inside Oregon contain grid cells; and outside Oregon do not contain grid cells;
- Are consistent with MPO model zones for MPO areas, including Portland in particular; and
- Total approximately 8,000 in number.

4.4 The external zones are consistent with the regions represented in the inter-regional social accounting matrix used to establish model-wide production totals.

4.5 The grid cells:
- Act as locations for allocating zonal totals into spatial patterns (done following known distributions) as post-processor after model simulations;
- Form a rigid 100 $m^2$ grid in the areas of dense activity that is relaxed to 1 $km^2$ grid in areas of sparse activity;
- Nest into internal zones;
- Are included only in zones in Oregon; and
- Total approximately 2.5 million in number.

4.6 The link tributary areas:
- Are collections of grid cells whose transport demand is loaded to transport network links;
- Are based on relevant transport networks;
- Nest into internal zones, which may require that a given link has more than one tributary area; and
- Total approximately somewhat more than the number of road links.

4.7 The model establishes a series of short-run equilibrium points at 1-year intervals to provide a quasi-dynamic representation of the evolution of the system through time.

4.8 In each 1-year interval between short-run equilibrium points the model-wide economic activity and demographics are updated to represent the point in time at the end of the year according to conditions established for the point in time at the start of the year. Then the short-run equilibrium for the point in time at the end of the year is determined with a redistribution of the updated economic activity and demographic totals among the internal zones and a redetermination of the resulting transportation supply and demand, using various lag terms to incorporate inertia effects as appropriate. When this short-run equilibrium has been established, then the next 1-year interval is considered.

4.9 The sequence of use among the model components and the flows of information among them simulating changes through time are indicated in Figure 3.

## 5. Transportation services and supply (networks)

5.1 The road network:
- Includes all roads down to local in rural (non-MPO) areas;
- Matches MPO model networks for MPO areas; and
- Is skeletal for external, becoming sparser with increasing distance from model area.

5.2 The urban passenger bus services network:
- Is synthetic for internal, providing implicit service representation as alternative ‘in-vehicle’ state on specific links, drawing from MPO models; and
- Has link tributary areas for urban bus services defined using collections of grid cells based on walking distances to stops.

5.3 The urban passenger rail services network:
- Is explicit for internal, draw from MPO models; and
- Has link tributary areas for walking access to urban passenger rail services defined using collections of grid cells based on walking distances to stations.

5.4 The intercity passenger bus services network:
- Is explicit for internal; and
- Is synthetic for external, on skeletal road network as basis.

5.5 The intercity passenger rail services network:
- Is explicit for internal; and
- Is increasingly synthetic for external, becoming increasingly synthetic with increasing distance from model area.

5.6 The goods and services rail services network:
- Is synthetic for internal, using distance-based cost structure on physical rails; and
- Is skeletal for external, becoming sparser with increasing distance from model area

5.7 The goods and services road services network:
- Does not distinguish between own-account and for-hire services; and
- Has vehicles permitted on links consistent with truck route regulations.

5.8 The water network is synthetic, with a distance-based cost structure on physical waterways

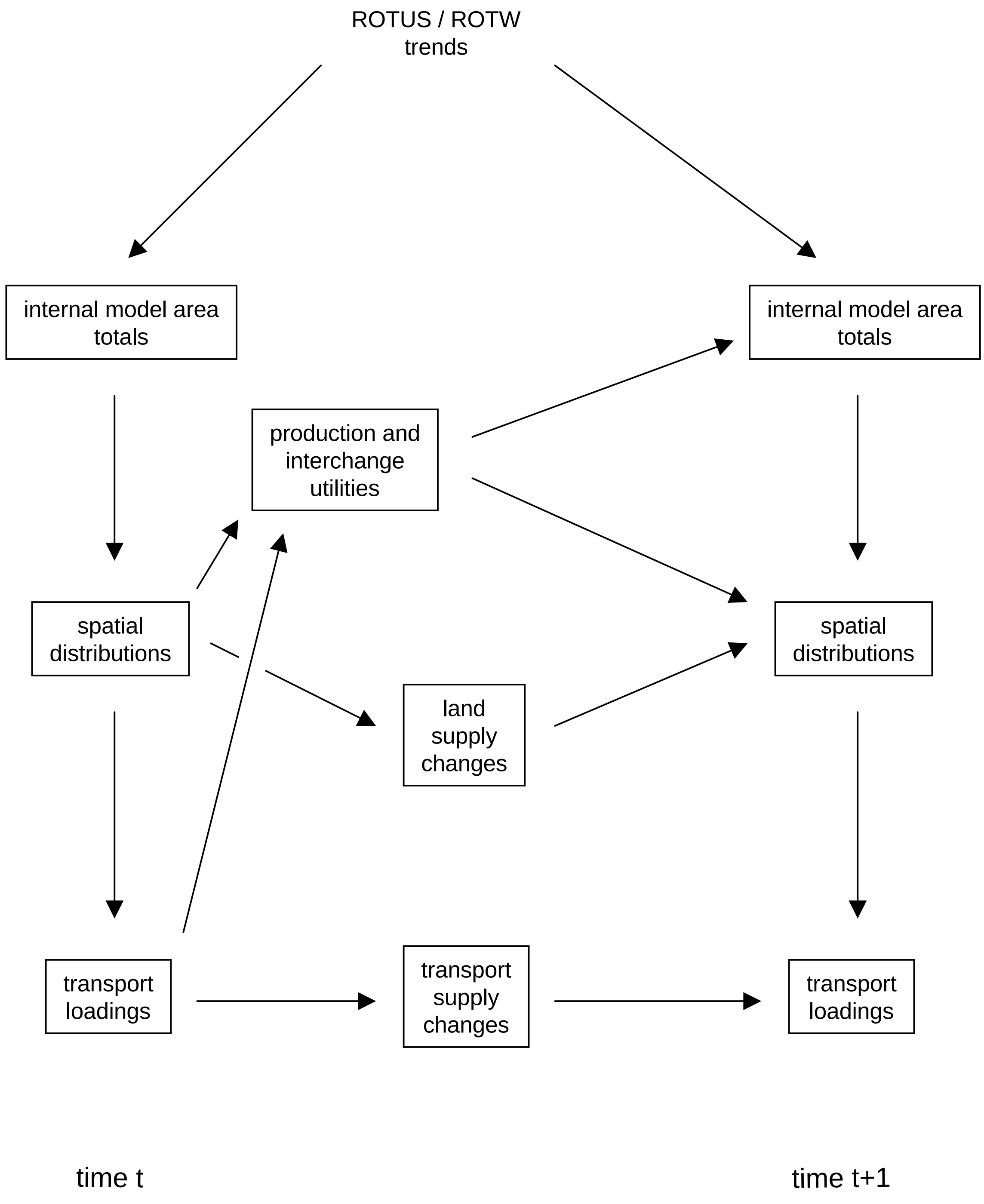


*Figure 3: Representation of temporal dynamics with model components*

5.9 The passenger air services use the airports as entry and exit points for interchanges with one end external.

5.10 The goods and services air services use the airports as entry and exit points for interchanges with one end external

## 6. Model-wide economic activity levels

6.1 The quantity of economic activity in the internal model area is represented in terms of the value of production in each of the industrial sectors listed in Table 4. The transfer of goods and services among these sectors is represented in terms of the value of commodity flow in each of the goods and services commodity categories listed in Appendix A.

*Table 4: Industry categories*

| Industry code | Industry description | SIC Codes | Principal labor codes |
|---|---|---|---|
| 1 | Agriculture in office space | | 49, 50, 52 |
| 2 | Agriculture in agricultural space | | 54 |
| 3 | Light industry in office space | | 49, 50, 52 |
| 4 | Light industry in light industrial space | | 53, 55, 60 |
| 5 | Heavy industry in office space | | 49, 50, 52 |
| 6 | Heavy industry in heavy industrial space | | 53, 55, 60 |
| 7 | Wholesale in office space | | 49, 50, 52 |
| 8 | Wholesale in warehouse space | | 55, 56, 60 |
| 9 | Retail in office space | | 49, 50, 52 |
| 10 | Retail in retail space | | 57, 60 |
| 11 | Hotel and accommodation | | all |
| 12 | Health care in office space | | 49, 50, 52 |
| 13 | Health care in hospital space | | 58 |
| 14 | Transporation handling in office space | | 49, 50, 52 |
| 15 | Transporation handling in depot space | | 55, 56, 60 |
| 16 | Other services in office space | | 49, 50, 52 |
| 17 | Other services in light industrial space | | 53, 55, 56, 60 |
| 18 | Other services in retail space | | 57 |
| 19 | Grade school education in office space | | 49, 50, 52 |
| 20 | Grade school education in grade schools | | 51 |
| 21 | Post-secondary education in office space | | 49, 50, 52 |
| 22 | Post-secondary education in institutional space | | 53, 55, 56, 59, 60 |
| 23 | Government in office space | | 49, 50, 52 |
| 24 | Government in government support space | | 53, 55, 56, 60 |

6.2 An inter-regional social accounting matrix, showing both ‘make’ (industry to commodity) and ‘use’ (commodity to industry) relationships, is used to simulate production totals for each industrial category for the internal model area and the total flows of commodities between other regions and the internal model area.

6.3 The internal model area is one region, and the results from the inter-regional social accounting matrix for this region provides the totals for the internal model area. The other regions cover the rest of North America and generally respect freeway tributary areas as follows:
- The rest of western Washington State not included in the internal zones; feeding from the north, I5 in particular;
- British Columbia; feeding from the north, I5 in particular;
- The rest of eastern Washington State not included in the internal zones; feeding from the northeast;
- The rest of northern Idaho not included in the internal zones; feeding from the northeast;
- Alberta; feeding from the northeast;
- The rest of southern Idaho not included in the internal zones; feeding from the east, I84 in particular;
- The Eastern US and Midwestern US; feeding from east, I84 in particular;
- Canada east of Alberta; feeding from east, I84 in particular;
- California; feeding from south, I5 in particular;
- Southwestern US and Southern US; feeding from south, I5 in particular;
- Mexico; feeding from south, I5 in particular; and
- The rest of the world beyond North America; feeding from ports and airports.

6.4 In general, the internal model area could be covered with several regions rather than just one, and the results from the inter-regional social accounting matrix for this entire set of regions used at the totals for the internal model area. This would allow different influences acting in the different regions to be represented separately.

6.5 The inter-regional social accounting matrix used to determine production totals for the regions is modified to allow some shifting of production to the model area region from all other regions, which occurs as a function of the production utilities in the internal zones relative to the external zones. These utilities indicate the overall attractiveness of production activities in the model area region relative to other regions. They are defined in the section concerning the allocation of production totals among internal zones, and are determined endogenously as part of the short-run equilibrium for the internal zones and specified exogenously for the other regions.

## 7. Model-wide demographic levels

7.1 The total number of people in the internal model area in each of a series of categories is determined, with the categories defined according to:
- Household type: based on number of household members, household income and household auto ownership together;
- Age category; and
- Occupation category.

7.2 The age categories are under 5 years, 5 to 15 years inclusive, 16 to 22 years inclusive, 23 to 64 years inclusive, 65 to 74 years inclusive; and over 75 years.

7.3 The occupation categories are broad classes consistent with standard occupation classifications (SOCs).

7.4 Year-by-year changes in the numbers of people in the various person categories are determined taking into account transitions in the current population and net migration.

7.5 Net migration (the combination of both in and out migration) for each person category is determined first as a function of production utilities for various population categories in the internal zones relative to the other regions and by employment to population ratios in the internal zones relative to the other regions.

7.6 The changes in the numbers of people in each person category are determined by accounting for a variety of shifts among categories. In particular:

- Shifts among age categories are based on cohort survival for changes in the current population;
- Shifts among household income categories and occupation categories are based on changes in average labor prices and the labor force participation rate in relevant occupation categories in the exchange zones in the internal model area;
- Shifts among household size categories are based on fixed transition rates for changes in current population household size categories, together with some further influences from changes in income and age distributions; and
- Shifts among household auto ownership categories, representing changes in auto ownership levels are influenced by changes in income, overall auto accessibilities, auto purchase prices and related auto operating costs changes and general long-term trends.

7.7 It should be noted that households are not represented explicitly as ‘behavioral units’ in the model formulation. All household-related influences are incorporated as household-type attributes of individuals. For example, it is not two-person households that demand residential space and own private vehicles; rather, it is people in two-person households that demand residential space and own private vehicles — and they do so according to the nature of people in such households because they are included in the two-person household category, thereby facilitating the representation of such behavior in the model.

7.8 The implied numbers of households in various categories in zones can be determined by grouping together the numbers of people in relevant categories. To the extent that it is deemed important to respect specific area-wide forecasts for the number of households in different categories, the corresponding numbers of people in different categories can be imposed at both the area-wide level and at the zone-specific level as part of the allocation to zones.

## 8. Spatial distribution of economic activities

8.1 Production activity value totals for the internal model area are allocated to internal model zones according to the same categories used in the determination of the totals for the internal model area as listed in Table 4; and the corresponding transfers of goods and services values among these production activities in different zones are distributed according to the same commodity categories considered in the determination of the totals as listed in Appendix A.

8.2 The total production activity is allocated among internal zones using a logit formulation with production location utilities. These production location utilities include:

- A size term;
- An inertia term, which is the quantity (proportion) of production activity in the zone in the previous year;
- A set of 'buying utilities', one for each input to the production process, which is a vector of composite utilities for purchasing and transporting the inputs to the production process from the set of available exchange locations, including space in the zone; this consists of a collection of 'buying accessibilities' for the zone;
- A set of 'selling utilities', one for each output from the production process, which is a vector of composite utilities for transporting and selling outputs of the production process at the set of available exchange locations; this constitutes a collection of 'selling accessibilities' for the zone;
- A set of composite utilities for business travel, one for each category of business travel considered;
- Location-specific taxes and subsidies on the production activity in particular; and
- Zone-specific constants.

8.3 This allocation is done jointly for all production activities together with the allocation of the internal model area population totals.

8.4 A 'critical mass' threshold must be exceeded in a given zone in order for the zone to be allocated a non-zero amount of production activity. Activity quantities or changes in activity quantities can also be allocated to zones exogenously as part of any given model run.

8.5 For a given industrial sector, the composite utility of the production location utilities for the full set of zones in the internal model area (the log-sum value) provides the production utility in the internal zones for that industrial sector, which is used in the determination of totals for the internal model area.

8.6 Commodity values are transported from production location zones to exchange location zones to consumption location zones. An exchange location is a (perhaps somewhat arbitrary) point in space where goods and services are transferred from producer to consumer. It is the geographic location of the relevant market, where the exchange price is determined. It is also the point where the cost (and more generally, the disutility) of transport stops being borne by the producer and starts being borne by the consumer.

8.7 For some commodity values, the exchange location is the same as production location. For others, the exchange location is the same as the consumption location. Whereas in general it is possible to have exchange locations that are separate from both production and consumption locations (possibly determined endogenously as part of the model operations); in the Oregon model all exchange locations are either production locations or exchange locations and are exclusively one or the other for a given commodity category. In particular, the exchange location is the same as the consumption location for all primary and secondary manufacturing goods and labor; and the exchange location is the same as the production location for all services, including all wholesale and retail margins. For land — which is treated as if it were a commodity even though it is not per se — the production location, exchange location and consumption location are all the same, and land is said to be 'non-transportable'.

8.8 When the exchange location is the same as either the production or the consumption location, then the disutility of transporting commodities between such 'same locations' is zero. This translates into a zero disutility rather than the corresponding intrazonal disutility when locations are treated in terms of a system of geographic zones and such 'same locations' are 'same zones'.

8.9 The flows of commodity values produced in a given production location zone are allocated to exchange location zones using logit formulations with 'selling interchange utilities'. These selling interchange utilities include:

- A size term;
- An inertia term, which is the quantity (proportion) of flow of commodity value from the production zone to the exchange zones in the previous year;
- The exchange price in the exchange zone; and
- The (dis)utility of transporting the commodity from the production zone to the exchange zone.

8.10 For a given production location zone and commodity, the composite utility of the selling interchange utilities for the full set of exchange zones (the log-sum value) provides the selling utility for that zone and commodity, which is used in the determination of the production location utility for that zone.

8.11 The flows of commodity values to a given consumption zone are allocated to (actually allocated to be coming from) exchange location zones using logit formulations with 'buying interchange utilities'. These buying interchange utilities include:

- A size term;
- An inertia term, which is the quantity (proportion) of flow of commodity value from the exchange zone to the consumption zone in the previous year;
- The exchange price in the exchange zone; and
- The (dis)utility of transporting the commodity from the exchange zone to the consumption zone.

8.12 For a given consumption location zone and commodity, the composite utility of the buying interchange utilities for the full set of exchange zones (the log-sum value) provides the buying utility for that zone and commodity, which is used in the determination of the production location utility for that zone.

8.13 The buying demand for a given commodity in a given exchange location is the sum of all the commodity flows allocated to be coming from that location. The selling supply for a given commodity in a given exchange location is the sum of all the commodity flows allocated to be going to that location. The exchange price for a given commodity in a given exchange location is the one that equates the buying demand with the selling demand at the location. In general, with a zone system, the buying and selling demands for a commodity are matched for groups of contiguous zones, forming 'markets', resulting in an exchange price that is common to all the zones in the group forming the market. The grouping of contiguous zones is different for different commodities:

- For some commodities, each zone is its own group, resulting in a different exchange price in each zone;
- For other commodities, zones are grouped to reflect different market areas in Oregon, resulting in a different exchange price in each market area; and
- For some commodities, all the internal zones together form a single group, resulting in a single exchange price for the entire internal model area.

8.14 At each year, an iterative process is used to adjust exchange prices and recalculate the quantities and allocations of buying and selling demands until a set of exchange prices that equates buying demands with selling demands is identified for each commodity in all the groups of zones forming 'markets'. The equation for updating the price in a given market from one iteration to the next uses the ratio of the buying demand over the selling demand in that market.

8.15 In a more general formulation, there could be inertia in the price in each exchange zone, with the price adjustment starting from the previous year price.

8.16 The consumption of commodities arising with production activities in a given zone is determined using production functions. The production function for a given economic sector indicates the goods and services, including labor and land, required to produce each unit of output produced by the sector. This is, in essence, a series of technical coefficients that indicate the quantity of input commodities required per unit of output. In general, these coefficients are themselves functions of the buying utilities for the corresponding commodities in the production zones, and for certain production activities these coefficients include the ability to substitute inputs (represented using a logit formulation) and may also be consistent with utility maximization (represented using some form or analog of the Stone-Geary formulation). The precise nature of the production function for each economic sector is to be established as part of the model calibration process.

## 9. Spatial distribution of demographics

9.1 The population totals in the various population categories are allocated to internal zones jointly with the allocation of production activities, using essentially the same approach used in the allocation of production activities. This also establishes the corresponding transfers of goods and services values between the population categories and the various other production activities in different zones. In the case of population, the 'commodity' that is 'produced' is labor and its transfer from home to other production activities gives rise to commute trips. The categories of labor used are consistent with those used in the definitions of the population categories.

9.2 The total population in each population category is allocated among internal zones using a logit formulation with residential location utilities. These residential location utilities include:

- A size term;
- An inertia term, which is the quantity (proportion) of population in that category in the zone in the previous year;

- A set of 'buying utilities', one for each input to the production process, which is a vector of composite utilities for purchasing and transporting the inputs to the production process (household demands) from the set of available exchange locations, including (residential) space in the zone; this consists of a collection of 'buying and shopping accessibilities' for the zone;
- A 'selling utility', which is the composite utility for transporting and selling the output of the production process (labor) at the set of available exchange locations; this constitutes a 'workplace accessibility' for the relevant occupation for the zone;
- A set of composite utilities for travel for all purposes other than work, reflecting the chaining of trips for these other purposes and thus indicating the 'actual' rather than the 'notional' generalized costs of travel for the buying utilities;
- A vector of terms indicating the aesthetic qualities of the zone;
- A term indicating school quality for the zone;
- A vector of terms indicating the income mix in the zone;
- A vector of terms indicating the age mix in the zone;
- Location-specific taxes on residential uses in particular; and
- Zone-specific constants.

9.3 For a given population category, the composite utility of the residential location utilities for the full set of zones in the internal model area (the log-sum value) provides the production utility in the internal zones for that population category, which is used in the determination of the shifts among the population categories for the entire internal model area for the next year.

9.4 The flows of labor values produced by the population in a given production location zone are allocated to exchange location zones (containing workplaces) using logit formulations with 'selling interchange utilities'. These selling interchange utilities include:

- A size term;
- An inertia term, which is the quantity (proportion) of flow of labor value from the production zone to the exchange zones in the previous year;
- The exchange price (wage or salary for labor) in the exchange zone; and
- The (dis)utility of transporting the commodity from the production zone to the exchange zone, which is the disutility of the commute trip for the worker.

9.5 For a given production location zone and population category, the composite utility of the selling interchange utilities for the full set of exchange zones (the log-sum value) provides the selling utility for that zone and population category, which is used in the determination of the residential location utility for that zone.

9.6 The flows of household production inputs to a given consumption zone are allocated to (actually allocated to be coming from) exchange location zones using logit formulations with 'buying interchange utilities'. These buying interchange utilities include:

- A size term;
- An inertia term, which is the quantity (proportion) of flow of commodity value from the exchange zone to the production zone in the previous year;
- The exchange price in the exchange zone; and

- The (dis)utility of transporting the commodity from the exchange zone to the consumption zone.

9.7 For a given consumption location zone and commodity, the composite utility of the buying interchange utilities for the full set of exchange zones (the log-sum value) provides the buying utility for that zone and commodity, which is used in the determination of the residential location utility for that zone.

9.8 Because the exchange location is the same as the consumption location for all labor, this means that the allocation from exchange locations to consumption locations reduces to a simple allocation, with all the labor consumed at the workplace coming from the exchange location and the buying utility faced by the employer reducing to just the relevant wage or salary for the labor at the workplace.

9.9 Exchange prices for labor (wages and salaries) that equate labor demands with labor supplies are determined in the same way that exchange prices are determined for other commodities in each year as described above. Each exchange zone is a separate market for each labor category. Thus, a different exchange price is established for each zone reflecting the differences in labor supply and travel costs among zones and thus impacting the attractiveness of zones as locations for production via the buying utilities and the production utilities. Labor consumption is elastic with respect to the buying utility for labor in the exchange zone.

9.10 The demand for inputs by population is determined using some form or analog of the Stone-Geary formulation, consistent with a utility maximizing framework for personal consumption. As indicated above, the precise nature of the production function for each economic sector is to be established as part of the model calibration process.

9.11 The total employment expressed in terms of the number of people in a given occupation category is determined for the entire internal model area together with the other totals for the internal model area — and this total is imposed on the distribution process for a given year. The total value, rather than the number of employed people, indicates the total quantity of labor consumed as determined in the distribution process. It is this value and the associated exchange price for labor that influences the shifts among occupations over the next year.

9.12 The parameters in the residential location utility functions vary across different person categories, which means that, for example, children and adults display different sensitivities to various components.

9.13 The implied numbers of households in various categories in zones can be determined by grouping together the numbers of people in relevant categories. In general, in a given zone there will not be the required number of people in a particular category to provide a whole number of households in the corresponding category. This is consistent with the aggregate person-based rather than disaggregate household-based nature of the model.

9.14 The demand for residential space is per person, not per household. But since household size is one of the defining attributes of each person category, it is possible to take into account the agglomeration of demand for residential space with different household sizes. Thus, for example, the per person demand for residential space by people in three-person households is one third of the corresponding per household demand for the corresponding three-person households.

9.15 To the extent that it is deemed important to respect specific area-wide forecasts for the number of households in different categories, the corresponding numbers of people in different categories can be imposed at the zone-specific level as part of the allocation of population to zones. This is done by introducing a further term to the residential location utility that is adjusted as part of each iteration in the determination of exchange prices.

9.16 It should be noted that the aggregate zonal quantities provided by the model constitute the zone-specific marginal distributions used as inputs to the disaggregate population synthesis process currently being developed as part of the TRANSIMS project.

## 10. Development and alteration of space

10.1 There is explicit representation of developed space (quantity available by type in each zone) and developer actions that give rise to changes in developed space. In the zones inside Oregon the quantity of developed space by type in a zone is the sum of the amounts available in the grid cells in the zone.

10.2 The types of developed space are defined according to:

- The nature of the built form and its suitability for different types of activities, including single family residential, multi-family residential, light industrial, heavy industrial, office, retail, warehouse, depot, hospital, grade school, post-secondary institutional, and government support; and
- The age of the space.

10.3 Economic activity and population consume developed space as part of the production process; at rates indicated in the corresponding production functions.

10.4 The amount of developed space consumed per unit of economic activity or population is elastic with to the buying utility for the space in the zone, which reduces to the exchange price in the zone because space is non-transportable. The inverse of the resulting rate of consumption is the occupation density for that category of space in the zone. The overall density of built form is the result of the development of space on land in the zone, which is the result of developer actions represented in the model. The density of activities in terms of employment or population per unit of land is the result of the combination of occupation densities, consumption rates and the density of built form, all of which is endogenous to the model.

10.5 The exchange price for developed space determined in the spatial allocation process in a given year acts as a ‘signal’ to reduce congestion in the location of activities and as a ‘signal’ to developers to take actions over the next year.

10.6 Developer actions include:

- New construction (conversion of vacant land); and
- Redevelopment with change in space type possible

10.7 Developer actions are based on:
- The supply of land with appropriate permitted use designation in zone;
- Exchange prices for developed space in various categories in zone and other nearby zones;
- Both local and aggregate demand for developed space;
- Development and alteration costs;
- Availability of services in zone; and
- Age of existing developed space.

10.8 Developer actions can be considered at the level of the grid cell, and the results at the zone level determined by summing the actions across the set of grid cells in the zone.

10.9 The quantities of developed or altered space in a given zone in a given year will not be continuous from zero. Rather, there will be some ‘stickiness’ at zero until certain price and/or demand thresholds have been passed, at which point there will be some minimum non-zero amount of development (depending on space category) consistent with the threshold production allocation totals for zones.

10.10 The supply of land is categorized by:
- Existing use in terms of the types of space currently occupying the land (including vacant);
- Permitted use zoning;
- Maximum allowable densities (where relevant); and
- Availability of services, specified exogenously for each zone in each year as a policy input.

10.11 The categories of permitted use for land are based on general nature of land use zoning definitions in Oregon, with a total of 6 to 8 categories, including:
- Low density residential,
- High density residential,
- Commercial,
- Light industrial,
- Heavy industrial,
- Agricultural,
- Forest, and
- Protected resources.

10.12 One or more types of developed space can locate on land of a given permitted use category in a given grid cell as appropriate.

10.13 Development densities are a function of the consumption of available land in the production of developed space, which is endogenous to the model. The interaction between demand and supply for developed space establishes the price for developed space in one year. This price influences developer actions from the current year to the next year, with the costs of alteration or redevelopment including the current year price for the developed space currently occupying the land and the costs of development including the current year price for vacant land based on representative space prices in the zone and adjacent zones.

## 11. Personal and household travel

11.1 The representation of the demand for travel arising from households is person based, categorized by household type, age category and occupation, consistent with the population categories.

11.2 Travel arising from households is represented in terms of home-based tours. These tours are categorized by the purpose for the primary stop and are allocated to 'standard' patterns.

11.3 The alternative purposes for the primary stop for these tours are:

- Commute (work or university for adults, school for children);
- Discretionary (non-commute and short distance);
- Long-distance recreational;
- Long-distance personal business;
- Long-distance visiting friends and relatives (social); and
- Long-distance other(s) to be defined

11.4 The 'standard' patterns for these tours are:

- Primary stop only;
- Intermediate stop before primary stop;
- Intermediate stop after primary stop; and
- Intermediate stops before and after primary stop.

11.5 The definitions of the travel market segments are based on person type and primary purpose of the tour.

11.6 The personal travel demand for home-based tours is allocated to various dimensions of travel using nested logit (see Figure 4) following the sequence:

- Generation of home-based tours;
- Allocation of tours to categories based on the purpose for the primary stop (with 'commute' included as an available category for those population categories with employment or university/school);
- Allocation of tours in each category to tour patterns;
- Allocation of trips in tour patterns to time of day alternatives, with a.m. peak, p.m. peak, and off-peak categories;
- Distribution of primary stop locations (note that the workplace distribution is already determined from spatial distributions of economic activity and population);
- Distribution of intermediate stop locations conditional on primary stop location;
- Mode split for tour between 'use private vehicle' and 'do not use private vehicle' alternatives;
- Mode split for each trip included in tour, with the set of available alternatives as follows (see Figure 5) these conditioned by result of mode split for tour (that is, for example, the '1p-auto' alternative is not available with the 'do not use private vehicle' alternative for the mode split for tour):
- For commute and discretionary (short distance):
  - Private (single person auto, two-person auto, 3+ person auto)
  - Public transport (walk access/egress at home end, auto access/egress at home end)
  - Telecommuting (for work interactions only)

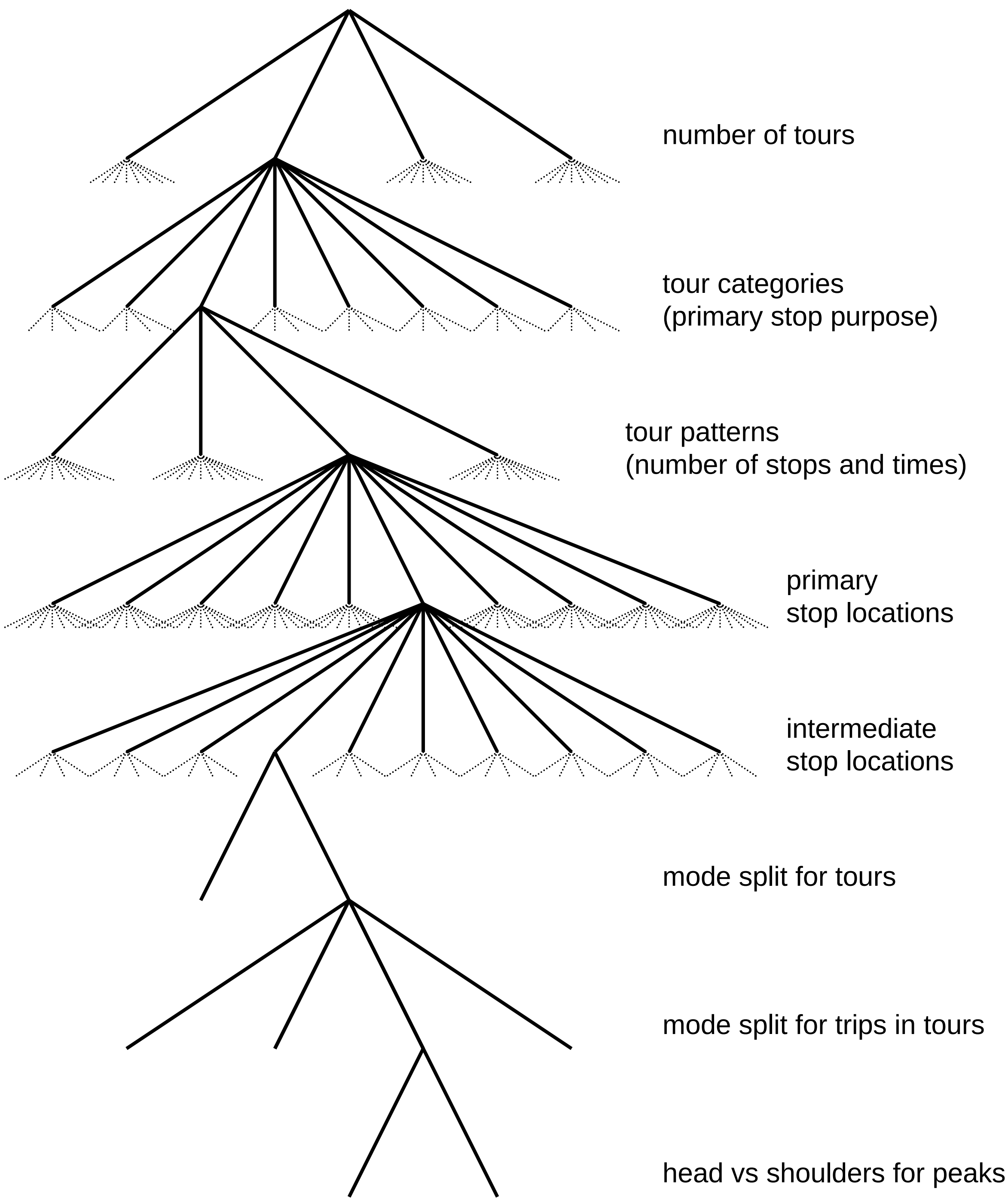


*Figure 4: Demand allocation structure for personal travel / household travel*

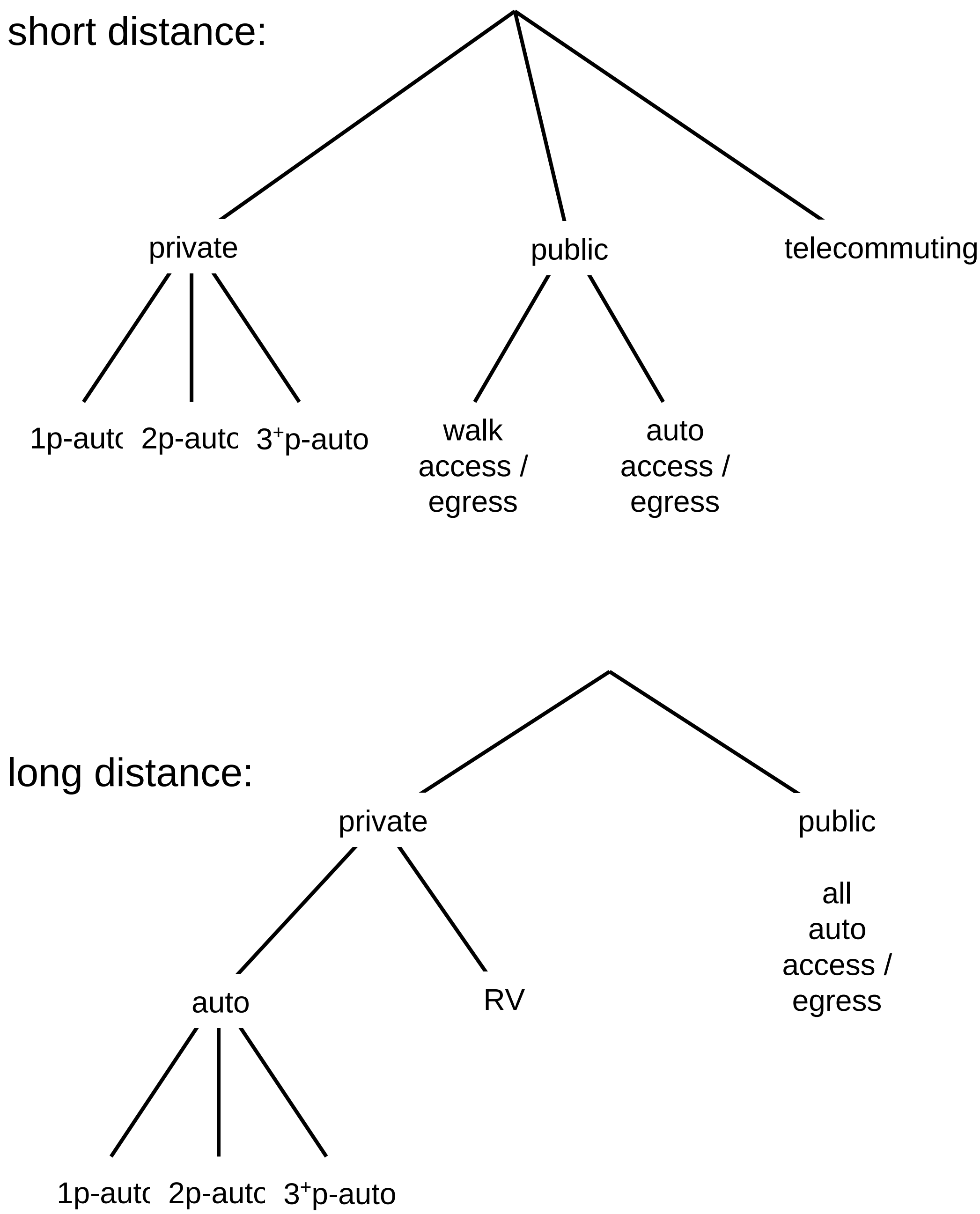


*Figure 5: Mode alternatives for trips in personal travel / household travel tours*

- For long distance, mode options are:
  - Private (single person auto, two-person auto, 3+ person auto, recreational vehicle)
  - Public (all auto access/egress at all ends)
- Allocation of auto trips in peak periods to ‘head’ and ‘shoulders’ of peak

11.7 Personal trips on the private and the public networks are assigned along with all other person travel and goods and services movements, a capacity-restrained stochastic user equilibrium is identified and the resulting travel times and costs are fed back through the nested logit structure to equilibrium. The public network is multi-modal and includes the network of services for urban bus, urban rail, intercity bus, intercity rail and air and that the selection between these is determined as part of the assignment process. Link specific constants for different modes act as mode specific constants.

11.8 The composite utility of travel — which is determined at the ‘top’ of nesting structure for the allocation of personal travel demand — is used in the residential location utility used in the spatial allocation of population. For categories of population in employment, the composite utility for the work trip is removed from this composite utility of travel, as it is accounted for elsewhere as part of the spatial distribution of economic activity and population.

11.9 Work-based tours with discretionary purposes, such as personal business errands or lunch, are also generated, distributed, split among modes and assigned (to the off-peak networks) in order to include this travel demand on the networks. But the composite utility of these tours is not used in the allocations of economic activity and population.

## 12. Goods and services shipments

12.1 Quantities of goods and services movements are represented in terms of value. These are categorized according to the goods and services categories listed in Appendix A.

12.2 Goods and services shipments flow from production location to exchange location to consumption location. These flows are determined as part of the spatial distributions of economic activities and population.

12.3 Mode split and assignment for goods and services shipment flows are done jointly as a simultaneous loading to a multimodal network representation of the supply of various combinations of available goods and services transport.

12.4 The mode alternatives included in the multimodal network representation are 2-axle truck, 3+ axle truck, rail, auto and van, water, and air cargo.

12.5 The loading to mode vehicles takes account of value to weight ratios.

12.6 The use of multimodal terminals as collection/distribution centers and break-in-bulk locations can be represented in two ways:

- One way is to use special links to represent such terminals in the multimodal goods and services network, with the associated handling costs included as part of the cost of traversing such links. Different routing possibilities, including direct full-truck routings and

collection/distribution/line-haul routings, would then be represented as alternative paths through the multimodal goods and services network.
- Another way is to include the activities of such terminals as a separate category of economic activity. Then the flows of production and consumption involving this economic activity could be used directly in the determination of the associated vehicle movements into and out of these terminals. This would avoid the need to allocate such terminals exogenously as part of the specification of the goods and services transport network.

12.7 Tours of less-than-load routings are developed for appropriate categories of goods and services movements using groups of destinations.

12.8 Trips ends for loaded vehicles are used as the basis for developing trip tables of empty vehicles, generating and distributing appropriately factored quantities of the trip ends for loaded vehicles consistent with observations of truck movements.

12.9 Mode-specific constants are included on relevant mode-specific links out from the special links representing transfer costs.

12.10 The goods and services movements on the multimodal goods network are assigned along with all other person trips on the private and public networks. A capacity-restrained stochastic user equilibrium is identified and the resulting travel times and costs are fed back through the nested logit structure to equilibrium. The multimodal goods and services network includes the networks for auto and van, trucking, rail, water and air cargo.

12.11 The generalized cost of the movement of goods and services on network is used in the production location utility for economic activity allocation.

## 13. Business travel

13.1 The representation of travel arising from business activities is person based. It is categorized by distance, including:
- Short-distance business activity; and
- Long-distance business activity.

13.2 This type of travel includes all business travel by persons in course of work. It includes all trips made as part of the business cycle apart from the delivery of goods and services to the consumer. In particular, it does not include travel by drivers together with associated crew of providers for goods and services shipments, both of which are included in the transport of goods and services directly.

13.3 Trips of this sort follow goods and services flows in forward and backward directions, both from producers to exchange points to consumers, and from consumers to exchange points to producers.

13.4 The person travel demand arising with business travel is allocated to various dimensions of travel using nested logit following the sequence:
- Generation of tours following goods and services flows in both forward and backward direction; only single stop tours considered;

- Allocation of trips in tour to time of day alternatives, with a.m. peak, p.m. peak, and off-peak categories;
- Mode split for tour between ‘use private vehicle’ and ‘do not use private vehicle’ alternatives;
- Mode split for each trip included in tour, with the set of available alternatives as follows (see Figure 6) these conditioned by result of mode split for tour (that is, for example, the ‘1p-auto’ alternative is not available with the ‘do not use private vehicle’ alternative for the mode split for tour):
- For short distance, mode options are:
  - Private (single person auto, two person auto, 3+ person auto)
  - Public transport (walk access/egress at home end, auto access/egress at home end)
- For long distance, mode options are:
  - Private (single person auto, two-person auto, 3+ person auto, recreational vehicle)
  - Public transport (all auto access/egress at all ends)
  - Teleconferencing
- Allocation of auto trips in peak periods to ‘head’ and ‘shoulders’ of peak

13.5 Business trips by persons are assigned to the private and public networks along with the other person trips and the goods and services movements. A capacity-restrained stochastic user equilibrium is identified and the resulting travel times and costs are fed back through the nested logit structure to equilibrium.

13.6 The composite utility of travel at the ‘top’ of nesting structure for allocation of business travel demand is used in the production location utility for economic activity allocation

## 14. Visitor travel

14.1 The representation of travel by visitors is person based. It is categorized by the purpose of the visit and the location of residence of the visitor.

14.2 The types of visit purpose include business, recreational, and visiting friends and relatives.

14.3 The categories of location of residence for visitors include within the internal model area and outside of the internal model area.

14.4 The total numbers of visitors in each category are allocated to staying locations (for the day represented by the model) in the internal zones as follows:

- For business purpose by those resident outside the internal model area: determine total for the entire model area using flows into the region for the internal model area in the inter-regional social-accounting matrix and then allocate this total using a Cobb-Douglas formulation with production values by industry, including the hotel and accommodation sector in particular, as independent variables;
- For business purpose by those resident in the internal model area: determine total for the entire internal model area by factoring the number of long distance business tours generated and staying in the internal model area as established in the business travel component and then allocate this total proportion to the distribution of associated primary stop locations for these business tours;

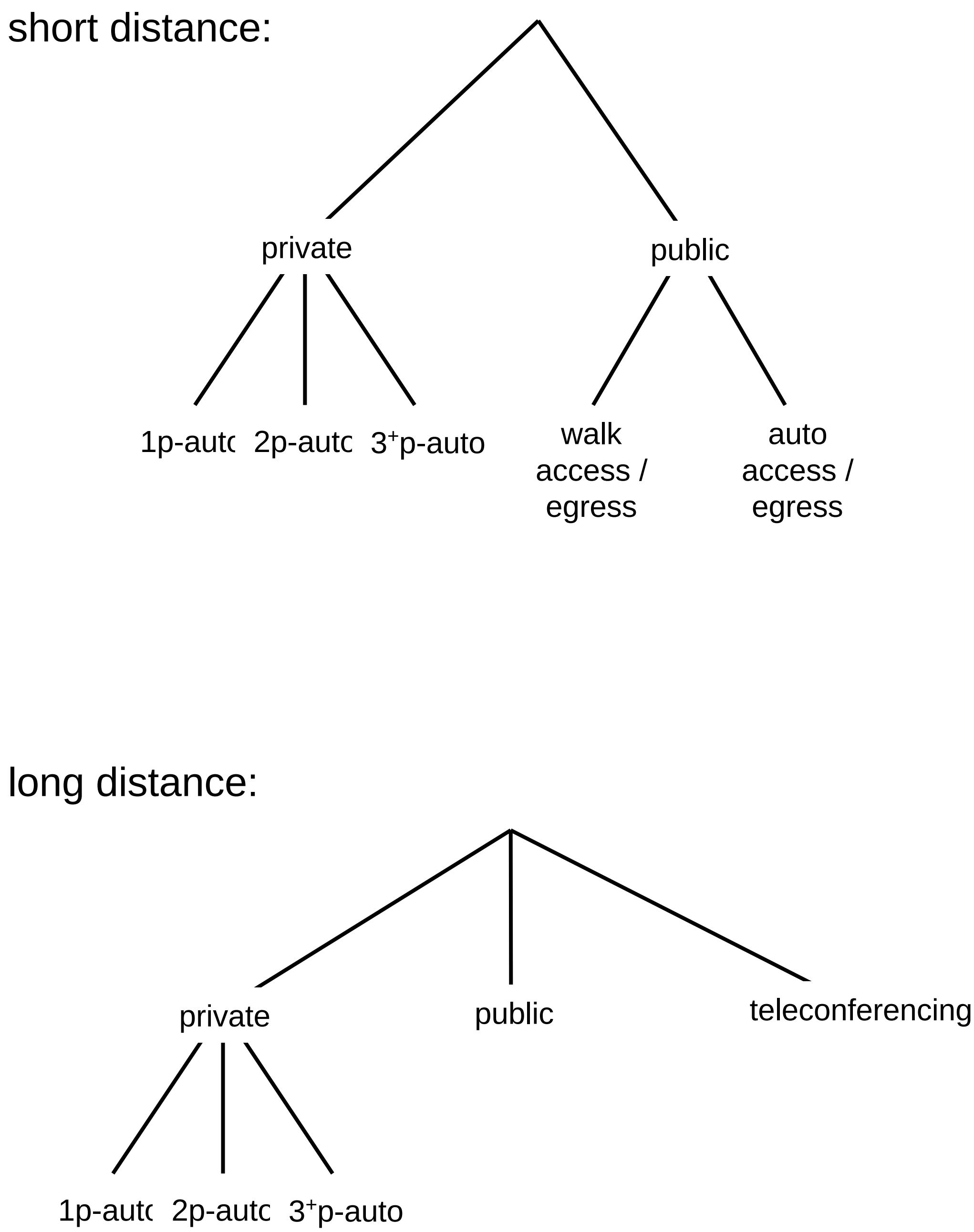


*Figure 6: Mode alternatives for trips in business travel tours*

- For recreational purpose by those resident outside the internal model area: determine total for the entire internal model area according to trends in visitor totals and then allocate this total using a Cobb-Douglas formulation with previous distributions for zones, hotel and accommodation production values, and indications of the sizes of special generators as independent variables;
- For recreational purpose by those resident in the internal model area: determine total for the entire internal model area by factoring the number of long distance recreational tours generated and staying in the internal model area as established in the personal travel component and then allocate this total according to the distribution of associated primary stop locations for these recreational tours;
- For visiting friends and relatives by those resident outside the internal model area: determine total for the entire internal model area by factors the population totals in various categories in the internal model area and then allocate this total among internal zones using a Cobb-Douglas with population totals and hotel and accommodation production values as independent variables; and
- For visiting friends and relatives by those resident in the internal model area: determine the total for the entire internal model area by factoring the number of long distance visiting friends and relatives tours generated and staying in the internal model area as established in the personal travel component and then allocate this total according to the distribution of associated primary stop locations for these personal tours

14.5 The staying-based tours by visitors in each category are generated, distributed, split among modes and times of day and assigned to the relevant networks along with all the other person travel in order to include this travel demand on the public and private networks. But the composite utility of these tours is not used in the allocations of economic activity and population.

## 15. Trips with at least one end external

15.1 For personal travel from home-based locations inside the internal model area, some primary and intermediate stops for both home-based and work-based tours are allocated to external zones, and thus are outside the internal model area. These result in both ‘internal to external’ and ‘external to internal’ trips.

15.2 Production activity located in internal zones can sell commodities at exchange locations in the external zones at fixed prices determined using indications provided by the inter-regional social-accounting matrix. The relative values of the selling utilities at exchange locations in the internal model zones versus the external zones influence the allocation of selling at exchange locations inside and outside the internal model area. Such selling at exchange locations outside the internal model area results in flows of exports from the model area and these are incorporated into the goods and services and the business travel components.

15.3 Similarly, consumption activity in internal zones can buy commodities at exchange locations in the external zones at fixed prices determined using indications provided by the inter-regional social accounting matrix. The relative values of the buying utilities at exchange locations in the internal model zones versus the external zones influence the allocation of buying at exchange locations inside and outside the internal model area. Such buying at exchange locations outside the internal model area results in flows of imports into the internal model area and these are incorporated into the goods and services and the business travel components.

15.4 In addition, production activity located in the external zones can sell commodities at exchange locations in the internal zones at prices that are a fixed amount in the external zones — presumably the same price at which consumption activities can buy the commodities in the external zones — plus the cost of transport to the exchange location zone. The exchange prices at the exchange locations in the internal zones will influence whether or not production activity located in the external zones sells commodities at these exchange locations. Such selling results in flows of imports to the internal model area and these are incorporated into the goods and services and the business travel components.

15.5 Similarly, consumption activity located in the external zones can buy commodities at exchange locations in the internal zones at prices that are a fixed amount in the external zone — again, presumably the same as the fixed price that production activity can sell the commodities in the external zone — plus the cost of transport from the exchange location. The exchange prices at exchange locations inside the model area will influence whether or not consumption activity located in the external zones buys commodities at these exchange locations. Such buying results in flows of exports from the internal model area and these are incorporated into the goods and services and the business travel components.

15.6 The mismatch between the import and export values established in the manner described immediately above and the analogous values established by the inter-regional social accounting matrix can be used to guide the determination of appropriate values for the representative prices and production utilities for the external zones. In particular, the total value of the flow of exports for a given commodity can be compared with the corresponding total value of the exports from the inter-regional social accounting matrix and the fixed prices indicated above could then be adjusted until these total values match. Similarly, the total value of the flow of imports for each commodity can be compared with the corresponding total value of the imports from the inter-regional social accounting matrix and the fixed prices identified above could then be adjusted until these total values match.

15.7 Personal tours that are based outside the internal model area and have a primary or intermediate stop in an internal zone but are not visitor trips into the internal model area — which results in a trip into followed by a trip back out of the internal model area — are included by generating and distributing the number of auto trip ends of this type in each zone using a function with some form of accessibility to population outside the internal model area and other zonal attributes as independent variables. This is done separately for the a.m. peak, p.m. peak and off-peak periods.

15.8 For external to external trips, observed trip tables for each mode category are factored using indications provided by the inter-regional social accounting matrix and then loaded to the relevant private, multimodal public, or multimodal goods and services networks at entry and exit points together with other trips. This is done separately for the a.m. peak, p.m. peak and off-peak periods for each of the following categories:

- Personal person trips on the private network;
- Personal person trips on the public network;
- Goods and services shipments by commodity category on the goods and services network;
- Business travel on the private network; and
- Business travel on the public network.

## Appendix A: Commodity categories, including goods and services, occupations, and land

| Group | Commodity code | Description | STCC |
|---|---|---|---|
| Goods and services | 1 | Farm products | 1 |
| | 2 | Forest products | 8 |
| | 3 | Fresh fish or marine products | 9 |
| | 4 | Metallic ores | 10 |
| | 5 | Coal | 11 |
| | 6 | Crude petroleum, natural gas or gasoline | 13 |
| | 7 | Nonmetallic minerals | 14 |
| | 8 | Ordnance or accessories | 19 |
| | 9 | Food or kindred products | 20 |
| | 10 | Tobacco products, excluding insecticides | 21 |
| | 11 | Textile mill products | 22 |
| | 12 | Apparel or other finished textile products or knit apparel | 23 |
| | 13 | Lumber or wood products, excluding furniture | 24 |
| | 14 | Furniture or fixtures | 25 |
| | 15 | Pulp, paper or allied products | 26 |
| | 16 | Printed matter | 27 |
| | 17 | Chemicals or allied products | 28 |
| | 18 | Petroleum or coal products | 29 |
| | 19 | Rubber or miscellaneous plastic products | 30 |
| | 20 | Leather or leather products | 31 |
| | 21 | Clay, concrete, glass or stone products | 32 |
| | 22 | Primary metal products, including galvanized | 33 |
| | 23 | Fabricated metal products | 34 |
| | 24 | Machinery, excluding electrical | 35 |
| | 25 | Electrical machinery, equipment or supplies | 36 |
| | 26 | Transportation equipment | 37 |
| | 27 | Instruments, photographic goods, optical goods, watches or clocks | 38 |
| | 28 | Miscellaneous products of manufacturing | 39 |
| | 29 | Waste or scrap materials not identified by producing industry | 40 |
| | 30 | Other (Miscellaneous) freight shipments | 41 |
| | 31 | Containers, carriers or devices, shipping, returned empty | 42 |
| | 32 | Waste hazardous materials or waste hazardous substances | 48 |
| | 33 | Construction services | |

| Group | Commodity code | Description | STCC |
|---|---|---|---|
| Goods and services (continued) | 34 | Pipeline transportation services | |
| | 35 | Transportation & storage services | |
| | 36 | Radio & television broadcasting services | |
| | 37 | Postal services | |
| | 38 | Utilities services | |
| | 39 | Wholesale margins | |
| | 40 | Retail margins | |
| | 41 | Other finance, insurance & real estate services | |
| | 42 | Business services | |
| | 43 | Education services | |
| | 44 | Health services | |
| | 45 | Amusement & recreation services | |
| | 46 | Accommodation services | |
| | 47 | Food services | |
| | 48 | Other personal & miscellaneous services | |
| Labor SOC codes | 49 | Managerial Labor | |
| | 50 | Professional Labor | |
| | 51 | Gradeschool Teaching Labor | |
| | 52 | Clerical Labor | |
| | 53 | Assembly and Fabrication Labor | |
| | 54 | Agricultural Labor | |
| | 55 | Semi-skilled Manual Labor | |
| | 56 | Unskilled Manual Labor | |
| | 57 | Retail Labor | |
| | 58 | Health Care Labor | |
| | 59 | Post-Secondary Teaching Labor | |
| | 60 | Other Labor | |
| Developed space | 61 | Single-family Residential | |
| | 62 | Multi-family Residential | |
| | 63 | Light Industrial Space | |
| | 64 | Heavy Industrial Space | |
| | 65 | Office Space | |
| | 66 | Retail Space | |
| | 67 | Warehouse Space | |
| | 68 | Depot Space | |

| Group | Commodity code | Description | STCC |
|---|---|---|---|
| Developed space (continued) | 69 | Hospital Space | |
| | 70 | Gradeschool Space | |
| | 71 | Post-Seconary Institutional Space | |
| | 72 | Government Support Space | |