Oregon Statewide Integrated Model (SWIM2)

Model Description

Draft Report version 2.5

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Executive Summary

The Oregon Department of Transportation has long been a leader in the development of statewide integrated transport-land use models. This document describes the functional form of the second generation model, defined as the Oregon Statewide Integrated Model (SWIM2). The SWIM2 model represents the behavior of the land use, economy, and transport system in the State of Oregon using a set of connected modules that cover different components of the full system, as follows:

- **ED** – The *Economics and Demographics* module determines modelwide production activity levels, employment, and imports/exports.
- **SPG** – The *Synthetic Population Generator* module samples household and person demographic attributes (SPG1) and assigns a household to an alpha zone (SPG2)
- **ALD** – The *Aggregate Land Development* module allocates modelwide land development decisions among study area a-zones considering floorspace prices and vacancy rates.
- **PI** – The *Production allocations and Interactions* module determines commodity (goods, services, floorspace, labor) quantity & price in all exchange zones to clear markets, including the location of business and households by beta zone.
- **PT** – The *Person Travel* module generates activity-based person trips for each study area person in the synthetic population, during a typical weekday.
- **CT** – The *Commercial Transport* module generates mode split for goods movement flows, and generates truck trips, combining shipments and possible transshipment locations, for a typical weekday.
- **ET** – The *External Transport* module generates truck trips from input O-D trip matrices representing import, export (within 75 miles) and through movements based on PI and external station growth rates.
- **TS** – The *Transport Supply* module assigns vehicle, truck, and transit trips (separately) to paths on the congested transport network for a 24-hour period, generating time and distance skims for AM and off-peak periods.

Two optional SWIM2 modules not shown in Figure 1:

- **EPF**– The *ED-PI Feedback* module is an optional simplified dynamic feedback to that adjusts the ED module's fixed modelwide economic forecast, considering the statewide composite location utilities by industry from the PI module.
- **SL** - The *Select Link* module generates SWIM2 highway assignment paths for later use in generating outputs such as select link results, subarea matrices, and route choice results.[1]

The Oregon Statewide Integrated Model (SWIM2) basic functionality has been calibrated, including the following:

- a three-stage approach to the calibration of the model has been implemented; the various parameters in each module have been sorted into three categories (labeled S1, S2 and S3) related to the three stages in the calibration when they are considered;

[1] PA currently assigns the trip tables in the CT, ET, and PT modules using EMME/3 software installed on the TLUMIP computer cluster.

- real-world (observed) values for more than 20 module outputs were established and used as targets for completing S2 (each modules in isolation) and initial S3 (full model) calibration, following the methods outlined herein;
- Calibration for a 1998 base year and trends over time was completed and shared with the TLUMIP Peer Review Panel in June 2008. [40] The CT and PT modules have undergone further updates and were re-calibrated in October 2010.

The following user interface improvements have been made to support the use of the Oregon Statewide Integrated Model (SWIM2):

- implementation of a Model Runner System Graphical User Interface (MrsGUI) for facilitating model use, such as scenario creation, starting and monitoring model runs, and facilitating scenario archiving;
- implementation of a database (VIZ DB and VIZ DB Micro) to house model zone, link, and micro-simulation outputs in standardized format, as well as a visualization tool (SWIM VIZ) that enables a user-friendly dynamic queries and visualization of the multi-year model output in maps and charts; [41]
- Maintenance of a SWIM User's Guide [1] including instructions for installing and running the model on the ODOT State Data Center (SDC) TLUMIP computer cluster, as well as other user information and instructions.

With this document and associated software, the Oregon SWIM2 functionality has been finalized and calibrated and is ready for policy application, which means the following:

- all modules are completed as documented herein, including software and inputs
- software was prepared to implement the full model as specified, as confirmed through testing and calibration;
- the values for the all parameters for each module have been developed, many estimated statistically;
- base year inputs for all modules have been developed or synthesized including auto and transit networks;

The Oregon SWIM2 has the following advantages over the first generation SWIM1 model, completed in 1999 using the TRANUS software. [27][31]

- endogenously-generated regional economic forecasts, based on exogenous national forecasts. (ED module);
- more comprehensive aggregate treatment of regional economic flows (PI module), including explicit representation of commodities separate from industries and explicit treatment of related exchange locations and exchange prices;
- separation of management (white-collar) and production (blue-collar) components of production activities and the associated separation of consumption of these activities
- much greater number of economic sectors considered in the economic and activity allocation modules (25 plus 14 white-collar sub-sectors compared to 12 in SWIM1), as well as two non-household institutions;
- consideration for significantly more goods commodities (42 compared to 12 in SWIM1), as well as services and labor occupations;
- much greater number of space categories considered in land development and in production and consumption activity allocation (19 categories compared to 2 in SWIM1);
- more intuitive zoning input used in land development (ALD), with 34 zoning codes;

- micro-level simulation of population (SPG module);
- much greater number of household sectors considered in activity allocation (PI module), stratified by household size as well as income group (18 compared to 3 in SWIM1);
- micro-simulation of daily travel for nearly 6 million people within the study area (PT module);
- micro-simulation of daily freight movement, including distribution centers (CT module) and a wider range of vehicle types and related configurations;
- improved geographic coverage, including internal modeling of a roughly 50-mile halo region around the state of Oregon, which has as much activity as the state itself;
- significantly more detailed zone (2,950 alpha zones and 518 beta zones compared to 125 zones in SWIM1) and network (over 53,000 links compared to nearly 2,000 in SWIM1);
- significantly higher temporal resolution options with time increments of 1 year rather than 5 years;
- implementation of a distributed-computing approach to help reduce run times for the SWIM2 modeling system.

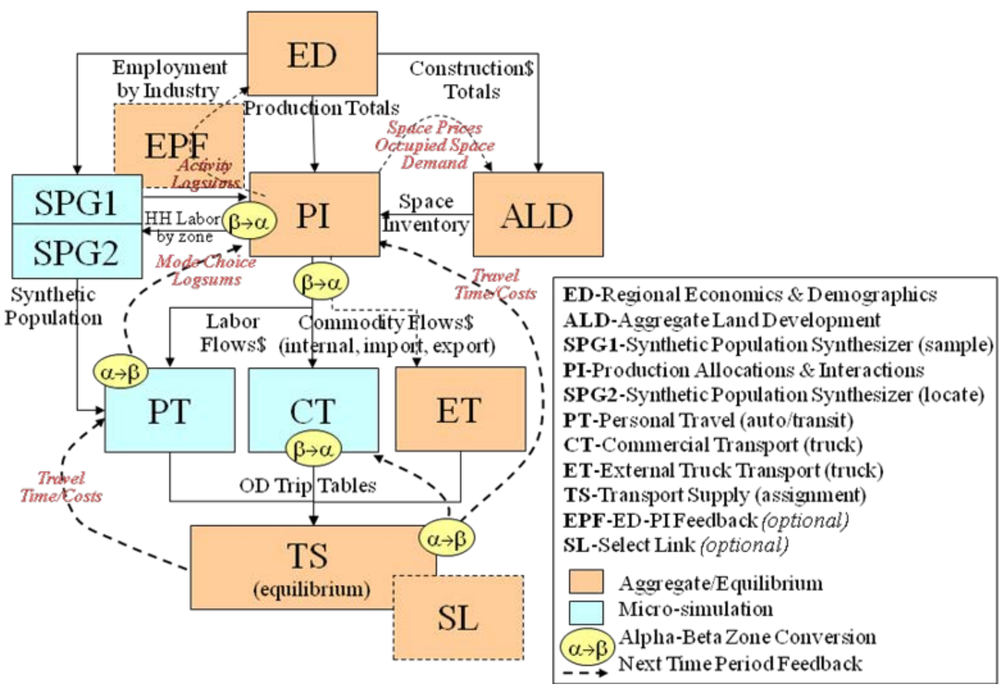
1.0 Introduction

The Oregon Statewide Integrated Model (SWIM2) is an integrated land use transport model covering the entire State of Oregon. It is a second generation model, drawing on previous work done on the First Generation based Statewide Model (SWIM1) and the Eugene-Springfield UrbanSim Model. The SWIM1 model [27] was a customized version of the TRANUS software. SWIM2 is a more disaggregate and complex customized framework that combines a PECAS spatial allocation model with activity-based micro-simulation transport models. SWIM2 augments the SWIM1 Model in more complex applications of Oregon statewide policy and investment decisions. Future SWIM2 model upgrades will be driven by policy application needs.

The development of both the first and second generation models was commissioned by the Oregon Department of Transportation (ODOT) as part of its Transportation and Land Use Model Improvement Program (TLUMIP) within the larger Oregon Model Improvement Program (OMIP). The model development has been undertaken by a series of teams led by Parsons Brinckerhoff, with HBA Specto, EcoNorthwest and The University of Washington playing key roles as sub-contractors. The program has also been guided by an international Peer Panel.[2]

The approach used in the development of the SWIM2 model has been to establish working versions and documentation of each of the modules shown in Figure 1.1, before proceeding with full system integration. The preparation and testing of the software code, preparation of validation/calibration data, establishing initial inputs and parameters, and own-module calibration were completed first. Integration of the modules to run through time as a unit was completed next. Full model calibration of all modules in both a base year and trends over time was completed and shared with the TLUMIP Peer Panel.[2][40] Further calibration has and will continue to be performed as needed to match newer data and ensure the model is best equipped to address ODOT policy applications.

Figure 1.1. Modules and Flows in the Oregon Statewide Integrated Model (SWIM2)



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[2] Frank Koppelman, Michael Wegener, David Simonds, Keith Lawton, Julie Dunbar, Kim Fisher.

The model is run in policy application mode for the period 2006-2030. The full model is run every 3 years, while the spatial-economic modules (ED-SPG1-ALD-PI) run every year. The run schedule is listed below, with new networks added in selected full model years in bold type:[3]

Full: **2006,** 2009**,** **2012,** 2015**,** **2018,** 2021**,** **2024** 2027 2030
Spatial: 2007,2008, 2010,2011, 2013,2014, 2016,2017, 2019,2020, 2022,2023, 2025,2026, 2028,2029

In May 2008, a single year run of the full SWIM2 model (4-period 4 assignment classes, 100 percent population sample) takes 10 hours with the spatial-economic models taking just over 3 hours, as detailed in Table 1.1. Runtime reduction strategies [WOC15rpt] may provide further improvements.

Table 1.1. Current SWIM2 Runtime by Module (October 2010)

SWIM2 Module(s)	Average Runtime (hh:mm:ss)	
	average	notes
ED	00:01:00	
ALD	00:01:00	
SPG1	00:01:00	
PI (daf)	00:45:00 (150 iter) 01:15:00 (400 iter) 02:19:00 (1600 iter)	00:01:00 Startup 00:00:10 per iteration average* 00:05:00 Wrap-up
SPG2 (without age constraint)	00:04:00	
PT (daf,100% sample)	02:45:00	
CT	00:09:00	
ET	<00:01:00	
TS (daf-hwy, monolith-transit)	00:35:00Highway (2 pd) 00:50:00 Highway (4 pd) 01:45:00 Transit (2 pd) 03:24:20 Transit (4 pd)	Assumes 6 class assignment (auto, 3 trucks, intercity and urban transit) in 2 or 4 (first/last year only) time periods.
Summary		
Spatial components	01:20:00 (every year)	Average, assuming 400 PI iterations
Transport components	07:13:33 (first/last year) 05:06:33 (otherwise)	Assumes 6-class 4-period assignment Assumes 6-class 2-period assignment
SWIM2 Full Model	10:24:18 (first/last year) 08:21:08 (otherwise)	Assumes 6-class 4-period assignment Assumes 6-class 2-period assignment
31 Year Model run	7.5 days (180 hrs)	2000-2030: 31spatial + 11*transport

* PI runtimes (iterations to convergence) can increase in later years, if floorspace/other resources are scarce.
daf =distributed application framework, using 6- computer TLUMIP cluster in Oregon State Data Center (SDC).
Source: SDC SCEN_1998for2005_Basefile_Oct2010.
Note: Only PI and PT logging statements have accuracy finer than 1 minute.

This report describes the working version of SWIM2 and its component modules, including data and calibration. 'Section 1.0 Introduction' provides background context. Section 2 describes common category definitions and the general calibration approach used in model development. Sections 3-12 individually discuss the component modules. Within each discussion, sections describe (1) the design of the module, including equations and processes used; (2) parameter development outlining the establishment of the values for the module parameters and inputs; (3) calibration including the development and comparison to observed 'target' data.

[3] In Calibration, SWIM22 was run for the period 1998-2006 or 1991-2000, with 1998 and 1991 the first predicted year and the full model was run in this year and every 3rd year thereafter. A 1990 and 2000 network were used in calibration. Multi-year reference network has been created for policy application..

2.0 Common Model Framework

This section discusses information about the Oregon Statewide Integrated Model (SWIM2) that is shared by all modules. This includes model area category definitions, the Application Orchestrator (AO) module and the calibration approach. Descriptions of the user interface modules (MrsGUI and SWIM VIZ) can be found in the SWIM2 Users Guide.[1]

2.1. Model Area Geography

The Oregon Statewide Integrated Model (SWIM2) operates at two geographic levels within the SWIM2 model area (Figure 2.1). Both encompass 36 Oregon and 39 (Halo) adjacent state counties. The halo encompasses a roughly 50-mile buffer around Oregon. A system of alpha zones (light and dark lines in Figure 2.1) is the most disaggregate zone system. There are 2,950 alpha zones in Oregon (2,575) and the Halo (excluding Reno, NV, the southern-most zone of Figure 2.1) and 12 external stations (Table 2.1 and Figure 2.2). The External Stations serve as model area entry/exit points or gateways to 6 World Market zones.

Figure 2.1. SWIM2 alpha zone and beta zone Systems

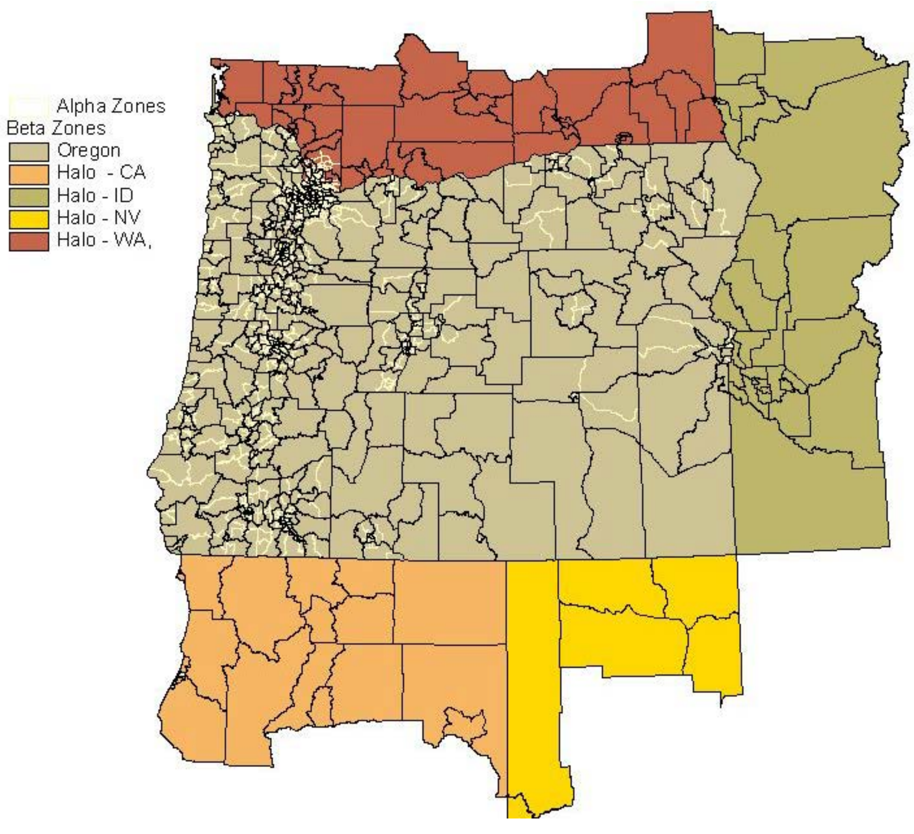
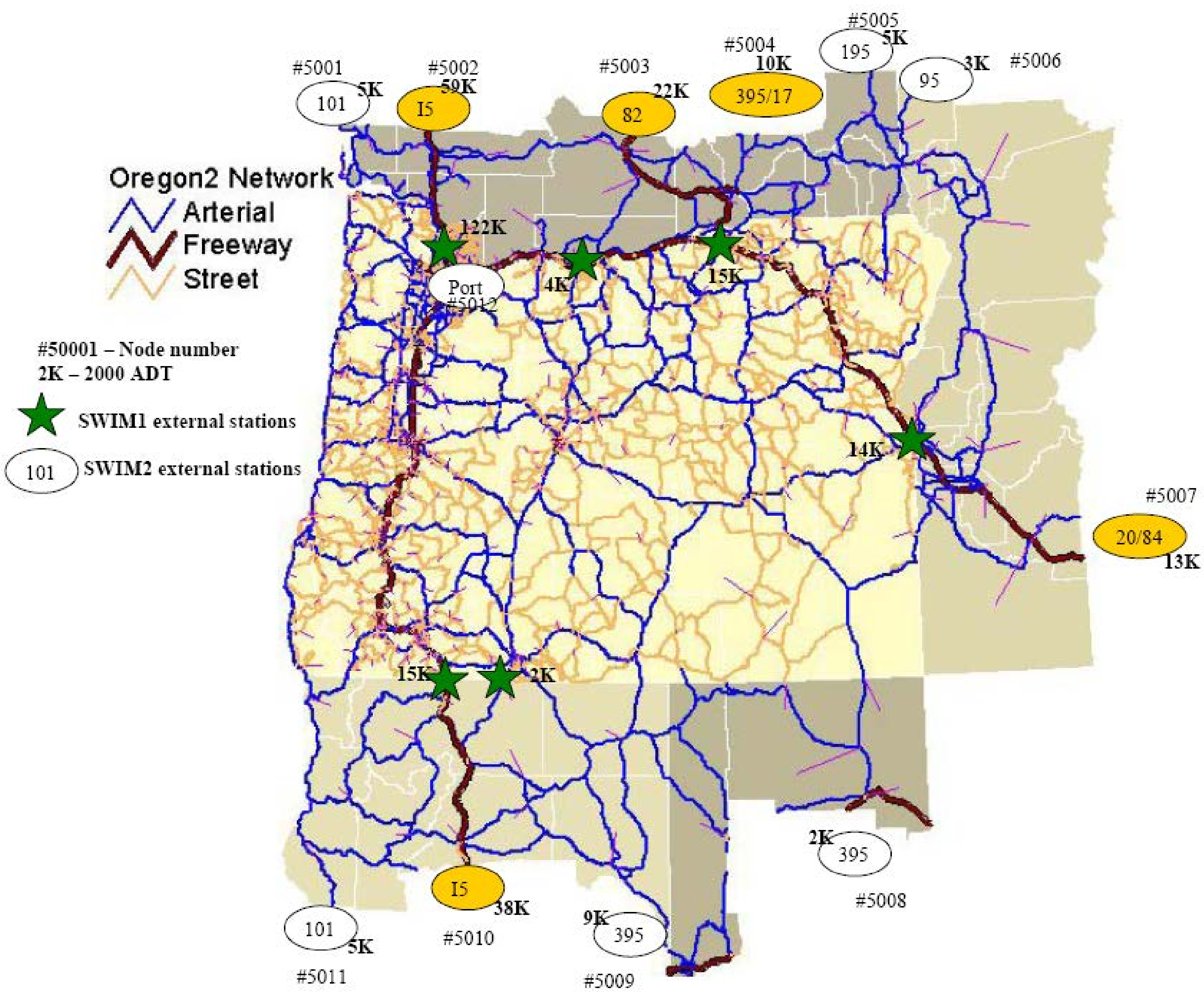


Table 2.1. SWIM2 External Stations

SWIM2 Node#	External Station Description
5001	US101 (WA)
5002	I-5 (WA)
5003	I-82 (WA)
5004	US395/WA17 (WA)
5005	US195 (WA)
5006	US95 (ID near WA border)
5007	I-84/US20 (ID)
5008	US95 (NV, just north of I-80)
5009	US395 (CA, just north of I-80)
5010	I-5 (CA)
5011	US101 (CA)
5012	Port of Portland Terminal 6

Figure 2.2. Map of SWIM2 External Stations



The PI module operates on a more aggregated beta zone system (dark lines in Figure 2.1) where the 12 External Stations are replaced by six World Markets (Table 2.2). There are 518 beta zones, collapsing zones only within Oregon, with a focus on the small urban zones. For example, the roughly 970 alpha zones in Portland are collapsed to approximate a set of 66 employment regions used by the Metro MPO model. In other urban areas, zones were collapsed based on a sliding population scale (approximately 25,000 persons per zone), respecting similar employment clusters and transportation commute sheds. In rural areas, homogenous public lands (e.g., BLM, National Forests) were collapsed, while retaining most county and all ACT[4] boundaries.

The six World Markets, used only in the PI module, are defined in Table 2.2 and Figure 2.3 and 2.4 including the assumptions on distance to reach these markets beyond the model halo boundary. It is assumed that goods transport by truck and rail is limited to the US (except Hawaii), Canada and Mexico. Imports and Exports to other regions in the world are shipped by barge, either from the Port of Portland or other US East or Southeast marine ports. The distance represents the weighted average distance from the halo boundary to the centroid of the World Market. In the case of the Oceanic market (zone 6005), an equivalent distance was identified that would result in the correct overall shipping costs, which varies by direction. The 'local' World Market 6006 is assumed to support commodities that are traded within 75 miles of the model area.[5]

These six World Markets link to the model transport network at the 12 External Stations of Figure 2.2, as shown in Table 2.2. These External Stations roughly parallel the likely rail as well as truck freight routes. The local 6006 world market, trading within 75 miles of the model boundary, is linked to the minor roadway External Stations that is all but I-5 (5002, 5010) and I-84 (5007).[6]

Table 2.2. PI World Market Zones and Distance Assumptions

Zone Number	Code	Distance beyond halo (miles)*	External Station/ Relevant Roads	World Market Definition
6001	N	240	5002 I-5	Washington State and Canada
6002	NE	800	5003 I-82 5004 US 395	Northern states of the Midwest
6003	E	1,200	5007 I-84	Central and Eastern part of the US and barge traffic through East and South Coast US ports
6004	S	460	5010 I-5	California,, Southwestern states and Mexico
6005	Ocean	1500 for imports, 600 for exports	Port of Portland	Rest of the world
6006	Local	75	5001, 5003, 5004, 5005, 5006, 5008, 5009, 5011	Local markets in neighboring states

* Assume 50 mph beyond halo to calculate equivalent travel time.
** Assumes $600-900 import and $700-2200 export costs to ship a Truck Equivalent Unit (TEU) between Portland and Japan (per may 2007 discussions with Port of Portland Staff).

[4] Area Commissions on Transportation (ACTs), used in Oregon transportation planning, provide a convenient way to divide the State into 12 areas.

[5] The assignment of external origin/destination regions to external stations is based on a fastest travel time analysis to the centroids of each external region. An assumption of 50mph is used to calculate the equivalent travel time. World Market 6005 assumesan equivalent distance that allows accurate oceanic shipping costs while using truck transport cost per mile as defined elsewhere in the PI module (CommoditiesI.csv). Oceanic time costs were assumed to be 0 as goods sent by ship tend to be less time-dependent. The Air mode was ignored, as it represents less than 1 percent of all goods movement in Oregon, and at most 2 percent of any single commodity's flows.

[6] Flows to and from World Market 6006 are currently not assigned; they represent less than 4% of overall goods flows.

Figure 2.3. World Markets in North America

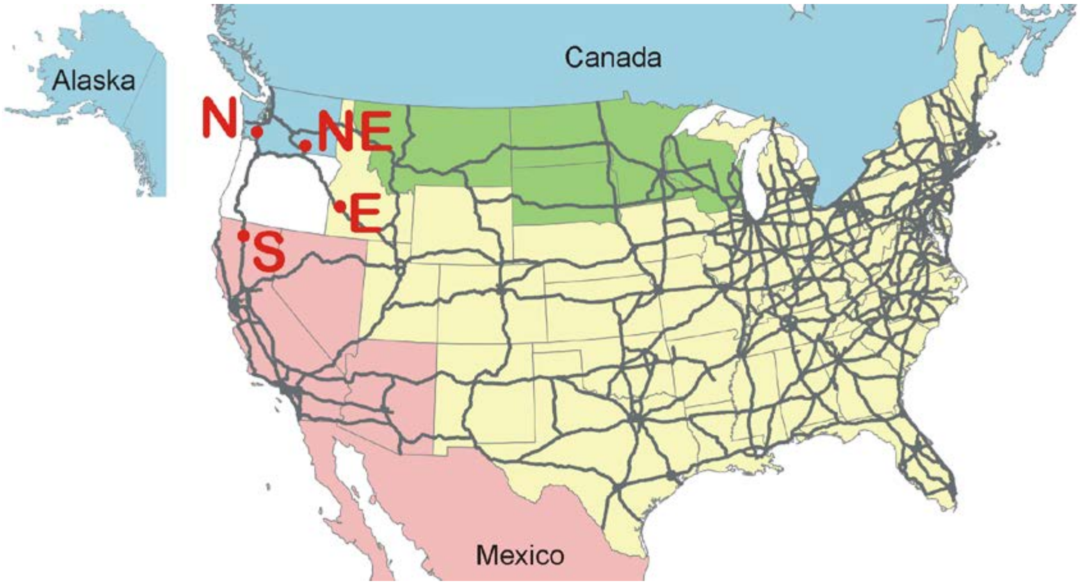
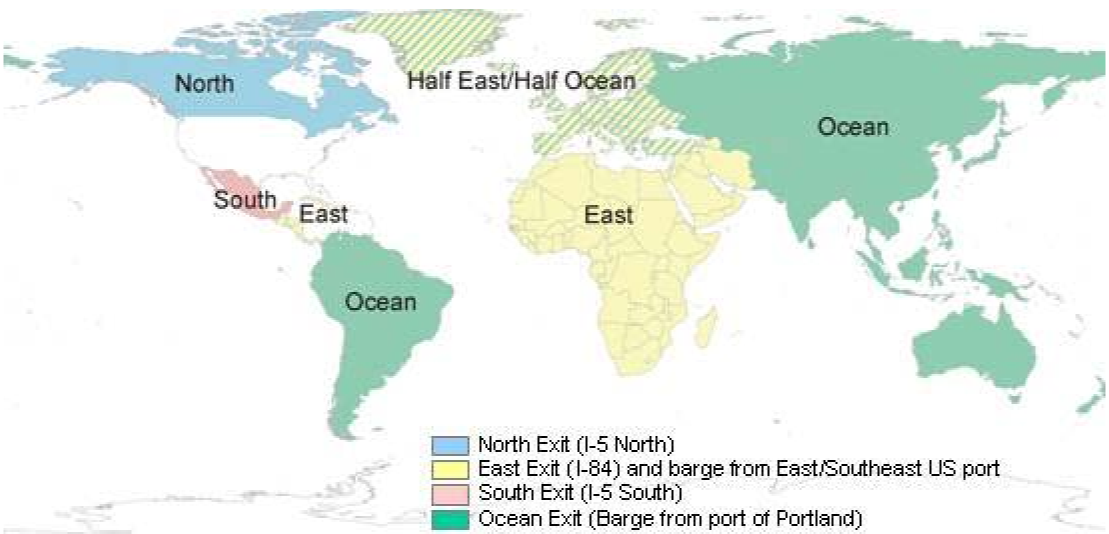
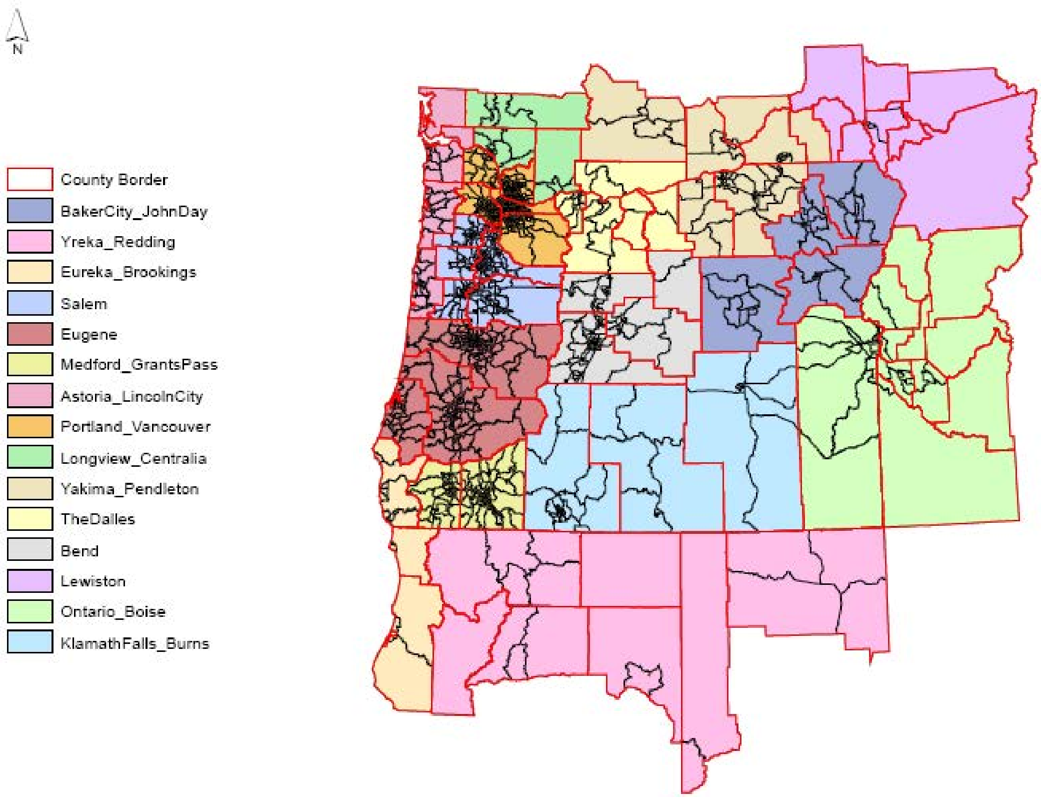


Figure 2.4. World Markets outside US



The ALD land use module uses a 15 region aggregation of the alpha zones for making land development decisions. These regions, shown in Figure 2.5 represent SWIM2 land development markets within the study area.

Figure 2.5. ALD Land Market Regions



2.2. Category Definitions

The SWIM2 model at its core, encapsulates a spatial input-output formulation that resides in the PI module. Figure 2.6 provides a summary of the Input-Output make and use table framework and the categories of activities and commodities used within them, showing the specific types of economic interactions represented in the model. Commodity production is represented in the make table at the top of Figure 2.2; commodity consumption is represented in the use table at the bottom; commodities ‘flow’ down the columns from where they are produced to where they are consumed. The general nature of the exchange location for each commodity category and the treatment of imports and exports are also indicated.

Tables 2.3 and 2.4 list the industry, government and household activity categories used in SWIM2. In general, a given industrial sector is split into blue-collar and white-collar (or ‘management’) components using associated ‘production’ and ‘office’ space, respectively. In this way the allocation processes in the module can consider the very different location behavior and space requirements of these two components. The few industries without separate management and production sites include FIRE, hotel, personal services, construction, and home-based services. Internal management activities strictly produce management services consumed by their corresponding industries. Home-based services are self-employed workers who sell their services to households (e.g., housekeepers, nannies, handymen). The brokerage portion of real estate, which uses labor and floorspace, was folded into FIRE. The remaining rents of the 'real estate' category, and other aspatial activities were folded into imports (if negative) or exports (if positive). These aspatial activities don't consume floorspace or labor and include private and institutional money flows (rents, enterprises, capital, federal/state/local government funding and investment, accounting/financial transactions, change in inventories, salvage).

Household activities are base on the 1990 Census PUMS categories of household income (1990$) and persons per household. Household activities include the production of labor and consumption of various goods (primarily through retail) and services. Industry and government activities include the production and consumption of goods and services. Note that internal money flows commodity, 'Money and Unclassified Goods' and SCTG41 Waste and Scrap, do not produce trips within CT and ET.

Tables 2.5 through 2.8 identify various commodities produced and consumed in the model, including study area imports and exports. Table 2.5 identifies the commodities tracked in the CT module, including 42 types of goods, based on standard commodity (SCTG) classifications.

Table 2.6 identifies the 16 services, including internal management services tracked in the PT Model. Internal Management Services, defined as 'value added office labor', spatially connect the production and office components of split industries. This commodity is the service provided by management and other office support workers to the production floor of the same industry. In many cases, this flow represents a relationship between two establishments of the same firm.

Labor is included as a commodity that is produced by households and consumed by economic production activities. As such, SPG respects the home end while PT respects the work end of labor flows produced by the PI module. Different labor occupation categories are treated as different commodity categories, as shown in Table 2.7.

Floorspace categories are shown in Table 2.8, while Table 2.1 identifies which floorspace types are used by each industry category. The ALD Module adjusts the inventory of developed floorspace available in alpha zones in any model period.

Figure 2.6. Summary of Commodities Made/Used by Various Activities in the Model

	commodities goods	internal management services	services	education services	retail services	domestic services	labor	residential space	non-residential space
producing activities (making)									
industry	goods production by industry	internal management services production by industry	services production by industry	education services production by industry	retail services production by industry				
government	goods produced by government		services production by government	education services production by government					
households						domestic services production by households	labor production by households		
export locations									
edge exit points	r						r		
airports & waterports points	r								
all production points			r	r	r				
exchange locations									
consumption points		x				x	x	n	n
production points	x		x	x				n	n
all zones									
selected zones									
import locations									
edge entry points	i		i				i		
airports & waterports points	i		i						
all production points									
consuming activities (using)									
industries	goods consumption by industry	internal management services consumption by industry	services consumption by industry	education services consumption by industry			labor consumption by industry		space consumption by industry
government	goods consumption by government		services consumption by government	education services consumption by government			labor consumption by government		space consumption by government
households	goods consumption by households - direct		services consumption by households	education services consumption by households	goods consumption by households - via retail	domestic services consumption by households		space consumption by households	

Table 2.3. Activities - Industries

Index*	Industry	Floorspace	Internal Service
2, 3	Agriculture And Mining	in Agriculture space	and Office space
7,8	Electronics And Instruments	in Light industry space	and Office space
10, 12	Food Products	in Heavy industry space	and Office space
11, 12	Food Products	in Light industry space	
23 , 24	Lumber And Wood Products	in Heavy industry space	and Office space
25, 27	Other Durables	in Heavy industry space	and Office space
26, 27	Other Durables	in Light industry space	
28, 30	Other Non-Durables	in Heavy industry space	and Office space
29, 30	Other Non-Durables	in Light industry space	
32, 33	Pulp And Paper	in Heavy industry space	and Office space
4, 5	Communications And Utilities	in Light industry space	and Office space
36, 37	Transport	in Depot space	and Office space
38, 39	Wholesale Trade	in Warehouse space	and Office space
34, 35	Retail Trade	in Retail space	and Office space
16, 18	Health Services	in Hospital space	and Office space
17, 18	Health Services	in institutional space	
19, 22	Higher Education	in institutional space	and Office space
21, 22	Lower Education	in Grade-school space	
14, 15	Government Administration	in Government Support space	and Office space
13	Forestry And Logging	in Logging space	
1	Accommodations	in Accommodation space	
9	Fire, Business, and Professional Services	in Office space	
31	Personal And Other Services And Amusements	in Retail space	
20	Home-based Services	(does not consume floorspace)	
6	Construction	(does not consume floorspace)	

* Second index is for ‘office’ portion of split industry.

Table 2.4. Activities - Household Income-Size Categories (1990$)

Code	Description	
HH0to5K1to2	Household Income $0 to 4,999	Household size 1 to 2 persons
HH5to10K1to2	Household Income $5,000 to 9,999	Household size 1 to 2 persons
HH10to15K1to2	Household Income $10,000 to 14,999	Household size 1 to 2 persons
HH15to20K1to2	Household Income $15,000 to 19,999	Household size 1 to 2 persons
HH20to30K1to2	Household Income $20,000 to 29,999	Household size 1 to 2 persons
HH330to40K1to2	Household Income $30,000 to 39,999	Household size 1 to 2 persons
HH40to50K1to2	Household Income $40,000 to 49,999	Household size 1 to 2 persons
HH50to70K1to2	Household Income $50,000 to 69,999	Household size 1 to 2 persons
HH70plusK1to2	Household Income over $70,000	Household size 1 to 2 persons
HH0to5K3plus	Household Income $0 to 4,999	Household size 3 or more persons
HH5to10K3plus	Household Income $5,000 to 9,999	Household size 3 or more persons
HH10to15K3plus	Household Income $10,000 to 14,999	Household size 3 or more persons
HH15to20K3plus	Household Income $15,000 to 19,999	Household size 3 or more persons
HH20to30K3plus	Household Income $20,000 to 29,999	Household size 3 or more persons
HH30to40K3plus	Household Income $30,000 to 39,999	Household size 3 or more persons
HH40to50K3plus	Household Income $40,000 to 49,999	Household size 3 or more persons
HH50to70K3plus	Household Income $50,000 to 69,999	Household size 3 or more persons
HH70plusK3plus	Household Income $70,000 and over	Household size 3 or more persons

Table 2.5. Commodities – Goods Categories

Goods	
SCTG01: Live animals and live fish	SCTG25: Logs and other wood in the rough
SCTG02: Cereal grains	SCTG26: Wood products
SCTG03: Other agricultural products	
SCTG04: Animal feed and products of animal origin n.e.c.	
SCTG05: Meat fish seafood and their preparations	SCTG27: Pulp newsprint paper and paperboard
SCTG06: Milled grain and bakery products	SCTG28: Paper or paperboard articles
SCTG07: Other prepared foodstuffs and fats and oils	SCTG29: Printed products
SCTG08: Alcoholic beverages	
SCTG09: Tobacco products	
	SCTG31: Nonmetallic mineral products
SCTG10: Monumental or building stone	SCTG32: Base metal in primary or semi-finished forms and finished basic shapes
SCTG11: Natural sands	SCTG33: Articles of base metal
SCTG12: Gravel and crushed stone	SCTG34: Machinery
SCTG13: Nonmetallic minerals n.e.c.	SCTG35: Electronic/electrical equipment and components
SCTG14: Metallic ores and concentrates	SCTG36: Motorized and other vehicles (including parts)
	SCTG37: Transportation equipment n.e.c.
SCTG15: Coal	
SCTG16: Natural Gas & Crude Petroleum	
SCTG17: Gasoline and aviation turbine fuel	
SCTG18: Fuel oils	SCTG38: Precision instruments and apparatus
SCTG19: Coal and petroleum products n.e.c.	SCTG30: Textiles leather and articles of textiles or leather
	SCTG39: Furniture mattresses and mattress supports lamps lighting fittings and illuminated signs
SCTG20: Basic chemicals	
SCTG21: Pharmaceutical products	SCTG40: Miscellaneous manufactured products
SCTG22: Fertilizers	SCTG41: Waste and scrap (not used in CT/ET)
SCTG23: Chemical products and preparations n.e.c.	
SCTG24: Plastics and rubber	Money and unclassified goods (not used in CT/ET)

Table 2.6. Commodities – Services Categories

Services	
Internal Management Services (B)	Transport (B)
Fire, Business, And Professional Services (B)	Communications And Utilities (B)
Personal And Other Services And Amusements (P)	Construction (B)
Health Services (P)	Government Administration (P)
Accommodations (B)	Higher Education (P)
Real Estate (P)	Lower Education (P)
Homebased Services (P)	
Retail Trade (P)	
Wholesale Trade (B)	

Note: Assumed to be primarily business (B) or personal (P) services

Table 2.7. Commodities - Labor Occupation Categories

Index	Labor Occupations	1990 US Census Occupation Codes
0	0_NoOccupation: Not employed	NA
1	1_ManPro: Managers/Professionals	0-82
2	1A_Health: Health Workers	83-112
3	2_PstSec: Post-Secondary Teachers	113-154
4	3_OthTchr: Other Teachers	155-162
5	4_OthP&T: Other Professional/Technical Office	163-262
6	5_RetSls: Retail Sales Workers	263-282
7	6_OthR&C: Other Retail/Clerical Office	283-402
8	7_NonOfc: Non-Office workers	all other

Table 2.8. Commodities - Floorspace Categories

Residential Floorspace	NonResidential Floorspace	Other Floorspace
FLR SFD (Single Family Home)	FLR Accommodation	FLR Agriculture (includes Mining)
FLR MH (Manufactured Home)	FLR Office	FLR Logging
FLR AT (Attached Home)	FLR Government Support	
FLR MF (Multi-family, Institutional)	FLR Retail	
FLR RRSFD (Rural Residential SFD)	FLR Warehouse	
FLR RRMH (Rural Residential MH)	FLR Depot	
	FLR Light Industry	
	FLR Heavy Industry	
	FLR Hospital	
	FLR Institutional	
	FLR Grade-school	

Table 2.9 identifies the various modes and vehicles used in the model to transport person and goods flows. Non-motorized passenger modes and non-truck freight modes are not assigned to the network.

Table 2.9. Modes and Vehicle Types

Trip Code	SDT	LDT	CT	ET	Trip Mode	Trip Mode Definition
Passenger (PT SDT and PT LDT)						
DA	X	X			Drive-Alone	Single-occupant auto
SR2	X	X			Shared-Ride 2	2 person occupant auto
SR3P	X	X			Shared-Ride 3+	3+ person occupant auto
WALK*	X				Walk	Walk
BIKE*	X				Bicycle	Bicycle
TRANSIT_WALK		X			Walk-Transit	Walk-Access Transit
TRANSIT_DRIVE		X			Drive-Transit	Auto-Access Transit
SCHOOL_BUS*	X				School bus	School bus (not assigned to the network)
AIR		X			Drive-Air	Drive-Access Air travel within the model area
HSR_DRIVE		X			Walk-HSR	Drive-Access intercity Rail
HSR_WALK		X			Drive-HSR	Walk-Access intercity Rail
Freight						
STK			X		Truck	
TRK1			X		TRK1	<34,000 lbs. (likely single-unit)
TRK2			X	X	TRK2	34,000 -64,000 lbs.
TRK3			X		TRK3	64,000 -80,000 lbs. (articulated)
TRK4			X	X	TRK4	80,000 - 105,500 lbs. (articulated)
TRK5			X		TRK5	>105,500 lbs. (articulated)
SAA*			X		Air	
SRR*			X		Freight Rail	
SWA*			X		Waterborne Freight	
SPA*			X		Pipeline	

* Not assigned to the network.

Table 2.10 provides a listing of all of the attributes of persons and households created in the SPG module and used in the PT module. The table also shows the 1990 Census-based coding categories for each attribute. The fields of the synthetic population used in the SWIM2 model are described below (asterisked values are synthesized by the model, others are retained with the drawn PUMS record). SPG controls only for workers per household, worker industry, and person age. SWIM2 assigns home location and work location based on PI labor flows:

- ***Household-Person File Link (HH_ID, PER_ID).*** The household attributes were linked to each person in the household, by storing a household (HH_ID) and person (PER_ID) id in the person file. HH_ID are numbered sequentially across the whole sample (starting with 1). PER_ID are numbered sequentially across all persons in a household.
- ***Household Attributes (PERSONS, AUTOS*).*** The number of persons and the total number of autos in the household. The Census auto value is updated by the PT module.
- ***Home Location (ALPHAZONE).*** The alpha zone location of the household, assigned by SPG2 (consistent with PI labor flows).
- ***Household Income (RHHINC).*** Total household income in units of 1989 dollars.
- ***Residential Floorspace Type (UNITS1, SINGLE_FAMILY*).*** The household's residential floorspace type is indicated by the number of units in the dwelling unit (UNITS1). In PT, a binary variable is created to indicate whether the dwelling unit is a single family unit.
- ***Demographics (AGE, SEX).*** Age and gender for each household member.
- ***Employment Information (RLABOR, OCCUP, INDUSTRY, ESR*, SW_OCC*, SW_SPLIT_IND*, WORKTAZ*).*** Employment status for each household member indicates whether each person is employed or not in labor force (RLABOR). If employed, PUMS occupation and industry from PUMS (OCCUP, INDUSTRY) are reassigned consistent with SWIM2 categories (SW_OCC and SW_SPLIT_IND). The PT module assigns a work location alpha zone (WORKTAZ) and employment status code (ESR)
- ***School Status (SCHOOL).*** School status of each household member representing whether the person was currently enrolled in school.

Other variables that could be retained in the 1990 Census PUMS household record include:

SERIALNO, GQINST, ROOMS, TENURE, ACRE10, ONEACRE, YRMOVED, COMMUSE, VALUE, RENT1, MEALS, BEDROOMS, WATER, SEWAGE, YRBUILT, CONDO, AGSALES, RTAXAMT, RFARM, RFAMINC, RWRKR89, RHHFAMTP, RNATADPT, RSTPCHLD, RFAMPERS, RNRLCHLD, RNONREL, R18UNDR, R60OVER, R65OVER, RSUBFAM

Other variables that could be retained in the 1990 Census PUMS person record include:

SERIALNO, RELAT1, RACE, MARITAL, RSPOUSE, RAGECHLD, YEARSCH, MOBILITY, MILITARY, DISABL1, DISABL2, MOBILLIM, HOURS, WORKLWK, MEANS, RIDERS, DEPART, TRAVTIME, TMPABSNT, LOOKING, AVAIL, YEARWRK, CLASS, WORK89, WEEK89, HOURS89, REARNING, RPINCOME, INCOME1

Table 2.10. Synthetic Population Household and Person Attributes

Household Attributes	
Code	Description
HH_ID	Household ID
AZONE*	Home Location alpha zone 0001-4141
PERSONS*	Number of Person (person records) in household
RHHINC	Household income (1989$) 0000000 .N/A(GQ/vacant/no income) -999999..9999999 .Total household income
AUTOS (PUMS version, replaced by PT-version)	Vehicles (1 ton or less) available 0. N/A (GQ/vacant) 1 . No vehicles 2 . 1 vehicle 3 . 2 vehicles 4 . 3 vehicles 5 . 4 vehicles 6 . 5 vehicles 7 . 6 vehicles 8 . 7 or more vehicles
UNITS1	Units in structure 00 .N/A or Group Quarters (MF) 01 .Mobile home or trailer (MH or RRMH) 02 .One-family house detached (SFD or RRSFD) 03 .One-family house attached (AT) 04 .2 Apartments (AT) 05 .3-4 Apartments (MF) 06 .5-9 Apartments (MF) 07 .10-19 Apartments (MF) 08 .20-49 Apartments (MF) 09 .50 or more apartments (MF) 10 .Other (MF)

Person Attributes	
Code	Description
HH_ID	Household ID
PER_ID	Person ID
AGE*	00 .Less than 1 year 01..89 .Age in years 90 .90 or more years old
SEX	0 .Male 1 .Female
SCHOOL	0 .N/A (less than 3 years old) 1 .Not attending school 2 .Yes, public school, public college 3 .Yes, private school, private college
RLABOR	Employment status 0 .N/A (less than 16 years old) 1 .Civilian employed, at work 2 .Civilian employed, with a job but not at work 3 .Unemployed 4 .Armed forces, at work 5 .Armed forces, with a job but not at work 6 .Not in labor force
OCCUP	Census Occupation ### (1990 Census Occupation codes)
INDUSTRY*	Census Industry ### (1990 Census Industry codes)
SW_OCCUP	SWIM2 Occupation (based on PUMS OCCUP fields) See Table 2.7 Index
SW_SPLIT_ IND*	SWIM2 Split Industry ('office' split from 'production') (based on SW_OCCUP and INDUSTRY fields) See Table 2.3 Index

From SPG output files: SynPopP.csv and SynPopH.csv

Household Attributes	
Code	Description
SINGLE_ FAMILY	Single Family 0. Multi-family household 1. Single-family household
AUTOS	Vehicles (1 ton or less) available 0. No vehicles 1 . 1 vehicle 2 . 2 vehicles 3 . 3 or more vehicles

Person Attributes	
WORKTAZ*	Work Location alpha zone 0001-4141 (assigned by PT work location choice model)
ESR	Simplified Employment Status 0. Not employed 1. Employed

From PT output files: personData.csv and householdData.csv

* SWIM2 only controls for workers per household, worker industry and person age.

Note: the head of household is the first person listed in SynPopH as taken from PUMS.

2.2. Running the Model

The SWIM2 model runs on a dedicated TLUMIP cluster of six quad-core computers housed in the Salem, Oregon State Data Center (SDC). A model-runner system graphical user interface (MrsGUI) is the key interface for users working with the model. Password-protected remote desktop access to the SDC TLUMIP compute cluster is also available. MrsGUI is designed to executes a series of commands that remotely does a variety of tasks on the Salem TLUMIP cluster, including: building scenarios, running the model, providing real-time status information, running post-processing Metrics, and the ability to pull Metric outputs and log files to the user's local computer.

MrsGUI essentially executes a series of scripts for the user to do each of these tasks, written in a mix of python, java, and ant languages. The ant commands execute the model's java code and provide logging output, by calling on the Application Orchestrator (AO) module.

The Oregon Statewide Integrated Model User's Guide [1], contains more information on the SDC TLUMIP cluster, remote access, MrsGUI installation, and instructions for running the model and post-processing Metrics scripts (using R/SQLite software). The rest of this section overviews the model directory structure, and key functionality of MrsGUI, and the AO module.

2.2.1. Directory structure

The Oregon Statewide Integrated Model (SWIM2) is designed for use within a directory structure form, shown in Figure 2.7. The structure separates user-modified inputs, parameters, base year inputs, from scenario outputs, simplifying the user interface and facilitating scenario backup/archiving.

After a scenario is created, all input files and code necessary to run the model are split among three folders: parameters (fixed after calibration), java_files (fixed software and configuration files), and user_inputs (select set of user-modifiable files). The user_inputs directory has sub-folders for each scenario and within each folder, a sub-folder for each year. The Analysis folder also has this scenario-year sub-folder structure. A user can set up "Child" scenarios that hinge off Base or "Parent" scenarios. Child Scenarios, like Base scenarios, contain their own year sub-folders that house all Child model user_inputs and outputs (including potential bootstrapped outputs copied in when the Child scenario was created).[7] Output scenario-specific log files and the command file used in DAF runs are housed in the scenario's ops folder. This folder structure is described in more detail below.

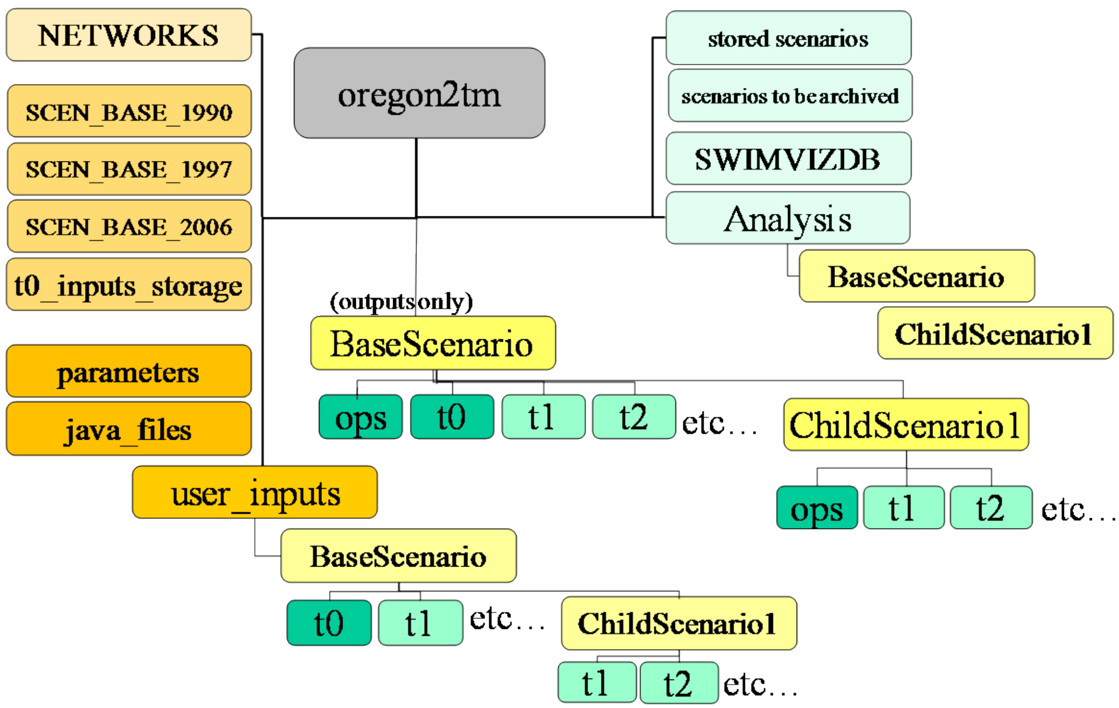
Each run of the model has its own Base Scenario directory structure which is a complete reference scenario run and stores full model outputs. Inputs would reside in the user_inputs, parameters, or as the output of other modules, in the current or previous year directory for the scenario. The Base Scenario/t0/ folder files would duplicate the t0_inputs_storage folder files, copied into the Base Scenario when created. Child scenarios would simply require the user to create a Child Scenario folder in the user_inputs folder with appropriate file changes from the base year stored in its scenario-year sub-folders. Running the model would generate the model outputs in the sub-folders of the Base Scenario or ChildScenario.[7]

Some files are constant over time and therefore the modules will always look in the base year t0 directory (or common reference directory) unless directed differently in the properties file. For

[7] Child scenario functionality has not been fully tested as of April 2010 and may be phased out.

example, a file of vehicle occupancies used by the TS module that applies to all years would be saved in the t0 TS subdirectory. If for example vehicle occupancies changed in future year tn, a separate file with the new occupancies is placed in the user_inputs scenario tn subdirectory along with a globalTemplate.properties file (indicating tn path to this file references). This latest occupancy file would then remain in effect until the end of the simulation or until a later year properties file was found.

Figure 2.7. Oregon Statewide Integrated Model (SWIM2) Directory Structure



2.2.2. Model Runner System Graphical User Interface (MrsGUI)

MrsGUI is a python program which runs on the user's local machine and communicates with a daemon program running on the SDC TLUMIP computer cluster. The daemon program provides a way for MrsGUI to interact with model runs and results without having to directly access the cluster on which the model runs and results reside. A summary description of the capabilities of MrsGUI version 3.1 is listed below, reflecting capabilities of the MrsGUI software (user end) as well as the daemon program (running on the SDC TLUMIP computer cluster).

Scenario interaction

- Create SWIM2 scenarios with space for scenario text description; ability to edit the scenario text
- List all available scenarios (even those not created through MrsGUI)
- Echo recent scenario command history (list of recent commands through MrsGUI)
- Identify scenarios actively running

Cluster interaction

- Select computers to use in a model run from a number of pre-set computer cluster configurations (typically 1 machine or all 8 machines)
- Query the status of each cluster machine (both connection status and whether machines are busy running a model scenario or not)

Model run interaction

- Select from a number of model run (ANT) targets to run on the chosen cluster configuration; selectable targets are built "on-the-fly" from a specially formatted ANT XML file. These targets indicate which modules to run for which years.
- Ability to run a target asynchronously, e.g., MrsGUI does not lock up (or need to remain open) for target to continue running
- Query the status of current model scenario runs (still running or finished)
- A Stop button that allows the user to stop a model run before complete, and close all active computers gracefully.
- Query for the last 50 lines of log files for a currently running model scenario; this can be set to update at preset intervals for logging updates
- Retrieve entire log files for a specified scenario; the log files are copied to the local computer and opened in a simple text viewer, allowing the logs to be saved/printed as needed.

Other

- Multiple MrsGUI's can access a single cluster at one time without any issues; multiple MrsGUI's can be run on a single machine simultaneously
- MrsGUI is not tied to a specific computer cluster; if the daemon program is set up on a non-SDC computer clusters, then additional configuration files (simple to produce) can be generated to allow MrsGUI to access the cluster of the user's choosing
- MrsGUI's look is relatively customizable: text size, window sizes, and background colors can be changed (and saved) depending on the user's preferences; multiple configurations can be saved and loaded as desired
- MrsGUI runs as a standalone executable and does not need any program environment or installation (other than Windows) to run.

2.2.3. SWIM VIZ Database and Visualization Tool

SWIM VIZ Database and Visualization tool was developed to dynamically visualize and inspect core multi-year SWIM2 model results and better understand SWIM2 operations. It contains both a Database (SWIM VIZ DB) and Adobe Flash application tool (SWIM VIZ Tool).

The SWIM VIZ DB conveniently organizes the core output data for all years of a scenario. Data is organized in a few tables at the Beta zone level. This standardized format facilitates further output processing using the SWIM VIZ Tool or other scripting, such as using sqlite and/or R software. The key tables are listed below, with more detail available in the SWIM VIZ DB documentation [4].

- **ACTIVITYLOCATIONS** – the quantity of activity generated by BZONE, such as industry 1990$, household, employment.
- **BUYSELLMATRIX** – the commodity flows from the PI module between beta zones, including the dollar flow of labor, goods, and services.
- **EXCHANGERESULTS** – PI beta zone information on the exchange of commodities (goods, services, labor, and floorspace), such as the quantity of demand and supply, price, etc,
- **FLR_INVENTORY** – ALD beta zone floorspace inventory and zoning capacity by type.
- **DC_LOGSUM** – average logsums by BZONE, trip PURPOSE, market SEGMENT.
- **TRIPS_SDT, Trips_LDT, Trips_CT** – aggregated trips and trip distances by *trip* origin BZONE from the various transport modules. Additional trip attributes specific to each module (e.g., commodity weights in CT, trip purpose in SDT and LDT) are also stored. There is a column of trips for each time period.
- **TRIPS_SDT_Home., TRIPS_LDT_Home, TRIPS_CT_Home** – same as above, except trips are aggregated by person trip household *home* BZONE origin and *truck tour* origin, rather than *trip* origin.
- **TRIPMATRIX** – combined trip matrices for each BZONE OD pair, time period, and mode from SDT, LDT, CT, and ET aggregated to common modes/truck classes.
- **LINK_DATA** – TS link assignment results (volumes, etc.) for each time period.
- **SKIM** – Travel distance, time, tolls for each BZONE OD pair t for peak and off-peak, auto and truck.
- **MODELWIDE** – various modelwide data typically associated with the ED module.
- Other tables, helpful to SWIM VIZ Tool: **ALLZONES**, **BZONE**, **TSTEP**

SWIM VIZ DB Micro houses the synthetic population (persons and households from SPG) as well as detailed tour and trip information for person (from PT) and internal trucks (from CT). The key tables are listed below with more detail available in the SWIM VIZ DB micro documentation [44] and SWIM2 Users' Guide.

- **HH** – represents all the households in the model and their key attributes, including description of any long distance tours.
- **PER** – represents all the persons in the model and their key attributes, including industry, work status.
- **TOUR_LDT_MICRO** – represents all the long distance (LDT) tours in the model, including their purpose, mode, origin and destination zones, times, and party size.
- **TRIP_LDT_MICRO** – represents all the LDT vehicle trips in the model, including their purpose, mode, origin and destination zones, and times.
- **TOUR_SDT_MICRO** – represents all the short distance (SDT) tours in the model, including their purpose, mode, origin and destination zones, and times.
- **TRIP_SDT_MICRO** – represents all the SDT person trips in the model, including their purpose, mode, origin and destination zones, and times.
- TRIP_CT_MICRO – represents all but the through truck trips (CT, not ET) in the model, including commodity, carrier type, weight, origin and destination zones, and times.

During model setup the user can flag that a scenario produce one or both of these VIZ DBs. Then a sqlite database for each year of the scenario is created after the model run completes, and compiled into a master scenario sqlite database that contains all years. A zipped version of the multi-year SWIM VIZ DB is copied to the ODOT FTP site facilitating remote users in obtaining this data.

2.2.4. Application Orchestrator (AO) Module

The AO module is a collection of components that directs the flow of the full SWIM2 Model. The key components of AO include:

- The Distributed Application Framework (DAF)
- Launching components (using Ant and ApplicationOrchestrator.java, and FileMonitor.java)
- Monitoring progress (using Logger.java)

The Oregon Statewide Integrated Model (SWIM2) consists of two types of components: monolithic and distributed. A monolithic application is one that is run on a single machine, more specifically inside a single Java Virtual Machine (Java VM), also referred to as a node. Currently, ED, ALD, SPG1, SPG2, CT and ET are monolithic. By contrast a distributed application is one that is run on multiple machines or inside several Java VMs, or in other words on more than one node. A collection of nodes that communicate with one another is called a 'cluster'. PI, PT, and TS are examples of distributed applications. These applications could be run monolithically but distributing the process over multiple nodes significantly decreases their run times. The code is broken up into 'tasks' and the tasks can be performed simultaneously on different nodes for a different set of objects. For example, in the case of PI, there is a task that calculates the composite buying and selling utilities for a single commodity. Because there are 84 commodities, this work can be distributed to 8 nodes for example, so that a buying and selling utility for 8 different commodities can be calculated at the same time. There is some coordination required when separating code into tasks as the data has to once again be combined. The Distributed Applications Framework (DAF) provides this coordination. The TS module uses a slightly different DAF framework (DAF3) than that of PI and PT (DAF2).

The Distributed Application Framework (DAF) code was written to handle the distribution of an application over multiple nodes.[2] DAF provides the communication mechanism, a messaging system, that allows the nodes to send messages to tasks on other nodes, receive messages and to 'listen' for messages from other nodes. Tasks 'listen' for messages to arrive in a work queue associated with that task. As soon as work arrives it is processed and a return message is usually sent. DAF also provides methods to start and stop all nodes in a cluster from a single node and to start an application from a node outside of the cluster.

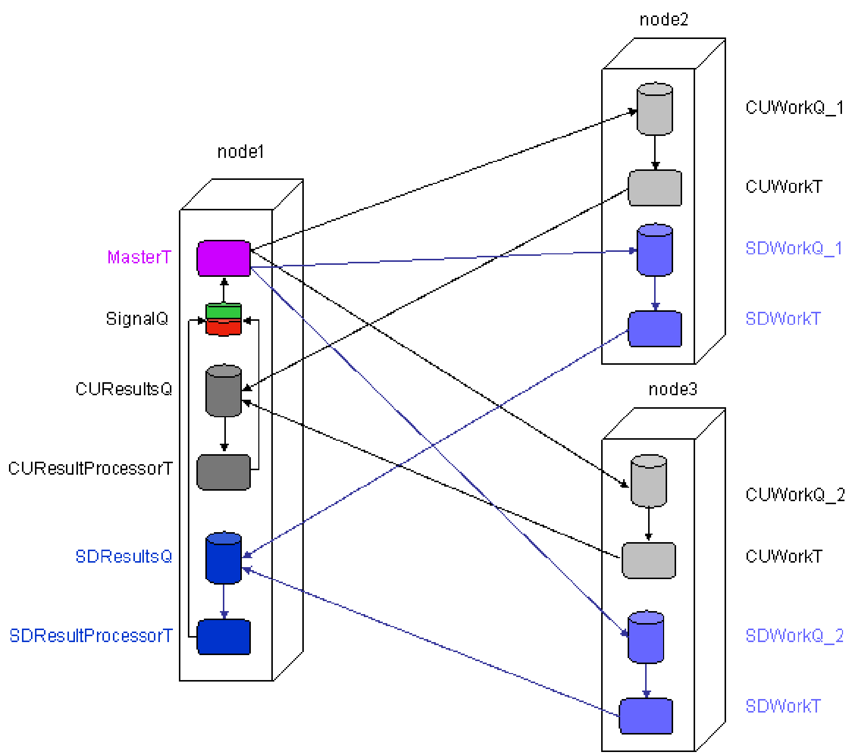
A 'daf.properties' file is used to define a 'daf cluster'. A cluster can be a single machine that runs multiple Java VMs with 1 task per VM or a cluster can be 5 machines running 5 Java VMs with 10 tasks running in each VM. Machine memory is the biggest constraint as each VM uses up to 8 GB or more of memory. The daf.properties file describes only the nodes and therefore the cluster is defined independent of the application that will be run on it. An application may utilize all nodes in a cluster or may only use a subset of available nodes. An application specific daf properties file is therefore also necessary to describe each task that the application will perform and assign it to a particular node. The work queues are also defined in the properties file where they are associated with a particular task and a particular node. MrsGUI codifies various set DAF configurations.

Figure 2.8 illustrates how PI might be distributed over three nodes. The PI tasks include a Master task, a CUWork task (computes the composite utilities of buying and selling a particular commodity in a particular exchange zone), an SDWork task (calculates the surplus and its derivative of a particular commodity in a particular exchange zone), two Result Processing tasks and associated work queues (see section 6.0 for more detail on the PI module).

Launching a Component

Launching monolithic (and distributed) components is currently being done using Pants. Pants stands for Python ANT Substitute and is a program which was created to replace the previous component launching program, Ant. One of the benefits of Pants are that it allows tasks to be specified in Python (as opposed to XML, which is what Ant used), which allows a natural "program flow" to be specified using standard programming idioms. Another advantage is that it stores an entire run sequence in a database, which allows the model run's sequence position to be determined, as well as allowing a run to be continued if it was stopped. Pants uses a definition file written in Python, which specifies targets which are accessible to the user. These targets build up a model sequence, which is then loaded into a database, and finally the sequence is executed using database queries to determine each step

Figure 2.8. Distributing the PI Module Over 3 Nodes



In the case of the monolithic components the Pants target (e.g., runED, runALD) located in the TlumipDef.py file starts a new Java VM on a machine in the cluster, instantiates the ApplicationOrchestrator object inside it and passes to it the name of the component (e.g., 'ed') to be started. ApplicationOrchestrator then simply creates an instance of the named component and calls its 'runModel' method. This assumes that the constructor of that component will read the appropriate properties file and configuration files. Properties files contain run-time information, such as the name of input files. Configuration files hold the things that do not change, such as internal parameter values. The component will then handle the rest of the processing. Each module component will clean up after their run and communicate with other components via data files, and thus, does not return data structures or other information to the orchestrator.

A distributed component is also launched using a Pants target so that the ApplicationOrchestrator is created inside its own node, as discussed above. For the distributed components, however, this node must start other nodes both on its local machine as well as nodes on remote machines in the cluster. A FileMonitor object is the mechanism by which the Orchestrator object communicates with DAF. The FileMonitor class works as follows:

A simple text file is used as a 'command file' and serves as a central command station. Each machine in a DAF cluster will create a FileMonitor object in a small Java VM. This object monitors the command file for changes. When a change in the lastDateModified attribute is detected, the FileMonitor reads the contents of the file and executes the command found therein.

Thus, to start a distributed application, the ApplicationOrchestrator object first writes 'StartNode' into the command file. AO waits for a short time and then writes 'StartCluster' into the command file, overwriting the previous command. The orchestrator again waits and then writes the name of the application that is supposed to run into the command file. The FileMonitors, detecting the changes, execute the appropriate code on their machine. AO then waits for the appearance of a 'done' file that will be written by the application when it has finished executing. When the done file appears, AO will write 'StopNode' into the command file and the FileMonitors will stop the java processes running on the machines.

For more information on the FileMonitor class, see additional reference on this topic [3].

Logging

AO uses logging statements generated by the individual modules to provide feedback to the users as to the module's progress. These log statements can be directed to the console or to a file as specified in a logging.properties that is shared by all components. The following logging output is generated automatically and written to the Scenario /ops directory during a model run:

- main_event.log – the main process log file.
- node[node number]_event.log – the log file for the DAF node on computer [node number].
- bootstrap_server_node[node number].log, bootstrap_client.log, fileMonitor_event.log – logs related to the inner workings of the DAF components.
- global_status.log – a global status log file.
- status.log – a module-level status log file.

In addition to the log files, at the end of each run, a Java program is run which reads the log files and summarizes the run at both a global and module level. The files created by the process (also placed in the /ops directory) are:

- ModuleSummary.csv – an overall summary of the runtimes of the various modules.
- PiConvergencesSummary.txt, PiIterationSummary.txt, PiMaxSurplus.csv, PiMeritMeasures.csv – summaries of PI module.
- PtIterationSummary.txt – a summary of the PT module.
- TsSummary.txt – a summary of the TS module.

2.3. Calibration Approach

A three-stage process is used to develop the values for the parameters in the various modules in the model.

In Stage 1 values are developed for certain 'S1' parameters in each module separately. The intention is that these first-stage values for the S1 parameters will remain fixed as the model development and calibration work progresses. When suitable observations of system behavior are available, statistical methods are used to estimate appropriate values for S1 parameters. In some cases, only a single observation is available, and direct methods are used to provide values. At this point it is not necessary that the modules can be run: the components of the modules are being 'assembled' and the outputs of the modules are not yet being considered.

In Stage 2 initial values are established for all of the parameters that are not S1 parameters, called the 'S2' parameters – considering the fit of each module in isolation. The fit for a given module concerns specified targets for outputs from the module, so the module needs to be run in order for it to provide these outputs. Thus, a full set of required inputs for each module needs to be developed, including all those provided by other modules and all those provided exogenously. In order to obtain reasonable values for the S2 parameters, these inputs need to be consistent with the specified targets, representing conditions similar to those that gave rise to the targets.

In Stage 3 the initial values established for certain sets of the S2 parameters are revisited – for all of the modules simultaneously, considering the fit of all modules together, with the full model running, so that inputs to the modules are coming from the other modules in the way they would for a model run. These re-visited S2 parameters are designated 'S3' parameters. The second and third stages together constitute a Bayesian updating process for these S3 parameters. Ideally, all parameter values would be revisited, but this is not possible for practical reasons. A weight sensitivity matrix can be used to explore the remaining lack-of-fit for the entire model, which can help identify the parameters to focus on in the third stage and which may lead to small changes in the details of the model design and specification.

The development of the values for the S1 and S2 parameters, in the first and second stage of the parameter development process, is described for each module in separate sections 3 to 10 below. This includes a description of the work done to get each module running, as required, using input values and certain interim values for parameters as required.

Certain initial values for the S2 parameters are revisited in Stage 3 of the parameter development process. Stage 3 includes the work necessary to get the entire set of all SWIM2 modules running in order to provide a fully integrated modeling system. All SWIM2 modules, excluding the optional EPF and SL components have completed this 3-step calibration process.

3.0 ED Module

The Regional Economics & Demographics (ED) module provides modelwide industry activity control totals (in 1990$), predictions of employment, as well as unemployment rate, and final demand by aggregated industry category. These annual forecast outputs are produced for the state of Oregon and expanded to the full model area. The demographic portions of the ED module are not used by other modules in the Oregon Statewide Integrated Model. The Ed module output of annual industry activity (in 1990$) is used by the PI module, employment is used by the SPG module and construction dollars are used by the ALD module. T he EPF module (if used) modifies the ED outputs (in response to PI modelwide industry location utility trends), prior to use by other modules.

3.1. Theoretical Basis

To obtain forecasts of output, income, and employment by industry that incorporates available information about the structure of the regional economy, an integrated input-output and macroeconomic model was implemented in SWIM2.

A variety of methods have been developed for combining, in one way or another, input/output models with econometric models. Sergio Rey at San Diego State has done a lot of work evaluating and refining integration strategies [4-6]. He divides integration strategies into three categories:

- **Embedding.** An embedded model is an econometric model with embedded input-output tables, which provide prior information about inter-industry linkages. Embedded models are used for forecasting and their output typically is in the form of employment (and perhaps income) by highly aggregated industry.
- **Linking.** Linked models feed the output of one model into the other model. The links may go either way (but not both ways). Linked models where the input-output model feeds the econometric model typically are used for evaluating the impacts of onetime shocks, but tend to overestimate impacts because of double counting (the econometric equations replicate in a dynamic way what the input-output model already accounted for statically). Linked models where the econometric model feeds the input-output model typically are used to disaggregate the forecasts from the econometric model.
- **Coupling.** Coupled models pass information in both directions, often simultaneously. Dick Conway's WPSM model and the George Treyz, et al.'s REMI model are examples. Coupled models provide the greatest degree of integration and allow each model to make the most use of information from the other.

Of the available integration strategies, coupling was chosen as best suited to our effort. An embedded model doesn't produce the disaggregate output we need and a linked model (econometric to input-output) doesn't take advantage of what we know about inter-industry linkages in its forecasting equations.

Dick Conway's Washington Projection and Simulation Model (WPSM) [7] comes very close to meeting our requirements and Conway has over twenty years' experience refining and using WPSM. C onway assisted in adapting his concepts for this project and provided many useful recommendations for our work.

The core of the ED economic model is a set of simultaneous linear equations representing the input-output structure of the region's economy. These predict the dollar value of production by sector. Additional linearized equations for various components of final demand and for the labor market are solved simultaneously with the input-output equations.

Final demand is divided into four categories: industry consumption, investment, and state and local government. Industry output is derived from collective industry consumption (intermediate and final demand). The national economic forecast serves as a proxy measure of export demand (actual imports and exports used in PI are derived from ED forecast industry activity and fixed production regional purchase coefficients, see Section 6.3.7). Consumption demand has four equations: motor vehicles, other durable goods, nondurable goods, and services. Investment demand has three components: residential structures, nonresidential structures, and equipment. The SWIM2 model does not contain an equation for investment in equipment, because there exist no data from which to estimate such an equation.

State and local government demand has three equations: education operating expenditures, other government operating expenditures, and government capital outlays (mostly construction).

Other equations in the regional model include employment (by sector), labor income (by sector), non-labor income, and labor-force participation. Population estimates are calculated from estimated employment, estimated unemployment rates, and estimated labor-force participation rates. Each period, ED modelwide employment by sector is sent to the SPG module and constrains the synthetic population, ED modelwide investment in residential/nonresidential structures (construction 1990$) is sent to ALD constraining zonal land development, and ED modelwide industry activity by sector (in 1990$) is sent to the PI module for zonal activity allocation.

3.2. Quantity Definitions and Categories

ED operates exclusively at the modelwide level. Due to data limitations, ED uses an aggregated set of industry sectors, listed below. ED source data was unable to distinguish between heavy/light industries and office/non-office employment. ED outputs are disaggregated using fixed relationships into the industry categories used in the SPG (Section 4.2) and PI (Table 2.1) modules. These fixed relationships rely on 1998 employment and IMPLAN data (see Section 6.7.1).

- ACCOMMODATIONS
- AGRICULTURE AND MINING
- COMMUNICATIONS AND UTILITIES
- CONSTRUCTION
- ELECTRONICS AND INSTRUMENTS
- FIRE BUSINESS AND PROFESSIONAL SERVICES
- FOOD PRODUCTS
- GOVERNMENT ADMINISTRATION
- HEALTH SERVICES
- HIGHER EDUCATION
- HOMEBASED SERVICES
- LOWER EDUCATION
- LUMBER AND WOOD PRODUCTS
- OTHER DURABLES
- OTHER NON-DURABLES
- PERSONAL AND OTHER SERVICES AND AMUSEMENTS
- PULP AND PAPER
- RETAIL TRADE
- TRANSPORT

- WHOLESALE TRADE

ED activity data output used by PI include the industries listed in Table 2.1 in addition to the following categories.

- Other institutions (capital, change in inventory, federal and state government, state/local education, NA) were collapsed into import (if negative) and exports (if positive).
  - Capitalists (IMPLAN categories: N/A, Capital, ChangeInInventory, Enterprises)
  - GovInstitutions (IMPLAN categories: StateLocalEd, StateLocalNonEd, StateLocalInvestment, FedGovDefense, FedGovNonDefense, FedGovInvestment)

3.3. Component Models

The ED regional economic model works by solving a set of linear equations. Among those equations are one for each industry, representing its input-output structure, several for various components of final demand, and several that predict employment, unemployment, and incomes from output and feed back into final demand. These components are detailed in the remainder of this section. Future efforts are anticipated to incorporate PI outputs to influence the Industry Output component.

- Investment Final Demand
- State and Local Government Final Demand
- Final Demand by sector
- Industrial Output by sector (derived from industry consumption final demand)
- Employment, Population, and Income

3.3.1. Investment Final Demand

The ED investment final demand model estimates the final demand for structures (residential and nonresidential) in Oregon. It uses the following general equations.

Residential Structures:

$$ORI/(USGDPD/100) = \beta_{0res} + \beta_{1res}\,(1 - (USMORR + 1)/(USINFL + 1)) + \beta_{2res}\,(OPOP(-1) - OPOP(-2)) + \beta_{3res}\,(OPOP(-2) - OPOP(-3)) \quad (3.01)$$

where:

ORI = Oregon residential investment (contract construction statistics and value of building permits)
USMORR = US 30-year mortgage rate (percent) (exogenous)
USINFL = US inflation rate (percent) (exogenous)
USGDPD = US gross domestic product price deflator (baseyear 2000 = 100.0) (exogenous)
OPOP(-lag) = Lagged Oregon population (Equation 3.14)
β_{0res} through β_{3res} = residential structures investment final demand coefficients (see Table 3.1)

Nonresidential Structures:

$$ONRI/(USGDPD/100) = \beta_{0nres} + \beta_{1nres}\,(USGDP/(USGDPD/100)) + \beta_{2nres}\,ONRSV(-1) + \beta_{3nres}\,(USNRSPI*((USRPRM/100)-USINFL) \quad (3.02)$$

where:

ONRI = Oregon non-residential investment (contract construction statistics and value of

building permits)
USNRSPI = US non-residential structures price index (baseyear 2000 = 100.0) (exogenous)
USRPRM = US prime interest rate (percent) (exogenous)
USINFL = US inflation rate (percent) (exogenous)
USGDPD = US gross domestic product price deflator (baseyear 2000 = 100.0) (exogenous)
USGDP = US gross domestic product (exogenous)
ONRSV(-lag)= Lagged Oregon non-residential stock value = ONRSV(-1) + ONRI
β_{0nres} through β_{3nres} = nonresidential structures investment final demand coefficients (see Table 3.2)

3.3.2. State and Local Government Final Demand

The ED state and local government final demand model estimates the final demand for public education (lower and higher education) and other governmental operating expenditures, as well as government capital outlay in Oregon. It uses the following general equations.

Lower Educational Operating Expenditure:

$$OGLE / (USGDPD/100) = \beta_{0led} + \beta_{1led} OYP(-1) + \beta_{2led} USGSPLOED \quad (3.03)$$

where:
OGLE = Oregon government expenditure on lower education (thousands)
OYP(lag) = Lagged Oregon personal income (thousands) (Equation 3.18)
USGDPD = US gross domestic product price deflator (baseyear 2000 = 100.0) (exogenous)
USGSPLOED = US gross domestic product of lower education (exogenous)
β_{0led} through β_{2led} = lower education final demand coefficients (see Table 3.3)

Higher Educational Operating Expenditure:

$$\ln((OGHE/(USGDPD/100))/OPOP(-1)) = \beta_{0hed} + \beta_{1hed} \ln((OYP(-1)/(USGDPD/100))/OPOP(-1)) \quad (3.04)$$

where:
OGHE = Oregon government investment for higher education (thousands)
OPOP(lag) = Lagged Oregon population (Equation 3.14)
OYP(lag) = Lagged Oregon personal income (thousands) (Equation 3.18)
USGDPD = US gross domestic product price deflator (baseyear 2000 = 100.0) (exogenous)
β_{0hed} through β_{1hed} = higher education investment final demand coefficients (see Table 3.4)

Other Government Operating Expenditures:

$$\ln(OGSLO / (USGDPD/100) / OPOP(-1)) = \beta_{0gov} + \beta_{1gov} \ln((OYP(-1)/(USGDPD/100))/OPOP(-1)) + \beta_{2gov} (OUNRT(-1)/100) + \beta_{3gov} TREND \quad (3.05)$$

where:
OGSLO = Oregon other state and local government expenditures (thousands)
OPOP(lag) = Lagged Oregon population (Equation 3.14)
OYP(lag) = Lagged Oregon personal income (thousands) (Equation 3.18)
OUNRT(lag) = Lagged Oregon civilian unemployment rate (percent) (Equation 3.12)
USGDPD = US gross domestic product price deflator (baseyear 2000 = 100.0) (exogenous)
TREND = the year (2000 = 99, 2001 = 100, etc.)
β_{0gov} through β_{3gov} = other governmental investment final demand coefficients (see Table 3.5)

State and Local Government Capital Outlay:

$$OGCO/(USGDPD/100) = \beta_{0cap} + \beta_{1cap}(OYP(-1)/OPOP(-1)) + \beta_{2cap}USGSPGOV \quad (3.06)$$

where:

OGCO = Oregon government capital outlay (thousands)
OPOP(lag) = Lagged Oregon population (Equation 3.14)
OYP(lag) = Lagged Oregon personal income (thousands) (Equation 3.18)
USGDPD = US gross domestic product price deflator (baseyear 2000 = 100.0) (exogenous)
USGSPGOV = US gross domestic product in government (exogenous)
β_{0cap} through β_{5cap} = state and local government capital outlay final demand coefficients (see Table 3.6)

3.3.3. Final Demand by Sector

The ED model predicts final demand by sector (OFD) as a linear function of the Oregon final demands by institutions and state and local governments described above and US final demands by consumers for motor vehicles, other durable goods, non-durable goods, and services, as well as US GDP (representing production) by that sector. These US variables are part of the external forecast input to the ED module. Oregon final demands by investment and government for the current model year are estimated in advance of estimating final demands by industry, so current-year estimates are available as dependent variables in these equations. The following general equation is used:

$$OFD_i/(USGDPD/100) = \beta_{0ofd,i} + \beta_{1ofd,i} * USODC + \beta_{2ofd,i} * USNDC + \beta_{3ofd,i} * USMVC + \beta_{4ofd,i} * USSC + \beta_{5ofd,i} * ORI + \beta_{6ofd,i} * ONRI + \beta_{7ofd,i} * OGHE + \beta_{8ofd,i} * OGLE + \beta_{9ofd,i} * OGCO + \beta_{10ofd,i} * OGSLO + \beta_{11ofd,i} * USGDP_i \quad (3.07)$$

where:

OFD_i = Oregon sales to final demand for industry sector i
USODC = US Other Durables consumption (exogenous)
USNDC = US Nondurables consumption (exogenous)
USMVC = US Motor Vehicle and Parts consumption (exogenous)
USSC = US Services consumption (exogenous)
ORI = Oregon Residential Structures Investment (Equation 3.01)
ONRI = Oregon NonResidential Structures Investment (Equation 3.02)
OGHE = Oregon Government Higher Education (Equation 3.04)
OGLE = Oregon Government Lower Education (Equation 3.03)
OGCO = Oregon Government Capital Outlay (Equation 3.06)
OGSLO = Oregon Other Government Operating Expenditure (Equation 3.05)
$USGDP_i$ = US Gross Domestic Product for industry sector I (exogenous)
$B_{0ofd,i}$ through $\beta_{11ofd,i}$ = Industrial output coefficients for industry *i* and final demand component *ofd* (see Table 3.7)

3.3.4. Industrial Output

The ED model predicts industry output by sector as a linear function of its sales to final demand (OFD) and its sales to all other industries. Sales to final demand (OFD) is a function of the US and Oregon-specific final demand consumption, and US GDP for that sector. These US variables are part of the external forecast input to the ED module. Oregon-specific output used by other industries is calculated using technical coefficients representing the amount purchased from the industry on the left hand side of the equation when producing one dollar's worth of output, times the other industry's output ($OOut_i$). Thus, output in any industry depends on the output of other sectors. A block of simultaneous linear equations is used, with one for each industry sector. By estimating all of the outputs at once as a system of linear equations, they can all be estimated without knowing any of them in advance. The following general equation is used:

$$OOut_i = \beta_{0out,i}\ OFD_i + \Sigma_{j \in I,\ j \neq i}\ OOut_j * TCoeff_j \qquad (3.08)$$

where:

i, j	=	indices for ED industry sectors
$OOut_i$	=	Oregon output for industry sector i
OFD_i	=	Oregon sales to final demand for industry sector i (Equation 3.07)
$TCoeff_j$	=	technical coefficient for industry j (see Table 3.8)
$\beta_{0out,i}$	=	industrial output coefficients for industry i (see Table 3.8)

Once output is calculated across all industries, activity output for two non-household institutions, Capitalists and Government Institutions, is generated as required for the PI module. ED apportions a fixed (based on 1998 data) amount of the industry output values calculated above as output generated by the two institution categories. The remainder stays with the original industry sector, as reported for use in the PI module. The following general equation is used:

$$OOut_k = \Sigma_{i \in I}\ OOut_i * Share_{i,k} \qquad (3.09)$$

where:

k	=	index for ED/PI non-household institutions (i.e., Capitalists and GovInstitutions)
i	=	index for ED industry sectors
I	=	set of all ED industry sectors
$OOut_k$	=	Oregon output for institution k
$Share_{i,k}$	=	fixed institution k share of industry I (see Table 3.8)

Once the full SWIM2 model is calibrated, the ED industrial output values can be adjusted to respond to composite utilities by industry from PI. This is currently executed as an ED post-processor in the ED-PI Feedback (EPF) module (see Section 11), and could in the future be accounted for directly as an expanantory variable in the ED functional form. ED's forecasts then become dependent on last year's PI output as well as on prior ED forecasts and the exogenous forecast of current-year national economic variables. The composite utility measure calculated by PI for imports and exports are indicators of the attractiveness of exports from Oregon and of imports to Oregon, considering the price and quantity information for each imported and exported commodity in each external World Market (represented as external zones). These indicators, together with the PI composite utility values for industries within the internal model zones, allow the level of region-wide economic activity to respond to changes in the cost of transporting goods within the region.

3.3.5. Employment, Population, and Income

The ED employment and population model estimates various indicators for employment (i.e., employment count, labor force participation rate, unemployment rate), population, and income (labor and non-labor income). It uses the general equations listed below.

<u>Employment:</u>

There is an equation to predict employment in each industry from its output (converted to GSP with fixed factors). The following general equation is used.

$$ON = \Sigma_{i \in I}\ OEMP_i \qquad (3.10)$$

$$\ln(OEMP_i) = \beta_{0emp,i} + \beta_{1emp,i} \ln(OOut_i) + \beta_{2emp,i} \ln(USEMP_i/(USGSP_i/(USGDPD/100))) \quad (3.11)$$

where:

i = index for ED industry sectors
ON = Oregon civilian persons employed
$OEMP_i$ = Oregon employment for industry sector i
$OOut_i$ = Oregon output for industry sector i (Equation 3.08)
$USEMP_i$ = US employment for industry sector I (exogenous)
$USGSP_i$ = US gross domestic product for industry sector i (millions) (exogenous)
USGDPD = US gross domestic product price deflator (baseyear 2000 = 100.0) (exogenous)
$\beta_{0emp,i}$ through $\beta_{2emp,i}$ = employment coefficients for industry i (see Table 3.10)

Note: when i=HombasedServices (HOME), USGSPi /(USGDPD/100) term is excluded

Unemployment Rate:

$$\ln(OUNRT) = \beta_{0uemp} + \beta_{1uemp} \ln(USUNRT) + \beta_{2uemp} \ln((ON / ON(-1)) / (USN / USN(-1))) \quad (3.12)$$

where:

ON = Oregon civilian persons employed (Equation 3.10)
USUNRT = US unemployment rate (exogenous)
USN = US employment (exogenous)
β_{0uemp} through β_{2uemp} = unemployment coefficients (see Table 3.10)

Labor Force Participation Rate:

For the purposes of this model, the labor force participation is defined as the proportion of the population that is employed. Data necessary to model the number of employable persons are not available, so we treat the entire population as employable, resulting in a lower rate than when conventionally defined. The labor force population rate increased steadily over the 20-year period over which the model was estimated, but is not expected to continue to increase. To accommodate that expectation, we freeze OLFPR at its year-2000 level in years after 2000.

$$OLFPR = (1 - AFTER2000) * (\beta_{0lfp} + \beta_{1lfp}\, OLFPR(-1) + \beta_{2lfp}\, ((ON/ON(-1))/(USN/USN(-1))) + OLFPR(-1) * AFTER2000 \quad (3.13)$$

where:

OLFPR = Oregon labor force participation rate (decimal) (Equation 3.13)
USN = US employment (exogenous)
ON = Oregon civilian persons employed (Equation 3.10)
AFTER2000 = One if after 2000; zero otherwise
β_{0lfp} through β_{2lfp} = labor force participation coefficients (see Table 3.12)

Population (Identity):

$$OPOP = (ON/(1-(OUNRT/100)))/OLFPR \quad (3.14)$$

where:

OPOP = Oregon population
ON = Oregon civilian persons employed (Equation 3.10)
OLFPR = Oregon labor force participation rate (percent) (Equation 3.13)
OUNRT = Oregon civilian unemployment rate (percent) (Equation 3.12)

Labor Income:

$$OLI = \Sigma_{i \in I} OLI_i \quad (3.15)$$

$$\ln(OLI_i/(USGDPD/100)) = \beta_{0linc,i} + \beta_{1linc,i} \ln(OOut_i) + \beta_{2linc,i} \ln(OEMPi) + \beta_{3linc,i} \ln(USUNRT) + \beta_{4linc,i} \ln((USGSP_i/(USGDPD/100))/USEMP_i) \quad (3.16)$$

where:

i = index for ED industry sectors
OLI = Oregon labor income (thousands)
OLI_i = Oregon labor income for industry sector i (thousands)
$OOut_i$ = Oregon output for industry sector i (Equation 3.07)
$OEMP_i$ = Oregon employment for industry sector i (Equation 3.11)
USUNRT = US civilian unemployment rate (percent) (exogenous)
$USGSP_i$ = US gross domestic product for industry sector i (exogenous)
USGDPD = US gross domestic product price deflator (baseyear 2000 = 100.0) (exogenous)
$USEMP_i$ = US employment for industry sector i (exogenous)
$\beta_{0linc,i}$ through $\beta_{4linc,i}$ = labor income coefficients for industry sector i (see Table 3.13)

Non-labor income:

$$\ln(ONLI) = \beta_{0nlinc} + \beta_{1nlinc} \ln(USNLI/USPOP) + \beta_{2nlinc} \ln(OPOP(-1)) \quad (3.17)$$

where:

ONLI = Oregon non-labor income (thousands)
USNLI = US non-labor income (thousands) (exogenous)
USPOP = US population (exogenous)
OPOP = Oregon population (Equation 3. 14)
β_{0nlinc} through β_{2nlinc} = non-labor income coefficients (see Table 3.14)

Personal income:

$$OYP = ONLI + \beta_{0pinc} OLI \quad (3.18)$$

where:

OYP = Oregon personal income (thousands)
ONLI = Oregon non-labor income (thousands) (Equation 3.17)
OLI = Oregon labor income (thousands) (Equation 3.15)
β_{0pinc} = personal income coefficient (see Table 3.14)

3.3.6. Override Option

Due to unrealistic future performance of certain variables in the ED model when based strictly on past economic trends, it is important to be able to override any data in the model. There are two exogenous files used to perform this function – absolute.csv and marginal.csv. These files are organized in matrix format, where the columns represent the full list of modifiable data variables and the rows are the specific years of the modification. The first column of data must contain years. In absolute.csv, every data point must contain a value – either the value to which to change the variable or –1 for no change. In marginal.csv, every cell must contain a value to add to the evaluated output generated by ED (so that 0 causes no effect).

When ED evaluates a variable, it will write to the data file (model_data.csv). If the value in the appropriate cell of the absolute.csv file is not "-1", the absolute.csv file value is written to the data file. Otherwise, the value of the ED-forecasted output plus the value of the appropriate cell in marginal.csv is written to the data file. Note that this is only done when ED computes a new value for a variable. Since all dependent variables in ED equations are evaluated prior to the equations in which they are used, overriding a dependant variable affects many other variables. For instance, overriding an output equation for the electronics industry will affect the labor income and employment for that industry.

This override function addresses cases where historical relationships used to estimate the ED module are unlikely to continue into the future. For instance, the electronics industry in Oregon has experienced rapid growth over the past twenty years. It is unlikely that this rate of growth will continue over the next twenty years, even if everything else remains the same. Since the model only has historical data to evaluate, it assumes that the historical relationship between growth in the electronics industry and other variables in the model will prevail in the future.

3.4. Software Implementation

The ED module is implemented in java, using the following main software classes:

- **CSVSplitter class.** Class used to split CSV data into multiple rows. Contains one method: split(). Split takes as parameters three files – one to read the data from, one to write the data to, and one descriptive file to tell the method how to split up the data. The last column in the descriptive file must contain the percentage of each data entry to splice into the new data entry.
- **DataHound class.** Wrapper around EDDataAccess to make ED independent of the data store implementation.
- **EDControl class.** Control for the model. Exposes the EDDataAccess used in the program. Also contains a method to run the model (this is the entry point for the start of every model).
- **EDDataAccess class.** Gets data from/puts data into CSV files. This is where the values for the independent variables come from.
- **Equation class.** Wrapper around a vector of equation elements and the name of the equation.
- **EquationElementFactory class.** Creates equation elements based on the values returned from the model specification interface.
- **EquationFactory class.** Creates Equations from the XMLModelSpecification passed to it.
- **IEquationElement.** Interface.
- **Linear class.** A wrapper for a linear submodel. Calling solve() will cause all the equations added to this class to be solved.
- **LinearEquation class.** Creates a set of simultaneous linear equations to solve.

- **Linearizer class.** Creates the matrices used to solve the linear equations.
- **LinearSolver class.** Solves a system of linear equations.
- **LinearTerm class.** Class that contains a variable in a linear submodel. Is used to 'switch the side' of the equation that the variable is on.
- **Model class.** Contains a vector of submodels. When the model is 'started,' will solve all the submodels.
- **ModelDescriptionGetter class.** Makes Models and SubModels based on the XML file that is passed to the class.
- **Operator class.** Wrapper of a string that contains the string representation of the operator.
- **Parameter class.** Wrapper of a string that contains the parameter value.
- **SimpleFunctions class.** A wrapper that will just cycle through the simple equations in a SubModel and call SimpleSolver.solve on all of them.
- **SimpleSolver class.** Class that is used to solve 'simple' equations. Its only public function is 'solve', which takes one equation.
- **SubModel class.** An abstract class for all SubModels (currently only Linear and SimpleFunctions).
- **SubModelFactory class.** Creates a model that can be solved from the XMLModelSpecification passed in. Returns a SubModel.
- **ModelDescriptionGetter class.** ModelDescriptionGetter reads the ED model descriptions, which are stored in an xml document.
- **Variable class.** A class that stores all the information that is given in the VariableXML tag. This includes the name, location, and year of the variable.
- **VariableStore class.** A class to keep track of all the variables in the model. Also keeps track of which variables are independent and which are dependent.
- **XMLModelSpecification class.** Class used to interface with the XML file that is loaded. This class works on one tag at a time, so it supplies many methods to cycle through the XML tags.

Files that ED generates for use by other modules are written to the appropriate /tn directory, as discussed in Section 2.2.7. However, the data that ED uses over time, resides in a single file, model_data.csv in the /t0 directory. Each row in that file represents a calendar year and all historical-year rows are completely filled in at model start. Future-year rows have data in the columns for national economic variables from an exogenous national forecast. As the model runs through time, the Oregon-specific columns are filled in. These Oregon forecast in [model_data.csv] in current year dollar units, are expanded to represent the full model area and 2000 dollar units for the ED outputs used by other modules.

3.5. S1 and S2 Module Parameters

The ED parameters are estimated from annual historical data from various sources, spanning the years 1980 to 2000. These data include national historical trend data on various price indices, mortgage rates, inflation, sector activity, population, personal income, and employment from the US Bureau of Economic Analysis (BEA), The US Census Bureau, the US Bureau of Labor Statistics, and Global Insight, Inc. Historical Oregon data includes home prices, gross state output, government capital outlay, population, personal income, and employment.

ED stores its parameters (all S2/S3 parameters) in an xml-format model description file that also specifies the functional form, estimation method, and estimation order for each equation and block of equations. Its parameter file contains the path to the model description file, the path to its data file, and the paths to the 'splitter' files that describe how to prepare outputs for the full model region in the categories required by other modules. The model description file describes each ED submodel, or block of equations, and the equations that make up each submodel. Each equation has a dependent variable and any number of combinations of independent variables and parameters and operators.

3.5.2. Investment Final Demand Parameters

The parameters in the ED Investment Final Demand model equations of Section 3.3.2 use the estimated values of Table 3.1. These values reflect modified in S2/S3 calibration. Final demand for equipment was not estimated.

Table 3.1. Residential Structures Parameters (ORI)

Symbol	Description	Value
β_{0res}	Constant	3940511
β_{1res}	Sensitivity to US mortgage rates	- 248748
β_{2res}	Sensitivity to Oregon population change (1-2 yr lag)	1.8006
β_{3res}	Sensitivity to Oregon population change (2-3 yr lag)	8.2964

Table 3.2. Nonresidential Structures Parameters (ONRI)

Symbol	Description	Value
β_{0nres}	Constant	17435013
β_{1nres}	Sensitivity to US GDP	1521.75
β_{2nres}	Sensitivity to lagged Oregon nonresidential structure value	-0.2290806
β_{3nres}	Sensitivity to US nonresidential structure prices	184651.89

3.5.3. State and Local Government Final Demand Parameters

The parameters in the ED State and Local Government Final Demand model equations of Section 3.3.3 used the estimated values of Table 3.3 through 3.6. These values reflect modifications during S2/S3 calibration.

Table 3.3. Lower Educational Operating Expenditure Parameters (OGLE)

Symbol	Description	Value
β_{0led}	Constant	379584
β_{1led}	Sensitivity to lagged Oregon per capita income	0.024943
B_{2led}	Sensitivity to US GDP of lower education	3.74823

Table 3.4. Higher Educational Operating Expenditure Parameters (OGHE)

Symbol	Description	Value
β_{0hed}	Constant	-3.865661127
β_{1hed}	Sensitivity to lagged Oregon per capita income	1.02330796

Table 3.5. Other Government Operating Expenditures Parameters (OGSLO)

Symbol	Description	Value
β_{0gov}	Constant	-2.678
β_{1gov}	Sensitivity to lagged Oregon personal per capita income	0.785
β_{2gov}	Sensitivity to Oregon unemployment rate	0.984
β_{3gov}	Change associated with model year	0.01535

Table 3.6. State and Local Government Capital Outlay Parameters (OGCO)

Symbol	Description	Value
β_{0cap}	Constant	-297504
β_{1cap}	Sensitivity to lagged Oregon per capita personal income	400196
β_{2cap}	Sensitivity to US GDP of Government	- 8.4983

3.5.4. Final Demand by Sector Parameters

The parameters in the ED Final Demand by Sector (OFD) model equations of Section 3.3.3 used the values in Table 3.7.

Table 3.7. Final Demand by Sector Parameters (OFD)

	β_0	β_1	β_2	β_3	β_4	β_5	β_6	β_7	β_8	β_9	β_{10}	β_{11}
ofd i	Constant	USODC	USNDC	USMVC	USSC	ORI	ONRI	OGHE	OGLE	OGCO	OGSLO	USGSPi
OFDACC	181.25											0.003381
OFDAGM	856.66	31.3572	-5.0888			0.0002762	-0.000127					0.003255
OFDCOM	7247.37	23.7095	5.1392	-11.3872	1.5964			-0.002625	-0.002171		0.0004256	-0.00446
OFDCON	0					0.001938	0.0005847			0.002155		
OFDELE	-32721.64	-126.5188	144.5808	61.3406	-25.6376						0.00312	0.06174
OFDFIR	254.24				0.2205	0.0003267	-0.0002636				0.0004918	0.000963
OFDFOO	1604.66											0.02931
OFDGOV	-217.07	-14.6652	19.3158	-2.5863	0.419	0.00003097	0.00004016	0.0008322	-0.000508	0.0001016	0.0001022	0.003928
OFDHEA	97.34				0.0534						0.0001799	0.01198
OFDHIED	95.09											0.009492
OFDHOME	-11.78				0.008657							0.006728
OFDLOED	-422.59								0.0007605			0.002435
OFDLUM	3000											
OFDOD	3734.95	31.5122				0.000799	0.000459				-0.00019	0.001188
OFDOND	-2412.41		6.3716		-0.5778						0.00003433	0.01059
OFDPERS	-1378.78	13.4855	-9.4525	-3.7142	1.1961	0.0002602	-0.00003239	0.002063			0.00009925	0.00008238
OFDPULP	1065.64											0.02487
OFDRET	-416.06	39.6826	-2.328	-18.5634	0.01866							0.01866
OFDTRA	-242.35	1.8107	-3.078	-1.3111	0.8164	-0.00008743	0.00002841			0.00007852	-0.00005005	0.01134
OFDWHO	-884.55											0.009104

3.5.5. Industry Output Parameters

The parameters in the ED Industrial Output ($OOut_i$) including sales to final demand (OFD_i) model equations of Section 3.3.4 use the estimated values in Table 3.8 (for institutions) and 3.9 (for industries).

Table 3.8. Institution Output Parameters ($OOUT_k$)

		Institution	
		Capitalists	GovInstitutions
$\alpha_{0out,k}$	Constant	8,497,034.975	1,000,000.000
$Share_{i,k}$	OACC		0.036291644
$Share_{i,k}$	OAGM	0.002225610	0.001732411
$Share_{i,k}$	OCOM	0.002443785	0.002249077
$Share_{i,k}$	OCON		
$Share_{i,k}$	OELE	0.001869649	0.000002095
$Share_{i,k}$	OFIR	0.000097154	0.003271444
$Share_{i,k}$	OFOO	0.000342522	0.000525571
$Share_{i,k}$	OGOV	0.000000094	0.000363134
$Share_{i,k}$	OHEA	0.000000497	0.176726011
$Share_{i,k}$	OHIED		0.350791860
$Share_{i,k}$	OHOME		
$Share_{i,k}$	OLOED		0.018570520
$Share_{i,k}$	OLUM	0.002470730	0.000153197
$Share_{i,k}$	OOD	0.002227184	0.000035478
$Share_{i,k}$	OOND	0.001911356	0.000969887
$Share_{i,k}$	OPERS	0.000038842	0.004666104
$Share_{i,k}$	OPULP	0.001700331	0.000168678
$Share_{i,k}$	ORET	0.001208178	0.011355737
$Share_{i,k}$	OTRA	0.000019390	0.000134516
$Share_{i,k}$	OWHO		

Table 3.9. Industrial Output Parameters by Industry Sector ($OOUT_i$) (1 of 3)

		ACCOMMODATIONS OACC	AGRICULTURE AND MINING OAGM	COMMUNICATIONS AND UTILITIES OCOM	CONSTRUCTION OCON	ELECTRONICS AND INSTRUMENTS OELE	FIRE BUSINESS AND PROFESSIONAL SERVICES OFIR	FOOD PRODUCTS OFOO
$\alpha_{0out,i}$	Out_i	0.6476	0.5187	0.6243	0.4250	0.4904	0.6918	0.2287
$\beta_{0out,i}$	Constant	181.2500	856.6600	7247.3700	0.0000	-32721.6400	254.2400	1604.6600
$\beta_{1out,us,i}$	USODC		31.3572	23.7095		-126.5188		
$\beta_{1out,us,i}$	USNDC		-5.0888	5.1392		144.5808		
$\beta_{1out,us,i}$	USMVC			-11.3872		61.3406		
$\beta_{1out,us,i}$	USSC			1.5964		-25.6376	0.2205	
$\beta_{2out,fd,i}$	ORI		0.0003		0.0019		0.0003	
$\beta_{2out,fd,i}$	ONRI		-0.0001		0.0006		-0.0003	
$\beta_{2out,fd,i}$	OGLE			-0.0022				
$\beta_{2out,fd,i}$	OGHE			-0.0026				
$\beta_{2out,fd,i}$	OGSLO				0.0022			
$\beta_{2out,fd,i}$	OGCO			0.0004		0.0031	0.0005	
$\beta_{3out,i}$	USGSPi	0.0034	0.0033	-0.0045		0.0617	0.0010	0.0293
$TCoeff_j$	OACC	1.0030	0.0025	0.0318	0.0182	0.0003	0.1125	0.0007
$TCoeff_j$	OAGM	0.0013	1.0867	0.0128	0.0167	0.0001	0.0276	0.0024
$TCoeff_j$	OCOM	0.0014	0.0067	1.0477	0.0430	0.0036	0.0460	0.0001
$TCoeff_j$	OCON	0.0013	0.0047	0.0064	1.0008	0.0005	0.0942	0.0001
$TCoeff_j$	OELE	0.0033	0.0005	0.0136	0.0126	1.1528	0.0504	0.0001
$TCoeff_j$	OFIR	0.0029	0.0002	0.0111	0.0015	0.0084	1.1495	0.0000
$TCoeff_j$	OFOO	0.0049	0.0816	0.0226	0.0067	0.0002	0.0463	1.0436
$TCoeff_j$	OGOV	0.0001	0.0005	0.0088	0.0364	0.0000	0.0152	0.0001
$TCoeff_j$	OHEA	0.0035	0.0009	0.0154	0.0047	0.0068	0.0929	0.0018
$TCoeff_j$	OHIED	0.0004	0.0002	0.0019	0.0128	0.0007	0.0293	0.0000
$TCoeff_j$	OLOED	0.0001	0.0001	0.0017	0.0199	0.0002	0.0102	0.0000
$TCoeff_j$	OLUM	0.0039	0.0036	0.0141	0.0037	0.0001	0.0296	0.0000
$TCoeff_j$	OOD	0.0039	0.0008	0.0197	0.0061	0.0203	0.0398	0.0001
$TCoeff_j$	OOND	0.0047	0.0012	0.0220	0.0081	0.0009	0.0607	0.0006
$TCoeff_j$	OPERS	0.0038	0.0022	0.0251	0.0363	0.0037	0.0884	0.0027
$TCoeff_j$	OPULP	0.0045	0.0012	0.0400	0.0182	0.0004	0.0375	0.0005
$TCoeff_j$	ORET	0.0019	0.0018	0.0169	0.0048	0.0003	0.0430	0.0219
$TCoeff_j$	OTRA	0.0037	0.0001	0.0205	0.0169	0.0007	0.0845	0.0001
$TCoeff_j$	OWHO	0.0036	0.0004	0.0241	0.0038	0.0063	0.0967	0.0002

Table 3.9. Industrial Output Parameters by industry sector ($OOUT_i$) (2 of 3)

		GOVERNMENT ADMINISTRATION	HEALTH SERVICES	HIGHER EDUCATION	HOMEBASED SERVICES	LOWER EDUCATION	LUMBER AND WOOD PRODUCTS	OTHER DURABLES
		OGOV	OHEA	OHIED	OHOME	OLOED	OLUM	OOD
$\alpha_{0out,i}$	Out_i	0.8932	0.6540	0.9172	1.0000	0.9426	0.3908	0.3255
$\beta_{0out,i}$	Constant	-217.0700	97.3400	95.0900	-11.7800	-422.5900	3000.0000	3734.9500
$\beta_{1out,us,i}$	USODC	-14.6652						31.5122
$\beta_{1out,us,i}$	USNDC	19.3158						
$\beta_{1out,us,i}$	USMVC	-2.5863						
$\beta_{1out,us,i}$	USSC	0.4190	0.0534		0.0087			
$\beta_{2out,fd,i}$	ORI	0.0000						0.0008
$\beta_{2out,fd,i}$	ONRI	0.0000						0.0005
$\beta_{2out,fd,i}$	OGLE	-0.0005				0.0008		
$\beta_{2out,fd,i}$	OGHE	0.0008						
$\beta_{2out,fd,i}$	OGSLO	0.0001						
$\beta_{2out,fd,i}$	OGCO	0.0001	0.0002					-0.0002
$\beta_{3out,i}$	USGSPi	0.0039	0.0120	0.0095	0.0067	0.0024		0.0012
$TCoeff_j$	OACC	0.0071	0.0000				0.0002	0.0021
$TCoeff_j$	OAGM	0.0020	0.0008	0.0001			0.0024	0.0055
$TCoeff_j$	OCOM	0.0049	0.0000	0.0002			0.0001	0.0058
$TCoeff_j$	OCON	0.0015	0.0000				0.0546	0.0191
$TCoeff_j$	OELE	0.0014	0.0000	0.0001			0.0001	0.0099
$TCoeff_j$	OFIR	0.0045	0.0001	0.0002			0.0001	0.0010
$TCoeff_j$	OFOO	0.0035	0.0000	0.0000			0.0002	0.0121
$TCoeff_j$	OGOV	1.0053	0.0000	0.0000			0.0000	0.0013
$TCoeff_j$	OHEA	0.0097	1.0117	0.0001			0.0002	0.0020
$TCoeff_j$	OHIED	0.0007	0.0000	1.0000			0.0000	0.0005
$TCoeff_j$	OLOED	0.0004	0.0000	0.0000			0.0000	0.0002
$TCoeff_j$	OLUM	0.0032	0.0000	0.0001			1.2664	0.0049
$TCoeff_j$	OOD	0.0035	0.0000	0.0002			0.0049	1.0417
$TCoeff_j$	OOND	0.0045	0.0000	0.0002			0.0006	0.0079
$TCoeff_j$	OPERS	0.0130	0.0001	0.0000			0.0007	0.0086
$TCoeff_j$	OPULP	0.0087	0.0000	0.0002			0.0752	0.0039
$TCoeff_j$	ORET	0.0031	0.0000				0.0001	0.0013
$TCoeff_j$	OTRA	0.0037	0.0002	0.0001			0.0003	0.0034
$TCoeff_j$	OWHO	0.0055	0.0000				0.0025	0.0026

Table 3.9. Industrial Output Parameters by industry sector ($OOUT_i$) (3 of 3)

		OTHER NON-DURABLES	PERSONAL AND OTHER SERVICES AND AMUSEMENTS	PULP AND PAPER	RETAIL TRADE	TRANSPORT	WHOLESALE
		OOND	OPERS	OPULP	ORET	OTRA	OWHO
$\alpha_{0out,i}$	Out_i	-2412.4100	-1378.7800	1065.6400	-416.0600	-242.3500	-884.5500
$\beta_{0out,i}$	Constant		13.4855		39.6826	1.8107	
$\beta_{1out,us,i}$	USODC	6.3716	-9.4525		-2.3280	-3.0780	
$\beta_{1out,us,i}$	USNDC		-3.7142		-18.5634	-1.3111	
$\beta_{1out,us,i}$	USMVC	-0.5778	1.1961		0.0187	0.8164	
$\beta_{1out,us,i}$	USSC		0.0003			-0.0001	
$\beta_{2out,fd,i}$	ORI		0.0000			0.0000	
$\beta_{2out,fd,i}$	ONRI						
$\beta_{2out,fd,i}$	OGLE		0.0021				
$\beta_{2out,fd,i}$	OGHE					0.0001	
$\beta_{2out,fd,i}$	OGSLO	0.0000	0.0001			-0.0001	
$\beta_{2out,fd,i}$	OGCO	0.0106	0.0001	0.0249	0.0187	0.0113	0.0091
$\beta_{3out,i}$	USGSPi	0.0112	0.2487	0.0285	0.0155	0.0150	0.0202
$TCoeff_j$	OACC	0.0084	0.0087	0.0006	0.0035	0.0243	0.0059
$TCoeff_j$	OAGM	0.0092	0.0071	0.0051	0.0009	0.0193	0.0522
$TCoeff_j$	OCOM	0.0023	0.0276	0.0001	0.0012	0.0114	0.0059
$TCoeff_j$	OCON	0.0098	0.0074	0.0003	0.0286	0.0248	0.0592
$TCoeff_j$	OELE	0.0084	0.0082	0.0008	0.0026	0.0070	0.0621
$TCoeff_j$	OFIR	0.0042	0.0052	0.0003	0.0023	0.0049	0.0062
$TCoeff_j$	OFOO	0.0155	0.0092	0.0145	0.0056	0.0510	0.1130
$TCoeff_j$	OGOV	0.0012	0.0014	0.0001	0.0003	0.0064	0.0017
$TCoeff_j$	OHEA	0.0097	0.0067	0.0006	0.0051	0.0061	0.0153
$TCoeff_j$	OHIED	0.0017	0.0019	0.0001	0.0004	0.0008	0.0023
$TCoeff_j$	OLOED	0.0007	0.0012	0.0000	0.0002	0.0003	0.0008
$TCoeff_j$	OLUM	0.0073	0.0090	0.0007	0.0037	0.0377	0.0674
$TCoeff_j$	OOD	0.0095	0.0136	0.0018	0.0038	0.0255	0.0778
$TCoeff_j$	OOND	1.0765	0.0113	0.0039	0.0042	0.0389	0.0612
$TCoeff_j$	OPERS	0.0129	1.0456	0.0006	0.0053	0.0089	0.0215
$TCoeff_j$	OPULP	0.0260	0.0138	1.0051	0.0046	0.0566	0.0779
$TCoeff_j$	ORET	0.0088	0.0073	0.0006	1.0044	0.0054	0.0149
$TCoeff_j$	OTRA	0.0042	0.0222	0.0002	0.0057	1.1769	0.0300
$TCoeff_j$	OWHO	0.0128	0.0117	0.0020	0.0037	0.0068	1.0258

3.5.5. Employment, Population, and Income Parameters

The parameters in the ED Employment, Population, and Income model equations of Section 3.3.5 use the estimated values in Tables 3.10 through Table 3.14. Additionally, the value of 0.855 is the parameter (β_{0pinc}) on the lagged labor income used in calculating Oregon personal income (OYP). This parameter was determined as the percent of total labor income that goes into the calculation of personal income, as seen over the past twenty years.[8]

Table 3.10. Employment Parameters by Industry Sector ($OEMP_i$)

			Constant	Sensitivity to industry output	Sensitivity to US employement/ output ratio
i		$OEMP_i$	$\beta_{0emp,i}$	$\beta_{1emp,i}$	$\beta_{2emp,i}$
ACC		ACCOMMODATIONS	6.9358	0.5921	-0.2896
AGM		AGRICULTURE AND MINING	6.1424	0.5686	-0.1664
COM		COMMUNICATIONS AND UTILITIES	2.5150	0.7665	0.4377
CON		CONSTRUCTION	3.6551	0.7307	0.3083
ELE		ELECTRONICS AND INSTRUMENTS	8.3538	0.2476	0.0232
FIR		FIRE BUSINESS AND PROFESSIONAL SERVICES	5.3359	0.6460	0.2429
FOO		FOOD PRODUCTS	9.8884	0.0672	-0.1270
GOV		GOVERNMENT ADMINISTRATION	6.2088	0.5982	-0.1270
HEA		HEALTH SERVICES	4.2715	0.7401	0.2330
HIED		HIGHER EDUCATION	6.2908	0.3584	0.6358
HOME		HOMEBASED SERVICES	5.2027	0.5506	0.0136
LOED		LOWER EDUCATION	7.9551	0.4373	0.0521
LUM		LUMBER AND WOOD PRODUCTS	4.2266	0.5615	0.5027
OD		OTHER DURABLES	4.9822	0.7410	0.3120
OND		OTHER NON-DURABLES	2.7135	0.8370	0.2390
PAP		PULP AND PAPER	6.4889	0.1692	0.5009
PERS		PERSONAL AND OTHER SERVICES AND AMUSEMENT	11.0910	0.6861	-0.6150
RET		RETAIL TRADE	0.9462	0.9740	0.7221
TRA		TRANSPORT	0.0711	0.9823	0.8072
WHO		WHOLESALE	-2.0291	1.1271	1.1860

Table 3.11. Unemployment Rate Parameters (OUNRT)

Symbol	Description	Value
β_{0uemp}	Constant	0.5620
β_{1uemp}	Sensitivity to US unemployment rate	0.7899
β_{2uemp}	Sensitivity to the ratio of Oregon and US employment growth	- 6.7718

Table 3.12. Labor Force Participation Rate Parameters (OLFPR)

Symbol	Description	Value
β_{0lfp}	Constant	0.9470
β_{1lfp}	Sensitivity to Oregon civilian labor force participation rate	- 0.3293
β_{2lfp}	Sensitivity to the ratio of Oregon and US employment growth	0.3628

[8] The definition of personal income on a state basis is unearned income plus earnings minus social security taxes plus or minus an adjustment for place of work/place of residence. The effect of the last two has been steady at around 15% of the sum of earnings and unearned income. We used the average over the last five years.

Table 3.13. Labor Income Parameters by Industry Sector (OLI_i)

		Constant	Sensitivity to Oregon gross state output sector i ($OGSP_i$)	Sensitivity to Oregon employment of sector i ($OEMP_i$)	Sensitivity to US unemploymen t rate (percent) (USUNRT)	US gross state output per employee of sector i ($OGSP_i$)
i	$OGSP_i$	$\beta_{0linc,i}$	$\beta_{1linc,i}$	$\beta_{2linc,i}$	$\beta_{3linc,i}$	$\beta_{4linc,i}$
ACC	ACCOMMODATIONS	12.6598	2.0090	-1.2477	0.2039	0.4307
AGM	AGRICULTURE AND MINING	-12.9184	1.2234	1.0770	-0.1608	-1.1841
COM	COMMUNICATIONS AND UTILITIES	-2.7373	0.9226	0.8626	-0.1653	-0.1627
CON	CONSTRUCTION	6.7159	0.7985	0.0728	-0.1152	-0.0996
ELE	ELECTRONICS AND INSTRUMENTS	3.4379	0.1622	1.0369	-0.0236	0.4221
FIR	FIRE BUSINESS AND PROFESSIONAL SI	3.2803	1.0191	0.3005	-0.0707	0.4458
FOO	FOOD PRODUCTS	2.2819	0.2715	0.8164	-0.0790	-0.3167
GOV	GOVERNMENT ADMINISTRATION	1.5753	0.6114	0.6703	0.0470	-0.1620
HEA	HEALTH SERVICES	8.0725	0.9492	-0.0658	-0.0059	0.1593
HIED	HIGHER EDUCATION	5.2784	0.7872	0.2689	-0.0189	-0.0094
HME	HOMEBASED SERVICES	7.1242	-0.1834	1.2336	0.1440	1.4263
LED	LOWER EDUCATION	5.6812	0.8058	0.2280	-0.0109	-0.1205
LUM	LUMBER AND WOOD PRODUCTS	3.8223	0.1457	0.8716	0.0048	0.0195
OD	OTHER DURABLES	2.0240	0.4113	0.8486	0.1168	0.2422
OND	OTHER NON-DURABLES	4.6532	0.7968	0.2056	-0.0635	-0.2184
PERS	PERSONAL AND OTHER SERVICES ANI	8.8321	0.9256	-0.3195	-0.0640	-0.2413
PULP	PULP AND PAPER	9.1751	0.0352	0.4872	0.0284	0.2848
RET	RETAIL TRADE	7.4092	1.0456	-0.2059	-0.0488	-0.2991
TRA	TRANSPORT	6.8994	-0.1470	0.9697	-0.0715	0.5116
WHO	WHOLESALE	3.0324	1.2377	-0.0714	-0.0848	-0.6615

Table 3.14. Non-labor (ONLI) & Personal (OYP) income Parameters

Symbol	Description	Value
	Non-Labor Income (ONLI)	
β_{0nlinc}	Constant	0.5312
β_{1nlinc}	Sensitivity to US non-labor per capita income	1.0049
β_{2nlinc}	Sensitivity to lagged Oregon population	0.9681
	Personal Income (OYP)	
β 0pinc	Sensitivity to Oregon labor income	0.855

3.5.6. Model Integration Factors

The ED module produces output for Oregon, not the full SWIM2 study area (Figure 2.1, excluding Reno, NV) nor the full model sectors (Table 2.1). When creating outputs used by the ALD, SPG, and PI modules (in the ED CSVSplitter class), ED applies expansion factors to expand the Oregon values to modelwide values, and splits the activity among the appropriate sectors used by these modules. Additionally, ED produces activity in constant year 2000 dollars (million$ investment, thousand$ activity), which are converted to constant 1990 dollars. The following equations are used in this conversion, applying the expansion factors listed in Tables 3.15 through 3.17. The expansion factors are based on Oregon and modelwide McGraw Hill/FW Dodge 1990-2002 new construction starts investment data (see Section 5.6.3), 1998 employment (see Section 6.7.1), and 1998 IMPLAN data.

$$ALDConstr_R = ORI*ALDFactor_R * (USGDPD_{1990}/100)/(USGDPD_{curyr}/100)*1,000 \quad (3.19)$$

$$ALDConstr_{NR} = ONRI*ALDFactor_{NR} * (USGDPD_{1990}/100)/(USGDPD_{curyr}/100)*1,000 \quad (3.20)$$

$$PIActivity_j = OOut_i*PIFactor_{i,j} * (USGDPD_{1990}/100)/(USGDPD_{2000}/100)*1,000,000 \quad (3.21)$$

$$SPGEmp_k = Emp_i*SPGFactor_{i,k} *1,000 \quad (3.22)$$

where:

x	=	index for floorspace category (residential, nonresidential)
i	=	index for ED industry sector (listed in Section 3.2)
j	=	index for PI industry sector (Table 2.1)
k	=	index for SPG industry sector (listed in Section 4.2)
$ALDConstr_x$	=	Modelwide construction spending for floorspace category x used by ALD (1990$)
$PIActivity_j$	=	Modelwide activity by industry sector j used by PI (1990$)
$SPGEmp_k$	=	Modelwide employment count by industry sector k used by SPG1
ORI, ONRI	=	Oregon Residential/NonResidential investment (contract construction statistics and value of building permits) output by ED (constant$)
$OOut_i$	=	Oregon activity by industry sector i output by ED (2000$)
Emp_i	=	Oregon employment count by industry sector i output by ED
$USGDPD_n$	=	US Gross Domestic Product deflator for year n (baseyear 2000 = 100)
$ALDFactor_x$	=	ED-ALD expansion factor for floorspace category x
$PIFactor_{i,j}$	=	ED-PI expansion factor from industry sector i to industry sector j
$SPGFactor_{i,k}$	=	ED-SPG expansion factor from industry sector i to industry sector k

Table 3.15. ED to ALD Expansion Factors

x	Floorspace Category	$ALDFactor_x$
r	Residential	1.703640
nr	NonResidential	1.559545

Table 3.16. ED to SPG Expansion Factors

ED Sector (i)	SPG Sector (k)	$SPGFactor_{i,k}$	Industry Factor
OEMPACC	ACCOMMODATIONS	1.549262144	1.55
OEMPAGM	AGRICULTURE AND MINING	1.894063631	1.89
OEMPCOM	COMMUNICATIONS AND UTILITIES	1.786351661	1.79
OEMPCON	CONSTRUCTION	1.624246883	1.62
OEMPELE	ELECTRONICS AND INSTRUMENTS-Light Industry	1.532897443	1.53
OEMPFIRP	FIRE BUSINESS AND PROFESSIONAL SERVICES	1.405098731	1.41
OEMPFOO	FOOD PRODUCTS-Heavy Industry	1.186373609	1.77
OEMPFOO	FOOD PRODUCTS-Light Industry	0.585135559	
OEMPGOV	GOVERNMENT ADMINISTRATION	1.616368374	1.62
OEMPHEA	HEALTH SERVICES-Hospital	0.595819325	1.65
OEMPHEA	HEALTH SERVICES-Institutional	0.258687942	
OEMPHEA	HEALTH SERVICES-Office	0.791127798	
OEMPHIED	HIGHER EDUCATION	1.682184147	1.68
OEMPHOME	HOMEBASED SERVICES	1.470513586	1.47
OEMPLOED	LOWER EDUCATION	1.662220165	1.66
OEMPLUM	FORESTRY AND LOGGING	0.305853642	1.53
OEMPLUM	LUMBER AND WOOD PRODUCTS-Heavy Industry	1.222704929	

OEMPDG	OTHER DURABLES-Heavy Industry	0.882950886	1.31
OEMPDG	OTHER DURABLES-Light Industry	0.423085525	
OEMPOND	OTHER NON-DURABLES-Heavy Industry	0.494369149	1.37
OEMPOND	OTHER NON-DURABLES-Light Industry	0.87355037	
OEMPPERS	PERSONAL AND OTHER SERVICES AND AMUSEMENTS	1.539805032	1.53
OEMPPAP	PULP AND PAPER-Heavy Industry	2.359546539	2.36
OEMPRET	RETAIL TRADE	1.555481116	1.56
OEMPTRAN	TRANSPORT	1.512021815	1.51
OEMPWHO	WHOLESALE TRADE	1.437068293	1.44

Table 3.17. ED to PI Expansion Factors

ED Sector (i)	PI Sector (j)	PIFactor $_{i,j}$	Industry Factor
OACC	ACCOMMODATIONS	1.534311	1.53
OAGM	AGRICULTURE AND MINING-Agriculture	1.638935	1.67
OAGM	AGRICULTURE AND MINING-Office	0.033172	
OCOM	COMMUNICATIONS AND UTILITIES-Light Industry	1.299233	1.45
OCOM	COMMUNICATIONS AND UTILITIES-Office	0.146714	
OCON	CONSTRUCTION	1.332668	1.33
OELE	ELECTRONICS AND INSTRUMENTS-Light Industry	1.255475	1.38
OELE	ELECTRONICS AND INSTRUMENTS-Office	0.120396	
OFIR	FIRE BUSINESS AND PROFESSIONAL SERVICES	1.925846	1.93
OFOO	FOOD PRODUCTS-Heavy Industry	1.005090	1.52
OFOO	FOOD PRODUCTS-Light Industry	0.479098	
OFOO	FOOD PRODUCTS-Office	0.036143	
OGOV	GOVERNMENT ADMINISTRATION-Government Support	1.310493	1.43
OGOV	GOVERNMENT ADMINISTRATION-Office	0.123774	
OHEA	HEALTH SERVICES-Hospital	0.477451	1.33
OHEA	HEALTH SERVICES-Institutional	0.110644	
OHEA	HEALTH SERVICES-Office	0.745494	
OHIED	HIGHER EDUCATION	1.376233	1.38
OHOME	HOMEBASED SERVICES	1.209467	1.21
OLOED	LOWER EDUCATION-Grade School	1.382910	1.44
OLOED	LOWER EDUCATION-Office	0.058829	
OLUM	FORESTRY AND LOGGING	0.355397	1.40
OLUM	LUMBER AND WOOD PRODUCTS-Heavy Industry	1.016561	
OLUM	LUMBER AND WOOD PRODUCTS-Office	0.031072	
OOD	OTHER DURABLES-Heavy Industry	0.758488	1.07
OOD	OTHER DURABLES-Light Industry	0.234261	
OOD	OTHER DURABLES-Office	0.073797	
OOND	OTHER NON-DURABLES-Heavy Industry	0.593037	1.11
OOND	OTHER NON-DURABLES-Light Industry	0.411096	
OOND	OTHER NON-DURABLES-Office	0.106770	
OPERS	PERSONAL AND OTHER SERVICES AND AMUSEMENTS	1.164514	1.16
OPULP	PULP AND PAPER-Heavy Industry	1.929021	1.99
OPULP	PULP AND PAPER-Office	0.062464	
ORET	RETAIL TRADE-Retail	3.748308	3.77
ORET	RETAIL TRADE-Office	0.022817	
OTRA	TRANSPORT-Depot	1.187769	1.30
OTRA	TRANSPORT-Office	0.114143	
OWHO	WHOLESALE TRADE-Warehouse	3.092470	3.30
OWHO	WHOLESALE TRADE-Office	0.202743	

3.6. Inputs and Outputs

ED requires current-year (and prior, if lags are included) data for each of the independent variables in the model. A forecast of national economic variables, including production by sector, that covers the entire period to be modeled, is required. This and other ED input data are listed in Table 3.17. The EPF module (chapter 11) modifies ED outputs prior to use by other modules, when operational, based on modelwide changes in economic conditions predicted by the PI module. It is anticipated that future versions of the ED module will be sensitive to modelwide activity (or prices) from the PI module directly as explanatory variables in its functional form.

Table 3.18. ED Inputs

Data Element	Source
Annual forecast of national data by sector [model_data.csv]	exog
Model equation specifications [EDmodel.xml]	exog
Marginal and absolute override data [marginal.csv] [absolute.csv]	exog
Category splitter files [ConstructionSplitter.csv] [EDtoSPGSectors.csv] [EDtoPIMini.csv][EDtoPISectors.csv]	exog
Modelwide composite utilities of production activity modelwide [ActivitySummary.csv]	PI (future)

The national economic forecast and historical values for variables input to the ED module are stored in a single data file [model_data.csv]. All forecast US data in this file are in constant dollar terms. This file also contains ED output of current year regional values after the model runs, which are used by ED in future years. ED generated outputs in model_data.csv are also in constant dollars, except for output ($OOut_i$) and sales to final demand (OFD_i), which are in year 2000 dollars. ED monetary outputs used by other modules -- PI activity dollars and ALD construction dollars -- are additionally written to files in the correct tn/ED directory in units of year 1990 dollars, consistent with the rest of the SWIM2 model.

3.6.1. National Economic Forecast

An exogenous national forecast is the key input to the ED module. All forecast data comes from Global Insight, Inc. (ODOT/OEA license). Since the Global Insight national forecast extends only to 2035, data past these years is extrapolated. These include forecast national trend data listed in Table 3.19.

Table 3.19. ED model_data.csv fields

Code	Description
	National Data (inputs)
USODC	US Other Durable Goods Consumption (billions, constant$)
USNDC	US Nondurable Goods Consumption (billions, constant$)
USMVC	US Motor Vehicle & Parts Consumption (billions, constant$)
USSC	US Services Consumption (billions, constant$)
GDP	US Gross Domestic Product (billions, constant$)
USGSPi	US Gross State Product for ED industry i (billions, constant$)
USPOP	US Population (millions)
USN	US Employment (millions)
USEMPi	US Employment in ED industry sector i (millions)
USUNRT	US Unemployment rate (%)
USNLI	US NonLabor Income (billions, constant$)
USINFL	US Inflation rate (percent)
USRPRM	US Prime interest rate (percent)
USMORR	US 30-year mortgage rate (percent)
USRSPI	US Residential structures price index (baseyear 2000=100)
USNRSPI	US NonResidential structures price index (baseyear 2000=100)
USGDPD	US Gross Domestic Product deflator (baseyear 2000=100)
TREND	Year
	Oregon Data (Historical inputs/Forecast outputs)
ORI	Oregon Residential Investment (thousands, 2000$)
ONRI	Oregon NonResidential Investment (thousands, 2000$)
ORSV	Oregon Residential Building Stock Value (thousands, 2000$)
ONRSV	Oregon NonResidential Building Stock Value (thousands, 2000$)
OGLE	Oregon government expenditures on lower education (thousands, 2000$)
OGHE	Oregon government expenditures on higher education (thousands, 2000$)
OGSLO	Oregon non-educational state and local expenditures (thousands, 2000$)
OGCO	Oregon government capital outlay (thousands, 2000$)
OOuti	Oregon activity output (millions, 2000$)
OFDi	Oregon Sales to Final Demand for ED industry sector i (millions, 2000$)
ON	Oregon Employment (thousands)
OEMPi	Oregon Employment for ED industry sector i (thousands)
OLFPR	Oregon Labor Force participation rate (percent)
OUNRT	Oregon unemployment rate (percent)
OPOP	Oregon Population (thousands)
OLI	Oregon Labor Income (millions, 2000$)
OLIi	Oregon Labor Income for ED Industry sector i (thousands, 2000$)
ONLI	Oregon Non Labor Income (thousands, 2000$)
OYP	Oregon Personal Income (thousands, 2000$)

Note: ED industry sectors are listed in Section 3.2

3.6.1. Historical National and Oregon Economic Data

Exogenous annual national and Oregon historical data are used to estimate as well as provide input to the various ED equations. This data spans the years 1980 to 2054. However, only the current and up to 4 year-lagged variables will be used as input (other years used in model estimation). Historical data comes primarily from US Bureau of Economic Analysis (BEA) data. These include historical trend data listed in Table 3.19. Industry categorization in the BEA data changed from SIC to NAICS-based industry classifications in 2000, making it difficult to provide historical data for the ED model after the year 2000.

3.6.1. User Modifications to Forecasts

Outputs can be overridden by variable and year if desired. There are two separate ways of doing this. The value of any ED input or output variable can be set to a certain amount higher or lower through the use of user-modifiable exogenous data file [marginal.csv]. Alternately, the variable can be set to an exact amount through a different data file [absolute.csv]. Changing a variable value using the latter method will always override any changes caused by the former method (see Section 3.3.6).

In the Oregon Statewide Integrated Model (SWIM2), ED outputs that are used by PI, ALD, and SPG, are shown in Table 3.20.

Table 3.20. ED Outputs

Data Element	users
Count of modelwide employment by SPG industry [JobDataForSPG1.csv]	SPG1*
Modelwide residential and nonresidential final demand of new construction$ [ConstructionDollarDataForALD.csv]	ALD*
Modelwide quantities of production activity ($ flow) by PI industry/institution [ActivityDollarDataForPI.csv]	PI*

* If the ED-PI Feedback module (EPF, Chapter 11) is operating, these files are updated prior to use by the SPG1, ALD, and PI modules.

3.7. Validation Targets

ED module equations are estimated from historical data, rather than calibrated to fit any particular year. The primary validation target for ED, therefore, is a good fit on historical data. A secondary requirement of ED validation is matching the Oregon Office of Economic Analysis (OEA) historical and 7-year forecast data. Both of these key targets (see Table 3.21), are measured in employment by industry.

Table 3.21. ED Validation Targets

Source	Year	SWIM2 Target
US Bureau of Economic Analysis (BEA)	1990-2000	Oregon employment by SIC industry
ODAS Office of Economic Analysis (OEA), Economic and Revenue Forecasts (June 2007 Quarterly Forecasts)	2001-2011	OEA Oregon historical/forecast employment by NAICS industry

The OEA forecasts are use sectors based on North American Industry Classification System (NAICS) industries, not the Standard Industrial Classification (SIC) used in SWIM2TM. As a result, aggregation of both ED output and OEA data are required to arrive at somewhat-comparable industry sectors, as shown in Table 3.22. Adjustments were made for OEA omission of farm and proprietor employment (including self-employment). These adjustments increased OEA forecasts by roughly 17 percent overall, and much more in Natural Resources and Mining, which includes Agriculture. This aggregation is based on year 2001 data where OEA provided both NAICS and SIC categorization. Even after adjusting and aggregating, comparable sector employment varies by up to 14 percent (construction sector), with most sectors within 6 percent, and total Oregon employment within 2 percent. The remaining differences result primarily from differences in sectoral definitions that are not covered up by aggregation.

Table 3.22. ED-OEA Comparable Sectors

Comparable Sector	ED Sectors	OEA Sectors**
Construction	OEMPCON	Construction (1.49)
Durable Manufacturing	OEMPDG OEMPELE OEMPLUM	Durable Manufacturing (1.05)
Non-durable Manufacturing and Information	OEMPFOO OEMPOND OEMPPAP OEMPCOM	Nondurable Manufacturing (1.06), Information (1.14)
Education	OEMPHIED OEMPLOED	Educational Services (1.49), Education State Government (0.98), Education Local Government (0.98)
Other Services and Trade	OEMPACC OEMPFIRP OEMPHEA OEMPPERS OEMPRET OEMPWHO	Retail Trade (1.26), Wholesale Trade(1.09), Financial Activities (1.69), Professional and Business Services (1.42), Health Care and Social Assistance (1.28), Leisure and Hospitality (1.22), Other Services (1.93)
Transport and Warehousing	OEMPTRAN	Transportation and Warehousing, and Utilities (1.21)
Government except Education	OEMPGOV	Government (0.98)***
Natural Resources and Mining	OEMPAGM*	Natural Resources and Mining
	OEMPHOME*	

* ED OEMPAGM employment is multiplied by 0.39 to account for OEA omission of non-farm employment. ED sector OEMPHOME is omitted entirely.
** OEA proprietor adjustments, listed in parentheses, account for OEA omission of sole proprietors.
*** Education is removed from the overall OEA Government sector for this comparable sector.

3.8. Initial Validation

The ED module was run from 1990 to 2050 and the reasonableness and stability of the output was validated. Initial testing showed that the equations fit well to historic data. The fit in the most-recent five years was examined most closely, to ensure that the model continues to fit well. Figure 3.3, below, shows the results of these runs along with OEA employment forecasts through 2012.

Certain sectors, did not match well to OEA-reported data for 2001-2006. For instance, the electronics industry in Oregon experienced rapid growth from 1980 to 2000, the period over which the model was estimated. It is unlikely that this rate of growth will continue over the next twenty years. Since the model only has historical data to evaluate, it assumes that historical relationships between the rate of growth in other industries and the rate of growth in electronics will continue. In order to fix this problem, an ability to override predicted data with exogenous values has been built into the model so that more realistic values can be used. These absolute and marginal files (see Section 3.3.6) will also be important when validating to future OEA employment forecasts.

When forecast national data was obtained after initial ED model estimation (ODOT purchased from Global Insight), an adjustment was made to the future year data to match the industry categories of the historical data. Not all the expected variables were available, and industry definitions were not consistent (NAICS, rather than SIC). A 20-

year data series with consistent variables was developed and used to re-estimate the ED equations.

As of June 2008, the ED calibration results indicate the following:

- ED is matching recent historical activity and employment data well, with a few exceptions noted below. These are shown in Figures 3.1, and 3.2 for employment and industry output forecasts, respectively.
    - The **Lumber and Wood Products** industry's output has been constrained by harvest restrictions that have nothing to do w ith demand for lumber, so the equation predicting lumber output was changed to contain only a constant term consistent with allowable harvest in the near future.
    - The forecasted output of the **electronics** industry was adjusted downward using the absolute.csv input file. This reflects the expectation that the large increase in electronics manufacturing during the 1990s in the state will persist, but future growth will be at a more reasonable rate.
    - The forecasted output of the **education** sector was adjusted by changing the structure of the equations. T he education sector output and the higher-lower education mix are subject to government investment decisions outside the model's purview. Recent increases in education spending have taken the form of increases in wages and benefits rather than increases in employment due. Since both industry output and employment are used in downstream models with an assumed fixed relationship, an effort was made to match employment rather than output trends.
    - The Construction industry was showing a higher-than-expected rate of growth. Construction in Oregon, particularly in the Portland area, over that past few decades has been brisk, including light rail lines, downtown and Pearl district development, and new housing. C hanging the equations that predict investment in residential and non-residential structures brought down the construction-industry forecast to more-reasonable levels. In the near future, ED now predicts lower construction employment than the OEA forecasts.
- ED's SIC-based industry categories are not a good match with OEA's NAICS-based industry categories. Thus, the comparison to OEA employment data provides only a general validation. E fforts to improve the industry match are planned and will involve converting to NAICS-based sectors within SWIM2.
- ED was consistently under-estimating population in the more-distant future relative to OEA forecasts, along with other variables that depend on popul ation. E D predicts population from employment and the relationship between employment and population changed significantly over the years upon which ED was estimated. The share of the population that participated in the workforce increased as women entered the workforce and as the proportion of the population that was of working age increased. N ow that most women are already in the workforce and the baby-boom generation is starting to retire, it is expected that the share of population participating in the workforce will no l onger increase. T o address this change in expectation, we "froze" the workforce participation rate at its year-2000 level.

- In 2010, in an attempt to better match OEA long range population forecasts through 2040, the specification and parameterization of ED's employment forecast were reviewed and modifications were tested. To achieve more control over the employment, and therefore population, forecasts, we tried simplifying the functional form of the employment equations making employee productivity in Oregon a linear function of employee productivity in the national forecast. Even with reduced employment growth, ED was either overshooting the OEA population targets after 2020 or undershooting targets before 2020. To bring out-year population forecasts down, we also changed the relationship between employment and population in years after 2020 by changing the assumed proportion of the population that is in the workforce. Doing so allowed us to match OEA forecasts both before and after 2020, but resulted in a slight dip in forecasted population in 2021. Ultimately, none of these modifications to ED were used. ODOT determined that matching OEA population forecasts in the out years (after 2020) was not essential, particularly since METRO, the largest MPO in the state also uses higher-than-OEA population forecasts for those years in its long-range planning. ODOT decided instead to retain the original ED formulation, applied to an updated Global Insight national forecast.

Comments:

- An ability to override ED predicted data with exogenous values (absolute.csv or marginal.csv input files) was built into the model (see Section 3.3.6). This override function will be used for all historical data (actual data override ED predictions), and for the output of the electronics industry. Once output is adjusted, employment and labor income take care of themselves. Year 2001, the first year of forecasted data, will be adjusted with marginal.csv to smooth the transition and avoid strange little jumps up or down in many sectors.
- The ED population equation and the labor force participation equation were both changed to address ED underestimating population, which led it to low estimates for other variables that depend on population in subsequent years. ED population forecasts are now higher than OEA's and significantly so in the distant future. It will be difficult to reconcile the two forecasts in the long term because the OEA forecast is a demographic forecast driven by cohort survival, fertility rates, and death rates and is unresponsive to employment-driven migration, while the ED forecast is driven by employment and workforce participation and ignores of age cohorts, fertility rates, and death rates.

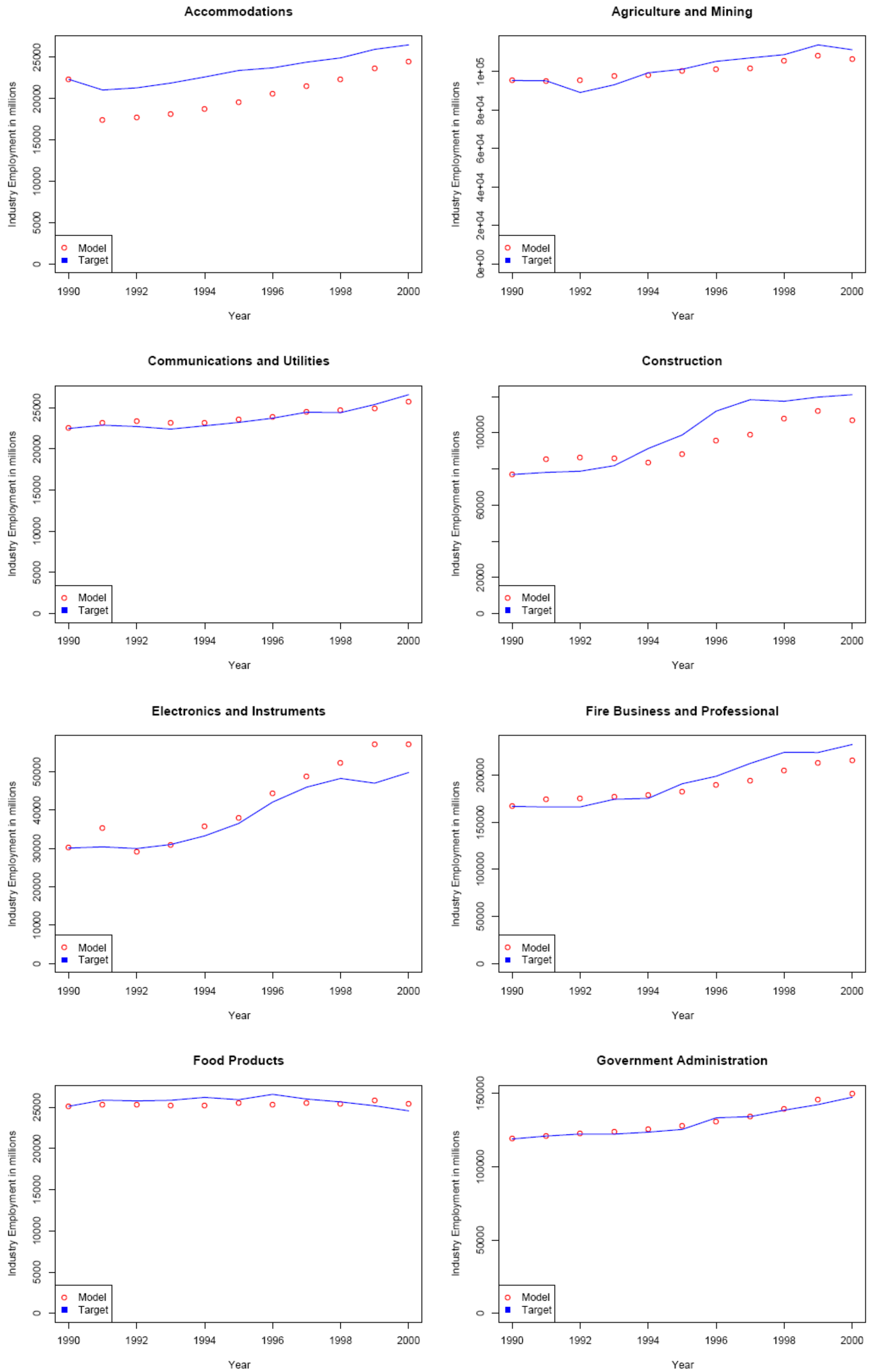
Future:

- Consider changing all sector definitions throughout the model to be aggregations of NAICS sectors. All new data is in NAICS sectors only. Unfortunately, historical data before 2000 is not available in NAICS sectors. Attempts by government agencies and private vendors to convert pre-2000 data to NAICS sectors have not been very successful. The problem of too few observations can be addressed by using quarterly data, but with fewer than ten years worth of observations, the available data cannot represent conditions over the full business cycle.

- Integrate PI-ED feedback mechanism, using historical streams of PI output (after full model calibration) that can be used as a new variable within selected components of the ED module.

In 2010, the SWIM2 model was compared against Oregon's July 1, 2010 long range population forecast, combined with the ED

Figure 3.1 1990-2000 comparison of ED & BEA Oregon employment (1of3)



Y:/models/tlumip/scenario_EDTestCarl_08Mar/t0/ed

Figure 3.1 1990-2000 comparison of ED & BEA Oregon employment (2of3)

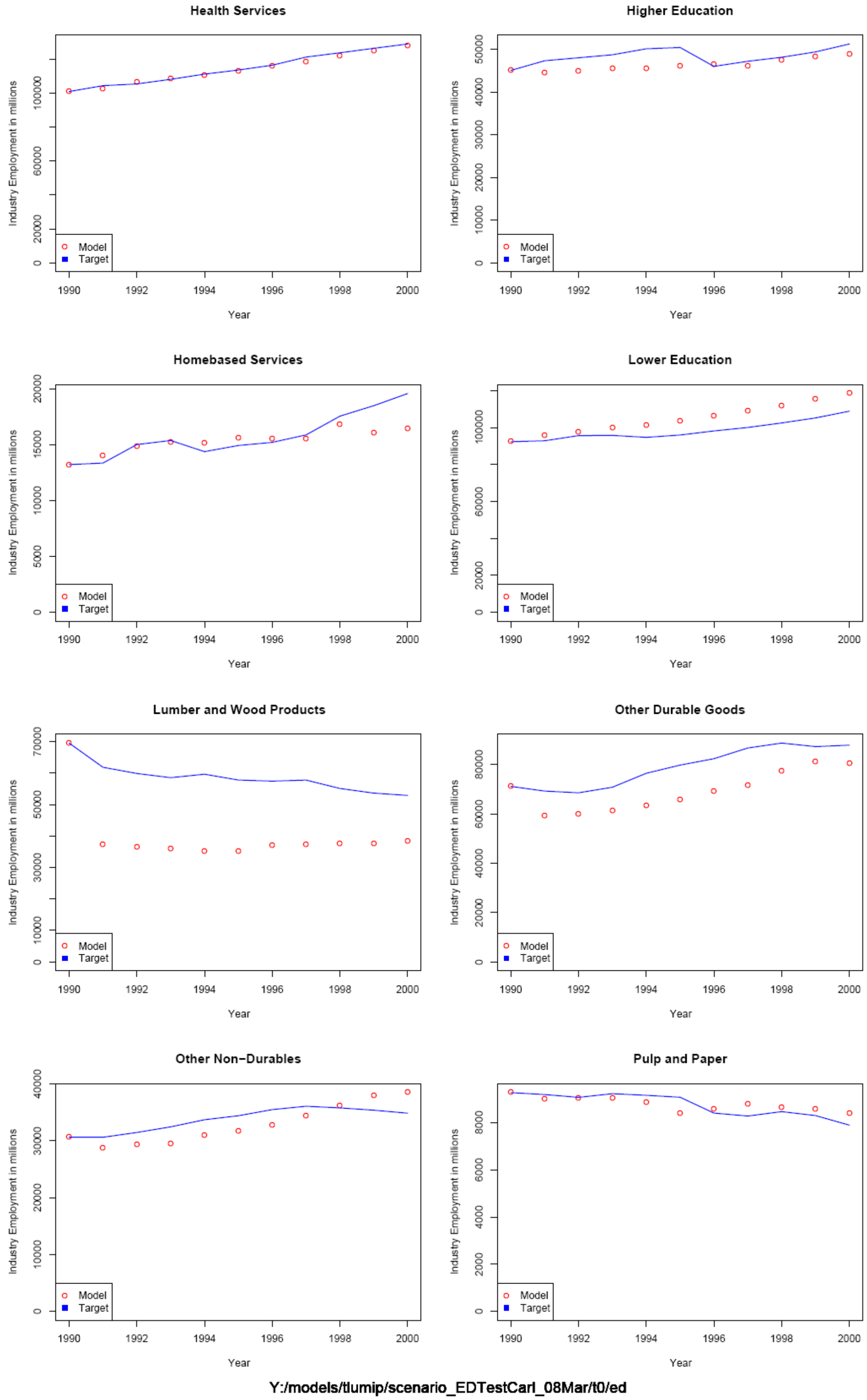


Figure 3.1 1990-2000 comparison of ED & BEA Oregon employment (3of3)

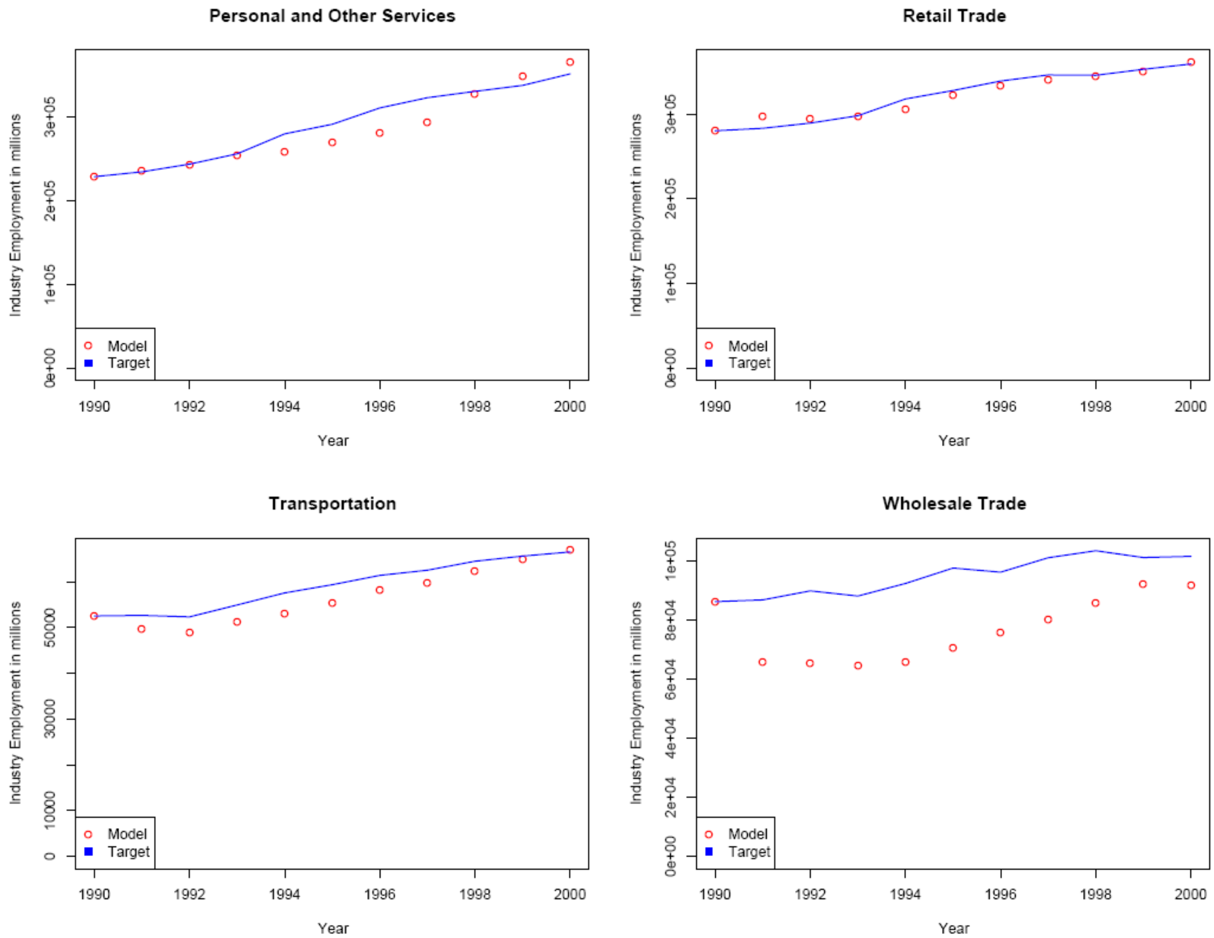


Figure 3.2 1990-2000 comparison of ED & BEA Oregon industry$ (1of3)

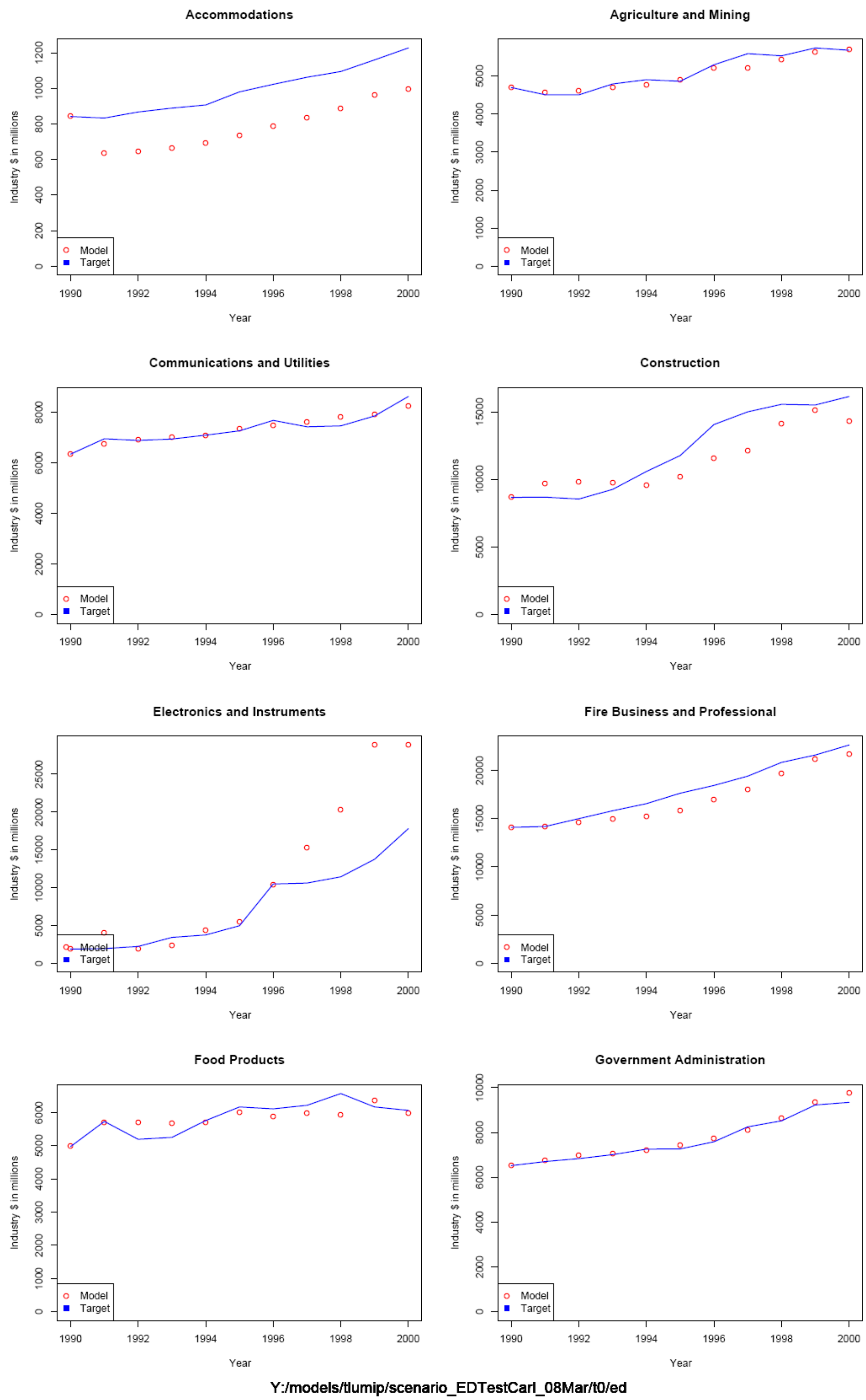
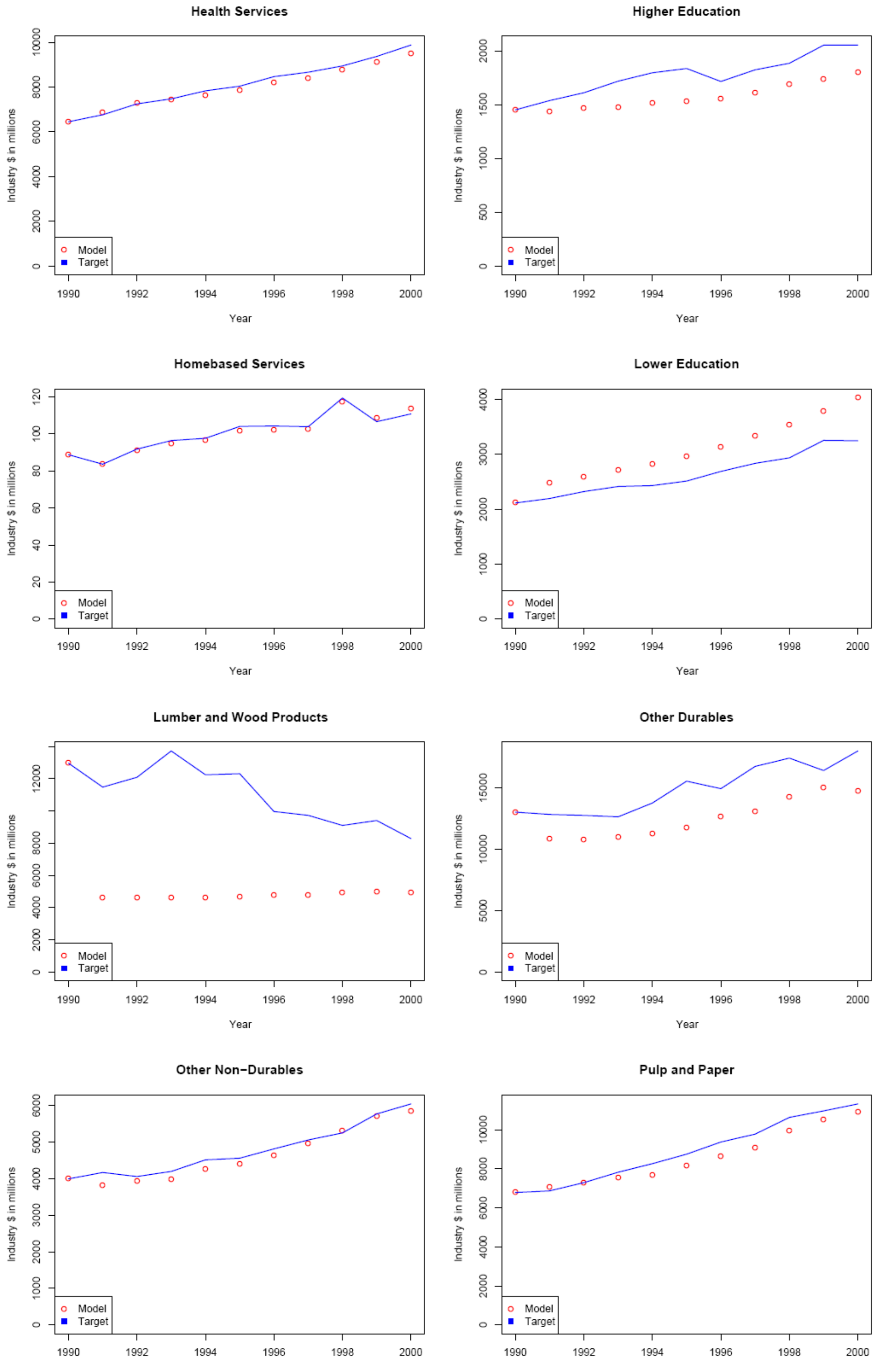


Figure 3.2 1990-2000 comparison of ED & BEA Oregon industry$ (2of3)



Y:/models/tlumip/scenario_EDTestCarl_08Mar/t0/ed

Figure 3.2 1990-2000 comparison of ED & BEA Oregon industry$ (3of3)

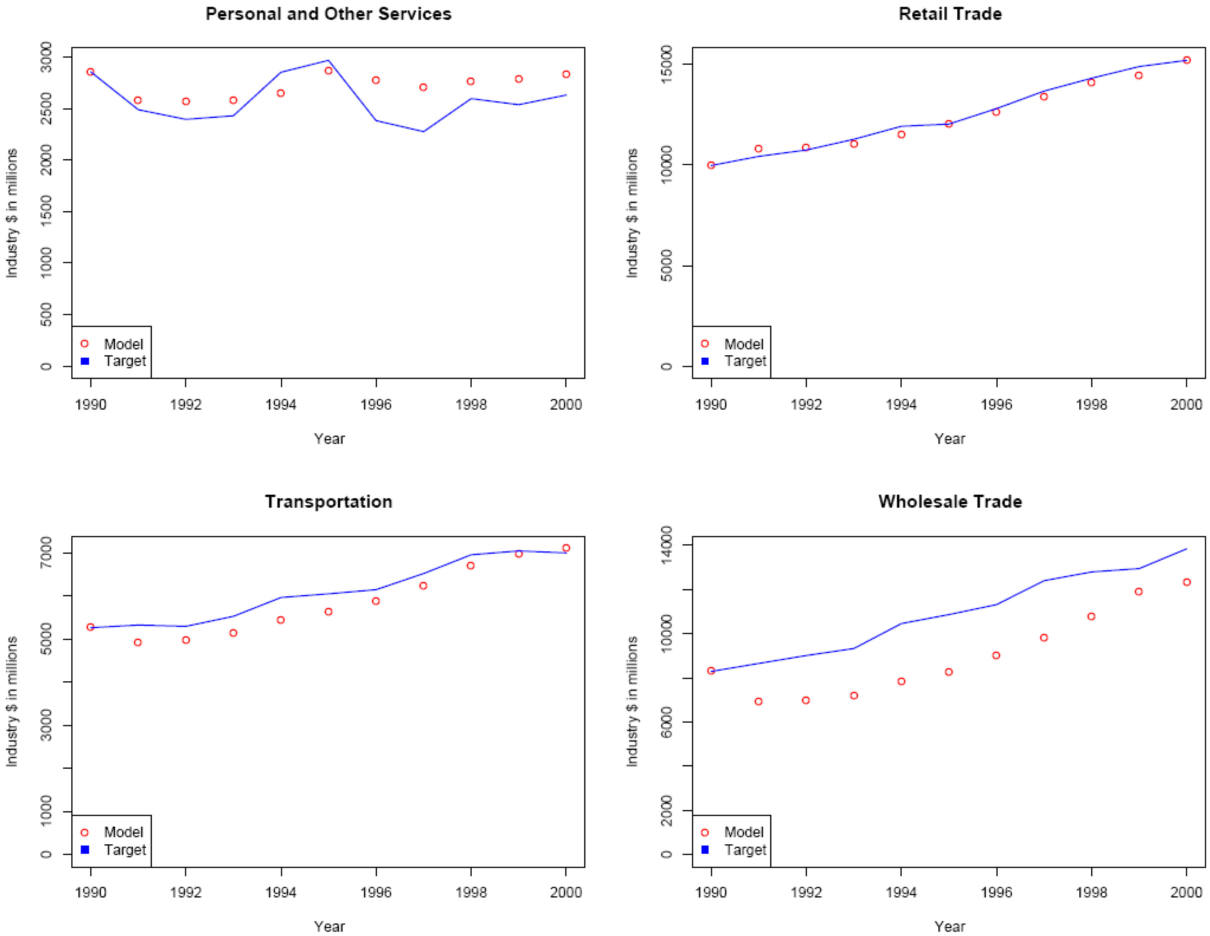


Figure 3.3. 1980-2040 Comparison of ED Forecasts & OEA (5/15/08) Employment

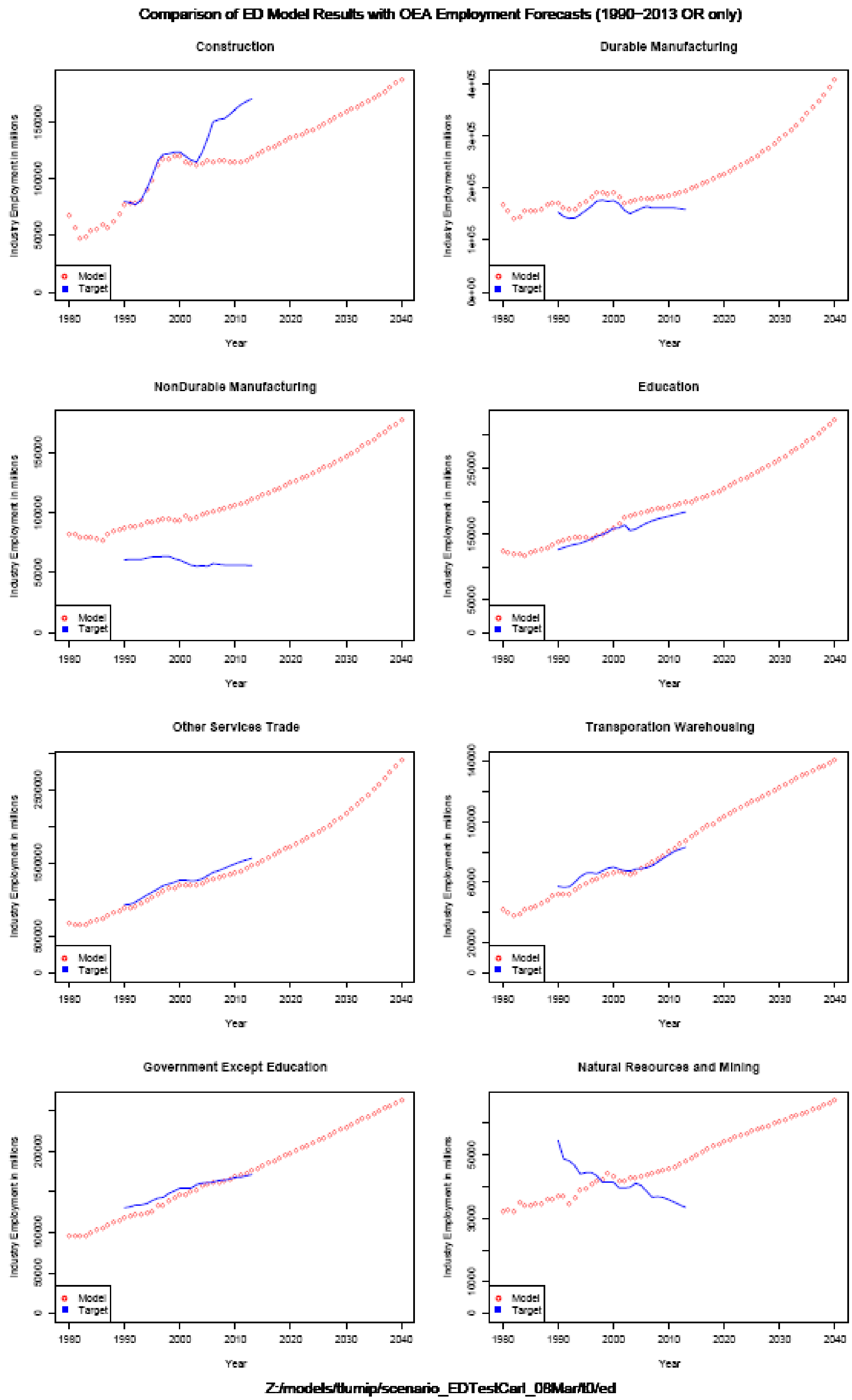


Figure 3.4. ED Forecast Employment forecast 2000-2040

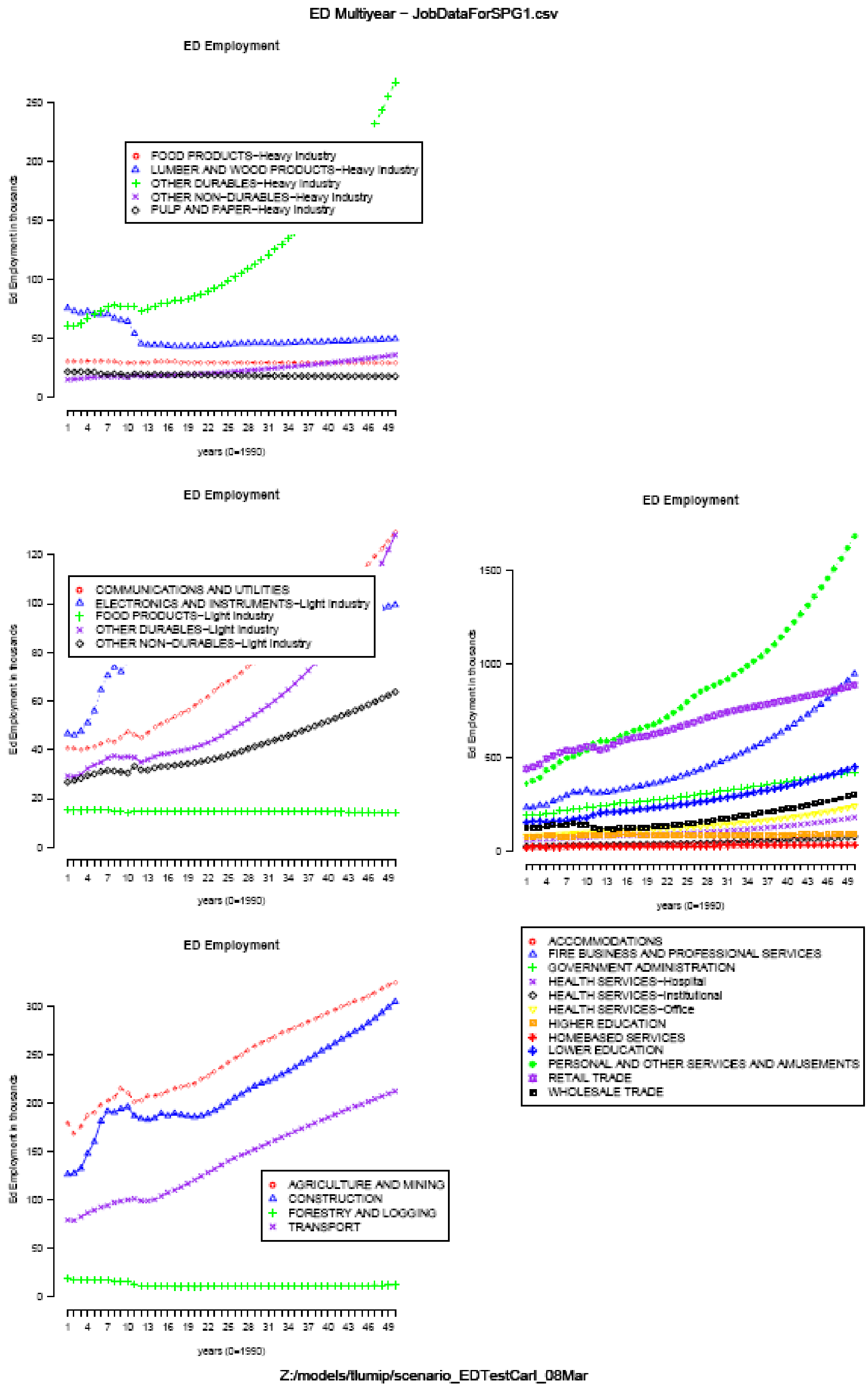
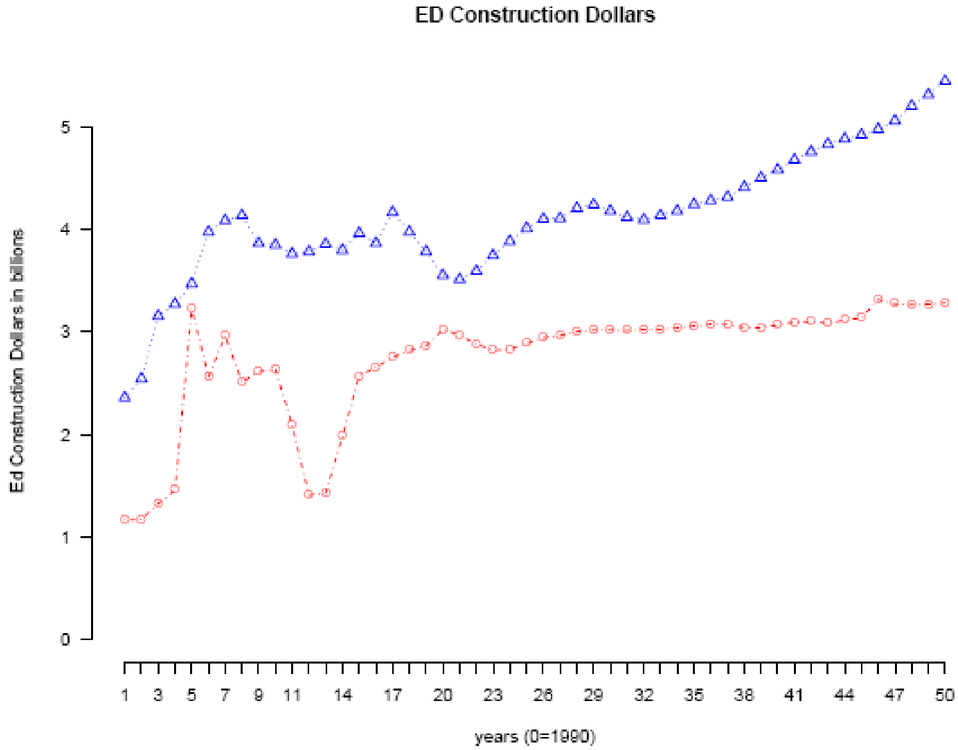


Figure 3.5. 1990-2040 ED Forecast Annual Construction Dollars



3.9. S3 Parameters

All estimated ED module coefficients, as well as the structure of the ED module (the number and composition of the equations) may be considered S3 parameters, subject to re-estimation and refinement as the full Oregon Statewide Integrated Model is tested and calibrated.

4.0 SPG Module

In each year, the Synthetic Population Generator (SPG) Module generates a synthetic population consisting of a set of PUMS household records. In aggregate the resulting PUMS records conform to modelwide workers per household and age distributions and a set of modelwide employment by industry forecast determined by the ED module. Each household is assigned a home location consistent with alpha zone labor production (i.e., the home end of the labor flow in dollars) by occupation and household category (i.e., household income and size) determined by the PI module. The output produced by the SPG module is a synthetic population of persons and households with PUMS attributes and assigned a home alpha zone, in the PUMS file format. Later in the same model year, PT adjusts and adds to the Synthetic population attributes produced by SPG.

4.1. Theoretical Basis

The SPG Module uses a two-stage procedure, referred to as SPG1 and SPG2 to generate a synthetic population, and to determine the alpha zone home locations for each household, respectively. The SPG1 procedure begins with the full set of PUMS records where the PUMS sample weights are adjusted using a table balancing methodology. The rows of the table consist of all the PUMS household records for the PUMAs covering the study area. The columns in the table correspond to the constraints to which the synthetic population is to conform; i.e. one column for each industry employment category (ED module constraint) and one column for each workers per household category and age group (exogenous constraint). The cell values in the table indicate the number of employed persons in each industry and age group for the household and which number of workers per household category the household record belongs. The table balancing procedure determines weights (i.e. expansion factors) for each PUMS household record so that when final weights have been determined, the weighted PUMS records conform to all the specified modelwide constraints, including ED regional employment totals by industry and modelwide households by workers per household and age categories.

Once this weighted set of PUMS households is determined, SPG2 allocates each individual household to an alpha zone, respecting labor flow constraints from PI in the form of dollars of labor production by occupation and alpha zone and total households by household category by alpha zone.[9]

The two allocation procedures, generating the initial weight or count of each PUMS household record and allocating those households to alpha zones, are referred to as modules SPG1 and SPG2, respectively. SPG1 is a deterministic table balancing process, while SPG2 is a stochastic allocation of home location. The development of SPG draws from references [14] and [17].

4.2. Quantity Definitions and Categories

SPG1 operates at a modelwide level, while SPG2 operates at an alpha zone level. SPG1 takes a count of employees in aggregated industry sectors from the ED module to constrain the set of households generated. Since SPG uses US Census PUMS data, its sectors must be defined using Census categories. As a result, SPG categories typically do

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[9] Although PI operates at the betazone level. A post-procesing method disaggregates elements of the labor flows to alphazones, based on endogenous land use inventory. This process is discussed in Section 6.3.7.

not include the internal management or ‘office’ split used in the PI Module. The SPG industry sectors are listed below:

- ACCOMMODATIONS
- AGRICULTURE AND MINING
- COMMUNICATIONS AND UTILITIES
- CONSTRUCTION
- ELECTRONICS AND INSTRUMENTS
- FIRE BUSINESS AND PROFESSIONAL SERVICES
- FOOD PRODUCTS-Heavy Industry
- FOOD PRODUCTS-Light Industry
- GOVERNMENT ADMINISTRATION
- HEALTH SERVICES-Hospital
- HEALTH SERVICES-Institutional
- HEALTH SERVICES-Office
- HIGHER EDUCATION
- HOMEBASED SERVICES
- LOWER EDUCATION
- FORESTRY AND LOGGING
- LUMBER AND WOOD PRODUCTS-Heavy Industry
- OTHER DURABLES-Heavy Industry
- OTHER DURABLES-Light Industry
- OTHER NON-DURABLES-Heavy Industry
- OTHER NON-DURABLES-Light Industry
- PERSONAL AND OTHER SERVICES AND AMUSEMENTS
- PULP AND PAPER
- RETAIL TRADE
- TRANSPORT
- WHOLESALE TRADE

A correspondence file [IndustryOccupationSplitIndustrycorrespondanced.csv] maps the PUMS-based SPG industries and occupations to the full SWIM2 categories (previously noted in Table 2.3 and 2.7). Both fields are included in the resulting Synthetic Population files. This file also provides default values for industry and occupation based on averages from the other PUMS fields, for records where PUMS had missing values.

The output of the SPG Module is a synthetic population, written as a pair of files in PUMS file format: a SynPopH.csv file with household attributes and a corresponding SynPopP.csv file with person attributes. The attributes of these files were shown previously in Table 2.8. Note that the original PUMS ID number (HH+Person), although not currently retained, could be added to allow linkage back to further household and person attributes if desired.

4.3. Component Models

The SPG Module works in two stages, identified as SPG1 and SPG2. The SPG1 module determines a set of households in the model area consistent with the total employment by industry forecast by the ED module and the pre-specified distribution of households by number of workers per household. The number of total regional households by household size and household income categories, determined by the SPG1 module, is read as input by the PI module.

The SPG2 module reads labor dollars of production by alpha zone and number of households by (household size and household income) category by alpha zone information from the PI module as well as the set of PUMS household and person records as determined by SPG1. The zonal labor dollars of production are used to calculate probability distributions that determine the allocation of household records to home alpha zones. These components and their subtasks listed below are detailed in the remainder of this section.

- Population Synthesis using a table balancing procedure(SPG1)
- Household Home Zone Assignment (SPG2)

It should be noted that some information associated with the original PUMS record sample is updated by values calculated endogenously through the operation of the SWIM2 module. SPG adds calculated fields to the SynPop files to match SWIM2 industry and occupation categories. Additionally, PT assigns a workplace location (based on the work end of the same PI labor flows) and updates the auto ownership information, and adjusts other minor attributes. These updated values are retained in the personData.csv and householdData.csv files (see Table 2.8), and the original SPG-generated synthetic population files are not updated.

4.3.1. Population Synthesis (SPG1)

The ED module determines the total employment by un-split industry for the entire model area.[10] The SPG1 module is intended to produce a set of households which are consistent with this forecasted employment. In other words, the SPG1 module determines a set of households with full attributes such that the number of employed persons by industry in those households matches the modelwide employment by industry forecast by the ED module. Unemployed households are also generated, consistent with the initial PUMS weights.

Due to mismatch between US Bureau of Economic Analysis job data and Census worker data, the ED forecasted jobs are adjusted by fixed factors into workers. This accounts for mismatches between industry categories as well as workers working multiple jobs.

Besides total employment by industry category, two other important characteristic of the synthetic population are controlled for in SPG1. One is the distribution of employed persons in households. The distribution of households by number of workers per household is important for the PT module. For this reason, the SPG1 module is further constrained to match the modelwide distribution of workers per household, by year provided in an input file. A second controlled attribute in SPG1 is age distributions. This attribute is important to travel models, as the population ages and travel behavior changes.

At the close of the SPG1 table balancing procedure, the PUMS households have no spatial attributes. This modelwide count of households is input to PI to allocate

[10] The ED module produced Oregon-only population (OPOP) consistent with ED's employment estimates but this is not used in subsequent SWIM2 modules.

household activity among zones. Thus SPG1 operates after the ED module, but before the PI module.

SPG1 Table Balancing Procedure – Initial Conditions

The table balancing procedure used by the SPG1 module is described with reference to a simplified test case illustrated in Tables 4.1 through 4.7, which only covers one of the two controlled variables, worker per household but not person age. A dding age is equivalent to adding additional columns to the example. Table 4.1 shows the test case data. The 25 rows in this table represent a sample of household records to be expanded. In the full model application, there are as many rows as there are PUMS records from all the PUMAs covering the model area. The columns in this table include an hh_weight field, a set of industry fields and a set of household category fields, representing constraints defined for the procedure. The cell values in the hh_weight field begin as the PUMS household weights, and are changed systematically during the balancing procedure. For simplicity, the test case assumes all PUMS household weights have a value of 1. In the full model application, each cell value would be multiplied by the PUMS household record weight (i.e., PUMS HOUSWGT field value). The cell value in the constraint fields are dependent on the hh_weight cell value and thus are also modified by the table balancing procedure. At the end of the procedure, the final values in the hh_weight field indicate the number of times each sample household record should be replicated in the TM synthetic population. T he table balancing procedure is run iteratively, with constraint cell values changing as a result of changes to the hh_weight values until all constraint field totals match the specified constraints.

In Table 4.1, the constraints specified for the test case are shown highlighted in yellow. The numbers shown in ***bold italics font*** in the lower highlighted area indicate constraints for the SPG1 procedure. The modelwide employment by industry category from the ED module adjusted using jobs-to-worker factors, and relative frequencies of the number of workers per household by household category are read as exogenous inputs. Jobs-to-worker factors were required to adjust for multiple jobs per person, absentees, and other unspecified differences between ED and SPG data sources. From these absolute worker totals, the relative frequency by industry category is determined. Likewise, from the relative frequencies of households by household category and ED-based workers over all industries, absolute number of modelwide households in each household category can be determined. The equation to calculate total households follows. For the Table 4.1 test case, the modelwide workers (ΣW_i) are constrained to 13,900 workers, leading to a value of 6,950 households (H).

$$H = \Sigma_n n * Share_n / \Sigma_i W_i \tag{4.01}$$

$$W_i = J_i * JtoWFactor_i \tag{4.02}$$

where:

n	=	number of workers per household (0, 1, 2, 3, or 4)
i	=	index of aggregated industry sector categories
H	=	SPG target for number of modelwide households
$Share_n$	=	Target share of n worker households of all households (exogenous)
W_i	=	SPG target for number of modelwide workers in industry sector i
J_i	=	ED-specified modelwide count of jobs in industry sector i
$JtoWFactor_i$	=	Factor to convert ED jobs to workers in industry sector i (exogenous)

Table 4.1. Initial Household Records and Constraints for SPG1 Matrix Balancing Procedure

Sample of Workers by Employment Category

Household	hh weight	Retail	Educ	Service	Govt	Mfr	Other	0 worker	1 worker	2 workers	3 workers	4 workers
1		1	1					0	0	1	0	0
2							1	0	1	0	0	0
3		2		1				0	0	0	1	0
4				1		1		0	0	1	0	0
5			2				1	0	0	0	1	0
6					2		2	0	0	0	0	1
7								1	0	0	0	0
8		1						0	1	0	0	0
9		1			1	1	1	0	0	0	0	1
10				1				0	1	0	0	0
11			1		2			0	0	0	1	0
12					1		1	0	0	1	0	0
13			1	1	1		1	0	0	0	0	1
14		1	2					0	0	0	1	0
15		1		1	1			0	0	0	1	0
16								1	0	0	0	0
17			1	1				0	0	1	0	0
18					2			0	0	1	0	0
19							1	0	1	0	0	0
20							1	0	1	0	0	0
21					1		1	0	0	1	0	0
22		1						0	1	0	0	0
23							1	0	1	0	0	0
24		1				1		0	0	1	0	0
25		1		1				0	0	1	0	0
		10	8	7	11	3	11	2	7	8	5	3
		20.00%	16.00%	14.00%	22.00%	6.00%	22.00%	8.00%	28.00%	32.00%	20.00%	12.00%
							50.00					

Regional Total Workers by Employment Category - Employment Targets							**Households by Workers per households - Household Targets**				
	2150	***1800***	***2800***	***2200***	***1950***	***3000***	556	1946	2224	1390	834
	15.47%	12.95%	20.14%	15.83%	14.03%	21.58%	***8.00%***	***28.00%***	***32.00%***	***20.00%***	***12.00%***
					Total Workers =	13900.00				Total Households =	6950

Note: For simplicity, this test case assumes an initial hh_weight value of 1 for all households, rather than the household-specific PUMS weight

Table 4.1 illustrates the starting conditions for the table balancing procedure. The household records and their initial constraint field values are determined from the Census PUMS dataset. The starting values of the hh_weight field would be the PUMS household weights (assumed to be 1 for all households in the test case of Figures 4.1, or could be adjusted by the user). The constraint values come from forecasts of regional employment by category (ED module) and a specified distribution of household attribute values (weighted Census PUMS or STF dataset).

SPG1 Table Balancing Procedure – First Iteration

Table 4.2 shows the expanded version of Table 4.1, after the hh_weight cell values are initialized. To do so, an initial hh_weight expansion factor is calculated as a ratio of the target and sample count of workers by industry, as follows:

$$InitFactor = \Sigma_i W_i / \Sigma_i SampleW_i \quad (4.03)$$

where:

i	=	index of industry sector categories
InitFactor	=	initial household expansion factor (initial hh_weight)
W_i	=	target workers by industry i (see Equation 4.2)
$SampleW_i$	=	household weight for each PUMS sample worker in industry i

Applying the expanded initial hh_weight values to all cells, results in an initial worker and household count estimate in each field cell, as shown in Table 4.2 (In the example, InitFactor = 13900/50=278). The column sums provide the total workers and total households estimated by category after this initial balancing step. Below the column sums in Table 4.2, the resulting relative distribution of workers and households by category are shown. This can be compared with the highlighted targeted distributions (consistent with those estimated in Table 4.1). The difference between the calculated field frequencies and their corresponding target frequencies indicates the amount of adjustment needed by category in order to satisfy all constraints. When this difference is minimal (meets a user-defined target threshold) for all constraints, the table is considered balanced.

In order to attain a balanced table, a series of systematic adjustments must be applied through the course of multiple iterations. In each iteration adjustment factors are calculated for each field constraint in turn. An adjustment factor is calculated as the ratio of the targeted count and most recent sample count for that field, as follows:

$$AdjFactor_k = TargetCount_k / \Sigma_r SampleCount_{k,r} \quad (4.04)$$

where:

k	= index for constraint field category (industry or household category)
r	= index for sample household record
$AdjFactor_k$	= sample adjustment factor for field k
$TargetCount_k$	= targeted count for field category k
$SampleCount_{k,r}$	= sample count in field category k from household record r

Table 4.2. SPG Table Balancing Procedure Example-After Initial hh_weight expansion factor

Initial Expansion Factor 278

Household	hh weight	Retail	Educ	Service	Govt	Mfr	Other	0 worker	1 worker	2 workers	3 workers	4 workers
1	278	278	278	0	0	0	0	0	0	278	0	0
2	278	0	0	0	0	0	278	0	278	0	0	0
3	278	556	0	278	0	0	0	0	0	0	278	0
4	278	0	0	278	0	278	0	0	0	278	0	0
5	278	0	556	0	0	0	278	0	0	0	278	0
6	278	0	0	0	556	0	556	0	0	0	0	278
7	278	0	0	0	0	0	0	278	0	0	0	0
8	278	278	0	0	0	0	0	0	278	0	0	0
9	278	278	0	0	278	278	278	0	0	0	0	278
10	278	0	0	278	0	0	0	0	278	0	0	0
11	278	0	278	0	556	0	0	0	0	0	278	0
12	278	0	0	0	278	0	278	0	0	278	0	0
13	278	0	278	278	278	0	278	0	0	0	0	278
14	278	278	556	0	0	0	0	0	0	0	278	0
15	278	278	0	278	278	0	0	0	0	0	278	0
16	278	0	0	0	0	0	0	278	0	0	0	0
17	278	0	278	278	0	0	0	0	0	278	0	0
18	278	0	0	0	556	0	0	0	0	278	0	0
19	278	0	0	0	0	0	278	0	278	0	0	0
20	278	0	0	0	0	0	278	0	278	0	0	0
21	278	0	0	0	278	0	278	0	0	278	0	0
22	278	278	0	0	0	0	0	0	278	0	0	0
23	278	0	0	0	0	0	278	0	278	0	0	0
24	278	278	0	0	0	278	0	0	0	278	0	0
25	278	278	0	278	0	0	0	0	0	278	0	0
		2780	2224	1946	3058	834	3058	556	1946	2224	1390	834
		20.00%	16.00%	14.00%	22.00%	6.00%	22.00%	8.00%	28.00%	32.00%	20.00%	12.00%
		15.47%	12.95%	20.14%	15.83%	14.03%	21.58%	8.00%	28.00%	32.00%	20.00%	12.00%
							13900.00					6950

Note: For simplicity, this assumes an initial hh_weight value of 1 for all households, rather than the household-specific PUMS weight.

The process begins by calculating the adjustment factor for the 1st field category. This adjustment factor updates the initial hh_weight values if and only if those households (rows) have non-zero entries in the field being adjusted. Subsequent updates to all field cell values are made and columns summed. After the adjustment factor is calculated and applied, the column sum in that field will match the targeted value (in absolute terms, not relative frequency).

Continuing our example, an adjustment factor of 0.77 (2150/2780) was calculated for the retail field. Table 4.3 shows the results of applying this adjustment factor. All households (rows) in the sample with non-zero retail workers were assigned a hh_weight of 215 (278*0.77). For example, household 1 has non-zero employed persons in constraint field 1, so its hh_weight is adjusted, while Household 2 has zero employed persons in constraint field 1, so its hh_weight is not. These new hh_weights are then applied to the other fields, leading to modified column sums for each field. Note also that the column sum of constraint field 1 matches the target exactly. The relative frequency and target relative frequency do not match at this point because the total workers estimated by the current set of hh_weights are too low (12,577 in sample vs. 13,900 target).

At this point, the process is repeated in the same manner for the each field in turn; calculating an adjustment factor, updating the hh_weight for those household with non-zero cell values in that field, updating the remaining field cells and the associated column sums. The results of making these adjustments to field 2, are shown in Table 4.4. Note that although the column sum for field 2 now matches the target exactly, the column sum of field 1 no longer matches its target, but is still somewhat close.

Subsequent adjustments are made for each of the industry fields and then each household category field until all fields have been updated. Note that after the last household field, only that field will be guaranteed to match its target, although the other fields should be closer in general than before the adjustments were made, and the table will have the correct total expanded workers and total expanded households compared to targets. The adjustment of the last household constraint field signals the end of the first table balancing procedure iteration. Table 4.5 shows the household sample resulting from the first table balancing iteration.

Table 4.3. SPG Table Balancing Procedure Example-After Iteration 1 adjustment to Retail field

Balancing Factor	0.773381295

Household	hh weight	Retail	Educ	Service	Govt	Mfr	Other	0 worker	1 worker	2 workers	3 workers	4 workers
1	215.00	215.00	215.00	0.00	0.00	0.00	0.00	0	0	215	0	0
2	278.00	0.00	0.00	0.00	0.00	0.00	278.00	0	278	0	0	0
3	215.00	430.00	0.00	215.00	0.00	0.00	0.00	0	0	0	215	0
4	278.00	0.00	0.00	278.00	0.00	278.00	0.00	0	0	278	0	0
5	278.00	0.00	556.00	0.00	0.00	0.00	278.00	0	0	0	278	0
6	278.00	0.00	0.00	0.00	556.00	0.00	556.00	0	0	0	0	278
7	278.00	0.00	0.00	0.00	0.00	0.00	0.00	278	0	0	0	0
8	215.00	215.00	0.00	0.00	0.00	0.00	0.00	0	215	0	0	0
9	215.00	215.00	0.00	0.00	215.00	215.00	215.00	0	0	0	0	215
10	278.00	0.00	0.00	278.00	0.00	0.00	0.00	0	278	0	0	0
11	278.00	0.00	278.00	0.00	556.00	0.00	0.00	0	0	0	278	0
12	278.00	0.00	0.00	0.00	278.00	0.00	278.00	0	0	278	0	0
13	278.00	0.00	278.00	278.00	278.00	0.00	278.00	0	0	0	0	278
14	215.00	215.00	430.00	0.00	0.00	0.00	0.00	0	0	0	215	0
15	215.00	215.00	0.00	215.00	215.00	0.00	0.00	0	0	0	215	0
16	278.00	0.00	0.00	0.00	0.00	0.00	0.00	278	0	0	0	0
17	278.00	0.00	278.00	278.00	0.00	0.00	0.00	0	0	278	0	0
18	278.00	0.00	0.00	0.00	556.00	0.00	0.00	0	0	278	0	0
19	278.00	0.00	0.00	0.00	0.00	0.00	278.00	0	278	0	0	0
20	278.00	0.00	0.00	0.00	0.00	0.00	278.00	0	278	0	0	0
21	278.00	0.00	0.00	0.00	278.00	0.00	278.00	0	0	278	0	0
22	215.00	215.00	0.00	0.00	0.00	0.00	0.00	0	215	0	0	0
23	278.00	0.00	0.00	0.00	0.00	0.00	278.00	0	278	0	0	0
24	215.00	215.00	0.00	0.00	0.00	215.00	0.00	0	0	215	0	0
25	215.00	215.00	0.00	215.00	0.00	0.00	0.00	0	0	215	0	0
		2150.00	2035.00	1757.00	2932.00	708.00	2995.00	556.00	1820	2035	1201	771
		17.09%	16.18%	13.97%	23.31%	5.63%	23.81%	8.71%	28.51%	31.88%	18.82%	12.08%
		15.47%	12.95%	20.14%	15.83%	14.03%	21.58%	8.00%	28.00%	32.00%	20.00%	12.00%
							12577.00					6383

Table 4.4. SPG Table Balancing Procedure Example -After Iteration 1 adjustment to Education field

Balancing Factor 0.884520885

Household	hh weight	Retail	Educ	Service	Govt	Mfr	Other	0 worker	1 worker	2 workers	3 workers	4 workers
1	190.17	190.17	190.17	0.00	0.00	0.00	0.00	0.00	0.00	190.17	0.00	0.00
2	278.00	0.00	0.00	0.00	0.00	0.00	278.00	0.00	278.00	0.00	0.00	0.00
3	215.00	430.00	0.00	215.00	0.00	0.00	0.00	0.00	0.00	0.00	215.00	0.00
4	278.00	0.00	0.00	278.00	0.00	278.00	0.00	0.00	0.00	278.00	0.00	0.00
5	245.90	0.00	491.79	0.00	0.00	0.00	245.90	0.00	0.00	0.00	245.90	0.00
6	278.00	0.00	0.00	0.00	556.00	0.00	556.00	0.00	0.00	0.00	0.00	278.00
7	278.00	0.00	0.00	0.00	0.00	0.00	0.00	278.00	0.00	0.00	0.00	0.00
8	215.00	215.00	0.00	0.00	0.00	0.00	0.00	0.00	215.00	0.00	0.00	0.00
9	215.00	215.00	0.00	0.00	215.00	215.00	215.00	0.00	0.00	0.00	0.00	215.00
10	278.00	0.00	0.00	278.00	0.00	0.00	0.00	0.00	278.00	0.00	0.00	0.00
11	245.90	0.00	245.90	0.00	491.79	0.00	0.00	0.00	0.00	0.00	245.90	0.00
12	278.00	0.00	0.00	0.00	278.00	0.00	278.00	0.00	0.00	278.00	0.00	0.00
13	245.90	0.00	245.90	245.90	245.90	0.00	245.90	0.00	0.00	0.00	0.00	245.90
14	190.17	190.17	380.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	190.17	0.00
15	215.00	215.00	0.00	215.00	215.00	0.00	0.00	0.00	0.00	0.00	215.00	0.00
16	278.00	0.00	0.00	0.00	0.00	0.00	0.00	278.00	0.00	0.00	0.00	0.00
17	245.90	0.00	245.90	245.90	0.00	0.00	0.00	0.00	0.00	245.90	0.00	0.00
18	278.00	0.00	0.00	0.00	556.00	0.00	0.00	0.00	0.00	278.00	0.00	0.00
19	278.00	0.00	0.00	0.00	0.00	0.00	278.00	0.00	278.00	0.00	0.00	0.00
20	278.00	0.00	0.00	0.00	0.00	0.00	278.00	0.00	278.00	0.00	0.00	0.00
21	278.00	0.00	0.00	0.00	278.00	0.00	278.00	0.00	0.00	278.00	0.00	0.00
22	215.00	215.00	0.00	0.00	0.00	0.00	0.00	0.00	215.00	0.00	0.00	0.00
23	278.00	0.00	0.00	0.00	0.00	0.00	278.00	0.00	278.00	0.00	0.00	0.00
24	215.00	215.00	0.00	0.00	0.00	215.00	0.00	0.00	0.00	215.00	0.00	0.00
25	215.00	215.00	0.00	215.00	0.00	0.00	0.00	0.00	0.00	215.00	0.00	0.00
		2100.34	1800.00	1692.79	2835.69	708.00	2930.79	556.00	1820.00	1978.07	1111.97	738.90
		17.40%	14.92%	14.03%	23.50%	5.87%	24.29%	8.96%	29.33%	31.88%	17.92%	11.91%
		15.47%	12.95%	20.14%	15.83%	14.03%	21.58%	8.00%	28.00%	32.00%	20.00%	12.00%
							12067.62					6204.9312

Table 4.5. SPG Table Balancing Procedure Example-After Iteration 1

Balancing Factor 0.9238079

Household	hh weight	Retail	Educ	Service	Govt	Mfr	Other	0 worker	1 worker	2 workers	3 workers	4 workers
1	133.75	133.75	133.75	0.00	0.00	0.00	0.00	0.00	0.00	133.75	0.00	0.00
2	279.39	0.00	0.00	0.00	0.00	0.00	279.39	0.00	279.39	0.00	0.00	0.00
3	400.88	801.77	0.00	400.88	0.00	0.00	0.00	0.00	0.00	0.00	400.88	0.00
4	763.83	0.00	0.00	763.83	0.00	763.83	0.00	0.00	0.00	763.83	0.00	0.00
5	299.23	0.00	598.46	0.00	0.00	0.00	299.23	0.00	0.00	0.00	299.23	0.00
6	194.42	0.00	0.00	0.00	388.84	0.00	388.84	0.00	0.00	0.00	0.00	194.42
7	278.00	0.00	0.00	0.00	0.00	0.00	0.00	278.00	0.00	0.00	0.00	0.00
8	200.16	200.16	0.00	0.00	0.00	0.00	0.00	0.00	200.16	0.00	0.00	0.00
9	355.14	355.14	0.00	0.00	355.14	355.14	355.14	0.00	0.00	0.00	0.00	355.14
10	428.10	0.00	0.00	428.10	0.00	0.00	0.00	0.00	428.10	0.00	0.00	0.00
11	194.39	0.00	194.39	0.00	388.77	0.00	0.00	0.00	0.00	0.00	194.39	0.00
12	148.01	0.00	0.00	0.00	148.01	0.00	148.01	0.00	0.00	148.01	0.00	0.00
13	284.45	0.00	284.45	284.45	284.45	0.00	284.45	0.00	0.00	0.00	0.00	284.45
14	214.37	214.37	428.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	214.37	0.00
15	281.13	281.13	0.00	281.13	281.13	0.00	0.00	0.00	0.00	0.00	281.13	0.00
16	278.00	0.00	0.00	0.00	0.00	0.00	0.00	278.00	0.00	0.00	0.00	0.00
17	286.05	0.00	286.05	286.05	0.00	0.00	0.00	0.00	0.00	286.05	0.00	0.00
18	137.11	0.00	0.00	0.00	274.22	0.00	0.00	0.00	0.00	137.11	0.00	0.00
19	279.39	0.00	0.00	0.00	0.00	0.00	279.39	0.00	279.39	0.00	0.00	0.00
20	279.39	0.00	0.00	0.00	0.00	0.00	279.39	0.00	279.39	0.00	0.00	0.00
21	148.01	0.00	0.00	0.00	148.01	0.00	148.01	0.00	0.00	148.01	0.00	0.00
22	200.16	200.16	0.00	0.00	0.00	0.00	0.00	0.00	200.16	0.00	0.00	0.00
23	279.39	0.00	0.00	0.00	0.00	0.00	279.39	0.00	279.39	0.00	0.00	0.00
24	357.14	357.14	0.00	0.00	0.00	357.14	0.00	0.00	0.00	357.14	0.00	0.00
25	250.11	250.11	0.00	250.11	0.00	0.00	0.00	0.00	0.00	250.11	0.00	0.00
		2793.72	1925.83	2694.54	2268.56	1476.10	2741.24	556.00	1946.00	2224.00	1390.00	834.00
		20.10%	13.85%	19.39%	16.32%	10.62%	19.72%	8.00%	28.00%	32.00%	20.00%	12.00%
		15.47%	12.95%	20.14%	15.83%	14.03%	21.58%	8.00%	28.00%	32.00%	20.00%	12.00%
							13900.00					6950

SPG1 Table Balancing Procedure – Subsequent Iterations

After the end of the first table balancing iteration, a check is performed to determine if any constraint fields differ from their targets. If any differ by more than a user-specified acceptable error, then another iteration of table balancing is performed. The hh_weights from the previous iteration are adjusted at the beginning of the new iteration, as the new iteration again calculates and applies adjustment factors for each constraint field, as described above. Table 4.6 shows the resulting table after 2 full table balancing iterations. Table 4.7 shows the results at the end of 20 table balancing iterations.

For the test case being explained here, 20 iterations were required to match targets within the margin of error. The final (20^{th} iteration) hh_weights resulted in a balanced table. Note that the sample columns sums and target values are very close for every category, as well as the relative frequencies. The adjustment factor applied in the last adjustment step (upper left corner of Figure 4.7) was very close to 1.0, an indicator that subsequent adjustments would be very slight.

These weights, after the final iteration, indicate the number of times each household record should be replicated in the SPG-produced synthetic population. In order to write out the population (consisting of replicated PUMS household records), it is necessary to round the fractional decimal hh_weight values produced by the table-balancing method to integer values. This is done by simple bucket rounding of the set of hh_weight values, which avoids significantly affecting the match between the final population's characteristics and the original constraints.[11]

Although not included in the example presented here, SPG1 also controls for age distributions, which would be represented as additional columns. The age distributions are a person-level attribute, not a household attribute, so the control totals would be used against the population to determine weights, which are then adjusted appropriately (based on each individual's source household) to become household weights. The process described above functions the same, only with columns representing the age categories being added to the balancing table.

Because age distributions are controlled at a population level, an accurate value for the total population in the region is needed to correctly develop the control totals. However, as with total households, there is no input into SPG with this value. SPG infers household totals by determining worker totals from ED outputs and applying workers-per-household values which are input into the model. In order to avoid another input into the model (which has to be maintained) and possible inconsistencies which it might introduce, a different tact was used for population totals. (As a note, if SPG controlled against household size distributions, those could be used to infer a population total.)

To generate a population total, SPG1 is run once through without controlling against age distributions, but controlling on employment and workers-per-household categories. The population total from the synthetic population produced by this SPG1 run is then used as the control population total, and SPG1 is run again, controlling on employment, workers-per-household, and age distributions.

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[11] Bucket rounding, used in many transport models, is a special type of rounding in which the accumulated rounding error of some elements is used to bias the next rounding operation.

Table 4.6. SPG Table Balancing Procedure Example -After Iteration 2

Balancing Factor 0.869082045

Household	hh weight	Retail	Educ	Service	Govt	Mfr	Other	0 worker	1 worker	2 workers	3 workers	4 workers
1	85.91	85.91	85.91	0.00	0.00	0.00	0.00	0.00	0.00	85.91	0.00	0.00
2	292.55	0.00	0.00	0.00	0.00	0.00	292.55	0.00	292.55	0.00	0.00	0.00
3	379.55	759.10	0.00	379.55	0.00	0.00	0.00	0.00	0.00	0.00	379.55	0.00
4	991.83	0.00	0.00	991.83	0.00	991.83	0.00	0.00	0.00	991.83	0.00	0.00
5	349.07	0.00	698.14	0.00	0.00	0.00	349.07	0.00	0.00	0.00	349.07	0.00
6	181.45	0.00	0.00	0.00	362.89	0.00	362.89	0.00	0.00	0.00	0.00	181.45
7	278.00	0.00	0.00	0.00	0.00	0.00	0.00	278.00	0.00	0.00	0.00	0.00
8	151.04	151.04	0.00	0.00	0.00	0.00	0.00	0.00	151.04	0.00	0.00	0.00
9	352.32	352.32	0.00	0.00	352.32	352.32	352.32	0.00	0.00	0.00	0.00	352.32
10	473.73	0.00	0.00	473.73	0.00	0.00	0.00	0.00	473.73	0.00	0.00	0.00
11	213.52	0.00	213.52	0.00	427.04	0.00	0.00	0.00	0.00	0.00	213.52	0.00
12	132.39	0.00	0.00	0.00	132.39	0.00	132.39	0.00	0.00	132.39	0.00	0.00
13	300.23	0.00	300.23	300.23	300.23	0.00	300.23	0.00	0.00	0.00	0.00	300.23
14	180.22	180.22	360.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	180.22	0.00
15	267.65	267.65	0.00	267.65	267.65	0.00	0.00	0.00	0.00	0.00	267.65	0.00
16	278.00	0.00	0.00	0.00	0.00	0.00	0.00	278.00	0.00	0.00	0.00	0.00
17	269.47	0.00	269.47	269.47	0.00	0.00	0.00	0.00	0.00	269.47	0.00	0.00
18	114.84	0.00	0.00	0.00	229.68	0.00	0.00	0.00	0.00	114.84	0.00	0.00
19	292.55	0.00	0.00	0.00	0.00	0.00	292.55	0.00	292.55	0.00	0.00	0.00
20	292.55	0.00	0.00	0.00	0.00	0.00	292.55	0.00	292.55	0.00	0.00	0.00
21	132.39	0.00	0.00	0.00	132.39	0.00	132.39	0.00	0.00	132.39	0.00	0.00
22	151.04	151.04	0.00	0.00	0.00	0.00	0.00	0.00	151.04	0.00	0.00	0.00
23	292.55	0.00	0.00	0.00	0.00	0.00	292.55	0.00	292.55	0.00	0.00	0.00
24	316.22	316.22	0.00	0.00	0.00	316.22	0.00	0.00	0.00	316.22	0.00	0.00
25	180.94	180.94	0.00	180.94	0.00	0.00	0.00	0.00	0.00	180.94	0.00	0.00
		2444.44	1927.71	2863.39	2204.59	1660.38	2799.49	556.00	1946.00	2224.00	1390.00	834.00
		17.59%	13.87%	20.60%	15.86%	11.95%	20.14%	8.00%	28.00%	32.00%	20.00%	12.00%
		15.47%	12.95%	20.14%	15.83%	14.03%	21.58%	8.00%	28.00%	32.00%	20.00%	12.00%
							13900.00					6950

Table 4.7. SPG Table Balancing Procedure Example -After Iteration 20

Balancing Factor 0.999874192

Household	hh weight	Retail	Educ	Service	Govt	Mfr	Other	0 worker	1 worker	2 workers	3 workers	4 workers
1	41.97	41.97	41.97	0.00	0.00	0.00	0.00	0.00	0.00	41.97	0.00	0.00
2	325.24	0.00	0.00	0.00	0.00	0.00	325.24	0.00	325.24	0.00	0.00	0.00
3	340.30	680.61	0.00	340.30	0.00	0.00	0.00	0.00	0.00	0.00	340.30	0.00
4	1236.52	0.00	0.00	1236.52	0.00	1236.52	0.00	0.00	0.00	1236.52	0.00	0.00
5	419.17	0.00	838.34	0.00	0.00	0.00	419.17	0.00	0.00	0.00	419.17	0.00
6	174.41	0.00	0.00	0.00	348.83	0.00	348.83	0.00	0.00	0.00	0.00	174.41
7	278.00	0.00	0.00	0.00	0.00	0.00	0.00	278.00	0.00	0.00	0.00	0.00
8	104.79	104.79	0.00	0.00	0.00	0.00	0.00	0.00	104.79	0.00	0.00	0.00
9	415.86	415.86	0.00	0.00	415.86	415.86	415.86	0.00	0.00	0.00	0.00	415.86
10	435.45	0.00	0.00	435.45	0.00	0.00	0.00	0.00	435.45	0.00	0.00	0.00
11	231.76	0.00	231.76	0.00	463.52	0.00	0.00	0.00	0.00	0.00	231.76	0.00
12	135.55	0.00	0.00	0.00	135.55	0.00	135.55	0.00	0.00	135.55	0.00	0.00
13	243.73	0.00	243.73	243.73	243.73	0.00	243.73	0.00	0.00	0.00	0.00	243.73
14	135.05	135.05	270.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	135.05	0.00
15	263.71	263.71	0.00	263.71	263.71	0.00	0.00	0.00	0.00	0.00	263.71	0.00
16	278.00	0.00	0.00	0.00	0.00	0.00	0.00	278.00	0.00	0.00	0.00	0.00
17	174.40	0.00	174.40	174.40	0.00	0.00	0.00	0.00	0.00	174.40	0.00	0.00
18	96.71	0.00	0.00	0.00	193.42	0.00	0.00	0.00	0.00	96.71	0.00	0.00
19	325.24	0.00	0.00	0.00	0.00	0.00	325.24	0.00	325.24	0.00	0.00	0.00
20	325.24	0.00	0.00	0.00	0.00	0.00	325.24	0.00	325.24	0.00	0.00	0.00
21	135.55	0.00	0.00	0.00	135.55	0.00	135.55	0.00	0.00	135.55	0.00	0.00
22	104.79	104.79	0.00	0.00	0.00	0.00	0.00	0.00	104.79	0.00	0.00	0.00
23	325.24	0.00	0.00	0.00	0.00	0.00	325.24	0.00	325.24	0.00	0.00	0.00
24	297.56	297.56	0.00	0.00	0.00	297.56	0.00	0.00	0.00	297.56	0.00	0.00
25	105.75	105.75	0.00	105.75	0.00	0.00	0.00	0.00	0.00	105.75	0.00	0.00
		2150.09	1800.30	2799.86	2200.17	1949.93	2999.65	556.00	1946.00	2224.00	1390.00	834.00
		15.47%	12.95%	20.14%	15.83%	14.03%	21.58%	8.00%	28.00%	32.00%	20.00%	12.00%
		15.47%	12.95%	20.14%	15.83%	14.03%	21.58%	8.00%	28.00%	32.00%	20.00%	12.00%
							13900.00					6950

4.3.2. Household Home Zone Assignment (SPG2)

The households generated by the SPG1 module contain the correct number of workers based on the jobs forecast from the ED module and are consistent with a distribution of number of workers per household. The SPG1 table balancing procedure ensures that these conditions are met in the generated synthetic population. The SPG1-generated synthetic population however have no spatial location.

The SPG2 module assigns a home alpha zone to each household, consistent with the home end of PI-produced labor flows. The SPG2 module runs after the PI module and accepts from the PI module for each alpha zone, the number of households in each household category (based on household income and size, see Table 2.2) located in the zone and the total labor dollar value ($Labor) by occupation produced by the households in the zone. These values are used to determine the probability of selecting a home alpha zone for each synthetic household from SPG1, as follows.

For each household,

for each person in the household:

- calculate the relative $Labor for their occupation code and industry code in each alpha zone by dividing the $Labor for their occupation and industry in the alpha zone by the total regional $Labor for the occupation and industry over all alpha zones.
- calculate the product of these relative $Labor over all employed persons in the household for each alpha zone. These products represent the density for choosing the alpha zone.
- convert the alpha zone densities to a cumulative density function with values in the range of 0.0 to 1.0 and select an alpha zone by Monte Carlo selection.
- if the total number of households allocated to the selected alpha zone for the household's income and size category does not exceed the total number as determined by PI, then allocate this alpha zone to this synthetic household.
- after allocating the alpha zone, decrement: (a) the available $Labor in the alpha zone for each of the occupation categories of the persons in the household by the $Labor per job for the corresponding categories; and (b) the available households per alpha zone for the household category.
- if the selected alpha zone has already been allocated its full allotment of the specific category of households, repeat the procedure to sample a different alpha zone.
- if a household has only unemployed persons, select an alpha zone by using the relative numbers of un-allocated households per alpha zone as sampling densities and make a Monte Carlo selection from the array of cumulative densities. After making the selection, check that the alpha zone is not already full for this household category and if not, adjust the available households per alpha zone and household category.

get next household and repeat.

When all households from SPG1 have been assigned a home location alpha zone, the synthetic household and person record files with PUMS attributes and alpha zone is written to comma delimited text files, SynPopH.csv and SynPopP.csv. This concludes the SPG module.

4.4. Software Implementation

The SPG1 table balancing procedure and SPG2 household assignment procedure are implemented in java code. The implementation of the SPG modules makes use of an array of objects to hold attributes of the household and persons (in the household) relevant to the generation of households (SPG1) and allocation to zones (SPG2) procedures. The array contains unique PUMS household record references, household and person attributes relevant to the balancing procedure, and a count of the number of times this PUMS household record appears in the final synthetic population (the integer hh_weight values determined by SPG1). This array of objects is fundamental to both SPG1 and SPG2. It is saved to disk as a serialized object in SPG1 so that it may be restored and used by procedures in SPG2. Note that the PI module runs after the SPG1 module and before the SPG2 module, thus the necessity to preserve theSPG1 objects in a disk file, to be restored after the PI module runs. Specifically for SPG1, the array maintains a count of the number of times each unique PUMS household appears in the entire synthetic population. This count, and the attributes maintained with the household records is used in SPG2 to produce frequency reports of total (modelwide) households and persons by such categories as occupation, industry, age, household income, number of workers per household, and size of the household. These summaries provided the basis for validation of the SPG1 module.

The SPG2 module uses the same array of household attribute objects so that the exact same households generated in SPG1 are allocated to zones in SPG2. A set of arrays maintaining: the total allocated and unallocated households by household category by zone; and labor dollars of production by occupation and industry by zone are used as part of the SPG2 procedure. The households in the array of household attribute objects are each selected in random order and allocated to a zone. The constraint on total households by household category by zone is held as a rigid constraint. The proportions of labor dollars by occupation and industry by zone are used as weights in determining the probabilities that a household resides in each zone, but not held as fixed constraints.

The constraint on total households by household category by zone in the SPG2 procedure allowed for a significant performance improvement in the implementation procedure. To do so, PUMS household records are partitioned into groups by the household category to which they belong. Labor dollars produced by occupation and zone are also categorized by household category. The SPG2 procedure to allocate SPG1 households to home zones can therefore be done independently by household category. This separation of computational effort allowed the SPG2 procedure to be implemented in java as a multi-threaded application. If SPG is run on a computer with multiple cores, then a separate thread for each core is created and set to work on the SPG2 procedure for one household category group of households. The households in more than one category can therefore be assigned zones by concurrently operating threads. In other words, for as many categories as there are processing cores, households can be assigned zones in parallel.

In addition to the generation and allocation procedures in SPG1, java software was developed for reading PUMS data records and extracting the necessary PUMS attributes and also for specifying and writing the full set of desired PUMS household and person (SynPopH.csv and SynPopP.csv) attributes files used by other modules.

A large intermediate binary scratch file [hharray.diskObject] is produced by SPG1 to house the PUMS sample prior to SPG2. This can be deleted when SPG2 is complete

4.5. S1 and S2 Module Parameters

SPG procedures use a fixed set of operations on input files and produce a fixed set of output files. The Census PUMS survey weights and jobs-to-worker parameters used in the SPG table balancing procedure are discussed below, while inputs distributions used as controls are described as inputs in Section 4.6.

The starting conditions for the SPG1 table balancing procedure include the household records and their initial hh_weight field values are taken from the 1990 Census PUMS dataset for PUMAs at least partially covered by the model area. Populations are built for the State of Oregon, and for selected PUMAs representing the halo counties outside of Oregon in Washington, Idaho, Nevada, and California. The starting values of the hh_weight value is the 1990 PUMS household weights, which could be adjusted by the user to represent different household mix of attributes if desired.

Job to Worker factors, shown in Table 4.8, are used to convert ED-generated job totals to SPG worker targets. The factors were calculated from 1990 jobs (Bureau of Economic Analysis dataset) and worker data (1990 weighted PUMS dataset) in Oregon plus Clark County, WA. Some factors are less than 1, implying differing industry definitions in the datasets, in addition to multiple jobs per worker. By applying these factors, the total change between ED jobs and SPG workers is accounted for. These factors are expected to stay fixed across all model years.

Table 4.8. Jobs to Worker Factors (JobsToWorkersFactor.csv)

Industry Sector	Aggregated Industry Sector	WorkersPerJob Factor
ACCOMMODATIONS	Services	0.752289068
AGRICULTURE AND MINING	Agriculture/Mining/Forestry	0.867448935
COMMUNICATIONS AND UTILITIES	Comm/Transport/Wholesale	0.962126966
CONSTRUCTION	Construction	0.991356391
ELECTRONICS AND INSTRUMENTS-Light Industry	Manufacturing	0.959627231
FIRE BUSINESS AND PROFESSIONAL SERVICES	Services	0.752289068
FOOD PRODUCTS-Heavy Industry	Manufacturing	0.959627231
FOOD PRODUCTS-Light Industry	Manufacturing	0.959627231
FORESTRY AND LOGGING	Agriculture/Mining/Forestry	0.867448935
GOVERNMENT ADMINISTRATION	Government/Education	0.646048881
HEALTH SERVICES-Hospital	Services	0.752289068
HEALTH SERVICES-Institutional	Services	0.752289068
HEALTH SERVICES-Office	Services	0.752289068
HIGHER EDUCATION	Government/Education	0.646048881
HOMEBASED SERVICES	Services	0.752289068
LOWER EDUCATION	Government/Education	0.646048881
LUMBER AND WOOD PRODUCTS-Heavy Industry	Manufacturing	0.959627231
OTHER DURABLES-Heavy Industry	Manufacturing	0.959627231
OTHER DURABLES-Light Industry	Manufacturing	0.959627231
OTHER NON-DURABLES-Heavy Industry	Manufacturing	0.959627231
OTHER NON-DURABLES-Light Industry	Manufacturing	0.959627231
PERSONAL AND OTHER SERVICES AND AMUSEMENTS	Services	0.752289068
PULP AND PAPER-Heavy Industry	Manufacturing	0.959627231
RETAIL TRADE	Retail	0.846859643
TRANSPORT	Comm/Transport/Wholesale	0.962126966
WHOLESALE TRADE	Comm/Transport/Wholesale	0.962126966

SPG input file: [JobstoWorkersFactor.csv]

The pre-specified margin of error for SPG1 table balancing procedure is defined such that that the differences between estimated total employment and target total employment overall employment categories and between total estimated households and target total households by workers per household categories are all less than 1.

4.6. Inputs and Outputs

The inputs and outputs of the SPG module are listed in Tables 4.9 and 4.10. SPG1 uses ED modelwide employment by industry and marginals from 1990 PUMS household/person sample list and OEA long-range population forecast. The SPG2 module accepts from PI for each alpha zone, the number of households in each household category (based on household income and size) located in the zone and the total labor dollar value by occupation produced by the households in the zone by household category. SPG1 modelwide sample is temporarily saved while the PI module is run, and is then written out with the assigned SPG2 home alpha zone.

Table 4.9. SPG Inputs

Data Element	SPG#	source
Modelwide employment by SPG industry [JobDataForSPG1.csv]	SPG1	ED
1990 PUMS sample list (with attribute states) of observed households/ persons [PUMSAXss.txt, where ss=ca, id, nv, or, wa]	SPG1	Exog
1990 PUMS data dictionary [pumsusdd.txt]	SPG1	Exog
Target Worker Per Household Distribution [workersPerHouseholdMarginalxYear.csv]	SPG1	Exog
Jobs to Worker Factors [JobsToWorkersFactor.csv]	SPG1	Exog
Crosswalk between SPG PUMS and SWIM2 industry categories [IndustryOccupationSplitIndustrycorrespondance.csv]	SPG1	Exog
Labor production (home end) 1990$ by occupation in alpha zones [laborDollarProduction.csv]	SPG2	PI
Count of household by alpha zone[ActivityLocations2.csv]	SPG2	PI
List of alpha zones by beta zones [alpha2beta.csv]	SPG2	Exog
Serialized Household Array object [hhArray.diskObject]	SPG2	SPG1

SPG outputs data used by PI and PT, as shown in Table 4.10. Modelwide SPG1 outputs are summarized by household income-size categories (Table 2.2) for allocation in the PI module. The SPG2 synthetic population files are augmented and used by the PT module to generate person trips within the model.

Table 4.10. SPG Outputs

Data Element	SPG#	users
Count of modeled households by category in study area [householdsByHHCategory.csv]	SPG1	PI
Serialized Household Array object [hhArray.diskObject]	SPG1	SPG2
Lists (with attribute states, including home alpha zone) of modeled households and persons resident in study area [SynPopH.csv][SynPopP.csv]	SPG2	PT
Count of modeled households by state/ alpha zone [spg2out_hh.csv]	SPG1	PI (next year)

4.6.1. User-Defined Marginal Distributions

In addition to meeting the ED count of employees by industry (after the adjustments previously noted in Section 4.5), SPG will also meet model-wide distributions of workers per household and persons by age group. The source for these marginal distributions is noted below.

Workers Per Household

Table 4.11 shows the baseyear distribution of households by workers per household [workersPerHouseholdMarginalxYear.csv]. These factors are used as targets in the SPG1 table balancing method. They are based on the weighted 1990 PUMS sample for those PUMAs within the full SWIM2 study area. These distributions are determined by the relative frequency of weighted households in those categories from the Census PUMS records. In calibration, it was found that retaining the 1990 Census distribution in all years was inadequate over time. Thus distributions for each year from 1990 to 2000 are provided in the input, interpolating between the 1990 and 2000 census values. These values are held constant in 2000 and all subsequent years.

Table 4.11. Target Worker Per Household Distribution

Workers Per Household	1990 Household Count	1990 Frequency	2000 Household Count	2000 Frequency
0	541,147	27.5%	573,736	25.8%
1	694,928	35.4%	810,020	36.5%
2	610,846	31.1%	698,343	31.5%
3	96,268	4.9%	109,910	5.0%
4	17,284	0.9%	22,240	1.0%
5	3,395	0.2%	4,175	0.2%
6	748	0.0%	830	0.0%
7	196	0.0%	432	0.0%
8	0	0.0%	118	0.0%
9	35	0.0%	56	0.0%
10+	73	0.0%	14	0.0%
Total	1,964,920	100.0%	2,219,874	100.0%

SPG input file: [workersPerHouseholdMarginalxYear.csv]
Source: 1990 and 2000 US Census PUMS data

Age Distribution

Table 4.12 shows the baseyear distribution of households by workers per household [oregonPersonsByAgeMarginalxYear.csv]. These factors are used as targets in the SPG1 table balancing method. They are based on the July 1, 2010 long-range population forecast by the Oregon Office of Economic Analysis (OEA). The 18 age groups of the OEA forecast are collapsed to 9 to keep the model manageable and still accommodate the needs of the PT module aggregations as well as other ODOT models that will likely use the results (MPO JEMnR, GreenSTEP and DVMT models). They cover only Oregon, but in the model, these distributions are assumed to apply to the full model area (Oregon plus halo).

Table 4.12. Target Worker Per Household Distribution

	Age Range								
Year	0-4	5-18	15-19	20-24	25-29	30-54	55-64	65-74	75+
1990	6.58%	14.03%	7.14%	6.72%	6.77%	37.04%	8.92%	6.38%	6.42%
1991	6.58%	14.03%	7.14%	6.72%	6.77%	37.04%	8.92%	6.38%	6.42%
1992	6.58%	14.03%	7.14%	6.72%	6.77%	37.04%	8.92%	6.38%	6.42%
1993	6.58%	14.03%	7.14%	6.72%	6.77%	37.04%	8.92%	6.38%	6.42%
1994	6.58%	14.03%	7.14%	6.72%	6.77%	37.04%	8.92%	6.38%	6.42%
1995	6.58%	14.03%	7.14%	6.72%	6.77%	37.04%	8.92%	6.38%	6.42%
1996	6.58%	14.03%	7.14%	6.72%	6.77%	37.04%	8.92%	6.38%	6.42%
1997	6.58%	14.03%	7.14%	6.72%	6.77%	37.04%	8.92%	6.38%	6.42%
1998	6.58%	14.03%	7.14%	6.72%	6.77%	37.04%	8.92%	6.38%	6.42%
1999	6.58%	14.03%	7.14%	6.72%	6.77%	37.04%	8.92%	6.38%	6.42%
2000	6.58%	14.03%	7.14%	6.72%	6.77%	37.04%	8.92%	6.38%	6.42%
2005	6.31%	13.39%	6.87%	6.99%	6.76%	35.98%	11.15%	6.25%	6.31%
2010	6.31%	12.60%	6.70%	6.76%	7.11%	34.55%	12.91%	7.09%	5.97%
2015	6.30%	12.44%	6.16%	6.63%	6.87%	33.75%	13.07%	8.86%	5.92%
2020	6.20%	12.50%	5.96%	6.10%	6.74%	33.39%	12.27%	10.32%	6.51%
2025	6.03%	12.44%	6.04%	5.92%	6.23%	33.48%	11.41%	10.55%	7.90%
2030	5.89%	12.23%	6.08%	6.03%	6.07%	33.19%	11.07%	10.05%	9.39%
2035	5.84%	11.99%	6.05%	6.08%	6.20%	32.76%	11.20%	9.48%	10.41%
2040	5.84%	11.83%	5.93%	6.06%	6.27%	32.14%	11.71%	9.29%	10.93%

SPG input file: [oregonPersonsByAgeMarginalxYear.csv]
Source: July 1, 2010 Oregon OEA long-range population forecast

4.7. Validation Targets

During validation, SPG1 output were compared with various attributes of the weighted 1990 US Census PUMS distributions used as input for the sample process. SPG2 output were be compared with geographically specific PUMS data (by PUMA). Additionally, SPG2 were tested to ensure it matched the home location distribution by alpha zone from PI (SPG2 input). The two key SPG targets (modelwide for SPG1 and by PUMA for SPG2) are shown in Table 4.13.

Table 4.13. SPG Validation Targets

Source	Year	SWIM2 Target
1990 US Census PUMS data (weighted)	1990 & 2000	Workers by occupation (Oregon and by PUMA)
1990 US Census PUMS data (weighted)	1990 & 2000	Households by SWIM2 Income-Size Category (Oregon and by PUMA)

4.8. Initial Validation

Initial baseyear SPG1 results were tabulated and compared with 1990 US Census PUMS attributes by several key variables: occupation, industry, workers per household, and household income. The tabulations were made for the entire synthetic population (to test SPG1) and by PUMA (to test SPG2) against the original PUMS data, so that sample biases could be evaluated both by category and geographically.

Currently, the SPG calibration results indicate:

- SPG1 is correctly synthesizing a modelwide population of over 5M persons that matches overall Census PUM distributions in terms of household category (income and size), user-supplied workers per household and age attributes, and matches ED regional employment by industry.
- SPG2 assignment of home alpha zone to each synthesized household matches the input PI data, per SPG2 design. The PI data input to SPG2 includes the home end labor production dollars by occupation in alpha zones (laborDollarProduction.csv) and Count of households by alpha zone (ActivityLocations2.csv). When PI does not match target labor production by zone (e.g., under-estimation in Oregon with overestimations in the other states), this is reflected in SPG2 log output.

Comments:

- A Jobs-to-Worker factor (by industry) was developed and applied to the ED modelwide jobs to convert them to workers in SPG1. This resulted from a mismatch uncovered between BEA reported jobs and Census reported workers.
- A table-balancing method was developed for SPG1 to constrain the sampled population by total workers per industry category and by total households by workers per household category. The targeted workers per HH distribution was developed from 1990 Census data, and is assumed to hold constant over time. The resulting population matched will by household size and income category with the exception of lower income and smaller household size categories. This result is probably due to the zero worker household table balancing constraint being only a household constraint due to no workers in the households as opposed to the 1 or more worker categories which are also influenced by the workers by industry constraints.
- The workers per household distribution was modified to change over time, using interpolated 1990 to 2000 values, rather than retaining 1990 values for all years.

Future:

- Add an additional constraint for 0 worker households by income, similar to the constraint for non-zero worker households. Constraints could be developed from 1990 PUMS data. To avoid overly constraining the model, this will only be introduced if warranted.
- Since SPG is constrained to only match workers, person age, and workers per household distribution, mismatches in other attributes may occur, e.g. number of households or persons, or bias in the location of large or small households. Additional constraints in SPG or other modules (e.g. reduce non-worker trip rates in PT), will be introduced if warranted.

4.9. S3 Parameters

When the full SWIM2 model is undergoing calibration, it is anticipated that SPG has no S3 parameters that will be utilized to improve overall model performance.

5.0 ALD Module

In each simulation year, the Aggregate Land Development (ALD) Module produces a floorspace inventory based on ALD annual increments and decrements of floorspace by category and alpha zone from:

- Total budgeted Dollar-value amounts of residential and nonresidential construction produced by the ED Module for the simulation year, and
- Inventories of floorspace by category and alpha zone for the previous simulation year.

The module works at two levels of spatial aggregation. Dollar-value construction amounts and decrease amounts (due to demolition and conversion) are allocated among 15 regions. (Land development markets tend to be regional in scope.) All subsequent allocations to floorspace categories and alpha zones are done by region.

The ALD Module's allocation processes use information from several sources:

- Residential and non-residential activity quantities from the PI module (allocation to regions)
- Floorspace occupancy rates from the PI module (allocation to space types within regions)
- Floorspace prices from the PI module (allocation to zones)
- Land area by comprehensive plan category and alpha zone as a model scenario input. (capacity used in allocation to zones)

5.1. Theoretical Basis

The ALD module determines the changes in floorspace by type in each alpha zone in each simulation year based on residential and non-residential construction forecasts (ED), floorspace prices and vacancies (PI), floorspace quantities (ALD), and the availability of land by comprehensive plan designation. It does this using a series of connected logit and Cobb-Douglas allocation models.

The change in floorspace for a model simulation year are based on the total dollar-value quantities of residential and non-residential floorspace construction determined for the year for the entire model area by the ED Module. These construction amounts include construction that replaces existing floorspace (lost though demolition or conversion) as well as construction of new floorspace on vacant land. The net change in floorspace is therefore the total value of floorspace constructed (from ED) minus the value of floorspace removed. The value of the floorspace removed is calculated as a fixed proportion of the value of floorspace constructed based on comparison of ED calibration data and net floorspace change calculated from FW Dodge data. ALD allocates the floorspace declines and increases separately rather than allocating the net change in order to better represent responses in the floorspace market to changing activity patterns over time.

The floorspace increase and decrease quantities are first allocated among 15 regions. All subsequent allocation to floorspace types and alpha zones is done within each region. The rationale for this approach is that markets for floorspace development tend to have a regional orientation, rather than a statewide or larger orientation. The regions used by the ALD module are collections of counties located near each other that tend to have close linkages with one another and/or share a similar geographic relationship to other regions. This was determined through expert judgment.

The residential and non-residential increases and decreases are allocated using Cobb-Douglas production functions where the inputs are the proportion of total activity in each region and the proportion of total activity change in each region. The form of these functions is the same for all residential and non-residential increase and decrease models, but with four different sets of estimated parameters (residential increase, non-residential increase, residential decrease, non-residential decrease).

After the dollar values of residential and non-residential floorspace increases and decreases have been allocated to regions, all subsequent steps are carried out on a regional basis. First, the residential and non-residential increases and decreases are split into the floorspace categories. This is done using logit models where the input variables are previous proportions of space by category and vacancy rates by category. Once the dollar values are split by category, they are converted into space (sqft) quantities using exogenously-specified construction cost rates.

Next, the floorspace increases and decreases of each type are allocated to alpha zones. Floorspace decreases are allocated using a Cobb-Douglas production function where the input variables are the existing proportion of that type of floorspace in each zone and the price determined by the PI module for that type of floorspace in the corresponding beta zone. Floorspace increases are allocated among the alpha zones also using a Cobb-Douglas formula. In this case, the inputs to the function are the existing proportion of that type of floorspace in each zone, the price determined by the PI module for that type of floorspace in the corresponding beta zone, and the capacity of each alpha zone to accommodate additional floorspace of the type. Floorspace capacity is a function of how much land is planned for development by plan category, the compatibility of each floorspace category with each plan category, and the allowable floor area ratio for each floorspace category in each plan category.

5.2. Quantity Definitions and Categories

ALD makes development changes at the alpha zone level, although initial allocation of space utilizes a set of 15 regions representing land development markets, previously shown in Figure 2.5. PI output data used as inputs to ALD is at the beta zone level.

ALD uses categories of floorspace listed previously in Table 2.1. Zoning categories and are identified in Table 5.1. The set of 33 zoning codes were developed to span local jurisdictional zoning codes. Data describing the allowed floorspace types and intensities are discussed with zoning inputs in Section 5.6.2.

Table 5.1. ALD Zoning Categories

Code	Name	Zoning Description
100	ureslo	Urban Low Density Residential
101	uresmed	Urban Medium Density Residential
102	uresmdh	Urban Medium High Density Residential
103	ureshi	Urban High Density Residential
104	umix	Urban Mixed Use
105	umixhi	Urban Mixed Use High
106	ucom	Urban Commercial
107	uindlt	Urban Light Industrial
108	uind	Urban Industrial
109	upub	Urban Public
110	uoth	Urban Other
111	ubigany	Urban Big City Any Use
112	uany	Urban Small City Any Use
200	rres	Rural Residential - Low Density
201	rcntr	Rural Center - Low density mixed use
202	rcom	Rural Commercial
203	rind	Rural Industrial
204	rpub	Rural Public - parks etc
205	rreserve	Indian Reservation Military DOE COE BOR
206	roth	Rural Other
207	rany	Rural Any Use
300	rfor	Rural Forest
301	ragfor	Rural Agriculture / Forest
302	rag	Rural Agriculture
303	rrange	Rural Range
304	rmine	Rural Mining
400	xrec	Protected Recreation Land
401	xagfor	Protected Agriculture and Forest
402	xcons	Protected Natural Areas and Conservation Zones
403	xhalo	Protected Rural Land in Halo
404	xother	Protected Other
405	xother2	Rural Zoning Not Resolved (slivers without data protect)
500	xwater	Water
600	xtp	Major Transportation ROW

5.3. Component Models

The objective of the ALD module is to identify where modelwide construction dollars (in 1990$) from the ED module will be spent, and in what type of development. The component models are as follows. Except as noted, each model step below has a residential model and a corresponding non-residential model.

1) **Total model-wide dollar values of residential and non-residential floorspace construction are allocated among 15 regions in the model area.** All subsequent allocations among floorspace types and alpha zones are done within each region. Construction dollars are allocated among regions using a Cobb-Douglas formulation where the independent variables are the region proportions of total activity in the previous year and the region proportions of the change in total activity over the previous two years. The model also incorporates region-specific constants. This process is described in more detail in Section 5.3.1.

2) **Total model-wide decreases in residential and non-residential floorspace (due to demolition or conversion) are estimated and allocated among regions.** The

model-wide value of the floorspace demolished or converted is calculated as a fixed proportion of the model-wide value of floorspace constructed. The model-wide decreases are allocated among regions using the same form of Cobb-Douglas production function as used to allocate the construction increases. Region-specific constants are also included. This process is described in more detail in Section 5.3.1.

3) **The regional increase values are allocated to floorspace categories** using a logit model where the utility is a function of vacancy rates and the previous quantities of floorspace by category. The model includes alternative specific constants for each floorspace type in each region. The allocated construction values by floorspace category are converted to floorspace area increases (square feet) using model-wide average floorspace construction costs. This process is described in more detail in Section 5.3.2.

4) **The regional floorspace decrease values are allocated to floorspace categories** using a logit model having the same form as the model for allocating regional increase values. The model includes alternative specific constants for each floorspace type in each region. Floorspace value decreases are converted into area measures (square feet) using the model-wide average floorspace construction costs since the decrease values represent the value of the space lost and not the cost of demolition or conversion. This process is described in more detail in Section 5.3.2.

5) **The regional floorspace decreases by floorspace category are allocated to alpha zones** using a Cobb-Douglas production function where the input variables are the proportion of total regional floorspace of the category in each zone, and the price determined by the PI module for that type of floorspace in the corresponding beta zone. The decrease in floorspace in any zone is not allowed to exceed the inventory of floorspace in the zone. This process is described in more detail in Section 5.3.3.

6) To allocate the region floorspace increases in each category to alpha zones it is necessary to calculate the capacity of each alpha zone for accommodating floorspace of each category. Floorspace capacity is a function of how much land is planned for development by plan category, the compatibility of each floorspace category with each plan category, and the allowable floor area ratio for each floorspace category in each plan category. A logit model is used **to allocate land by plan category to floorspace categories.** Floor area ratios are used to convert land area to floor area capacity. This process is described in more detail in Section 5.3.4.

7) **Floorspace increases for each region and category are allocated to alpha zones** using a Cobb-Douglas production function where the inputs are the proportion of total regional floorspace of the category in each zone, the price determined by the PI module for that type of floorspace in the corresponding beta zone, and the floorspace capacity for the category in each zone. This process is described in more detail in Section 5.3.5.

5.3.1. Allocation of Modelwide Construction Dollars into Regional Dollar Value Increases and Decreases

The first function of ALD is to separately allocate dollar-value production of residential and non-residential construction from the ED module for the entire model area among 15 r egions in the model area. In addition, since the total value of construction in the entire model area includes the replacement of floorspace that is removed somewhere in the model area as well as net new floorspace, it is necessary to calculate the value of residential and non-residential floorspace decreases and allocate them to the regions as well.

Construction dollars are allocated among regions using a Cobb-Douglas model where the independent variables are the region proportions of total activity in the previous year and the region proportions of the change in total activity over the previous two years. The equation has the form:

$$NIVQ_r = NIVQ \cdot (A_r / \Sigma_r A_r) \tag{5.01}$$

with:

$$A_r = (ActProp_r + \beta_{1v})^{\beta 2v} \cdot (ActChgProp_r + \beta_{3v})^{\beta 4v} \cdot Asc_r \tag{5.02}$$

where:

NIVQ	=	modelwide total residential (nonresidential) construction value from ED *[ConstructionDollarDataforALD.csv]*
$NIVQ_r$	=	residential (nonresidential) construction value for region r
A_r	=	Cobb-Douglas production function for region r (estimated)
$ActProp_r$	=	proportion of total modelwide residential (nonresidential) activity occurring in region r (see notes below)
$ActChgProp_r$	=	proportion of total modelwide residential (nonresidential) activity change occurring in region r (see notes below)
$\beta_{1v}, \beta_{2v}, \beta_{3v}, \beta_{4v}$	=	coefficients estimated separately for residential and nonresidential construction (estimated)
Asc_r	=	alternative specific constant for region estimated separately for residential and nonresidential construction

Decreases in the value of floorspace are calculated from the modelwide construction total and allocated to regions as follows:

$$NDVQ_r = D_f \cdot NIVQ \cdot (CD_r / \Sigma_r CD_r) \tag{5.03}$$

with:

$$CD_r = (ActProp_r + \beta_{1v})^{\beta 2v} \cdot (ActChgProp_r + \beta_{3v})^{\beta 4v} \cdot Asc_r \tag{5.04}$$

where:

NIVQ	=	modelwide total residential (nonresidential) construction value from ED *[ConstructionDollarDataforALD.csv]*
$NDVQ_r$	=	residential (nonresidential) value of floorspace decrease for region r
D_f	=	modelwide proportion of residential (nonresidential) floorspace construction value that replaces floorspace removed from the model area
CD_r	=	Cobb-Douglas production function for region r (estimated)
$ActProp_r$	=	proportion of total modelwide residential (nonresidential) activity occurring in region r (see notes below)

$ActChgProp_r$ = proportion of total modelwide residential (nonresidential) activity change occurring in region r (see notes below)

$\beta_{5v}, \beta_{6v}, \beta_{7v}, \beta_{8v}$ = coefficients estimated separately for residential and nonresidential decreases (estimated)

Asc_r = alternative specific constant for region estimated separately for residential and nonresidential decreases (estimated)

The measure of activity used to calculate the proportions of total activity and the proportions of activity change is measured using the "quantity" output from the PI module. This is households, in the case of residential activities, and annual output in 1990 dollars, in the case of non-residential activities (from PI *ExchangeResults.csv* output aggregated to ALD regions).

The proportion of activity change is calculated after the regional activity change values are rescaled by subtracting the minimum regional value from all regional values. The rescaling is necessary to assure that the activity change proportions are in the range of 0 to 1. For the first two simulation years, when there is no computable activity change, it is assumed that all regions have an equal proportion of the activity change.

5.3.2. Allocation of Regional Dollar Increases and Decreases into Floorspace Types

Regional residential and non-residential floorspace construction and decreases are allocated separately to the floorspace categories using a logit model with utility functions that include regional vacancy rates by floorspace category and proportions of previous year floorspace value in each floorspace category. In calibration, the second term in Eq. 5.06 was modified from the construction cost value, to the PI value (based on prior year PI floorspace prices). Thus, this term serves not only as a size measure, but also as a signal for which floorspace types are in demand (indicated by higher prices), which helps to allocate construction dollars more effectively.

The logit model for floorspace construction has the form:

$$NIVQ_{f,r} = NIVQ_r \cdot (\exp(\lambda_{q1} \cdot U_{f,r}) / \Sigma_f \exp(\lambda_q \cdot U_{f,r})) \qquad (5.05)$$

with:

$$U_{f,r} = \beta_{q1,f} \cdot VacRate_{f,r} + \beta_{q2} \cdot \ln(TVQ_{f,r} / \Sigma_f TVQ_{f,r}) + ASC_{f,r} \qquad (5.06)$$

where:

$NIVQ_{f,r}$ = value of floorspace construction allocated to category f in region r

$NIVQ_r$ = total value of floorspace construction in region r (Equation 5.01)

$U_{f,r}$ = utility of floorspace category f in region r

λ_{q1} = dispersion parameter of the logit model (estimated separately for residential and non-residential floorspace construction)

$VacRate_{f,r}$ = average vacancy rate for floorspace category f in region r in the previous year (calculated from PI *ExchangeResults.csv* space use and ALD *FloorspaceInventory.csv* total space inventory)

$TVQ_{f,r}$ = dollar value of floorspace category f in region r in the previous year (calculated from ALD *FloorspaceInventory.csv* floorspace inventory and *ExchangeResults.csv* prior-year PI module square foot values of floorspace by category)

$\beta_{q1,f}$ = coefficient estimated separately for residential and non-residential construction (estimated)

β_{q2} = sensitivity coefficient for the previous year zone proportion of total floorspace of this type (estimated)

$ASC_{f,r}$ = alternative specific constant for construction of floorspace category f in region r (estimated)

The logit model for floorspace decreases has the form:

$$NDVQ_{f,r} = NDVQ_r \cdot (\exp (\lambda_{q2} \cdot U_{f,r}) / \Sigma_f \exp (\lambda_q \cdot U_{f,r})) \quad (5.07)$$

with:

$$U_{f,r} = \beta_{q3,f} \cdot VacRate_{f,r} + \beta_{q4} \cdot \ln (TVQ_{f,r} / \Sigma_f TVQ_{f,r}) + ASC_{f,r} \quad (5.08)$$

where:

$NDVQ_{f,r}$ = value of floorspace decrease allocated to category f in region r

$NDVQ_r$ = total value of floorspace decrease in region (Equation 5.03)

$U_{f,r}$ = utility of floorspace category f in region r

λ_{q2} = dispersion parameter of the logit model estimated separately for residential and non-residential floorspace construction (estimated)

$VacRate_{f,r}$ = average vacancy rate for floorspace category f in region r in the previous year (calculated from PI *ExchangeResults.csv* space use and ALD *FloorspaceInventory.csv* total space inventory)

$TVQ_{f,r}$ = dollar value of floorspace category f in region r in the previous year (calculated from ALD *FloorspaceInventory.csv* floorspace inventory and exogenous *ConstructionCosts.csv* square foot values of floorspace by category)

$\beta_{q3,f}$ = coefficient estimated separately for residential and non-residential construction (estimated)

β_{q4} = sensitivity coefficient for the previous year zone proportion of total floorspace of this type (estimated)

$ASC_{f,r}$ = alternative specific constant for decrease in floorspace category f in region r (estimated)

The regional average vacancy rate for a given category of floorspace is calculated as follows:

$$VacancyRate_{f,r} = (\Sigma_{\alpha,r} PrevQ_{f,\alpha,r} - \Sigma_{\beta,r} Occupied_{f,\beta,r})/(\Sigma_{\alpha,r} PrevQ_{f,\alpha,r}) \quad (5.09)$$

where:

α = index representing alpha zones in region r

β = index representing beta zones in region r

$PrevQ_{f,\alpha,r}$ = building area-based quantity of total floorspace of category f in zone α of region r in the previous year (ALD previous year *FloorspaceInventory.csv* by alpha zone)

$Occupied_{f,\beta,r}$ = building area-based quantity of occupied floorspace of category f in zone β of region r in the previous year (PI previous year *ExchangeResults.csv* by beta zone)

The dollar-value quantity of floorspace in each category f in each region is converted into an equivalent area-based quantity (in building sqft) using modelwide average unit construction costs (per building sqft) specified exogenously. It is calculated as follows:

$$NIQ_{f,r} = NIVQ_{f,r} / ConstrCost_f \tag{5.10}$$

$$NDQ_{f,r} = NDVQ_{f,r} / ConstrCost_f \tag{5.11}$$

where:

$NIQ_{f,r}$ = building area-based quantity of floorspace construction allocated to category f in region r

$NIVQ_{f,r}$ = value of floorspace construction allocated to category f in region r (Equation 5.05)

$NDQ_{f,r}$ = building area-based quantity of floorspace decrease allocated to category f in region r

$NDVQ_{f,r}$ = value of floorspace decrease allocated to category f in region r (Equation 5.07)

$ConstrCost_f$ = modelwide average unit construction costs for floorspace category f (exogenous *ConstructionCosts.csv*).

5.3.3. Allocation of Zonal Floorspace Decrease

Regional decreases in the quantity of floorspace in each category are allocated among alpha zones in each region using a Cobb-Douglas model where the input variables are the proportion of total regional floorspace of the category in each zone, and the price determined by the PI module for that type of floorspace in the corresponding beta zone. The equations for this model are as follows:

$$DQ_{f,\alpha,r} = NDQ_{f,r} \cdot (B_{f,\alpha,r} / \Sigma_\alpha B_{f,\alpha,r}) \tag{5.12}$$

with:

$$B_{f,\alpha,r} = (PrevProp_{f,\alpha,r})^{\beta 3f} \cdot (Price_{f,\alpha,r})^{\beta 4f} \tag{5.13}$$

where:

α = index representing a specific alpha zone

$DQ_{f,\alpha,r}$ = decrease in quantity of floorspace category f in alpha zone α in region r

$NDQ_{f,r}$ = building area-based quantity of floorspace decrease allocated to category f in region r (Equation 5.11)

$PrevProp_{f,\alpha,r}$ = share of previous year regional floorspace quantity of category f in alpha zone α (using ALD previous year *FloorspaceInventory.csv*)

$Price_{f,\alpha,r}$ = previous year price of floorspace quantity of category f in the beta zone in which alpha zone α is located (PI previous year *ExchangeResults.csv*)

β_{3f}, β_{4f} = allocation coefficients (estimated separately for residential and non-residential decreases)

5.3.4. Land Capacity Calculation

To allocate the region floorspace increases in each category to alpha zones it is necessary to calculate the capacity of each alpha zone for accommodating floorspace of each category. Floorspace capacity is a function of how much land is planned for development by plan category, the compatibility of each floorspace category with each plan category, and the allowable floor area ratio for each floorspace category in each plan category. The following logit model is used to proportion land by plan category to floorspace categories:

$$LandProp_{f,z} = \exp(U_{f,z}) / \Sigma_f \exp(U_{f,z}) \tag{5.15}$$

with:

$$U_{f,z} = \lambda_p (stc \cdot size_f + \ln(Compat_{f,z})) \tag{5.16}$$

$$size_f = \ln(LandSQFT_f) / \lambda_p \tag{5.17}$$

and with the constraint that: $\exp(U_{f,z}) \geq 0$

and where:

$LandProp_{f,z}$	=	proportion of zoning category z land area allocated to floorspace type f
$U_{f,z}$	=	utility of allocating land in zoning code z to floorspace type f
$size_f$	=	size term accounting for modelwide variation of different floorspace types (estimated)
$Compat_{f,z}$	=	compatibility of floorspace type f in zoning category z (exogenous, *zoning_compatibility.csv*)
stc	=	parameter for the sensitivity to the size term (estimated)
λ_p	=	dispersion parameter for the sensitivity to input compatibility matrix (estimated)
$LandSQFT_f$	=	baseyear modelwide land area devoted to each floorspace type (exogenous, *landSQFTxFLR.csv*)

The capacities for each floorspace category in each alpha zone are calculated from the proportional allocation of zoning categories to floorspace categories, the inventory of zoning by type and alpha zone, and maximum floor area ratios by zoning type and floorspace category as follows:

$$Cap_{f,\alpha} = LandProp_{f,z} \cdot ZoneArea_{z,\alpha} \cdot FAR_{f,z} \tag{5.18}$$

with the constraint that: $Cap_{f,i} \geq PrevQ_{f,i}$

where:

$Cap_{f,\alpha}$	=	building area capacity for floorspace category f in alpha zone α
$LandProp_{f,z}$	=	proportion of zoning type z land area allocated to floorspace type f (Equation 5.15)
$ZoneArea_{z,\alpha}$	=	land area with zoning type z in alpha zone α (exogenous, *LandSQFTxZoning.csv*)
$FAR_{f,z}$	=	maximum floor-to-area ratio for floorspace category f in zoning type z (exogenous, *far.csv*)

5.3.5. Allocation of Zonal Floorspace Increase

The regional floorspace construction quantities are allocated to alpha zones. These allocated quantities are then added to the updated floorspace inventory after decreases have been apportioned to yield the new floorspace qualities by alpha zone. A Cobb-Douglas model is used to allocate the construction among the alpha zones as follows:

$$IQ_{f,\alpha,r} = NIQ_{f,r} \cdot (C_{f,\alpha,r} / \Sigma_{\alpha,r} C_{f,\alpha,r}) \quad (5.19)$$

with:

$$C_{f,\alpha,r} = (PrevProp_{f,\alpha,r} + \beta_{9f})^{\beta 5f} \cdot (Price_{f,\alpha,r})^{\beta 6f} \cdot (1 - \beta_{7f} \cdot (PrevDQ_{f,\alpha,r} / Cap_{f,\alpha,r})^{\beta 8f}) \quad (5.20)$$

$$PrevDQ_{f,\alpha,r} = PrevQ_{f,\alpha,r} - DQ_{f,\alpha,r} \quad (5.21)$$

and with the constraints that:

$$PrevDQ_{f,\alpha,r} \geq 0$$

$$Cap_{f,\alpha,r} \geq PrevQ_{f,\alpha,r}$$

where:

α = index representing a specific alpha zone

$IQ_{f,\alpha,r}$ = increase in quantity of floorspace category f in alpha zone α in region r

$NIQ_{f,r}$ = building area-based quantity of floorspace construction allocated to category f in region r (Equation 5.10)

$PrevProp_{f,\alpha,r}$ = share of previous year region r floorspace quantity of category f in alpha zone α (using ALD previous year *FloorspaceInventory.csv*)

$Price_{f,\alpha,r}$ = previous year price of floorspace quantity of category f in the beta zone in which alpha zone α is located (PI previous year *ExchangeResults.csv*)

$PrevDQ_{f,\alpha,r}$ = updated quantity of floorspace category f in alpha zone α in region rafter the decreases are taken into account

$PrevQ_{f,\alpha,r}$ = building area-based quantity of total floorspace of category f in zone α of region r in the previous year (ALD previous year *FloorspaceInventory.csv* by alpha zone)

$DQ_{f,\alpha,r}$ = decrease in quantity of floorspace category f in alpha zone α in region r (Equation 5.12)

$Cap_{f,\alpha,r}$ = building area capacity for floorspace category f in alpha zone α (Equation 5.18)

β_{5f}, β_{6f}, β_{7f}, β_{8f}, β_{9f} = coefficients (estimated separately for residential and non-residential decreases)

After this allocation of increases in floorspace, the resulting new quantities in each zone are determined, as follows:

$$CurrQ_{f,\alpha,r} = PrevDQ_{f,\alpha,r} + IQ_{f,\alpha,r} \quad (5.15)$$

where:

$CurrQ_{f,\alpha,r}$ = the area-based quantity of floorspace category f in zone i in the current year

5.3.6 Completing the Floorspace Inventory

ALD produces an output file identifying the total floorspace by floorspace type and alpha zone. Total floorspace includes the residential and non-residential components discussed above. To this are added productive land sqft of agricultural and logging lands in each alpha zone. In the future, after-market additions to floorspace could also be added at this point, as user inputs.

Agriculture and Logging Lands

For the Oregon Statewide Integrated Model (SWIM2), productive agriculture and logging lands are assumed to be fixed in quantity and location (*PIAgForestFloorspace.csv*). ALD initially strips the agriculture and logging lands from the previous year floorspace input and adds these same quantities back onto the new residential/nonresidential floorspace inventory before producing the current year floorspace output. It should be noted that these categories are in units of land sqft, not building-area based sqft as in other floorspace types.

Additionally, PI requires a consistent use of floorspace per employee per year in a given industry (see Section 6.6.3). Thus, an PI-version of the agriculture and logging lands was developed for the baseyear. Fixed factors were generated to convert between the alpha zone based lands and the adjusted PI-lands. These were applied to the full ALD agriculture and logging lands to generate the floorspace input required by PI.

In the future, it is anticipated that ALD could be modified rather easily to allow agriculture and logging lands to be created directly from the zoning coverage. Thus if in future year the area covered by agriculture and logging zoning categories decreased, so would the available lands, which would in turn affect the amount of agriculture and logging production activity when used into the PI module. This would require linking the various agriculture, rangeland, mining, and forestry zoning categories to the baseyear productive agriculture and logging lands obtained from census and state forestry departments.

5.4. Software Implementation

ALD is implemented in the R statistical programming language and called using R CMD BATCH from java.[8] The work was started in the R language because some of the operations were drawn from R work used in the first generation, SWIM1 model. The use of R also facilitated the use of evolutionary algorithms to estimate the model coefficients.

Three scripts are required to run the ALD module: ALD.R, ALD_Inputs.R, and ALD_Functions.R. ALD.R is the main script which calls the other two scripts and steps through the ALD process. The main program, ALD.R, calls ald_inputs.R. ALD.R is split into five main sections. The first section parses the arguments to R CMD BATCH and identifies the locations of the code and data directories, builds the names of the directory paths.

The second section calls the ALD_Functions.R script which defines a number of functions which carry out the different portions of the ALD model described above. The main functions are:

- allocateConstToRegions
- allocateDecreaseToRegions
- allocateFloorProd
- allocateFloorDecrease
- calcFloorCapacity
- calculateFloorDecrease
- allocateIncrease

The notation used in the code closely follows the notation in the equations. The variable names are similar to the variable names in the equations. The dimensionality of variables is noted using a special 'dot' notation. For example, $PrevProp_{f,\alpha,r}$ is notated as PrevProp.AxFx.

Abbreviations for the dimensions follow the period in the variable name. In this case, the object is a matrix where the rows refer to alpha zones (Ax) in a region, and the columns refer to floorspace types (Fx).

The third section calls the ALD_Inputs.R script which identifies the input data file names, the model coefficients files, and then loads the data and coefficients.

The fourth section performs all of the ALD module calculations and creates all of the output data objects.

The last section writes out all of the results of the calculation of floorspace quantities that are used by PI in the current year and used by ALD in the following year. In addition, a number of files are written out to help in the diagnosis of ALD outputs. Furthermore the R workspace is saved so that the state of all the variables in the ALD simulation can be examined.

At the close of the module, a 'complete' message is returned to AO.

5.5. S1 and S2 Module Parameters

Most of the ALD module parameters are S2 parameters which were calibrated through a parameter search process used to find the best fit. Two of the parameters, however, are S1 parameters which were calculated directly from calibration data. These are:

- Modelwide floorspace unit construction costs by floorspace category ($ConstrCost_f$) discussed in Section 5.5.1; and
- Modelwide residential and non-residential floorspace value decrease factors (Df) discussed in Section 5.5.2.

The target data used in calibrating all the ALD sub-models are 1990-2000 annual net change in county building stock (sqft) by floorspace type, purchased from McGraw Hill FWDodge. This data and it's preparation for use in model calibration is discussed in Section 5.6.1.

The calibration of S2 parameters has been challenging because of the relative complexity of the model and data limitations. Calibration of ALD requires the estimation of 76 parameters and 34 alternative specific constants. These include the parameters and alternative specific constants for both the decrease and increase functions. The floorspace data though, only provide observations for net changes in floorspace. They do not provide separate observations for floorspace decreases and increases. Because of the large number of parameters and the lack of observed data on decreases and increases, the estimation process was split into steps and an automated search process using evolutionary algorithms was used for estimating parameters for three of the steps. The steps are as follows:

- Calibration of land capacity model parameters (Section 5.5.3);
- Calibration of model parameters for allocating modelwide construction dollars into regional dollar value increases and decreases (Section 5.5.4);
- Calibration of model parameters for allocating regional dollar increases and decreases into floorspace types (Section 5.5.5); and,
- Calibration of model parameters for allocating regional floorspace decreases and increases to alpha zones (Section 5.5.6).

A parameter search process using evolutionary algorithms was applied in the last three steps. Although there are differences in how an evolutionary algorithm has been applied to each step, the basic approach is the same and incorporates the following elements:

1. The algorithm starts with a set of 1000 - 2000 parameter combinations that are established by random draws from pre-established parameter ranges.

2. The algorithm iterates through a number of evolutionary cycles. The number of cycles is established in order that model results converge to calibration target values. The following procedures are carried out in each cycle:

- The model is run for each parameter combination and the goodness of fit of the result with calibration targets is calculated.
- The best-fitting parameter combinations are identified and retained for the next cycle. The number that is retained is gradually reduced through the cycles to force convergence on a solution (e.g. first retaining 100 for several cycles, then 75, then 50, and then 25).
- Additional combinations are added to the ones that are retained to expand the set back to its original size. These additional combinations are generated from the retained combinations by recombining parameters from randomly selected combinations and by choosing new values randomly from within the range of values of the retained combinations.

This evolutionary algorithm approach has worked successfully for estimating the ALD parameters. More details of the calibration steps and results follow, with more detail in reference [38].

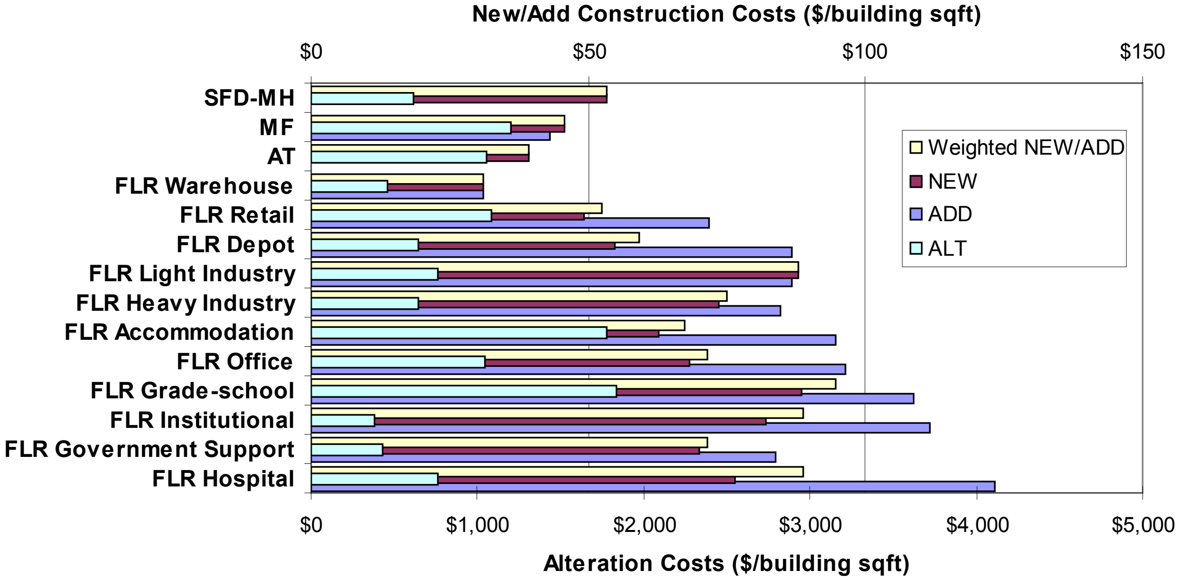
5.5.1. Unit Construction Cost Rates

Unit costs for construction were developed from FWDodge Construction starts database reflecting actual construction in the 75-county study area between 1990 and 2002. Construction costs were converted into 1990 constant dollars using USGSP deflators from the ED module. Study area averages ($/sqft in 1990 dollars) were estimated by dividing total construction, demolition, and clean-up costs incurred, by the increase in space (sqft). Table 5.2 identifies how the FWDodge space categories were mapped to the model floorspace types. The weighting is based on available space of each type within the study area. Figure 5.1 identifies the resulting unit construction cost rates for new constructions (NEW), space additions (ADD), and the significantly higher cost alteration of space (ALT). An average of the NEW and ADD space categories, weighted by the type of space added over the ten-year period, also shown in Figure 5.2, were used as input to ALD.

Table 5.2. Mapping SWIM2-FWDodge Building Space Types

		Oregon2 Floorspace Type														
	FWDodge Category	FLR Accommodation	FLR Depot	FLR Government Support	FLR Grade-school	FLR Heavy Industry	FLR Hospital	FLR Institutional	FLR Light Industry	FLR Office	FLR Retail	FLR Warehouse	SFD, RRSFD	AT	MF	
AMUSE	Amusement, Social and Recreational Bldgs										100.0%					100%
AUTO	Parking Garages and Automotive Services										100.0%					100%
DORM	Sudent Housing, Nursing Home Facilities							100.0%								100%
EDUC	Schools, Libraries, and Labs (nonmfg)				83.9%			15.7%		0.4%						100%
HEALTH	Hospitals and Other Health Treatment						25.8%	19.6%		54.6%						100%
HOTEL	Hotels and Motels	100.0%														100%
MFG	manufacturing Plants, Warehouses, Labs					60.4%			39.6%							100%
MISCNR	Miscellaneous Nonresidential Buildings		100.0%													100%
OFFICE	Office and Bank Buildings									100.0%						100%
PUB	Government Service Buildings		43.9%	56.1%												100%
REL	Religious Buildings										100.0%					100%
STORES	Stores and Restaurants			25.8%							74.2%					100%
WARE	Warehouses (excl. manufacturer owned)		43.5%									56.5%				100%
ONEFAMILY	Single Family Residential												100.0%			100%
TWOFAMILY	Two Family Residential													100.0%		100%
APARTMENTS	Apartments														100.0%	100%

Figure 5.1. Statewide Average Construction Costs



5.5.2. Modelwide Floorspace Value Decrease Factors

Residential and non-residential floorspace decrease factors were computed by comparing the average floorspace construction values produced by the ED module for the period between 1990 and 2000, with the value of the change in floorspace computed from the FW Dodge data for the same period. The latter was calculated by multiplying the change in square footage computed from the FW Dodge data for each floorspace category by the unit construction cost rates estimated in Section 5.5.1. The resulting decrease factors estimated in this way were 0.12 for residential and 0.39 for nonresidential. Comparison of forecast and independent data in this way is rational but not a very rigorous exercise, required in the face of limited data. In 2010, after early use of the model indicated that non-residential floorspace availability limitations from ALD were contributing to PI module convergence issues over time, these coefficients were revisited. As such, during calibration it was felt that a reduction in the non-residential factor was a reasonable action. Under this effort, the residential factor of 0.12 was applied to both residential and non-residential space types, significantly reducing the non-residential demolition. Some further sensitivity testing of this value may be of useful.

The values currently used by ALD are 0.12 for residential and nonresidential value. These D_f values are stored in ALDResCoefficients.csv and ALDNresCoefficients.csv, respectively.

5.5.3. Land Capacity Calculation Parameters

The values of the Land Capacity Calculation parameters discussed in Section 5.3.2, after S2 validation, including the dispersion parameter (λ_p), and size term and coefficient ($size_f$, stc), are shown in Table 5.3. In validation, significant adjustments were also made to the exogenous inputs of the compatibility matrix, and FAR data.

The resulting compatibility matrix, defining the compatibility of each floorspace type within any zoning category, is shown in Table 5.8. The resulting maximum FAR data by floorspace type and zoning category is shown in Table 5.9. T he $size_f$ term represents modelwide land area devoted to each floorspace type, developed from a modelwide GIS 30m grid coverage of built form (Development Type and Quantity of space) synthesized for the SWIM2 LD module. [10]

Table 5.3. ALD Land Capacity Function Parameters

Parameter		Value
λ_p	Dispersion parameter	2
stc	Size parameter	1
$size_f$	FLR MH	162,108,178
	FLR MF	332,968,136
	FLR AT	121,871,581
	FLR SFD	1,613,005,882
	FLR RRMH	102,920,077
	FLR RRSFD	576,739,816
	FLR Accommodation	43,873,240
	FLR Depot	184,717,340
	FLR Government Support	42,741,010
	FLR Grade-school	108,479,870
	FLR Heavy Industry	122,165,040
	FLR Hospital	21,333,110
	FLR Institutional	31,808,110
	FLR Light Industry	99,570,790
	FLR Office	190,689,900
	FLR Retail	333,876,050
	FLR Warehouse	36,508,630

ALD Input File:[LandSQFTxFLR.csv]

5.5.4. Model Parameters for Allocating Modelwide Construction Dollars into Regional Dollar Value Increases and Decreases

ALD parameters were calibrated for functions that split ED module model wide residential and nonresidential construction dollars into region-level dollar increases and decreases (see section 5.3.1). For the purposes of S2 calibration, data from the Bureau of Economic Analysis' Regional Economic Information System (REIS) to measure activity. Employment was used as the measure of activity related to non-residential floorspace. Population was used as the measure of activity related to residential floorspace. In S3 calibration, PI activity data will be used. The parameters for the increase and decrease functions were calibrated simultaneously using evolutionary algorithms. A population of 2000 parameter combinations was generated at random from a set of defined parameter bounds and run through 42 e volutionary steps to find the best fitting parameter combination. In each evolutionary step, increases and decreases were calculated and summed to calculate a n et change by region. The RMSE error between the calculated regional net changes and the regional changes calculated from the FW Dodge data was used as a fitness measure it identify the best fitting parameter combinations. The best fitting combinations were then modified through "crossovers" or "mutations" to produce a new population of 2000 parameter combinations used in the next step. Figure 5.2 shows an example of convergence of residential floorspace increase function parameters. Figure 53 shows a corresponding example of the convergence of model net results to the FW Dodge target values for four regions. The resulting alternative specific constants are included in Tables 5.3 and 5.4 for nonresidential and residential floorspace types, respectively. The values for the four Cobb-Douglas production parameters are shown in Table 5.5.

Figure 5.2. Convergence of Residential Parameter Values

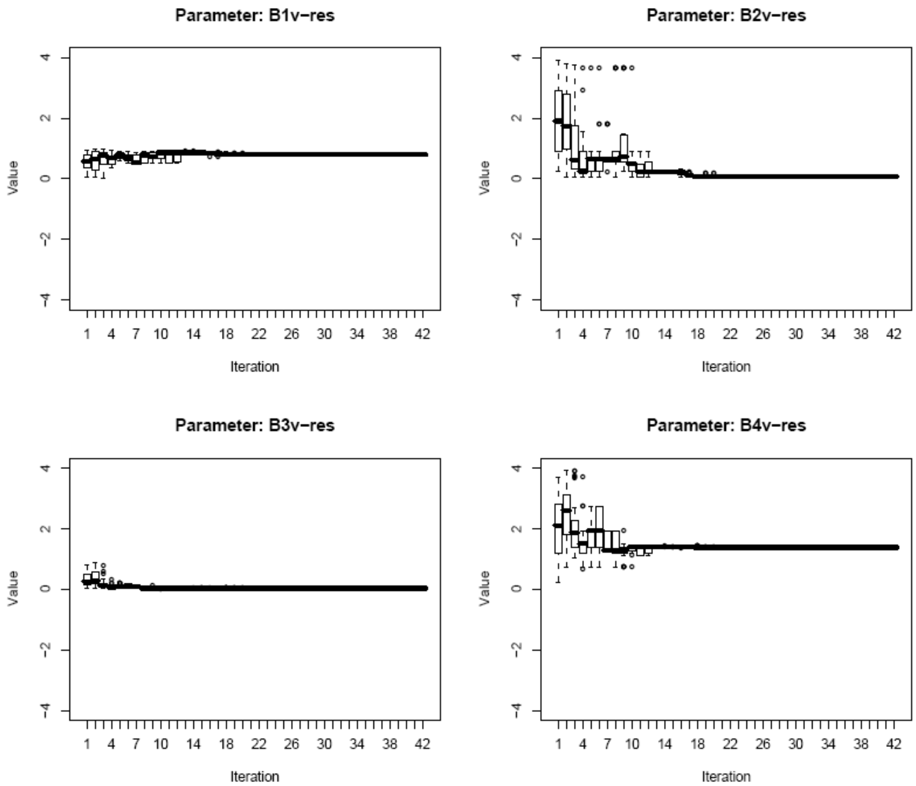


Figure 5.3. Convergence of Model Results to FW Dodge Target Values

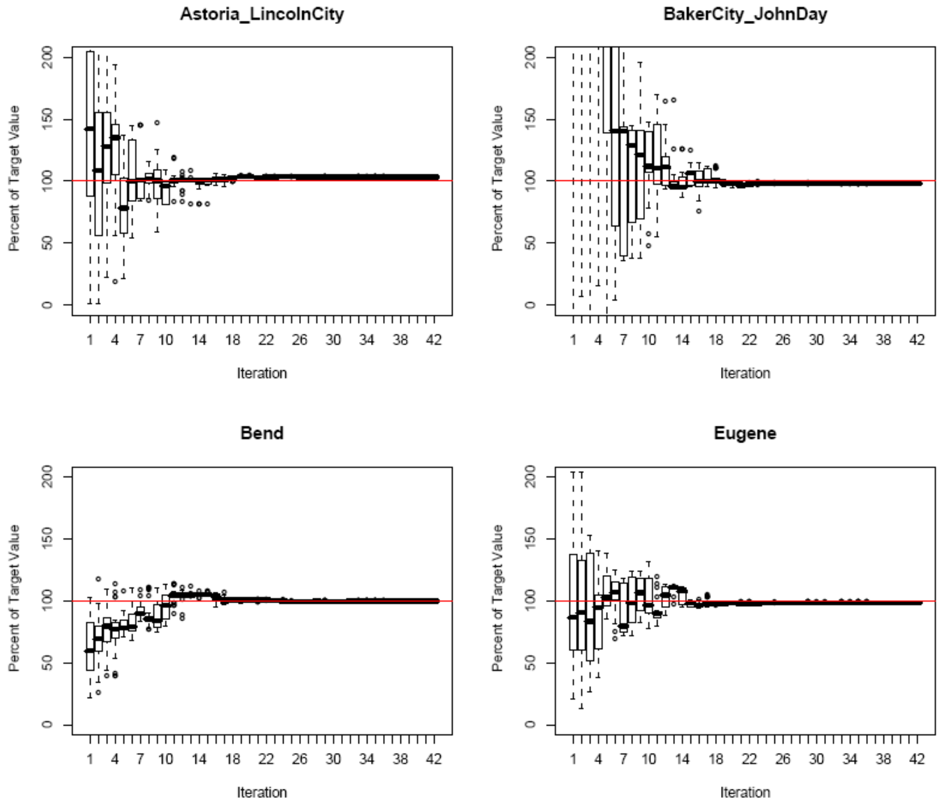


Table 5.4. Alternative Specific Constants to Allocate Regional Construction Dollars to Floorspace Types - Non Residential

Region	FLR Accommodation	FLR Depot	FLR Government Support	FLR Grade-school	FLR Heavy Industry	FLR Hospital	FLR Institutional	FLR Light Industry	FLR Office	FLR Retail	FLR Warehouse
INCREASE											
Astoria_LincolnCity	0.944702	0.235614	-0.259910	0.207471	-2.907440	0.432939	-0.081280	-1.401530	-0.741630	0	-0.80103
BakerCity_JohnDay	0.586089	1.625532	1.801039	1.407736	1.504913	1.514356	1.926353	0.767333	0.735611	0	-0.21093
Bend	-0.884470	0.423798	-0.349120	0.394332	-1.880110	-0.661790	-1.066460	-2.156670	-0.397320	0	-2.45611
Eugene	0.699288	0.948542	-1.294870	-0.517360	-1.251130	0.616967	-0.096580	-0.903660	0.458251	0	-1.07190
Eureka_Brookings	0.183214	0.072535	0.413877	-0.792110	-1.361930	0.714911	0.367652	-0.367840	-1.051680	0	-0.81388
KlamathFalls_Burns	2.007493	0.904102	0.418304	-0.045670	-2.060080	1.614082	0.350857	0.120022	0.476692	0	-0.56112
Lewistown	1.140614	1.039634	0.021470	1.676284	-0.949050	1.471895	0.627516	-1.017900	0.443534	0	-0.66874
Longview_Centralia	0.145686	0.783508	-0.723700	-0.682170	-0.822890	0.524477	-1.092800	-1.209510	-0.484420	0	-0.81174
Medford_GrantsPass	-0.008700	-0.121280	-0.623880	-0.288720	-0.944310	0.050372	-0.001280	-0.684090	-0.257270	0	-1.07863
Ontario_Boise	0.277807	0.494493	-0.394450	0.146705	-0.856080	-0.350780	-0.223810	-0.876460	0.371850	0	-1.44383
Portland_Vancouver	0.086280	1.083125	-1.308010	-0.080430	-0.828400	-1.003140	-0.586460	-0.067400	-0.086880	0	-1.14624
Salem	0.687471	1.323692	-0.206050	0.244056	-2.442220	0.217611	-0.171280	-2.377680	-0.019380	0	-0.99943
TheDalles	-1.261090	-0.51397	-0.821790	0.332557	-2.600690	1.032134	0.389188	-3.854760	-0.361730	0	-1.24701
Yakima_Pendleton	0.483384	1.80530	-0.398530	1.823500	0.272279	0.328345	1.068840	0.151031	0.850889	0	-0.50899
Yreka_Redding	-0.096830	-0.16398	0.622854	0.014584	-1.37370	0.844414	1.112208	-2.005020	0.295520	0	-0.95297
DECREASE											
Astoria_LincolnCity	2.763757	-0.854408	0.550963	-0.588357	2.171298	-0.293591	-0.729383	1.650154	0.827490	0	-0.810913
BakerCity_JohnDay	-0.891268	1.010798	2.249196	2.157934	1.961006	-1.042788	1.813892	-0.465579	0.459310	0	-1.913085
Bend	-0.460973	2.013159	2.660423	3.029211	2.405165	0.022755	0.053865	2.891694	1.527273	0	-1.002809
Eugene	-0.040206	2.570598	-3.038275	0.235208	1.123078	2.402918	-0.522408	-0.052002	0.954050	0	0.541387
Eureka_Brookings	1.101352	0.885427	1.274713	0.741928	3.300662	0.772333	1.338762	3.018789	1.374824	0	-0.496001
KlamathFalls_Burns	0.781087	0.145467	-0.085089	-0.134997	-0.002645	0.367056	-1.208864	0.117831	-0.319939	0	-2.070174
Lewistown	1.274683	1.499027	0.648288	2.126220	1.051077	0.914092	-0.326581	-0.350138	0.496095	0	-0.821363
Longview_Centralia	0.393504	1.158247	-0.788388	0.676693	1.232855	1.975634	-2.210476	1.070667	0.726616	0	-0.175315
Medford_GrantsPass	-0.147762	0.387470	-0.288341	0.058904	2.180457	-1.012891	1.545078	2.765504	-0.164663	0	0.073767
Ontario_Boise	0.584221	1.205850	-0.251980	-1.078799	2.275093	0.240065	-0.487524	1.986376	-0.335838	0	0.519281
Portland_Vancouver	1.363668	3.348070	0.122153	0.825876	-0.962027	-2.057667	0.743412	0.649737	1.054240	0	0.410136
Salem	-0.082270	0.369023	1.562376	1.748439	0.128730	0.642501	-0.449637	-0.071461	0.692468	0	-1.009280
TheDalles	-2.619944	-2.514178	-3.461466	-3.148120	-1.094045	-3.291059	-2.679318	3.974732	-1.877617	0	-2.478947
Yakima_Pendleton	-1.287373	-1.349710	-1.908386	2.254272	2.243717	-1.789344	2.383304	2.847587	0.956473	0	-1.576993
Yreka_Redding	1.226759	-0.823016	1.439139	1.297564	0.675903	2.622162	-0.211855	0.785988	1.974681	0	0.561401

ALD Input files: [ALDAsc1.RgFn.csv] increase, [ALDAsc2.RgFn.csv] decrease

Table 5.5. Alternative Specific Constants to Allocate Regional Construction Dollars to Floorspace Types -Residential

Region	FLR MH	FLR MF	FLR AT	FLR SFD	FLR RRMH	FLR RRSFD
INCREASE						
Astoria_LincolnCity	0.599185	-0.09141	0.128806	0	0.32678	0.208994
BakerCity_JohnDay	-0.28148	-0.27616	-0.43235	0	-0.27724	-0.34203
Bend	0.516327	-0.53798	-0.08595	0	0.838234	0.705884
Eugene	0.117779	0.386703	0.844898	0	-0.20865	0.002161
Eureka_Brookings	-0.06574	-3.14471	-3.61438	0	-0.14144	0.498804
KlamathFalls_Burns	0.260061	-0.22102	0.365183	0	0.421043	0.180597
Lewistown	-0.21071	-0.0555	-0.01667	0	-0.46303	0.319172
Longview_Centralia	0.271002	-0.43668	-0.34781	0	0.264514	1.194059
Medford_GrantsPass	0.638162	0.274419	0.659648	0	0.395957	0.306998
Ontario_Boise	-0.15147	-0.94255	-0.60234	0	-1.02368	0.039501
Portland_Vancouver	0.056183	0.073551	0.083727	0	-0.73026	0.168127
Salem	0.330187	0.338436	0.381144	0	-0.20455	0.058002
TheDalles	0.448967	-0.12737	-0.0613	0	0.656301	1.422753
Yakima_Pendleton	-0.36111	-0.34582	-0.45934	0	-0.86607	0.432256
Yreka_Redding	-0.09976	-0.24731	-1.02394	0	0.283882	0.943806
DECREASE						
Astoria_LincolnCity	-1.84316	-2.11438	-3.64243	0	-0.34124	0.111757
BakerCity_JohnDay	-2.84376	-2.54353	-3.50431	0	-3.5544	-2.39588
Bend	-2.31471	-2.72093	-2.86904	0	-0.16878	1.979141
Eugene	-2.09872	-2.08561	-1.92973	0	-3.51411	-0.59056
Eureka_Brookings	-0.72992	0.928168	1.34931	0	-3.59163	2.059602
KlamathFalls_Burns	-0.7994	-2.39492	-1.91467	0	-2.25349	-0.95675
Lewistown	-2.24869	0.179987	-3.12329	0	-1.48853	-1.38146
Longview_Centralia	-2.3721	-2.68488	-1.009	0	-1.44889	3.038585
Medford_GrantsPass	-1.02841	0.355648	-2.98606	0	0.255433	0.244647
Ontario_Boise	-0.05595	-1.92675	-0.26284	0	-0.67294	3.677403
Portland_Vancouver	-2.94502	-3.14238	-1.00111	0	-3.17513	3.70538
Salem	-3.3574	-0.15295	-0.62065	0	-2.34857	-2.15255
TheDalles	-1.2888	-1.5701	-2.09202	0	-1.66081	1.975529
Yakima_Pendleton	-1.36691	-0.85531	-0.24308	0	-1.40415	3.92212
Yreka_Redding	-0.20314	-1.31216	-2.26709	0	-2.96348	3.482707

ALD Input files: [ALDAsc1.RgFr.csv] increase, [ALDAsc2.RgFr.csv] decrease

Table 5.6. ALD Cobb Douglas Parameters

Parameter		Nonresidential	Residential
β_{1v}	Activity Proportion additive term	0.278924	0.707674
β_{2v}	Activity Change Proportion additive term	1.968482	1.608066
β_{3v}	Activity Proportion Power	0.399309	0.167152
β_{4v}	Activity Change Proportion power	2.360545	1.960843

ALD Input files: [ALDNresCoefficients.csv], [ALDResCoefficients.csv]

5.5.5. Model Parameters for Allocating Regional Dollar Increases and Decreases into Floorspace Types

The search space to find the best fit of parameters for the allocation of regional dollar development changes into floorspace type (see Section 5.3.2) was very large, because of the significant number of alternative specific constants. Both the increase and decrease functions require an alternative specific constant for every combination of region and floorspace type. In order to get convergence, and to "maximize" the share of "behavior" explained by the model parameters vs. the alternative specific constants, the process of calibrating this step was split into two parts. In the first part, the range of possible values for the alternative specific constants was constrained. 36 evolutionary steps were run to get the best fit results for the parameters. The best results from the first part were then processes through a second round of 25 evolutionary steps where the alternative specific constants were varied through a wider range of values. Figure 5.4 shows an example of the convergence of the proportional distribution of model net floorspace change to the FW Dodge target proportions for the Bend region. Tables 5.7 and 5.8 provide estimated parameter values.

Figure 5.4. Convergence of Bend Region Model Floorspace Results to FW Dodge Target Values

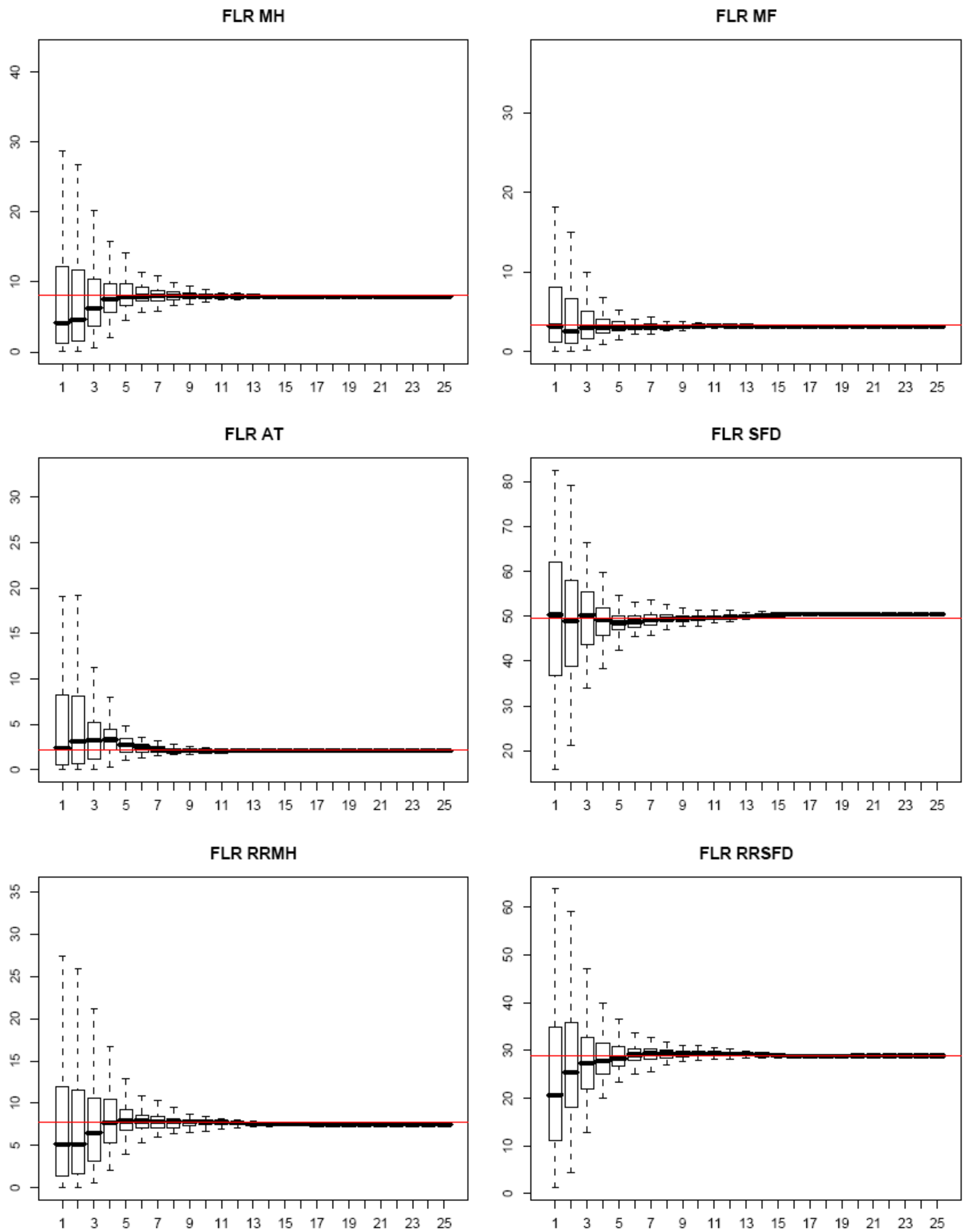


Table 5.7. ALD Parameters for Allocation to Floorspace Types

Parameter		Increase	Decrease
NONRESIDENTIAL			
$\lambda_{q1}, \lambda_{q1}$	Dispersion parameter	0.577946	0.309236
β_{q1}, β_{q3}	Sensitivity to Vacancy Rate		
	FLR Accommodation	-0.448740	-1.390874
	FLR Depot	-0.685066	-1.770418
	FLR Government Support	-0.717076	-1.998696
	FLR Grade-school	-1.081031	-1.048652
	FLR Heavy Industry	-2.992417	-0.667520
	FLR Hospital	-0.463261	-1.030110
	FLR Institutional	-0.387125	-1.058415
	FLR Light Industry	-2.197701	-1.830717
	FLR Office	-2.128987	-2.648114
	FLR Retail	-0.509895	-1.394915
	FLR Warehouse	-1.922216	-1.823896
β_{q2}, β_{q4}	Sensitivity to Prior Year Proportion	0.874475	0.932353
RESIDENTIAL			
$\lambda_{q1}, \lambda_{q1}$	Dispersion parameter	1.016924	1.48071
β_{q1}, β_{q3}	Sensitivity to Vacancy Rate		
	FLR MH	-2.68199	2.09219
	FLR MF	-3.84517	2.71393
	FLR AT	-3.60789	2.21573
	FLR SFD	-2.24556	1.47095
	FLR RRMH	-1.49781	1.55033
	FLR RRSFD	-1.97620	3.11092
β_{q2}, β_{q4}	Sensitivity to Prior Year Proportion	0.993564	0.881172

ALD Input files: [ALDNresCoefficients.csv], [ALDResCoefficients.csv]

Table 5.8. ALD Allocation to Floorspace Types Alternative Specific Constants

	Decrease		Increase	
Region	Res	Nres	Res	Nres
Astoria_LincolnCity	1.096045	1.418537	0.818734	0.613019
BakerCity_JohnDay	2.229466	2.421756	0.211028	0.748413
Bend	0.861347	1.622688	1.760991	1.282921
Eugene	2.202831	0.84171	1.284622	0.88153
Eureka_Brookings	1.922644	2.066115	0.64163	0.553066
KlamathFalls_Burns	1.983228	1.88033	0.290382	0.581193
Lewistown	0.677176	1.861535	0.389397	0.841779
Longview_Centralia	2.741183	1.784763	0.788709	0.870355
Medford_GrantsPass	2.079388	1.805548	1.347415	1.049417
Ontario_Boise	1.105793	1.87858	1.848916	1.773291
Portland_Vancouver	1	1	1	1
Salem	0.92188	1.096171	1.286465	1.229872
TheDalles	1.762743	1.432503	0.280946	0.370376
Yakima_Pendleton	2.340363	1.857325	0.899579	1.754938
Yreka_Redding	1.906525	1.445523	0.699018	0.821611

ALD Input files: [ALDAsc3.RgFc.csv] increase, [ALDAsc4.RgFc.csv] decrease

5.5.6. Model Parameters for Allocating Regional Floorspace Decreases and Increases to Alpha zones

The parameters influencing the zonal-level decrease and increase of floorspace by type, described in sections 5.3.3 and 5.3.4, were calibrated against the FW Dodge county change in net floorspace stock. In other words, upon completion of the net change in floorspace by alpha zone and type, the results are summed to the county level and compared with the FW Dodge data. As with the previous two steps, an evolutionary algorithm was used to calibrate the parameters. Unlike the other steps, however, there are no alternative specific constants, so the number of parameters to calibrate is smaller (but not small). This allowed there to be fewer evolutionary rounds. This was also necessary because these models have many more computations and require significantly more computing time per round. Only twelve evolutionary rounds were used. The results are not nearly as good as the in the previous two steps. This is to be expected in part because this step creates a substantial disaggregation of the results. It is expected that this will improve in the S3 calibration. Resulting parameter values are shown in Table 5.9.

Table 5.9. ALD Zonal Floorspace Allocation Parameters

Parameter		Nonresidential	Residential
DECREASE			
β_{3f}	Prior Year Proporation Dispersion	1.963554	1.248889
β_{4f}	Price Dispersion	-0.269004	-0.271316
INCREASE			
β_{5f}	Prior Year Proporation Dispersion	1.729279	1.160029
β_{6f}	Price Dispersion	0.347738	0.284712
β_{7f}	Prior Year Saturation factor	0.248170	0.052244
β_{8f}	Prior Year Saturation dispersion	5.817253	6.642847
β_{9f}	Prior Year Proportion additive term	0.002111	0.000673

ALD Input files: [ALDNresCoefficients.csv], [ALDResCoefficients.csv]

5.6. Inputs and Outputs

ALD inputs and outputs are listed in Tables 5.10 and 5.11. ALD requires current year construction activity values from ED and previous year activity (2-year) occupancy and price data from PI. Vacancy rates are calculated as the ratio of previous year PI occupied floorspace to previous year ALD total floorspace quantity. Zoning-based land capacities by alpha zone are exogenously developed for each year using GIS. Values for $ConsCost_f$ are drawn from FWDodge construction starts data between 1990 and 2001. Additional ALD definition files are also required to run the model. Detailed descriptions of several ALD input data are discussed in the remainder of this section

ALD produces a current year floorspace inventory for PI (and for use in ALD in the next year). The agriculture and logging lands are adjusted in the PI file, as discussed in Section 5.3.6 In addition to the outputs used by other modules, ALD prints a series of diagnostic files listed also in Table 5.11.

Table 5.10. ALD Inputs

Data Element	Source
Modelwide construction activity$ for residential ($res), and nonresidential ($nres) categories [ConstructionDollarDataForALD.csv]	ED
Beta Zone activity demand (HHs and industry$ by type) [ExchangeResults.csv]	Current year PI
Modelwide occupied floorspace (Msqft) by floorspace category [ExchangeResults.csv]	Current year PI
Unit prices for residential and nonresidential space in alpha zones [ExchangeResults.csv]	Current year PI
Building square footage (thousands) by alpha zone (row) and floorspace type (col) [FloorspaceInventory.csv]	Previous year ALD
Alpha-beta zone conversion [alpha2beta.csv]	exog
Modelwide space construction costs by floorspace type [ConstructionCosts.csv]	exog
Matrix of land square feet by alpha zone and zoning category (user-modified GIS Zoning Grid cross tab) [LandSQFTxzoning.csv]	exog
Matrix of floor to area ratios by floorspace type (rows) and zoning category (cols) [far.csv]	exog
Matrix of compatibility values (0 to 1=best) by floorspace type (row) and zoning category (col) [zoning_compatibility.csv]	exog
Definition files [floorspace_definitions][zoning_definitions]	exog
Land Capacity Size term values [LandSQFTxFLR.csv]	exog

Table 5.11. ALD Outputs

Description	Users
Building square footage (millions) (landsqft for agriculture and logging) by alpha zone (row) and floorspace type (col) [FloorspaceInventory.csv]	PT, next year ALD
PI-format building square footage (millions) (landsqft for agriculture and logging) by alpha zone (row) and floorspace type (col) [FloorspaceI.csv]	PI
Inputs/outputs for ALD Modelwide Construction 1990$ into Floorspace Types model [FloorspaceDiagnostics.csv]	diagnostics
Floorspace type split within each zoning category [FloorspaceProportionsByZoning.csv]	diagnostics
Building space increase for each floorspace type in each alpha zone [Increments.csv][Increments_Matrix.csv]	PI, diagnostics
Land sqft of each floorspace type in each alpha zone [LandAllocations.csv]	diagnostics
Building sqft zoning capacity of each floorspace type in each alpha zone [ResidentialCapacity.csv] [NonresidentialCapacity.csv]	diagnostics
Ratio of floorspace after decrease (but before increase) to total floorspace capacity [CapacityUtilization.csv]	diagnostics
Building Msqft decrease of each floorspace type in each alpha zone [ResidentialDecrease.csv] [NonresidentialDecrease.csv]	diagnostics
Decrease utility for each floorspace type in each alpha zone [ResidentialDecreaseUtilities.csv] [NonresidentialDecreaseUtilities.csv]	diagnostics
Building Msqft increase of each floorspace type in each alpha zone [ResidentialIncrease.csv] [NonresidentialIncrease.csv]	diagnostics
Increase utility for each floorspace type in each alpha zone [ResIncreaseUtilities.csv] [NonresIncreaseUtilities.csv]	diagnostics
Building Msqft after decrease (before increase) of each floorspace type in each alpha zone [ResQuantititesAfterDecrease.csv] [NonresQuantititesAfterDecrease.csv]	diagnostics
Log file for ALD run [ald.Rout]	diagnostics
R workspace from most recent run [.RData]	diagnostics
Matrix of alpha zone/floorspace types where capacity less than floorspace quantity (after decrease) [ResLowCapacity.csv] [NonresLowCapacity.csv]	diagnostics

5.6.1. Baseyear Floorspace Estimates

Floorspace is difficult to gather statewide at any sub-county level. For the baseyear, a modelwide floorspace inventory (by alpha zone) was synthesized covering four categories:

- residential building floorspace (building sqft),
- non-residential housing floorspace (building sqft),
- productive agricultural lands (land acres), and
- productive logging timberlands (land acres).

An initial estimate of floorspace quantities based on census (residential) and purchased FWDodge data (nonresidential) proved to be inconsistent with census-based zonal targets, and floorspace use rates defined in the PI module (see Section 6.5.2). As a result, a second attempt was made to synthesize a baseyear floorspace inventory from the PI use rates and zonal activity targets directly, as follows:

$$SQFT_{z,f} = UseRate_{a,f} \times ActivityTarget_{z,a} \times (1 + VacancyRate_{z,f}) \qquad (5.17)$$

where:

$SQFT_{f,z}$ = Synthesized Floorspace quantity (sqft) of floorspace type f in zone z

$UseRate_{a,f}$ = Modelwide target use of floorspace f by activity a (Section 6.5.2)

$ActivityTarget_{z,a}$ = Target quantity of activity a in zone z (Census HHs and IMPLAN employment)

$VacancyRate_{z,f}$ = Target quantity of activity a in zone z (Census STF3 vacancies for residential, or 7% nonresidential)[12]

The synthesized floorspace inventory using this approach proved to be excessively large (high vacancy rates) and resulted in homogenous prices across all zones. As a result, an involved process was used to iteratively trim the floorspace quantities while constraining the process to meet the following targets:

- modelwide vacancy rates by floorspace type from 2000 Census (residential) and mid-1990s real estate sales reports (nonresidential),
- modelwide activity use of each residential floorspace type from 2000 Census PUMS (sqft/HH),
- alpha zone-level floorspace prices by floorspace type ($/building sqft) from mid-1990s real estate sales reports (selected urban areas) and early 1990s Tax Assessor Data used in SWIM1 model development (outside urban areas, converted from $/land sqft).

The process involved iteratively running the PI module as follows. The resulting floorspace more accurately represented both floorspace price variations and vacancy rates:

- Reduce floorspace inventory to match target modelwide vacancy rates by floorspace type (alpha zone);
- Iteratively calibrate PI modelwide activity use of floorspace type (offset parameters) while constraining to alpha zone activity targets. To save runtime, this was first done

[12] Census includes vacant units, including seasonal/vacation homes by block group (Table STF327, Fields H0060001-8), prorating the census-based block group data by the area in each alphazone.

at a county zone level, and then the county offsets were transferred to the more disaggregate beta zone level for fine tuning;

- As needed, adjust the floorspace inventory to match target modelwide floorspace price targets. This tended to reduced price outliers caused by the above steps, but worked against reducing vacancy rates.
- Repeat additional adjustments to floorspace inventory to match target modelwide vacancy rates (and to a lesser extent zonal floorspace prices), as needed, repeating this multi-step process until vacancy rates were within the target range and prices were reasonable.

This process was applied to all nonresidential floorspace types and single-family (SFD) residential floorspace type. Residential calibration was complicated by the fact that all household types are allowed to use multiple floorspace types. However since residential space in the model is dominated by SFD type, the above adjustments were made to SFD only. The inventory of other residential floorspace types was derived from the resulting SFD space based on 2000 census mix of dwelling units in each alpha zone.

Agricultural and logging lands are inventoried in units of land area (acres) rather than building space (sqft). Acres of agriculture lands were identified from the 1997 Census of Agriculture for each county in the study area. Agriculture lands include acres of farmland defined in the 1997 census as cropland or other land (i.e., land in house lots, ponds, roads, wasteland), excluding woodlands and pasture-only non-croplands. Data omissions were estimated from other categories and/or prior 1992/1987 census data. Mining lands (quarries, strip mines, gravel pits), taken directly from 1990 USGS NLDC GIS land coverage, were added to the Agriculture lands. [10]

County timberland[13] acres were identified from the respective natural resource departments in each state (all mid-1990's data)[14] to represent the long-term supply of harvestable forestland.

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[13] Timberland is defined by the USFS as Forest land capable of growing 20 cubic feet or more per acre per year (mean annual increment at culmination in fully stocked, natural stands) of industrial wood and not in a reserved status through removal of the area from timber utilization by statute, ordinance, or administrative order; and not in a withdrawn status where it is pending consideration for reserved status.

[14] Sources of Timberland data:

· Timber Resource Statistics for Western Oregon 1999, US Department of Agriculture, Forest Service, Pacific Northwest Research Station, Resource Bulletin PNW-237 (Oct 2002); Table 3-Estimated area of timberland, by county and owner class, western Oregon (Jan 1997).

· Timber Resource Statistics for Eastern Oregon 1999, US Department of Agriculture, Forest Service, Pacific Northwest Research Station, Resource Bulletin PNW-238 (Dec 2002); Table 3-Estimated area of timberland, by county and owner class, eastern Oregon (1999).

· Timber Resource Statistics for Eastern Washington, US Department of Agriculture, Forest Service, Pacific Northwest Research Station, Resource Bulletin PNW-RB-201 (revised Feb 1995); Table 3-Area of timberland outside National Forests, by county and owner, Eastern Washington (Jan 1992).

· Timber Resource Statistics for Western Washington, US Department of Agriculture, Forest Service, Pacific Northwest Research Station, Resource Bulletin PNW-RB-218 (1997); Table 10-Area of Timberland by county/owner (1992).

· California Department of Forestry (CDF), California Forest and Rangeland Resources Assessment, Updated California Forest Statistic Abstract; Table G-27-Area of Timberland by county/owner (1994-1998).

The allocation of these county estimates to alpha zones, used the distribution of agriculture, mining, range, and forest lands (outside of urban areas), as identified in a 30m grid GIS land cover database of the study area. This land cover database was built primarily from the following sources. Additional details can be found in [10]:

- mid-1990s Pacific Northwest Ecosystem Research Consortium (PNWERC) data covering the Willamette Valley
- 1990 US Geological Survey (USGS) National Land Cover Dataset (NLCD)
- 1995 DLCD Urban Growth Boundaries
- 1993 Portland Metro Regional Land Information System (RLIS)
- 1993 Clark County Planning Department general land use coverage,
- 1991 Western Oregon Industrial Forestland Ownership GIS coverage, Oregon State Department of Forestry
- Various 2002 Environmental Systems Research Institute (ESRI) GIS shape files (e.g., federal lands, landmarks, airports, schools, hospitals, water, census urban places)

5.6.2. Zoning Data

In ALD, several zoning inputs are required. This includes a set of zoning categories, associated allowable floorspace types and maximum intensities (floor-area-ratios, FARs), and the amount of land (sqft) of each of these categories within each study area alpha zone. In the future, the user should be able to modify at least the GIS zoning coverage in future years. The 33 zoning categories, previously defined in Table 5.1, were developed to span local jurisdictional zoning codes. Since the model is long-term in nature, comprehensive plans were used over more dynamic zoning data.

The zoning code indicates the type and intensity of development allowed. Compatibility measures, on a 0 to 1(best) scale, the likelihood of each floorspace type to occur within each zoning category. Maximum Floor-Area-Ratios are used to calculate the floorspace capacity allowed by the zoning coverage. For the baseyear, these are shown in Tables 5.12 and 5.13. Both were developed from expert judgment.

The amount of land (sqft) of each zoning category within each study area alpha zone is developed from a GIS 30m grid coverage of these zoning categories across the study area. This GIS coverage is then tabulated to result in the land area within each zoning category and alpha zone.

· US Department of Agriculture, Forest Service, Forest Inventory and Analysis Database (FIADB); Table 2-Area of timberland by county and ownership class, for Idaho (1991), and Nevada (1989)

Table 5.12. ALD Zoning-Development Type Compatibility

	FLR MH	FLR MF	FLR AT	FLR SFD	FLR RRMH	FLR RRSFD	FLR Accommodation	FLR Depot	FLR Government Support	FLR Grade-school	FLR Heavy Industry	FLR Hospital	FLR Institutional	FLR Light Industry	FLR Office	FLR Retail	FLR Warehouse
ureslo	H	NP	M	VH	VL	VL	NP	NP	NP	M	NP	NP	L	NP	NP	NP	NP
uresmed	H	L	H	VH	VL	VL	NP	NP	NP	M	NP	NP	L	NP	NP	NP	NP
uresmdh	H	H	VH	H	VL	VL	NP	NP	NP	M	NP	NP	L	NP	NP	NP	NP
ureshi	M	VH	VH	M	NP	NP	NP	NP	NP	M	NP	NP	L	NP	NP	NP	NP
umix	L	VH	VH	M	NP	VL	M	L	H	M	L	M	M	L	H	VH	VL
umixhi	VL	VH	M	M	NP	VL	VH	L	VH	L	L	L	VH	L	VH	VH	VL
ucom	VL	L	L	L	NP	NP	VH	L	H	L	VL	H	M	L	VH	VH	VL
uindlt	VL	VL	VL	VL	NP	NP	L	M	M	L	M	L	L	VH	M	L	H
uind	VL	VL	VL	VL	NP	NP	VL	VH	L	VL	VH	VL	VL	VH	M	L	VH
upub	NP	NP	NP	NP	NP	NP	NP	L	M	M	NP	L	L	NP	NP	NP	NP
uoth	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
ubigany	H	VH	VH	VH	H	H	H	H	H	VH	M	H	VH	M	VH	VH	M
uany	VH	VH	VH	VH	M	M	VH	VH	VH	VH	VH	VH	VH	VH	VH	VH	VH
rres	L	NP	VL	M	VH	VH	L	VL	VL	M	NP	NP	VL	NP	VL	VL	VL
rcntr	H	M	M	VH	VH	VH	L	VL	M	M	L	L	L	M	M	M	L
rcom	M	L	L	M	L	L	H	L	M	L	L	L	L	M	VH	VH	VL
rind	NP	NP	NP	NP	NP	NP	L	M	M	L	H	L	L	H	L	L	M
rpub	NP	NP	NP	NP	NP	NP	NP	L	L	L	NP	NP	VL	NP	NP	NP	NP
rreserve	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
roth	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
rany	VH	H	H	VH	H	H	H	H	H	H	H	H	H	H	H	H	H
rfor	NP	NP	NP	NP	VL	VL	NP	VL	VL	NP	NP	NP	NP	VL	NP	NP	VL
ragfor	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
rag	NP	NP	NP	NP	VL	VL	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
rrange	NP	NP	NP	NP	VL	VL	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
rmine	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
xrec	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
xagfor	NP	NP	NP	NP	VL	VL	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
xcons	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
xhalo	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
xother	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
xother2	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
xwater	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
xtp	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP

Note: Compatibility measures the likelihood of each floorspace type to occur within each zoning category;
VH=Very High (1), H=High(0.8), M=Medium(0.5), L=Low(0.2), VL=Very Low(0.1), NP=Not Allowed (0)
Compatibility of ureslo and ragfor for rural residential development (RRSFD, RRMH) was downgraded after S2 calibration, to reflect current restrictions.
ALD Input file: [zoning_compatibility.csv]

Table 5.13. ALD Maximum Floor-Area-Ratios (FARs)

	FLR MH	FLR MF	FLR AT	FLR SFD	FLR RRMH	FLR RRSFD	FLR Accommodation	FLR Depot	FLR Government Support	FLR Grade-school	FLR Heavy Industry	FLR Hospital	FLR Institutional	FLR Light Industry	FLR Office	FLR Retail	FLR Warehouse
ureslo	0.2	0	0.44	0.31	0.1	0.15	0	0	0	0.3	0	0	0.3	0	0	0	0
uresmed	0.5	0.7	0.53	0.37	0.1	0.15	0	0	0	0.3	0	0	0.3	0	0	0	0
uresmdh	0.5	1	0.53	0.45	0.1	0.15	0	0	0	0.3	0	0	0.3	0	0	0	0
ureshi	0.5	2	0.53	0.6	0	0	0	0	0	0.3	0	0	0.3	0	0	0	0
umix	0.5	3	0.6	0.37	0.1	0.18	3	1	2	0.3	0.3	3	1	2	3	2	1
umixhi	0.5	5	0.7	0.6	0.1	0.18	5	1	4	0.3	0.5	3.5	4	3	10	3	1
ucom	0.5	1	0.53	0.45	0	0	3	1	2	0.3	0.3	3	0.3	2	2	1.5	1
uindlt	0.5	0.7	0.53	0.45	0	0	3	1	1.5	0.3	0.3	3	1	2	0.5	0.5	1
uind	0.5	0.7	0.53	0.45	0	0	3	1	1.5	0.3	3	3	1	2	0.5	0.5	1
upub	0	0	0	0	0	0	0	1	2	0.3	0.3	3	0.3	2	0	0	1
uoth	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ubigany	0.5	1.15	0.53	0.45	0.1	0.15	3	1	2	0.3	2	2	1	2	2	1	1
uany	0.5	0.7	0.53	0.37	0.1	0.15	2	1	2	0.3	1	2	0.3	1	0.5	0.5	1
rres	0.3	0.5	0.2	0.31	0.02	0.04	0.2	0.3	0.4	0.3	0	0	0.3	0	0.2	0.2	0.3
rcntr	0.4	0.7	0.3	0.37	0.07	0.09	0.2	0.3	0.4	0.3	1	0.5	0.3	1	1	0.2	0.3
rcom	0.4	0.7	0.3	0.3	0.07	0.09	1	0.3	0.4	0.2	1	1	0.2	0.3	0.2	0.2	0.3
rind	0	0	0	0	0	0	1	0.3	0.4	0.2	0.5	1	0.2	0.3	0.2	0.2	0.3
rpub	0	0	0	0	0	0	0	0.3	1	0.2	0	0	0.2	0	0	0	0.3
rreserve	0.1	0.15	0.1	0.05	0.07	0.01	0	0	0	0.1	0	0	0	0	0.1	0.1	0
roth	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
rany	0.3	0.5	0.2	0.31	0.07	0.09	1	0.3	1	0.2	0.5	1	0.2	0.3	0.2	0.2	0.3
rfor	0	0	0	0	0.02	0.04	0	0.3	0.4	0	0	0	0	0.3	0	0	0.3
ragfor	0	0	0	0	0.001	0.001	0	0	0	0	0	0	0	0	0	0	0
rag	0	0	0	0	0.001	0.001	0	0	0	0	0	0	0	0	0	0	0
rrange	0	0	0	0	0.001	0.001	0	0	0	0	0	0	0	0	0	0	0
rmine	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
xrec	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
xagfor	0	0	0	0	0.001	0.001	0	0	0	0	0	0	0	0	0	0	0
xcons	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
xhalo	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
xother	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
xother2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
xwater	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
xtp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

ALD Input file: [far.csv]

In the baseyear four key zoning data sources were used to develop the GIS zoning coverage:

- 1999 PNWERC for the Willamette Valley (Salem, Albany, Corvallis, Eugene),
- late 1980s DLCD for rural areas in Oregon,
- 1995 Clark County (WA) and 1993 Portland Metro zoning data,
- ESRI federal lands and reservation GIS coverage, and
- land cover data on existing protected areas, water features, and major transportation rights of way.

Initially, a zoning coverage was developed for the full study area, using LCDC in rural Oregon, ESRI protected Federal lands in rural halo, and uany or ubigany in urban areas. Forest areas in the halo not directly protected were zoned rural residential (rres). Urban areas were bound by urban growth boundaries in Oregon, urban growth area in Clark County, WA and Census Designated Places elsewhere. The dividing line between ubigany and uany is roughly a population of 10,000.

This initial coverage was updated with more detailed urban zoning data obtained from local MPOs and the PNWERC dataset. This urban layer added detailed local zoning data in the four Portland-Vancouver metropolitan area counties: Multnomah, Washington, Clackamas, and Clark County, WA. Less detailed PNWERC zoning and density information was used to provide various zoning categories within the larger cities in the Willamette Valley including: Salem, Albany, Corvallis, and Eugene. As a result of this layer, zoning in the larger urban areas was improved, while rural communities/centers and smaller Oregon and halo urban areas continue to assume a permissive zoning. Additionally, because of the mismatch between data sets, some areas along the edges of the larger cities are also zoned permissively. Major water and transportation rights-of-way from a land cover GIS data were overlaid to bar development in these locations. An adjustment was also made in the Portland Metro area to correct the zoning of protected publicly owned lands (e.g., parks, schools, cemeteries). Any publicly owned lands within the Metro area (using RLIS parcel data) that had an agriculture/forest-type GIS land coverage were rezoned as urban public (originally zoned residential). Details on GIS processing to develop the zoning and land cover datasets can be found in [10].

5.6.3. Floorspace Quantity Calibration Targets

FW Dodge purchased 1990-2000 building stock data was purchased for the 75-county study area (Oregon and Halo). Initially developed as a baseyear nonresidential floorspace estimate, but when inconsistencies were found with census activity, the FWDodge-based floorspace inventory's change in floorspace was used as a calibration target at a county level. The 12 FWDodge nonresidential building stock categories, including both vacant and occupied space, were disaggregated to the 11 floorspace types in the Oregon Statewide Integrated Model (Table 5.6) and to alpha zones, using 1998 employment estimates by industry and alpha zone (discussed in Section 6.7.1). The primary FWDodge space categories that were split using employment estimates are:

- Split of institutional and office space from FWDodge education & health space types,
- Split of light and heavy industry from FWDodge industry space types,
- Government services use of FWDodge retail space
- Split of depot space from FWDodge public and warehouse building stock, and
- Split of FWDodge DORM space among residents (90 percent of space) and employees (10 percent)[15]

[15] FWDodge's DORM space accounts for roughly 0.5 percent of total residential and 1 percent of total nonresidential building stock in the study area in 1998. The chosen approach will assume ten percent of the FWDodge dorm building stock, which includes educational residence halls and nursing homes, are institutional space used by employees. The remaining 90 percent is assumed to be (multi-family) residential space. All prisons are included in governmental support employee space, while prisoners are housed in multi-family housing. Alternate approaches considered for dealing with group quarters ranged in

Initially an artificial floorspace estimate based on employment was generated by applying floorspace consumption rates, which varied by industry and land use intensity (discussed with employment estimates in section 6.7.1). The space rates (sqft per employee), shown in Table 5.13, are based on Portland Metro data and engineering judgment with calibrating adjustments to match available FWDodge space (note that in SWIM2, Construction and Homebased Services industries do not consume floorspace). In this calibration process, government employment space consumption rates (including government use of retail space) were found to be roughly equivalent to office workers (200 sqft per employee). This is lower than expected, possibly due to 24hour-7days per week staffing of police and fire facilities, as well as a high level of mobile government workers that don't use much space. This would be expected to be offset somewhat by large public spaces (courthouses, city buildings, etc.). Land use intensity is calculated as a logged scale of combined population and employment per zone area (see discussion with employment in Section 6.7.1).

Table 5.14. Floorspace Consumption Rates (sqft per employee)

		Land Use Intensity				
PI Industry	Floorspace	VeryHigh	High	Medium	Low	DEFAULT
ACCOMMODATIONS	FLR Accomodation	690	770	850	800	800
AGRICULTURE AND MINING-Office	FLR Office	210	240	270	250	251
COMMUNICATIONS AND UTILITIES-Light Industry	FLR Light Industry	600	660	750	710	705
COMMUNICATIONS AND UTILITIES-Office	FLR Office	160	180	200	190	186
ELECTRONICS AND INSTRUMENTS-Light Industry	FLR Light Industry	560	620	750	750	747
ELECTRONICS AND INSTRUMENTS-Office	FLR Office	170	190	200	200	195
FIRE BUSINESS AND PROFESSIONAL SERVICES	FLR Office	140	150	170	160	161
FOOD PRODUCTS-Heavy Industry	FLR Heavy Industry	340	380	800	800	798
FOOD PRODUCTS-Light Industry	FLR Light Industry	560	620	1040	1040	1037
FOOD PRODUCTS-Office	FLR Office	170	190	200	200	195
GOVERNMENT ADMINISTRATION-Government Support	FLR Government Support	170	190	210	200	200
GOVERNMENT ADMINISTRATION-Office	FLR Office	170	190	200	200	195
HEALTH SERVICES-Hospital	FLR Hospital	250	250	250	250	250
HEALTH SERVICES-Institutional	FLR Institutional	200	220	240	230	225
HEALTH SERVICES-Office	FLR Office	160	180	200	190	186
HIGHER EDUCATION	FLR Institutional	200	220	240	230	225
LOWER EDUCATION-Grade School	FLR Grade-school	640	710	790	750	750
LOWER EDUCATION-Office	FLR Office	140	150	170	160	161
LUMBER AND WOOD PRODUCTS-Heavy Industry	FLR Heavy Industry	430	480	680	680	684
LUMBER AND WOOD PRODUCTS-Office	FLR Office	210	240	270	250	251
OTHER DURABLES-Heavy Industry	FLR Heavy Industry	340	380	740	740	741
OTHER DURABLES-Light Industry	FLR Light Industry	560	620	980	980	975
OTHER DURABLES-Office	FLR Office	170	190	200	200	195
OTHER NON-DURABLES-Heavy Industry	FLR Heavy Industry	340	380	800	800	798
OTHER NON-DURABLES-Light Industry	FLR Light Industry	560	620	1040	1040	1037
OTHER NON-DURABLES-Office	FLR Office	170	190	200	200	195
PERSONAL AND OTHER SERVICES AND AMUSEMENTS	FLR Office	120	140	150	140	143
PULP AND PAPER-Heavy Industry	FLR Heavy Industry	430	480	1060	1060	1064
PULP AND PAPER-Office	FLR Office	210	240	270	250	251
RETAIL TRADE-Office	FLR Office	120	140	150	140	143
RETAIL TRADE-Retail	FLR Retail	300	330	370	350	350
TRANSPORT-Depot	FLR Depot	510	570	630	600	600
TRANSPORT-Office	FLR Office	200	220	250	240	236
WHOLESALE TRADE-Office	FLR Office	170	190	200	200	195
WHOLESALE TRADE-Warehouse	FLR Warehouse	710	770	830	800	800

complexity. Simplistically, the model could be structured to ignore the residential demands of all group quarters and simply allocate employees to utilize the entire space. A second more involved method would add a new floorspace category, DORM, and a new HA household category, GroupQuarters. The floorspace would then be split among these uses, but allow more behavioral treatment than the institutional/multi-family space of the current approach.

5.6.4. MetroScope Forecast Data

In 2010, SWIM2 model runs were compared with Portland area forecast floorspace and employment as used in the MetroScope model for the Portland Metro 2009-2030 Preliminary Housing Needs Analysis report (May 2009). The results, shown in Table 5.15 indicate that the models compare favorably. Overall, SWM2 floorspace and employment are roughly 89 to 95 percent of those used in the Portland model. SWIM2 has slightly higher growth rates between 2010 and 2030, resulting in larger activity and space in 2030, particularly for nonresidential floorspace.

Table 5.15. Comparison of SWIM2-MetroScope Forecast Floorspace and Employment

MetroScope										
	sqft		sqft		CAGR	HH or Emp		HH or Emp		CAGR
NRes floorspace	2010		2030			2010		2030		
manuf sf	119,202,497	20%	161,330,222	21%	1.5%	239,875	23%	345,267	23%	1.8%
ware sf	165,542,462	27%	179,167,847	23%	0.4%	80,935	8%	96,614	7%	0.9%
retail sf	113,180,313	19%	144,785,031	19%	1.2%	277,381	27%	385,302	26%	1.7%
gen off sf	74,235,785	12%	109,481,674	14%	2.0%	215,845	21%	331,108	22%	2.2%
med sf	36,522,716	6%	52,485,557	7%	1.8%	105,158	10%	161,953	11%	2.2%
gover sf	95,611,521	16%	118,215,937	15%	1.1%	120,916	12%	155,646	11%	1.3%
	604,295,293	100%	765,466,268	100%	1.2%	1,040,110	100%	1,475,890	100%	1.8%
Res floorspace										
OSF+RSF	1,538,575,121	89%	1,993,466,115	84%						
OMF+RMF	185,163,584	11%	393,524,372	16%						
	1,723,738,705	100%	2,386,990,487	100%	1.6%	937,020		1,303,050		1.7%

SWIM2 (SCEN_2006to2040_Reference.db, 9/27/10)										
	sqft		sqft		CAGR	HH (2020) or Emp (2019)		HH or Emp		CAGR
NRes floorspace	2010		2030			2010		2030		
manuf sf	74,204,111	15%	117,480,131	14%	2.3%					
ware sf	33,350,274	7%	65,752,125	8%	3.5%					
retail sf	144,402,404	29%	237,058,678	28%	2.5%					
gen off sf	109,510,227	22%	163,824,717	19%	2.0%					
med sf	8,598,212	2%	15,957,684	2%	3.1%					
gover sf	52,602,676	11%	95,571,409	11%	3.0%					
FLR Depot (gov/ware)	56,588,529	11%	135,261,757	16%	4.5%					
FLR Institutional (gov/medical)	13,233,316	3%	23,944,951	3%	3.0%					
	492,489,749	100%	854,851,452	100%	2.8%	932,775		1,403,281	100%	2.1%
Res floorspace										
SFD (SFD+RSFD+MH+RRMH)	1,112,999,870	83%	1,642,248,039	84%						
MF (MF, AT)	230,842,213	17%	313,264,659	16%						
	1,343,842,083	100%	1,955,512,698	100%	1.9%	756,426		1,145,607		2.1%

5.7. S3 parameters

During S3 calibration, the three calibration steps using evolutionary algorithms were repeated using activity quantities, floorspace occupancy, and price data from the S2 calibrated PI module. The ALD and PI modules were then jointly run through time to determine how well the behavior of each is affecting the other. The most important behavior of ALD with respect to the rest of the model system was that it provides an appropriate amount of increase in floorspace supply in zones where the rest of the system indicates that floorspace demand is high, and little increase (or even a slight decrease) in floorspace supply in zones where the rest of the system indicates that floorspace demand is low. This appropriate response of development meeting demand was observed in initial sensitivity testing, with reasonable floorspace price increases.

The local signal for the demand for floorspace is the price of that floorspace that emerges from the PI module after PI accounts for changes in economic conditions and accessibilities. The PI module was calibrated in S2 calibration to match floorspace price distributions. No further adjustments were deemed necessary in ALD price sensitivity parameters β_{4f} and β_{6f} to ensure that over several years ALD responds with increased or decreased supply before prices reach unreasonable levels, particularly in zones where development capacity remains. Should the modelwide average prices or vacancy rates change unreasonably over time, β_{2f} and ASC_f parameters may also be adjusted.

6.0 PI Module

The Production Allocations and Interactions (PI) module[16] represents the regional economic relationships among industry, households and institutions within the model. In each period, PI takes the aggregate modelwide activity totals (1990$ of production and imports/exports) from the ED module, counts of modelwide households from the SPG1 module, the available floorspace by alpha zone from the ALD module, and travel accessibilities from the PT and TS modules and locates the various actors (industry and households), generates a set of economic flow matrices for each commodity, and determines the technology (the commodities made and used including labor and floorspace) for each activity for each beta zone. PI also determines the quantity of floorspace occupied by industry and households, given a fixed floorspace supply inventory from the ALD module.

PI labor flows are used in the SPG module to locate households (home end) and in the PT module to locate workplaces (work end). The flow of goods (including imports and exports) is used by the CT and ET modules. These uses are employed in the current year, while ALD uses PI allocation of demand in the prior two years to allocate regional construction dollars among 15 regions, and prior year vacancy rates and prices to identify the floorspace types and zonal location for such development. The EPF module (Chapter 11) makes use of the overall quality of industry operations (logsums) to influence the ED regional forecast totals in the next year. Finally, the previous year PI-generated location of activities influences current-year PI activity location decisions.

The overall approach to the allocations done in the PI module was represented diagrammatically in Figure 2.5. Commodities (columns) are produced and consumed (goods, services, labor, floorspace) both for the study area and for import and export. Economic actors (rows) (industries, government, households) separately account for import make and export use activities in addition to modelwide make and use.

6.1. Theoretical Basis

PI is an aggregate representation based on spatially-disaggregated forms of extended input-output make and use tables, with variable technical coefficients. This approach represents a specialized adaptation of a social accounting matrix. Categories of activity produce ‘commodities’ as indicated in the make table and consume these ‘commodities’ as indicated in the use table, where these ‘commodities’ include goods and services, labor and space (land and floorspace). These commodities are moved from where they are produced (in zones) to where they are consumed (in zones) in a series of connected allocations that are influenced by travel conditions and commodity prices among other factors.

For each zone there are two ‘lowest’ level PI logit allocation models for each category of commodity considered in the model. The first is an allocation of the quantities purchased among various 'exchange locations' where they are sold to other activities. The second is an allocation of the quantities sold among the various exchange locations where they are bought by other activities. The utility of each alternative in these models is influenced by

[16] The SWIM2 PI module is a pre-cursor of the ActivityAllocation (AA) half of the PECAS model [PECAS]

the commodity price at the exchange location, and the characteristics of transporting the commodity to or from the exchange location. The composite utility values from these two 'lowest-level' logit models are called the 'buying utility' and the 'selling utility' for the commodity in the zone. They are used as the transportation-related inputs into the 'middle' level logit allocation process for allocating the production and consumption of commodities by activities. The 'middle' level model essentially sets the activity's technology or mix of commodities produce (made) or consumed (used) by an activity and zone. From there, the resulting composite utilities of production and consumption are fed into the location utilities used at the 'highest-level' to allocate categories of activities (industries and households) to the land use zones.

The exchange locations are location-specific markets for commodities, where sellers sell commodities to buyers. Commodity prices are established at exchange locations 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 location in the zone they are consumed. (e.g., for labor, this occurs in the employment zone, where the labor is exchanged and the price set) or purchased in the location (zone) they are produced (e.g. for retail goods this is at the retail establishment, where the goods are exchanged and the price is set). Thus for each commodity in each zone, one of the logit allocation models (either the buying or the selling) consists of only one alternative. For land and floorspace commodities, which are non-transportable, the exchange location must equal the production and consumption locations, and so both the lowest level allocation models consist of only one alternative.

The import and export of goods commodities that are physically transported by vehicles, enter the system at six specific external exchange locations termed World Markets. The import and export quantity at each external World Market and internal exchange location are determined as functions of the exchange price in both locations, so that as prices rise more imports are attracted and as prices fall more exports are produced. The import and export functions tie the economy in the model to the rest of the world.

6.2. Quantity Definitions and Categories

PI operates at the beta zone level, although some outputs are expanded to the alpha zone level (see Figure 2.1) for use in the SPG2 and PT modules. For import and export of goods commodities, PI uses a set of 6 World Market Zones, which are allocated to 12 external stations in the CT and ET modules for TS assignment. World Markets were defined in Table 2.2 and mapped in Figures 2.3 and 2.4.

PI uses the industry and household activity categories of Tables 2.3 and 2.4 and goods, services, labor, and floorspace commodity categories defined in Tables 2.5 through 2.8. Two additional actors are used only in the PI and ED modules to complete the accounting of money flows, as discussed in section 3.2: Capitalists and Government Institutions.

6.3. Component Models

The objective of the PI module is to find a market clearing price equilibrium solution to a series of activity allocation equations, including the following components. These components are detailed in the remainder of this section.

- Production Activity allocation (modelwide)
- Production and consumption allocation (technology)
- Buying and selling allocation (to exchange locations)
- Imports and exports
- Floorspace Imports
- Equilibrium Solution
- P-Processor Integration

6.3.1. Production Activity Allocation

The 'highest' level PI allocation model allocates activities to zones consistent with the 'middle' level technology assumptions (Section 6.3.2) and 'lowest' level's transportation assumptions (Section 6.3.3). The modelwide total quantity of production activity for each activity category is input to the PI module, per outputs from the ED (industry$) and SPG (households) modules. This amount is allocated in the 'highest' level model among the Beta zones using a logit allocation as follows. The utility is sensitive to the composite utilities (CUProd and CUCons) from the 'middle' level PI module (see Section 6.3.2):

$$W_{a,z} = TW_a \cdot (\exp (\lambda_a \cdot LU_{a,z}) / \Sigma_{z \in Z} (\exp (\lambda_a \cdot LU_{a,z}))) \qquad (6.01)$$

with:

$$LU_{a,z} = \alpha_{size,a} \cdot 1/\lambda_a \cdot \ln[Size_{a,z}] + \alpha_{inertia,a} \cdot \ln (PrevW_{a,z} + InertiaConst_a) + Constant_{a,z} + \Sigma_{v \in V} (\alpha_{a,v} \cdot X_{v,z}) + \alpha_{prod,a} \cdot CUProd_{a,z} + \alpha_{cons,a} \cdot CUCons_{a,z} \qquad (6.02)$$

where:

z	=	index representing land use zones; *PecasZonesI[ZoneNumber]*
Z	=	the set of all land use zones;
a	=	index representing activity categories; *ActivitiesI[Activity]*
c	=	index representing commodity categories; *CommoditiesI [Commodity]*
$W_{a,z}$	=	quantity of activity a in zone z; *ActivityLocations[Quantity]* (from previous year PI output)
TW_a	=	modelwide total quantity of activity a; *ActivitiesI[Size]* (from ED and SPG module outputs)
$LU_{a,z}$	=	location utility for a unit of activity a in zone z; *ActivityLocations[LocationUtility]*
$Size_{a,z}$	=	representation of relative size of zone z for activity a, indicating the *a priori* expected share of production activity a for zone z; *ActivityZonalValuesI[SizeTerm]*
$PrevW_{a,z}$	=	the proportion of modelwide quantity of production activity a in zone z in the previous time period; *baseyear in ActivityZonalValuesI[InitialQuantity]*
v	=	index representing 'other' zonal attributes;
V	=	the set of all 'other' zonal attributes; (not currently implemented)
$X_{v,z}$	=	one of the 'other' zonal attributes;
$CUProd_{a,z}$	=	composite utility associated with production by activity a in zone z, defined in equation 6.08 and discussed below; *ActivityLocations[ProductionUtility]*
$CUCons_{a,z}$	=	composite utility associated with consumption by activity a in zone z, defined in equation 6.09 and discussed below;

ActivityLocations[ConsumptionUtility]

$\alpha_{size,a}$ = utility function coefficient for the sensitivity to size for activity a; *ActivitiesI[SizeTermCoefficient]*

$\alpha_{inertia,a}$ = utility function coefficient for the sensitivity to the previous proportion of activity a in zone z, representing inertia in allocation of activity a; *ActivitiesI[InertiaTermCoefficient]*

$InertiaConst_a$ = coefficient modifying the sensitivity to the previous portion of activity a in zones, that reduces the importance of the quantity when the previous quantity is small; *ActivitiesI[InertiaTermConstant]*

$\alpha_{a,v}$ = utility function coefficient for the sensitivity to the 'other' zonal attribute $X_{v,z}$;

$Constant_{a,z}$ = utility function alternative specific constant for zone z for allocation of activity a; *ActivityZonalValuesI[ZoneConstant];*

$\alpha_{prod,a}$ = utility function coefficient for the sensitivity to composite utility associated with production for activity a; *ActivitiesI[ProductionUtilityScaling]*

$\alpha_{cons,a}$ = utility function coefficient for the sensitivity to composite utility associated with consumption for activity a; *ActivitiesI[ConsumptionUtilityScaling]*

λ_a = utility function dispersion parameter for allocation of activity a. *ActivitiesI[Location DispersionParameter]*

$\alpha_{size,a} \cdot 1/\lambda_a \cdot \ln [Size_{a,z}]$ = size effect in utility function, to account for larger zones acquiring a l arger share, all other things being equal; *ActivityLocations[SizeUtility]*

The 'other' zonal attributes, $X_{v,z}$ in Eq. 6.02, not yet implemented, would vary depending on the production activity being allocated. For residential activities, these 'other' attributes could include representations of various amenities relevant to housing location choice, including school quality, general noise levels, air quality, open space density, municipal taxation levels and possibly zonal-level income distributions and racial compositions.

The floorspace allocation size term $Size_{a,z}$ in Equation 6.02 are calculated based on the current year floorspace inventory from the ALD module. The total amount of floorspace in all relevant categories is summed to give the size term. Table 2.1 showed the category of space relevant to each industry activity (one-to-one mapping). A ll six residential floorspace types (Table 2.6) are relevant to each household category.

The modelwide location composite utility for a given activity category, the basis for assessing the changes in modelwide consumer surplus by production activity, is determined consistent with equations 6.01 and 6.02 as follows:

$$CLU_a = (1/\lambda_a) \cdot \ln (\Sigma_{z \in Z} \exp (\lambda_a \cdot LU_{a,z})) \qquad (6.03)$$

where:

CLU_a = modelwide location composite for a unit of activity a. *ActivitySummary[OverallUtility]output*

Changes in CLU_a for a given activity category can be used to calculate measures of the changes in consumer benefit for the activity category arising with the policy actions input to the model. These measures can help assess quality of life and business attractiveness for different household and industrial categories as represented.

This composite utility of location decisions by households and industry are used by the EPF model, when operational, in the next period to influence modelwide economic activity forecasts by industry sector in the next model period (see Chapter 11). A future upgrade to the ED module could implement this term as an explanatory variable directly in the ED functional form.

6.3.2. Production and Consumption Allocation (Technology)

The 'middle' level PI logit allocation models allocate the amount of production (make) and consumption (use) by each activity in each zone. This essentially sets the activity's technology or mix of commodities made/used.

The make and use technical coefficients indicating the rates at which activities produce and consume commodities are elastic, representing opportunities for substitution (between inputs in consumption and between by-products in production), as follows. For commodities with fixed technical coefficients (per Figure 2.6), the second discretionary term will be zero. Currently industries are allowed substitution of labor and floorspace commodities:

$$M_{c,a,z} = MMin_{c,a} + MDisc_{c,a} \cdot (\exp(\lambda_{m,a} \cdot UIProd_{c,a,z}) / (\Sigma_{c\in C} \exp(\lambda_{m,a} \cdot UIProd_{c,a,z}) + \exp(\lambda_{m,a} \cdot U_{nmp}))) \quad (6.04)$$

with:

$$UIProd_{c,a,z} = MDisc_{c,a} \cdot CUSell_{c,a,z} \quad (6.05)$$

and

$$U_{c,a,z} = UMin_{c,a} + UDisc_{c,a} \cdot (\exp(\lambda_{u,a} \cdot UICons_{c,a,z}) / (\Sigma_{c\in C} \exp(\lambda_{u,a} \cdot UICons_{c,a,z}) + \exp(\lambda_{u,a} * U_{nmc}))) \quad (6.06)$$

with:

$$UICons_{c,a,z} = UDisc_{c,a} \cdot CUBuy_{c,a,z} \quad (6.07)$$

where:

c	=	index representing commodity category
C	=	set of all commodity categories
$M_{c,a,z}$	=	make technical coefficient for production of commodity c by activity a in zone z, indicating the quantity of commodity c produced per unit of activity a; *ZonalMakeUse[Coefficient] where [MorU]='M'*
$U_{c,a,z}$	=	use technical coefficient for consumption of commodity c by activity a in zone z, indicating the quantity of commodity c consumed per unit of activity a; *ZonalMakeUse[Coefficient] where [MorU]='U'*
$UIProd_{c,a,z}$	=	utility of producing the potential discretionary amount of commodity c associated with a unit of activity a in zone z
$UICons_{c,a,z}$	=	utility of consuming the potential discretionary amount of commodity c associated with a unit of activity a in zone z
$MMin_{c,a}$	=	minimum amount of commodity c made per unit of activity a; *MakeUseI[Minimum] where [MorU]='M'*
$MDisc_{c,a}$	=	potential discretionary amount of commodity c made per unit of activity a; *MakeUseI[Discretionary] where [MorU]='M'*

$UMin_{c,a}$ = minimum amount of commodity c used per unit of activity a; *MakeUseI[Minimum] where [MorU]='U'*

$UDisc_{c,a}$ = potential discretionary amount of commodity c used per unit of activity a; *MakeUseI[Discretionary] where [MorU]='U'*

$CUSell_{c,a,z}$ = composite utility associated with selling a unit of commodity c produced by activity a in zone z; *ActivityLocations[ProductionUtility]*

$CUBuy_{c,a,z}$ = composite utility associated with buying a unit of commodity c consumed by activity a in zone z; *ActivityLocations[ConsumptionUtility]*

U_{nmp} = utility of non-modeled production; *ActivitiesI[UtilityOfNonModelledProduction] or -∞ if ActivitiesI[NonModeledProduction] is false*

U_{nmc} = utility of non-modeled consumption *ActivitiesI[UtilityOfNonModeledConsumption] or -∞ if ActivitiesI[NonModeledConsumption] is false*

$\lambda_{m,a}$ = utility function dispersion parameter for allocation of by-product substitutes made by activity a; *ActivitiesI[ProductionSubstitutionNesting]*

$\lambda_{u,a}$ = utility function dispersion parameter for allocation of input substitutes used by activity a. *ActivitiesI[ConsumptionSubstitutionNesting]*

The composite utilities associated with production (accessibility to commodity markets) and consumption (accessibility to commodity inputs) by activity a in zone z, as used in the 'higher' PI allocation model of activity location (Equation 6.02 above), are as follows:

$$CUProd_{a,z} = \left(\Sigma_{c\in C}\, MMin_{c,a} \cdot CUSell_{c,a,z} \right) + \left(1 / \lambda_{m,a} \right) \cdot \ln \left[\Sigma_{c\in C} \exp\left(\lambda_{m,a} \cdot UIProd_{c,a,z} \right) + \exp(\lambda_{m,a} \cdot U_{nmp}) \right] \quad (6.08)$$

and

$$CUCons_{a,z} = \left(\Sigma_{c\in C}\, UMin_{c,a} \cdot CUBuy_{c,a,z} \right) + \left(1 / \lambda_{u,a} \right) \cdot \ln \left[\Sigma_{c\in C} \exp\left(\lambda_{u,a} \cdot UICons_{c,a,z} \right) + \exp(\lambda_{u,a} \cdot U_{nmc}) \right] \quad (6.09)$$

These composite utilities weight the accessibilities for buying and selling individual commodities consistently with the production and consumption (technology) options for the activity. The 'higher' PI logit allocation model's location utility (Equation 6.02) for an activity that consumes a large amount of a commodity will be strongly influenced by the 'middle' level PI composite utility of buying that commodity, and the location utility of an activity that produces a large amount will be strongly influenced by the 'middle' level PI composite utility of selling. As such, the last two terms in the activity location utility of Equation 6.02 provide overall indications of the accessibility of the zone for the activity consistent with the technology of the production process for the activity.

6.3.3. Buying and Selling Allocation

This section covers the two 'lowest' level PI logit allocation models in each Beta Zone for each category of commodity considered: (1) an allocation of the quantities purchased among various 'exchange locations' where they are sold to other activities; and (2) an allocation of the quantities sold among the various exchange locations where they are bought by other activities. The utility of each alternative in these models is influenced by the commodity price at the exchange location and the characteristics of transporting the commodity to/from the exchange location.

The total quantities of commodities produced and consumed by each activity in each zone are calculated using the technical coefficients ($M_{c,a,z}$ and $U_{c,a,z}$) from the middle' PI technology model (Section 6.3.2) and the zonal activity ($W_{a,z}$) located in that zone from the 'highest' PI allocation activity model (Section 6.3.1), as follows:

$$TP_{c,z} = \Sigma_{a\in A} M_{c,a,z} \cdot W_{a,z} \quad (6.10)$$

and

$$TC_{c,z} = \Sigma_{a\in A} U_{c,a,z} \cdot W_{a,z} \quad (6.11)$$

where:

a = index representing activity category

A = set of all activity categories

$W_{a,z}$ = quantity of activity a in zone z; *ActivityLocations[Quantity]* (Eq. 6.01)

$M_{c,a,z}$ $U_{c,a,z}$ = Make and Use technical coefficients (Eq. 6.04 and 6.06)

$TP_{c,z}$ = total quantity of commodity c produced in zone z. *ExchangeResults[Supply]*.

$TC_{c,z}$ = total quantity of commodity c consumed in zone z. *ExchangeResults[Demand]*.

The total quantity of each commodity produced by production activities in a given zone is allocated among exchange locations (where it is sold) as follows:

$$S_{c,z,k} = TP_{c,z} \cdot (\exp (\lambda_{s,c} \cdot SU_{c,z,k}) / \Sigma_{k\in K} \exp (\lambda_{s,c} \cdot SU_{c,z,k})) \quad (6.12)$$

with:

$$SU_{c,z,k} = (1/\lambda_{s,c}) \cdot \delta_{size,s} \cdot \ln[Size_{s,c,k}] + \delta_{price,s} \cdot Price_{c,k} + \delta_{\square ran,s} \cdot Tran_{c,z,k} \quad (6.13)$$

where:

k = index representing exchange locations (Beta zones);

K = set of all exchange locations;

$S_{c,z,k}$ = quantity of commodity c produced in zone z that is allocated to (go to) exchange location k; *selling_$commodity.zmx*

$SU_{c,z,k}$ = utility for selling to exchange location k a unit of commodity c produced in zone z;

$Size_{s,c,k}$ = representation of relative size of exchange location k for selling commodity c, indicating the *a priori* expected share of commodity c sold in exchange location k; *ExchangeImportExportI[SellingSize]*

$Price_{c,k}$ = unit exchange price for commodity c in exchange location k; *ExchangeResults[Price]*

$Tran_{c,z,k}$ = utility for transporting a unit of commodity c from zone z to exchange location k when selling, calculated in equation 6.20;

$\delta_{\square ize,s}$ = utility function coefficient for the sensitivity to size when selling; *CommoditiesI[SellingSizeCoefficient]*

$\delta_{\square ran,s}$ = utility function coefficient for the sensitivity to transport utility when selling; *CommoditiesI[SellingTransportCoefficient]*

$\lambda_{s,c}$ = utility function dispersion parameter for allocation of selling of commodity c. *CommoditiesI[SellingDispersionParameter]*

In the case of selling, the coefficient $\delta_{price,s}$ is positive.

The transport-related composite utility for selling commodity c from all producers in zone z (independent of the producing activity) is determined consistent with equations 6.12 and 6.13, as follows:

$$CUSell_{c,z} = (1/\lambda_{s,c}) \cdot \ln(\Sigma_{k \in K} \exp(\lambda_{s,c} \cdot SU_{c,z,k})) \quad (6.14)$$

The selling composite utility for commodity c in zone z when produced by activity a in particular, as used in equations 6.05 and 6.08, is then established as follows:

$$CUSell_{c,a,z} = \phi_{s,c,a} \cdot CUSell_{c,z} + USellRef_{c,a} \quad (6.15)$$

where:

$\phi_{s,c,a}$ = factor adjustment to the composite utility of selling commodity c by activity a; *MakeUseI[UtilityScale] where [MorU]='M'*

$USellRef_{c,a}$ = offset adjustment to the composite utility of selling commodity c by activity a. *MakeUseI[UtilityOffset] where [MorU]='M'*

The scaling ($\phi_{s,c,a}$) and offset adjustments ($USellRef_{c,a}$) have been found useful in calibration to adjust the effect of individual buying and selling composite utilities on production utilities and thus on location utilities (usually remove by setting $\phi_{s,c,a}$ to zero).

The allocation of quantities consumed in the exchange zones where they are purchased is analogous to the allocation of quantities produced as described above. Specifically, the total quantity of each commodity consumed by a production activity in a given zone is allocated among exchange locations (where it is bought) as follows:

$$B_{c,z,k} = TC_{c,z} \cdot (\exp(\lambda_{b,c} \cdot BU_{c,z,k}) / \Sigma_{k \in K} \exp(\lambda_{b,c} \cdot BU_{c,z,k})) \quad (6.16)$$

with:

$$BU_{c,z,k} = (1/\lambda_{b,c}) \; \delta_{size,b} \cdot \ln[Size_{b,c,k}] + \delta_{price,b} \cdot Price_{c,k} + \delta_{tran,b} \cdot Tran_{c,k,z} \quad (6.17)$$

where:

$B_{c,z,k}$ = quantity of commodity c consumed in zone z that is allocated to (come from) exchange location k; *Buying_$commodity.zmx*

$BU_{c,z,k}$ = utility for buying from exchange location k a unit of commodity c consumed in zone z;

$Size_{b,c,k}$ = representation of relative size of exchange location k for buying commodity c, indicating the *a priori* expected share of commodity c bought in exchange location k; *ExchangeImportExportI[BuyingSize]*

$Price_{c,k}$ = price of a unit of commodity c in exchange location k;

$Tran_{c,k,z}$ = utility for transporting a unit of commodity c from exchange location k to zone z, calculated in equation 6.20;

$\delta_{size,b}$ = utility function coefficient for the sensitivity to size when buying; *CommoditiesI[BuyingSizeCoefficient]*

$\delta_{price,b}$ = utility function coefficient for the sensitivity to price when buying; *CommoditiesI[BuyingPriceCoefficient]*

$\delta_{tran,b}$ = utility function coefficient for the sensitivity to transport utility when buying; *CommoditiesI[BuyingTransportCoefficient]*

$\lambda_{b,c}$ = utility function dispersion parameter for allocation of buying of commodity c. *CommoditiesI[BuyingDispersionParameter]*

In the case of buying, the coefficient $\delta_{price,b}$ is negative.

The transport-related composite utility for buying commodity c from all buyers in zone z (independent of the consuming activity) is determined consistent with equations 6.12 and 6.13, as follows:

$$CUBuy_{c,z} = (1/\lambda_{b,c}) \cdot \ln\left(\Sigma_{k \in K} \exp(\lambda_{b,c} \cdot BU_{c,z,k})\right) \quad (6.18)$$

The buying composite utility for commodity c when consumed by activity a in particular, as used in equations 6.07 and 6.09, is then established as follows:

$$CUBuy_{c,a,z} = \phi_{b,c,a} \cdot CUBuy_{c,z} + UBuyRef_{c,a} \quad (6.19)$$

where:

$\phi_{b,c,a}$ = factor adjustment to the composite utility of buying commodity c by activity a; *MakeUseI[UtilityScale] where [MorU]='U'*

$UBuyRef_{c,a}$ = offset adjustment to the composite utility of buying commodity c by activity a. *MakeUseI[UtilityOffset] where [MorU]='U'*

The utility for transporting a unit of commodity c from any zone j to any zone k, $Tran_{c,j,k}$, is calculated from up to three transport-related interchange attribute values (output by the PT and TS modules) as follows:

$$Tran_{c,j,k} = \kappa_{c,1} \cdot IntAtt_{1,j,k} + \kappa_{c,2} \cdot IntAtt_{2,j,k} + \kappa_{c,3} \cdot IntAtt_{3,j,k} \quad (6.20)$$

where:

$IntAtt_{1,j,k}$ = value for attribute 1 (skim name) from zone j to zone k used to calculate the utility for transporting a unit of commodity c; *CommoditiesI[InterchangeName1]*

$IntAtt_{2,j,k}$ = value for attribute 2 (skim name) from zone j to zone k used to calculate the utility for transporting a unit of commodity c; *CommoditiesI[InterchangeName2]*

$IntAtt_{3,j,k}$ = value for attribute 3 (skim name) from zone j to zone k used to calculate the utility for transporting a unit of commodity c; *CommoditiesI[InterchangeName3]*

$\kappa_{c,1}$ = utility function coefficient for the sensitivity to attribute 1 when transporting a unit of commodity c; *CommoditiesI[InterchangeCoefficient1]*

$\kappa_{c,2}$ = utility function coefficient for the sensitivity to attribute 2 when transporting a unit of commodity c; *CommoditiesI[InterchangeCoefficient2]*

$\kappa_{c,3}$ = utility function coefficient for the sensitivity to attribute 3 when transporting a unit of commodity c; *CommoditiesI[InterchangeCoefficient3]*

An 'exchange regime' is specified for each commodity c. This exchange regime indicates the spatial nature of the exchanges available for the commodity. For example, some commodities are only exchanged where they are produced – and thus the exchange zone must be the zone of production. The exchange regime for each commodity c is designated using single-letter code, as follows:

CommoditiesI[ExchangeType]

- 'c' = exchanged only in consumption zones (where the seller pays transport costs);
- 'p' = exchanged only in production zones (where the buyer does all

transporting);

‘a’ = exchanged in any zone (where both buyer and seller share transport costs);

‘n’ = non-transportable (where the commodity is consumed in the same zone where it is produced);

‘s’ = exchanged only in specified zones (both buyer and seller share transport costs, but exchanges occur in only certain zones). *ExchangeImportExport[SpecifiedExchange]=’TRUE’ for zones where exchanges occur.*

In the SWIM2 module, the following transport-related travel attributes ($IntAtt_{\#,j,k}$) are used as defaults (exchange type ‘s’ is not currently used.):

- For labor flows/commuting, mode choice logsums from the prior-year PT module is used. Labor is consider exchange type ‘c.’
- For goods commodities, TS prior-year skim output of distance, time, and tolls are used. All goods are considered exchange type ‘p.’
- Floorspace has no transport attributes and is considered exchange type ‘n.’

6.3.4. Imports and Exports

The quantities of imports and exports for a given commodity in a given exchange zone are determined using:

$$Q_{c,i,k} = QRef_{c,i} + \Delta_{c,i} \cdot ([G_i-1]/[G_i+1]) + \mu_{c,i} \cdot (Price_{c,k} - PriceRef_{c,i}) \quad (6.21)$$

and

$$Q_{c,e,k} = QRef_{c,e} + \Delta_{c,e} \cdot ([G_e-1]/[G_e+1]) + \mu_{c,e} \cdot (Price_{c,k} - PriceRef_{c,e}) \quad (6.22)$$

with:

$$G_i = \exp (\eta_{c,i} \cdot (Price_{c,k} - PriceRef_{c,i})) \quad (6.23)$$

and

$$G_e = \exp (\eta_{c,e} \cdot (Price_{c,k} - PriceRef_{c,e})) \quad (6.24)$$

where:

$Q_{c,i,k}$ = quantity of commodity c imported to exchange location k; *ExchangeResults[Imports]*

$Q_{c,e,k}$ = quantity of commodity c exported from exchange location k; *ExchangeResults[Exports]*

$QRef_{c,i}$ = quantity of commodity c imported to exchange location when the unit exchange price for commodity c in exchange zone k is at its import reference level $PriceRef_{c,i}$; *ExchangeImportExport[ImportFunctionMidpoint]*

$QRef_{c,e}$ = quantity of commodity c exported from exchange location when the unit exchange price for commodity c in exchange zone k is at its export reference level $PriceRef_{c,e}$; *ExchangeImportExportI[ExportFunctionMidpoint]*

$PriceRef_{c,i}$ = reference price per unit for import of commodity c; *ExchangeImportExportI[ImportFunctionMidpointPrice]*(from Equation

6.25 for floorspace)

$PriceRef_{c,e}$	=	reference price per unit for export of commodity c; *ExchangeImportExportI[ExportFunctionMidpointPrice]*
$Price_{c,k}$	=	unit exchange price for commodity c in exchange location k (Equation 13); *ExchangeResults[Price]*
$\Delta_{c,i}$	=	function coefficient for the rate of increase in imports of commodity c for exponent term; *ExchangeImportExportI[ImportFunctionDelta]*
$\mu_{c,i}$	=	function coefficient for the rate of increase in imports of commodity c for linear term; *ExchangeImportExportI[ImportFunctionSlope]*
$\eta_{c,i}$	=	function coefficient for sensitivity to difference in exchange price for commodity c concerning increase in imports of commodity c for exponent term; *ExchangeImportExportI[ImportFunctionEta]*
$\Delta_{c,e}$	=	function coefficient for the rate of increase in exports of commodity c for exponent term; *ExchangeImportExportI[ExportFunctionDelta]*
$\mu_{c,e}$	=	function coefficient for the rate of increase in exports of commodity c for linear term; *ExchangeImportExportI[ExportFunctionSlope]*
$\eta_{c,e}$	=	function coefficient for sensitivity to difference in exchange price for commodity c concerning increase in exports of commodity c for exponent term. *ExchangeImportExportI[ExportFunctionEta]*

In the case of imports, the coefficient $\Delta_{c,i}$ is positive and the coefficient $\mu_{c,i}$ is positive provided $\eta_{c,i}$ is positive. In the case of exports, the coefficient $\Delta_{c,e}$ is negative and the coefficient $\mu_{c,e}$ is negative provided $\eta_{c,e}$ is positive.

6.3.5. Floorspace Imports

The supply of floorspace in each zone by floorspace type is treated as an 'import.' Floorspace is not a true import, but can be treated as an import in the sense that it has a fixed short-term supply calculated separately in the ALD module. Short-term floorspace import functions in the form of equation 6.21 are generated internally by PI based on the fixed short-term inventory of physical space established by ALD.

Floorspace import functions are used to calculate demand for floorspace by the activity in each zone considering the physical amount of floorspace inventory reported in ALD. Each floorspace import function is a short-term supply curve for floorspace of a single type, and represents the tendency for portions of available floorspace inventory to be left vacant in the short-term if prices are too low. (The floorspace is supplied by landlords whose short-term behavior is represented using the same equations that are used to calculate the imports of other commodities, as shown in Section 6.3.4.) The price-vacancy relationship used is shown in Figure 6.1:

Figure 6.1. Floorspace Import Function

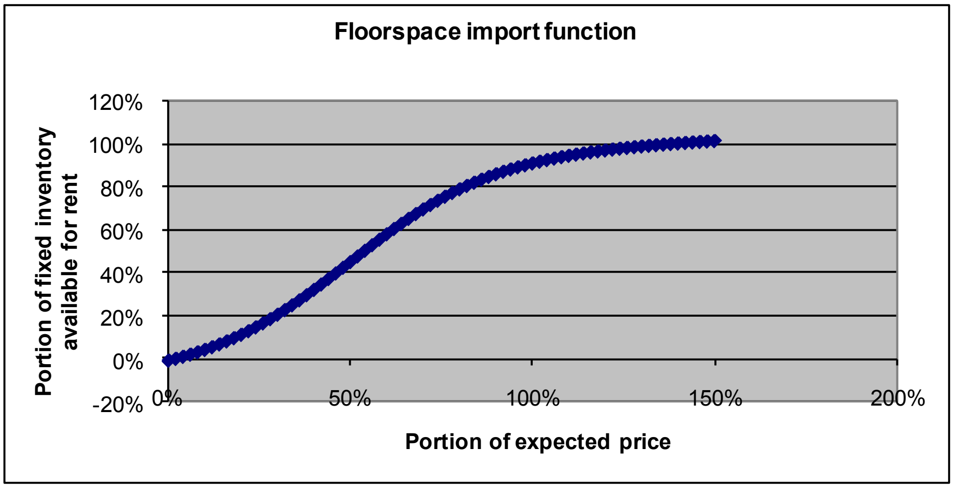


Figure 6.1 shows that at the expected price (100% on the x-axis), over 90 percent of the available floorspace will be used (10% vacant); as prices decline more and more of the space will be left vacant; if prices were to reach zero all available floorspace supply would be utilized (0% vacant). The chosen logistic representation of the import curve allows the amount of floorspace used in a zone to exceed 100 percent of the fixed short-term supply at very high prices (and drop below 0 percent at negative prices) in order to allow the search procedure to find for more reasonable prices during PI's own price search iterations.

The following floorspace-specific import equations are used in the PI import function (in place of the more general Eqs. 6.22 through 6.24 used by all other imports found in Section 6.3.4):

$$PriceRef_c = \alpha_{Price,f} \cdot FLRPriceRef_f \tag{6.25}$$

$$QRef_c = \alpha_{Qty,f} \cdot FLRQtyRef_f \tag{6.26}$$

$$\Delta_c = \alpha_{\Delta,f} \cdot FLRQtyRef_f \tag{6.27}$$

$$\eta_c = \alpha_{\eta,f} / FLRPriceRef_f \tag{6.28}$$

$$\mu_c = (\alpha_{\lambda,f} / FLRPriceRef_f) \cdot FLRQtyRef_f \tag{6.29}$$

where:

f = index of floorspace categories

$FLRPriceRef_f$ = commodity-specific annual price ($/Msqft) for (imported) floorspace type f *CommoditiesI.csv[ExpectedPrice]* (also used as a starting price for zones with no starting price)

$FLRQtyRef_f$ = current year quantity of (imported) floorspace of type f *FloorspaceI.csv[BldgMSQFT]*

$\alpha_{Price,f}$ $\alpha_{Qty,f}$, $\alpha_{\Delta,f}$, $\alpha_{\eta,f}$, $\alpha_{\lambda,f}$ = floorspace-specific parameters to be adjusted in calibration. *FloorspaceSupplyI.csv [FOPrice], [MidpointPrice], [FDelta], [Feta], [FSlope]*

6.3.6. Equilibrium Solution

The quantities of each commodity being bought and sold in each exchange zone by the activities in the model area (not imports or exports)are calculated as a sum of the buying and selling quantities solved for in the PI 'middle' technology model (see Section 6.3.2), as follows:

$$TBD_{c,k} = \Sigma_{z \varepsilon Z} \; B_{c,z,k} \qquad (6.30)$$

and

$$TSD_{c,k} = \Sigma_{z \varepsilon Z} \; S_{c,k,z} \qquad (6.31)$$

where:

c = index of commodity

k, z = index of zones, when paired indicate origin, destination zone

Z = set of all model zones

$B_{c,z,k}$ = quantity of commodity c consumed in zone z that is allocated to (come from) exchange location k; *Buying_$commodity.zmx*(Equation 6.16)

$S_{c,k,z}$ = quantity of commodity c produced in zone z that is allocated to (go to exchange location k; *Selling_$commodity.zmx*(Equation 6.12)

$TBD_{c,k}$ = total quantity of commodity c being bought in exchange zone k b y all activities in the model area; *ExchangeResults[InternalBought]*

$TSD_{c,k}$ = total quantity of commodity c being sold in exchange zone k b y all activities in the model area; *ExchangeResults[InternalSold]*

The quantities of each commodity being bought and sold in each exchange zone in total (by the activities in the model area as well as imports and exports) – also called the aggregate demand and aggregate supply for commodity c in exchange zone k – are calculated as follows:

$$TDem_{c,k} = Q_{c,i,k} \cdot \square\square\square\square\square\square \Sigma_{z \varepsilon Z} \; B_{c,z,k} \qquad (6.32)$$

$$TSup_{c,k} = Q_{c,e,k} \square\square\square\square\square\square \cdot \square\square\square\square\square\square \Sigma_{z \varepsilon Z} \; S_{c,k,z,} \qquad (6.33)$$

where:

$TDem_{c,k}$ = aggregate demand for commodity c in exchange zone k by all activities in the model area;

$TSup_{c,k}$ = aggregate supply for commodity c in exchange zone k by all activities in the model area;

$Q_{c,i,k}$ = quantity of commodity c imported to exchange location k; *ExchangeResults[Imports]* (Equation 6.21)

$Q_{c,e,k}$ = quantity of commodity c exported from exchange location k; *ExchangeResults[Exports]* (Equation 6.22)

At convergence these bought and sold amounts in a given zone, $TDem_{c,k}$ and $TSup_{c,k}$ are equal. T his amount is also the referred to as the 'exchange quantity' for the commodity in the zone:

$$TE_{c,k} = TDem_{c,k} = TSup_{c,k} \qquad (6.34)$$

where:

$TE_{c,k}$ = exchange quantity for commodity c in exchange zone k.

Since PI solves the system using numerical methods, equation 6.34 is not solved exactly, but within a certain convergence tolerance. The residual commodity amount, $TSup_{c,k} - TDem_{c,k}$ is reported as output to allow user checks for appropriate convergence tolerance. *ExchangeResults[Surplus].*

At convergence, the PI model provides the following at the Beta zone level prior to post-processing of some results to the Alpha zone level (see Section 6.3.7):

- consistent (household and industry$) activity allocations by activity category by zone;
- commodity flow quantities from production zone to consumption zone via exchange zone;
- imports and exports by exchange zone; and
- exchange prices by commodity by exchange zone.

6.3.7. P-Processor Integration

To facilitate PI's interaction with other SWIM2 modules, a PI p-processor is used to both create PI input files and post-process PI output files into the appropriate format.

The PI pre-processor produces the following files used as working inputs to PI. These files pull data from other SWIM2 modules and previous year PI outputs:

- Current year modelwide activities in *ActivitiesW.csv[size]* field are culled from:
  - a base file *ActivitiesI.csv*, ED module industry/institution production activity in 1990$ *ActivityDollarDataForPI.csv[factor]*
  - SPG1 module household counts *householdsByHHCategory.csv [spg1Households]*
  - Modelwide Imports and Exports for goods commodities are calculated from the above plus exogenous fixed regional purchase coefficients in the *ImportShareByCommodity.csv* file.
- Current year fixed floorspace inventory in *FloorspaceW.csv* file, updates the current year ALD module floorspace output *FloorspaceI.csv* with fixed production-based quantities of agriculture and forest lands (in acres) found in the *PIAgForestFloorspace.csv* file (see Section 6.6.3).
- Zone-specific size terms *ActivitiesZonalValuesW.csv[InitialQuantity]* come from:
  - a base file *ActivitiesZonalValuesI.csv*,
  - ALD output current year construction activity *Increments.csv[IncMSQFT]*
  - previous year PI zonal activity output *ActivityLocations.csv[Quantity]* for non-construction activities
- Current year technical coefficients *MakeUseW.csv[Minimum] and [Discretionary]* are culled from base file *MakeUseI.csv* with adjustments made to industry labor use. No adjustment is made in the reference year 1998, but other years' industry labor use rates are scaled based on the SPG to ED HHs per employees, relative to the 1998 reference year ratios (found in *GlobalTemplate.properties [pi.98.productivity.rate]).*

Selected PI outputs (Table 6.12) are also disaggregated to the Alpha zone level by the PI post-processor for use in other SWIM2 modules. Several of these PI p-processor activities are detailed below.

Alpha Zone Activity and Commodity Totals

PI works at the beta zone level, and allocates modelwide activity to beta zones. The PI post- processor knows the distribution of floorspace by alpha zone from the ALD module. By assuming that, at the disaggregate level, individual units of an activity (e.g., the space required for an individual worker) only use a single floorspace type, the PI output beta zone activity totals can be allocated to alpha zones. The following formulation is used to produce alpha zone activity levels *[ActivityLocations2.csv]*:[17]

$$W_{a,\alpha} = W_{a,z} * \Sigma_{f\in F} (U_{f,a,z}/\Sigma_{f1\in F}(U_{f1,a,z})) * FLR_{f,\alpha}/\Sigma_{\alpha 1\in z}FLR_{f,\alpha 1} \quad (6.35)$$

where:

$W_{a,\alpha}$	=	amount of activity a in alpha zone α, *ActivityLocations2.csv[Quantity]*
$W_{a,z}$	=	amount of activity a in beta zone z, *ActivityLocations.csv[Quantity]*
$U_{f,a,z}$	=	amount of floorspace commodity f consumed per unit of activity a in beta zone z, *MakeUseW[marginal] and [discretionary]*
F	=	set of floorspace types used by activity a in beta zone z
$FLR_{f,\alpha}$	=	amount of floorspace type f in α-zone α, *FloorspaceW.csv[BldgMSQFT]*
$\alpha 1\in z$	=	set of α-zones located in beta zone z, *FloorspaceZonesI.csv*.

Labor Flow Marginals

In other SWIM2 modules, PI labor flows at the beta zone are used to assign home location (SPG2) and workplace (PT). The flows are expanded to alpha zone flows in the respective modules using PI-generated alpha zone labor flow marginals. These marginals are generated by the PI post-processor essentially expanding the PI beta zone labor production (at the home end) and consumption (at the workplace end) vectors to alpha zones. To do so, PI first expands the overall activity values into alpha zones (Eq.6.35 for *ActivityLocations2.csv*) and then applies the PI output technical coefficients (*MakeUseW.csv*) to these values. The technical coefficients are assumed to be equivalent for all alpha zones within a beta zone. T he results are used in the PT module's Workplace Location Choice model (*LaborDollarProductionSum.csv* and *LaborDollarConsumptionSum.csv* by occupation and household category) and SPG2 module's Household Home Zone Assignment module (*LaborDollarProduction.csv LaborDollarConsumption.csv* by occupation) in the current year. Labor consumption is summed across occupation and industry categories while labor production is summed across occupation and household categories. The 'sum' versions of the files used by PT, are only categorized by occupation for production and consumption.

Additional adjustments to PI inputs are noted below:

Scaled Labor Use Coefficients

Due to social and technological changes between 1990 and 2000, labor production per household has increased since 1990 inputs (e.g., increased women participation in the workforce), while labor consumption per industry activity (e.g., rising labor productivity) decreased. To address this net effect in the PI module, the initially assumed fixed labor use coefficients, are dynamically scaled relative to a 1998 baseyear productivity (source of initial IMPLAN-based make and use technical coefficients). This requires calculating a

[17] A similar process is used to develop alpha zone commodity quantities (in binary and csv formats) [FloorspaceZoneTotalMakeUse.csv]. However, this file has not been fully debugged and should not be used.

current year productivity (jobs/$M) from current year ED jobs by industry (*JobDataForSPG1.csv)* and ED industry output dollars (*IndustryDollarsForPI.csv)*. This current year productivity (jobs/$M) is divided by the fixed 1998 productivity rate (0.094129335 jobs/Activity$M found in *globalTemplate.properties*) to calculate the current year 'LaborUseScaling factor'. This scaling factor is applied to the 1998 *MakeUseI.csv* file use coefficient for all labor occupations (*[Minimum] and [Discretionary]* fields) and stored in the working *MakeUseW.csv* file used in the current year PI run.

<u>Modelwide Commodity Imports and Exports</u>

PI treats the import and export of goods as a separate set of commodities that are allocated among external World Markets (see Section 6.6.5). Thus, the modelwide imports and exports by commodity must be provided as input to PI. These values are generated dynamically each model year as a function of overall use or production of the commodity within the model area (ED industry output multiplied by PI make/use coefficients), and fixed regional purchase coefficient (import share of all internal commodity use), while preserving the implied net imports (imports-exports) set by the fixed PI make and use coefficients. The calculations performed before PI each model year updates the size term for the (SCTG goods commodities) importers and exporters in the ActivitiesW.csv file as follows:

$$\text{Imports}_c = \text{Regional purchase coefficient}_c * \text{Use}_c \tag{6.36}$$

$$\text{Exports}_c = \text{Make}_c - \text{Use}_c + \text{Imports}_c \tag{6.37}$$

and:

$$\text{Use}_c = \Sigma_i\ (\text{IndustryOutput}_i * \text{UseCoeff}_{ic}) \tag{6.38}$$

$$\text{Make}_c = \Sigma_i\ (\text{IndustryOutput}_i * \text{MakeCoeff}_{ic}) \tag{6.39}$$

where:

Imports_c = current year modelwide imports of commodity c

Exports_c = current year modelwide exports of commodity c

Use_c , Make_c= current year modelwide consumption/production by all industries/households of commodity c

IndustryOutput_i = ED current year modelwide output for industry i

UseCoeff_{ic}, MakeCoeff_{ic} = PI fixed industry i production (or consumption) of commodity c per unit of industry output (from *[MakeUseI.csv]*)

Regional purchase coefficient_c = Fixed import share of modelwide consumption of commodity c *([ImportShareByCommodity.csv]*, see Table 6.1)

Table 6.1. 1998 Regional Purchase Coefficients

SCTG	Description	Import Share Of Modelwide Use
SCTG01	Live animals and live fish	26%
SCTG02	Cereal grains	84%
SCTG03	Other agricultural products	37%
SCTG04	Animal feed and products of animal origin n.e.c.	85%
SCTG05	Meat fish seafood and their preparations	44%
SCTG06	Milled grain products and preparations and bakery products	56%
SCTG07	Other prepared foodstuffs and fats and oils	57%
SCTG08	Alcoholic beverages	84%
SCTG09	Tobacco products	100%
SCTG10	Monumental or building stone	93%
SCTG11	Natural sands	83%
SCTG12	Gravel and crushed stone	83%
SCTG13	Nonmetallic minerals n.e.c.	97%
SCTG14	Metallic ores and concentrates	10%
SCTG15	Coal	88%
SCTG16	NATURAL GAS & CRUDE PETROLEUM	92%
SCTG17	Gasoline and aviation turbine fuel	99%
SCTG18	Fuel oils	99%
SCTG19	Coal and petroleum products n.e.c.	91%
SCTG20	Basic chemicals	64%
SCTG21	Pharmaceutical products	89%
SCTG22	Fertilizers	78%
SCTG23	Chemical products and preparations n.e.c.	83%
SCTG24	Plastics and rubber	94%
SCTG25	Logs and other wood in the rough	43%
SCTG26	Wood products	40%
SCTG27	Pulp newsprint paper and paperboard	70%
SCTG28	Paper or paperboard articles	84%
SCTG29	Printed products	76%
SCTG30	Textiles leather and articles of textiles or leather	84%
SCTG31	Nonmetallic mineral products	91%
SCTG32	Base metal in primary or semi-finished forms and in finished basic shapes	97%
SCTG33	Articles of base metal	89%
SCTG34	Machinery	65%
SCTG35	Electronic and other electrical equipment and components and office equipment	56%
SCTG36	Motorized and other vehicles (including parts)	87%
SCTG37	Transportation equipment n.e.c.	97%
SCTG38	Precision instruments and apparatus	46%
SCTG39	Furniture mattresses and mattress supports lamps lighting fittings and illuminated signs	66%
SCTG40	Miscellaneous manufactured products	93%
SCTG41	Waste and scrap	16%

Source: 1998 IMPLAN data. Calculated as Imports/(Imports+UseFromRegion). SCTG16-18 not currently used.
PI Input file: [ImportShareByCommodity.csv]

6.4. Software Implementation

As an equilibrium model, PI must find a mathematical solution. The exchange zones simulate markets where the aggregate supply (the sum of the selling allocations together with the quantity of imports, both elastic with respect to the exchange price in equation 6.32 for demand and 6.33 for supply) meets the aggregate demand (the sum of the buying allocations together with the quantity of exports). The PI module numerically solves for the equilibrium solution, adjusting the exchange prices in the exchange locations until all the markets clear, that is, where TDem $_{c,k}$ = TSup $_{c,k}$ within a specified tolerance or convergence criteria (set in the *globalTemplate.properties* file)

The search algorithm calculates the partial derivative of the total surplus demand (excess of demand by buyers and exporters over supply by sellers and importers) in each exchange zone with respect to the price in that exchange zone, repeating this for all commodities in all exchange zones. The derivatives with respect to prices in other zones or for other commodities are assumed to be zero, and a price change is calculated. A step adjustment factor is applied to the step to speed and aid convergence. If a step results in a lower aggregate sum-of-squares surplus demand, then the step adjustment factor is increased slightly for the next iteration. If a step results in a higher aggregate sum-of-squares surplus demand, then the step is abandoned, the step adjustment factor is reduced substantially, and a new and smaller step is calculated to replace the abandoned one.

The PI module is implemented in java, using the following main set of object classes:

- Activity type (AggregateActivity class)
- Commodity type (Commodity class)
- Set of make coefficients and associated formula indicating the byproduct production possibilities for an activity (ProductionFunction class)
- Set of use coefficients and associated formula indicating the different production methods available for an activity (ConsumptionFunction class)
- The amount of each activity in each zone(AmountInZone class)
- The tracking of the amounts of commodities bought, sold, imported and exported in each exchange (Exchange class)
- The logit model to allocate the commodities bought by a zone (i.e. produced within a zone) amongst the available exchanges (BuyingZUtility class)
- The logit model to allocate the commodities sold to a zone (i.e. consumed within a zone) from amongst the available exchanges (SellingZUtility class)
- Tracking each of the flows between production and consumption points and the exchanges (CommodityFlowArray class)
- Each zone (AbstractTAZ and alpha zone classes)
- The formula for the imports and exports in each zone (LogisticPlusLinearFunction class)
- The calculation of the transport disutility from the matrix of travel times and distances (TimeAndDistanceTravelUtilityCalculator class)

The software process for each iteration of the search procedure involves requesting that each AggregateActivity class allocate the total region-wide quantity of activity (from ED and SPG modules) to the various AmountInZone classes ('highest' level PI location allocation model); the AmountInZone classes are used to report the composite utility of locating in each zone. The AmountInZone class in turn allocates the production and consumption quantities of commodities using the ProductionFunction and ConsumptionFunction classes ('middle' level PI technology choice module); the ProductionFunction and ConsumptionFunction classes are used to report the utility of consuming and producing in the zone (used by the 'highest' level PI module). The BuyingZUtility class and SellingZUtility class allocate the resulting commodities bought and sold by an activity in a zone to amongst the exchanges, updating the flows in the CommodityFlowArray ('lower' level PI transport-related allocation model).

The lowest level of this chain of allocations is the most computationally intensive. Once the prices are established at the beginning of the iteration, the 'lowest' level model uses the BuyingZUtility and SellingZUtility classes to calculate the Buy and Sell composite utilities of equations 6.14 and 6.19 repeatedly during an iteration. Since these composite utilities do not change as long as the prices are not changing, these values are cached during an iteration and second and subsequent requests for the same composite utility value during an iteration return the previously computed value.

The PI module can run on a single machine, or it can be distributed across multiple machines. When distributed, the 'lowest' level allocations of buying and selling locations for commodities consumed or produced in a zone (BuyingZUtility and SellingZUtility classes) are farmed out to various machines by a master process. In each iteration of the search algorithm first the calculations of CUSell and CUBuy ('lowest' level allocation model) are distributed, with each work task being the calculation of the set of CUSell and CUBuy for all zones for a single commodity. Later in the same iteration the allocation of amounts bought and sold to exchange zones ('middle' level technology choice) is distributed, with each work task being the allocation of the amounts bought and sold in each consumption and production zone to the exchange zones for a single commodity.

At convergence in the distributed set-up, the master task knows the exchange zone results but not the flow matrices by commodity that were used to calculate the exchange zone results. Worker tasks are created, again with one task for each commodity, to recalculate and write out the flow matrices by commodity.

The following parameters are used to used to set the convergence criteria and control the iteration process in PI ([globalTemplate.propertes]).

```
# Use these to control the PI runtime parameters

pi.maxIterations=1600
pi.initialStepSize=0.04
pi.minimumStepSize=0.02
pi.maximumStepSize=2.0
pi.localPriceStepSizeAdjustment=0.5
pi.converged=80000000
pi.globalSurplusTolerance = 0.001
```

6.5. S1 and S2 Module Parameters

The PI module requires a number of parameters. These parameters are identified in the following sections as S1, S2 or S3 parameters, following the three-stage calibration approach in Section 2.2. The specific process used to determine the chosen values for each parameter are indicated in the following sections.

6.5.1. Production Activity Allocation Parameters

Table 6.2 identifies the estimated parameters of the 'highest' level PI production activity allocation module, discussed in Section 6.3.1. No 'other' zonal attributes ($X_{v,k}$ in Eq.6.02) are currently specified.

Table 6.2. PI Production Activity Allocation Parameters

Parameter	Description	
$\alpha_{size,a}$	Utility function coefficient for the sensitivity to size	S1
$\alpha_{inertia,a}$	Utility function coefficient for the sensitivity to the previous proportion of activity a in zone z, representing inertia in allocation of activity a	S3
$InertiaConst_a$	Coefficient modifying the sensitivity to the previous portion of activity a in zones, that reduces the importance of the quantity when the previous quantity is small; *ActivitiesI[InertiaTermConstant]*	S3
$Constant_{a,z}$	Utility function alternative specific constant for zone z for allocation of activity a;	S2
$\alpha_{prod,a}$	Utility function coefficient for the sensitivity to composite utility associated with production for activity a;	S1/S3
$\alpha_{cons.a}$	Utility function coefficient for the sensitivity to composite utility associated with consumption for activity a;	S1/S3
λ_a	Utility function dispersion parameter for allocation of activity a.	S2

The alternative zone-specific constants for the allocation of activity ($Constant_{a,z}$) were initially adjusted in calibration to provide an exact match to observed baseyear distributions of employment and population (using an automated PI "constrained" run process to match zonal targets in *ActivityZonalValuesI.csv* with constants output in *LatestActivityConstants.csv*). If the $Constant_{a,z}$ are applied too early they can dilute the behavioral representation of the model, leaving little response left for the calibration of appropriate values for the other parameters representing the behavioral response of actors. Thus many of these constants may be left at zero, and those that end up being non-zero will likely be calibrated after values for the other S2 parameters are established.

Several coefficients allow sensitivity to composite utility associated with production and consumption (α_{prod}, α_{cons}) in the 'highest' level activity allocation utility function. During calibration, the values shown in Table 6.3 were established. The Substitution Nesting parameter values are dependent upon the LocationDispersionParameters.

Table 6.3. PI Production and Consumption Activity Allocation Parameters

Activity Categories	λ_a	α_{size}	$\alpha_{inertia}$	$InertiaConst_a$	Selling Coefficient $\lambda_{m,a}$	Selling Coefficient $\alpha_{prod,a}$	Buying Coefficient $\lambda_{u,a}$	Buying Coefficient $\alpha_{cons,a}$
Industry	Calibrated values	1	1	1	Calibrated values	1	Calibrated values	1
Households	Calibrated values	1	1	1	Calibrated values	1	Calibrated values	1
Institutions	Calibrated values	1	1	1	Calibrated values	1	Calibrated values	1
SCTG Importers & Exporters	1	1	1	1	1	1	1	1

Notes: U_{nmc} is true for all but Importer/Exporters & Institutions with calibrated utility values
U_{nmp} is false for all activities with utility value of -100.
α_{size} values are S1 parameters (see Section 4.2.5)
PI input file *ActivitiesI.csv* file:
λ_a = LocationDispersionParameter α_{size} = SizeTermCoefficient
$\alpha_{inertia}$ = InertiaTermCoefficient $InertiaConst_a$ = InertiaTermConstant

$\lambda_{m,a}$ = ProductionSubstitutionNesting
$\lambda_{u,a}$ = ConsumptionSubstitutionNesting
U_{nmc} = NonModeledConsumption
$\alpha_{prod,a}$ = ProductionUtilityScaling
$\alpha_{cons,a}$ = ConsumptionUtilityScaling
U_{nmp} = NonModeledProduction

Several dispersion activity allocation parameters are S2 parameters. They include the dispersion parameter for the allocation of activity (λ_a) in the production activity allocation utility function and additional dispersion parameter for the allocation of by-product and input substitutes made by each activity ($\lambda_{m,a}$, $\lambda_{u,a}$) in the production and consumption allocation utility functions. The coefficients of inertia, $\alpha_{inertia}$, in production allocation activity reflects the sensitivity to the previous proportion of each activity in each zone are currently set to zero. U_{nmc} and U_{nmp} affect the ability of activities to produce and consume less or more of commodities without substituting production and consumption to other modeled commodities.

6.5.2. Production and Consumption Allocation Parameters (Technology)

Table 6.4 identifies the estimated parameters of the PI production activity allocation module, discussed in Section 6.3.2. The dispersion parameters values are shown previously in Table 6.3. The values of the other listed parameters are discussed in the remainder of this section.

Table 6.4. PI Production and Consumption Allocation Parameters

Parameter	Description	
$MMin_{c,a}$	Minimum amount of commodity c made per unit of activity a	S1
$MDisc_{c,a}$	Potential discretionary amount of commodity c made per unit of activity a	S1
$UMin_{c,a}$	Minimum amount of commodity c used per unit of activity a	S1
$UDisc_{c,a}$	Potential discretionary amount of commodity c used per unit of activity a	S1/S2 for floorspace
$\lambda_{m,a}$	Utility function dispersion parameter for allocation of by-product substitutes made by activity a	S2, S3
$\lambda_{u,a}$	Utility function dispersion parameter for allocation of input substitutes used by activity a.	S2, S3
$M_{c,a,z}$	Make technical coefficient for commodity c produced by activity a in zone z	S1
$U_{c,a,z}$	Use technical coefficient for commodity c used by activity a in zone z	S1
U_{nmp}	Utility of non modeled production	S2/S3
U_{nmc}	Utility of non modeled consumption	S2/S3

<u>Fixed Make Technical Coefficients data preparation</u>

Make and Use tables from the 1998 IMPLAN Social Accounting Matrix (SAM) were obtained for the study region (Oregon statewide and Halo counties). Make coefficients are also called 'by-product coefficients' and use coefficients are also called 'absorption coefficients.'

Within the SAM, modelwide make and use tables identify the dollar value of both domestic and foreign, production and consumption of various commodities, by both industry and institutions. An additional Use of Factors table, provides the dollar amount of factors used by each industry. The ‘Employment Compensation’ factor was called out specifically in PI as labor wages. Other IMPLAN factors (i.e., Proprietary Income, Other Property Income, Indirect Business Taxes) were dispersed among the various industries. [12]

PI models goods flows (in units of 1990$) rather than money flows found in IMPLAN input-output table. In an input-output table, the ultimate purchaser of a commodity is assumed to purchase the commodity itself from its producer and, if wholesale and/or retail trade were involved, to purchase only the wholesale and retail margins from the trade sectors. This allows an input-output model to reflect changes in the quantity demanded of a particular commodity in the production of that commodity. This essentially imposes a distribution system on the flow of goods, by consolidating various ‘value added’ and margin components of a good’s purchase price into a physically meaningful warehouse/retail distribution system with full value of the goods between each location, allowing correct translation into goods movement.[18] To mimic the flow of goods, we 'demargined' the trade sectors for use in PI. [11] This required assumptions about the distribution system of each commodity depending on whether the flow represents intermediate (purchases by one industry of the output of another) or final demand (purchase by institutions such as households and government for consumption). The demargined make and use tables show commodities being bought by the trade sectors and resold.

Tables of paths for each commodity for final consumption by consumers and for intermediate consumption (producers buying raw materials) were developed. There are four general paths:

- Producer to wholesaler to retailer to consumer
- Producer to wholesaler to consumer
- Producer to retailer to consumer
- Producer to consumer

Each of these general paths was split into specific paths representing all of the possible combinations of regional and external producers, wholesalers, retailers, and consumers.

The split at each level between regional and external was defined by IMPLAN make data. The split between the four general paths was manually specified for each commodity based on the attributes of the commodity and its markets. Most consumer purchases were assumed to be primarily through retail. Producer purchases were assumed to be mostly through wholesalers or directly from other producers. Some commodities purchased by producers, such as motor fuel and furniture, were assumed to pass through retailers.

The industries and commodities in the demargined IMPLAN make table were aggregated into the industries and commodities used in PI. Most industries were then split into sub industries based on the types of floor space occupied. Some industries had their production space split between, for example, light industrial space and heavy industrial space. Several also were split to distinguishing line-production (e.g., factory floor) from management (in offices), reflecting their use of different floorspace types, important to correctly locating activity. The method to split these industries essentially involved: (1)

[18] Before demargining, when a consumer purchases a good in IMPLAN, the purchase is represented as a payment for the raw good from the sector that produced it, plus the purchase of transport from the transport sectors, and the purchase of trade margin (or markup) from the trade sectors. This accurately attributes the production component of different goods to the consumption of those goods, but does not represent the physical distribution system of goods.

moving a portion of labor in each base industry to a new sector-specific office industry in the Make table, based on modelwide employment estimates (Section 6.7.1); (2) adding an equal amount of internal services/management to the use table of the base industry, representing the production industry's purchase of management services; (3) splitting the make and use of commodities between the production/office industries in proportion to their employment (shifting as much FIRE services to the office industry as possible). This required the following assumptions: constant average wages across floorspace types; constant labor productivity (1990$ worth of output produced per dollar of labor) across production floorspace types within unsplit industries; and constant production functions for the production industry portion across floorspace types The remainder of the industry's output was assigned to that industry in production space.

For industries with multiple types of production space, output in production space was split proportional to employment by detailed IMPLAN commodity. E ach detailed IMPLAN commodity was assigned to one of the production space types. IMPLAN employee compensation was divided into household income-occupation groups based on US Census household income data (synthetic population). IMPLAN total compensation by industry was spread to occupations based on the distribution of employees by occupation within each industry. In future updates, this compensation distribution should be updated to take into account differences in average wage between occupations.

The resulting demargined, split make table was used to derive make coefficients for each combination of PI industry and commodity. A make coefficient represents the proportion of an industry's total output that is represented by a particular commodity. M ake coefficients sum to 1.0 for any given industry.

<u>Fixed Use Technical Coefficients data preparation</u>

As with the make table data, use table data were derived from 1998 IMPLAN Social Accounting Matrix for the study area (Oregon plus Halo). U se coefficients are also called 'absorption coefficients.' The IMPLAN use table was aggregated and demargined in the same manner as the make table. If an industry was split between multiple types of production space, use of inputs in production space was split proportional to employment by detailed IMPLAN industry. Each detailed IMPLAN industry was assigned to one of the production space types.

The resulting demargined, split use table was used to derive Use coefficients for each combination of PI industry and commodity. A use coefficient represents the proportion of an industry's total output that is represented by the use of a particular commodity. Industries use labor of various occupations. Households are the only consumer of home-based services and Internal Management Services are only consumed by associated industries.

After initial calibration, it w as found necessary to reallocation the consumption expenditures for education so households, rather than government consume education. Tracking education dollars in the economy, households pay government through taxes for the consumption of education. Thus, IMPLAN-based PI inputs showed government consuming 90% of lower education and 60% of higher education, thus PI incorrectly co-located education and government activity, rather than education and households. PI input technical coefficients were updated to shift education use from government to households.

To do so, the MakeUseI.csv use parameters were adjusted as follows: 100% of Lower Education and roughly 98% of Higher Education dollars (numerator in the use coefficient) were assumed to be consumed by households rather than government, using the schedule of Table 6.5 by household category. The Higher Education figure is consistent with the 1% industry use of this service per unit of output. Table 6.5 allocation, among HH categories, is based on the original household use of Higher and Lower Education services. The corresponding household use of government was also adjusted accordingly, to make expenditures balance.

Table 6.5. Allocation of shifted Government Education Dollars among Households

	Higher Education	Lower Education
HH0to5k	10%	2%
HH5to10k	8%	2%
HH10to15k	5%	3%
HH15to20k	5%	2%
HH20to30k	7%	11%
HH30to40k	11%	10%
HH40to50k	12%	13%
HH50to70k	20%	26%
HH70kUp	22%	30%

Technology substitution parameters

Potential make and use discretionary amount of commodity used per unit of activity ($MDisc_{c,a}$, $UDisc_{c,a}$) in production and consumption allocation function allow some technical substitution. This is specified for each combination of activity (industry, institutions, households) and commodity (goods, services, labor, floorspace). Initially, substitution was only allowed on the make and use of labor and the use of floorspace. The minimum make of labor was set at 50 percent of the IMPLAN value with a discretionary amount of 60 percent of total IMPLAN labor make for all categories. The minimum use of labor was set at 50 percent of the IMPLAN value (labor compensation) with a discretionary amount of 62.5 percent of total IMPLAN labor use for all categories. Floorspace was also set at a 90 percent minimum, with 50 percent discretionary of the total available floorspace per unit value of industry-specific production (sqft per dollar). These values are shown in Table 6.6.

Household and industry use of floorspace accounts only for the quantity of occupied space. The floorspace import function (described above) allows the amount of used space to be less than the total built-form inventory from ALD, accounting for vacancy.

In addition, U_{nmc} and U_{nmp} are S2 parameters, to be adjusted to achieve an overall elasticity of labor consumption and production by industries and households. Initially, U_{nmc} was set to negative infinity (-100 used) and U_{nmp} to 1 for all activities. Initial dispersion values for the allocation of by-product and input substitutions by activity used in the production and consumption allocation utility function were shown previously in Table 6.3

Table 6.6. PI Technology Substitution Parameters

Commodity Categories	Make Technical Coefficients Parameters				Use Technical Coefficients Parameters			
	$MMin_{c,a}$	$MDisc_{c,a}$	$\phi_{s,c,a}$	$USellRef_{c,a}$	$UMin_{c,a}$	$UDisc_{c,a}$	$\phi_{b,c,a}$	$UBuyRef_{c,a}$
G&S by Industry & HHs	IMPLAN Tech Coeff	0	1	0	IMPLAN Tech Coeff	0	1	0
G&S by Institutions	IMPLAN Activity	0	1	0	IMPLAN Activity	0	1	0
Labor	0.5 of IMPLAN	0.6 of IMPLAN	1	Calibrated values	0.5 of IMPLAN Wages/ IMPLAN IndMake	0.625 of IMPLAN Wages/IMPLAN IndMake for all labor categories	1	Calibrated values
Floorspace	NA	NA	NA	NA	0.9 of Floorspace/ Industry 0 for household use of residential space	0.50 of Floorspace/ industry total use of space by household category	1	0
Importers use of Imports & Exporters use of Exports	1	0	1	0	1	0	1	0

Note: MMin values are S1 parameters (see section 4.2.1/4.2.2).
PI input file MakeUse.csv.
$MMin_{c,a}$ = Minimum (where MorU='M') $MDisc_{c,a}$ = Discretionary (where MorU='M')
$\phi_{s,c,a}$ = UtilityScale (where MorU='M') $USellRef_{c,a}$ = UtilityOffset (where MorU='M')
$UMin_{c,a}$ = Minimum (where MorU='U') $UDisc_{c,a}$ = Discretionary (where MorU='U')
$\phi_{b,c,a}$ = UtilityScale (where MorU='U') $UBuyRef_{c,a}$ = UtilityOffset (where MorU='U')

6.5.3. Buying and Selling Allocation Parameters

Table 6.7 identifies the estimated parameters of the PI buying and selling Allocation module, discussed in Section 6.3.2. The values of the parameters are discussed in the remainder of this section.

Table 6.7. PI Buying and Selling Allocation Parameters

Parameter	Description	
$\delta_{size,s}$	Utility function coefficient for the sensitivity to size;	S1
$\delta'_{size,b}$	Utility function coefficient for the sensitivity to size;	S1
$\delta_{price,s}$	Utility function coefficient for the sensitivity to price when selling;	S1
$\delta'_{price,b}$	Utility function coefficient for the sensitivity to price when buying;	S1
$\delta'_{tran,s}$	Utility function coefficient for the sensitivity to transport utility;	S2
$\delta'_{tran,b}$	Utility function coefficient for the sensitivity to transport utility;	S2
$\lambda_{s,c}$	Utility function dispersion parameter for allocation of selling of commodity c.	S2
$\lambda_{b,c}$	Utility function dispersion parameter for allocation of buying of commodity c.	S2
$\phi_{s,c,a}$	Factor adjustment to the composite utility of selling commodity c by activity a	S1/S2
$\phi_{b,c,a}$	Factor adjustment to the composite utility of buying commodity c by activity a	S1/S2
$USellRef_{c,a}$	Offset adjustment to the composite utility of selling commodity c by activity a.	S1, S2 for labor
$UBuyRef_{c,a}$	Offset adjustment to the composite utility of buying commodity c by activity a	S1, S2 for labor/floorspace
$\kappa'_{c,dist}$	Utility function coefficient for the sensitivity to trip distance when transporting a unit of commodity c	S1
$\kappa_{c,time}$	Utility function coefficient for the sensitivity to trip travel time when transporting a unit of commodity c	S1
$\kappa_{c,logsum}$	Utility function coefficient for the sensitivity to trip mode choice composite utility when transporting a unit of commodity c	S1

Buying and selling allocation parameters

Buying and selling allocation S2 parameters include the dispersion parameter for allocation of buying and selling commodities ($\lambda_{s,c}$,$\lambda_{b,c}$), as well as the coefficients for the sensitivity to transport utility ($\delta□_{tran,b}$, $\delta□_{tran,s}$). The initial values for these parameters are shown in Table 6.8. Also shown is the exchange type assumed in the initial PI runs, which determines the location for the exchange. Floorspace is assumed non-transferable (n), while all other commodities are exchanged in any zone (a). Future runs may restrict non-floorspace exchanges to occur either in the production (p) or consumption (c) zone.

Table 6.8. PI Buying and Selling Allocation Parameters by Commodity

Commodity Categories	Buying Activity Allocation Coefficients				Selling Activity Allocation Coefficients				Exchange Type
	$\lambda_{b,c}$	$\delta_{ize,b}$	$\delta_{price,b}$	$\delta_{tran,b}$	$\lambda_{s,c}$	$\delta_{size,s}$	$\delta_{price,s}$	$\delta_{tran,s}$	
Goods	Calibrated Values	1	-1	See Table 6.9	Calibrated Values	1	1	See Table 6.9	P
Services	Calibrated Values	1	-1	See Table 6.9	Calibrated Values	1	1	See Table 6.9	Mix of p and c*
Labor	Calibrated Values	1	-1	See Table 6.9	Calibrated Values	1	1	See Table 6.9	C
Floorspace	5	1	-1	0	5	1	1	0	n

Note: *These services are type 'c' others are 'p': Construction, FIRE, Homebased Services, Internal Services
PI input file *CommoditiesI.csv:*
$\lambda_{b,c}$ = BuyingDispersionParameter; $\delta_{ize,b}$ = BuyingSizeCoefficient
$\delta_{price,b}$ = BuyingPriceCoefficient; $\delta_{tran,b}$ = BuyingTransportCoefficient
$\lambda_{s,c}$ = SellingDispersionParameter; $\delta_{size,s}$ = SellingSizeCoefficient
$\delta_{price,s}$ = SellingPriceCoefficient; $\delta_{tran,s}$ = SellingTransportCoefficient

For residential space, residential buying size terms are also used ($Size_{b,c,k}$ in equation 6.17). These buying size terms are calculated as the quantity of space type c in zone k divided by the total of all residential space types in zone k. (All other buying size terms and selling size terms are left at their default value of 1.0).

Buying and selling composite utility includes allowance for factor and offset adjustments. All factor adjustments, $\phi_{s,c,a}$., are set to 1 and the offset adjustments, $USellRef_{c,a}$ and $UBuyRef_{c,a}$ are set to 0 (Table 6.7). It is expected that in some cases, as calibration progresses, the factor adjustment may be set to 0 to completely remove the effect of individual buying and selling composite utilities on production utilities and thus on location utilities.

Time and Cost Weights for Transporting Commodities

Transport cost coefficients weigh the relative value of time and distance in the transport utility function. The PI transport function includes the overall sensitivity to transport ($\delta□_{ran,b}$ and $\delta□□_{ran,s}$), as well as commodity-specific time and distance coefficients, or commodity-specific coefficients on mode-choice logsums.

The transport coefficient is essentially the inverse of the economic value per trip, allowing the time and distance parameters to be in units of cost per vehicle trip. These costs take into account variations in commodity value (labor or goods) and vehicle occupancy (tons or persons per vehicle). Goods transport costs are incurred at the production end (buying), while services (management and other) and labor transport costs are born at the consumption end (selling) of the exchange. Floorspace is non-transportable, so there are no transport costs (coefficients set to 1 or 0). These parameters are defined in the CommoditiesI.csv PI input file.

Freight commodity time and cost rates were calculated primarily with data from a 2000 WSDOT statewide modeling effort. In many cases, STCC commodity data was converted into the SCTG-classification used in PI, weighted by 1999 IMPLAN production data (Make value). The catch-all 'Money and unclassified goods' commodity's values are an average of all other goods. These transport costs are currently being modified to allow user-specified mode/vehicle operating costs, and endogenized other cost, wage, and mode split components. The transport coefficients are calculated as follows. Figure 6.2 shows the relationship assumed to calculate value of time for service-related trips:

For goods:

$\delta_{tran,b}$ and $\delta_{tran,s}$ (trip/$ of goods) = 1/($ payload value)
$\kappa_{c,time}$ ($/vehicle-min) = ($ per veh-hr) / (60min/hr) [user-input]
$\kappa_{c,dist}$ ($/vehicle-mile) = ($ per ton-mile) * (Tons per vehicle) [user-input]
$\kappa_{c,logsum}$ ($/mode choice utility) = 0

which is based on assuming:

100% truck mode split [CT output (future)]
$ payload value = $ per ton*Tons per vehicle
$ per vehicle-hr = $16.50/Medium truck hour (other modes 0) [user-input]
$ per ton-mile by mode = $0.10 for MedTruck ($.03 for Rail, $3 for Air, $0.01 for Barge) [user-input]
$ per ton, ranging from $7 to 73,300/Ton ($10,600/Ton average)
Tons per vehicle: 9 to 22 Tons/Truck (average 15.6 Tons/Truck, 51Tons/railcar) [CT output (future)]

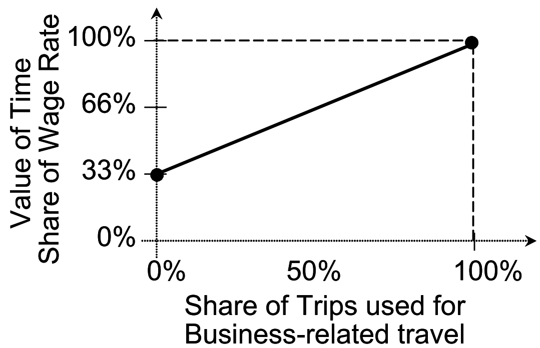
For labor/services:

$\delta_{tran,b}$ and $\delta_{tran,s}$ (trip/$ of production value) = (Trips per day) / ($ of production value)
Labor: $ of production value = ($Economic wage per hour) * (8 hours/day)
Service: $ of production value = ($Annual Industry Use of Commodity) / (Annual vehicle trips)
$\kappa_{c,time}$ = ($Economic wage per hour)/(60min/hr)
(only for selected services)
$\kappa_{c,dist}$ = ($Operating cost per veh-mile)/(Auto occupancy)
(only for selected services)
$\kappa_{c,logsum}$ = 1/$OPC cost parameter for associated logsum (PT module estimated parameters)
(for all other services and labor/commute)

which is based on assuming:

100% auto mode split
Trips per day = 1 for labor commute trips, 1.5 for services (assuming some trip chaining)
$Economic wage per hour = ($Wage per hour) * (%BusinessPurposeTrips * 67% + 33%)
$Wage per hour = 1990 US Census Oregon PUMS wage rates by occupation [PI data (future)]
%BusinessPurposeTrips = 1998 Oregon IMPLAN share of total commodity used by industry (IndustryUse/[household use+institution use]) [PI data (future)]
$Annual Industry Use of Commodity = 1998 Oregon MPLAN data by trip purpose [PI data (future)]
Annual vehicle trips = 1994-1996 Oregon Travel Behavior Survey by trip purpose
Auto Occupancy = 1994-1996 Oregon Travel Behavior Survey by trip purpose [user-input]
$Operating cost per veh-mile = $0.12/mile, consistent with PT module [user-input]

Figure 6.2. Value of Time based on Wage Rate and Business Travel share of Trips



Buying and selling price sensitivity coefficients

The coefficients for the sensitivity to price when buying or selling ($\delta_{price,s}$□□ $\delta_{price,b}$), found in the buying and selling allocation utility functions, are set to 1 f or all commodities, positive when selling and negative when buying. These are shown in Table 6.9. Thus the utility function is in units of equivalent 1990$.

Table 6.9. PI Transport Coefficients (per unit of production)

	Dispersion		Buying Coefficients			Selling Coefficients			Interchange Coefficients*			Interchange Skim file			Exchange	GOF	Expected
				utils/$	$/util		utils/$	$/util									
Commodity	Buying	Selling	Size	Price	Transport	Size	Price	Transport	1	2	3	1	2	3	Type	Wghting	Price
FLR Agriculture	5	5	1	-1	0	1	1	0	0	0	0	betapkautotime	betapkautodist	betapkautotoll	n	1000	15000
FLR Logging	5	5	1	-1	0	1	1	0	0	0	0	betapkautotime	betapkautodist	betapkautotoll	n	1000	15000
FLR Hospital	1.00E-06	1.00E-06	1	-1	0	1	1	0	0	0	0	betapkautotime	betapkautodist	betapkautotoll	n	1000000	10000000
FLR Light Industry	1.00E-06	1.00E-06	1	-1	0	1	1	0	0	0	0	betapkautotime	betapkautodist	betapkautotoll	n	1000000	7000000
FLR Retail	1.00E-06	1.00E-06	1	-1	0	1	1	0	0	0	0	betapkautotime	betapkautodist	betapkautotoll	n	1000000	12000000
FLR Office	1.00E-06	1.00E-06	1	-1	0	1	1	0	0	0	0	betapkautotime	betapkautodist	betapkautotoll	n	1000000	6500000
FLR Depot	1.00E-06	1.00E-06	1	-1	0	1	1	0	0	0	0	betapkautotime	betapkautodist	betapkautotoll	n	1000000	1500000
FLR Heavy Industry	1.00E-06	1.00E-06	1	-1	0	1	1	0	0	0	0	betapkautotime	betapkautodist	betapkautotoll	n	1000000	7000000
FLR Warehouse	1.00E-06	1.00E-06	1	-1	0	1	1	0	0	0	0	betapkautotime	betapkautodist	betapkautotoll	n	1000000	4500000
FLR Institutional	1.00E-06	1.00E-06	1	-1	0	1	1	0	0	0	0	betapkautotime	betapkautodist	betapkautotoll	n	1000000	10000000
FLR Accommodation	1.00E-06	1.00E-06	1	-1	0	1	1	0	0	0	0	betapkautotime	betapkautodist	betapkautotoll	n	1000000	10000000
FLR Government Support	1.00E-06	1.00E-06	1	-1	0	1	1	0	0	0	0	betapkautotime	betapkautodist	betapkautotoll	n	1000000	6500000
FLR Grade-school	1.00E-06	1.00E-06	1	-1	0	1	1	0	0	0	0	betapkautotime	betapkautodist	betapkautotoll	n	1000000	10000000
FLR SFD	1.00E-06	1.00E-06	1	-1	0	1	1	0	0	0	0	betapkautotime	betapkautodist	betapkautotoll	n	1000000	4000000
FLR AT	1.00E-06	1.00E-06	1	-1	0	1	1	0	0	0	0	betapkautotime	betapkautodist	betapkautotoll	n	1000000	4000000
FLR MH	1.00E-06	1.00E-06	1	-1	0	1	1	0	0	0	0	betapkautotime	betapkautodist	betapkautotoll	n	1000000	4000000
FLR RRMH	1.00E-06	1.00E-06	1	-1	0	1	1	0	0	0	0	betapkautotime	betapkautodist	betapkautotoll	n	1000000	4000000
FLR RRSFD	1.00E-06	1.00E-06	1	-1	0	1	1	0	0	0	0	betapkautotime	betapkautodist	betapkautotoll	n	1000000	4000000
FLR MF	1.00E-06	1.00E-06	1	-1	0	1	1	0	0	0	0	betapkautotime	betapkautodist	betapkautotoll	n	1000000	10000000
SCTG01	75	75	1	-1	4.46E-05	1	1	0	-0.275	-2.15	-0.01	betapktrk1time	betapktrk1dist	betapktrk1toll	p	1	1
SCTG02	9.41	9.41	1	-1	0.000326	1	1	0	-0.275	-2.15	-0.01	betapktrk1time	betapktrk1dist	betapktrk1toll	p	1	1
SCTG03	80	80	1	-1	4.57E-05	1	1	0	-0.275	-2.15	-0.01	betapktrk1time	betapktrk1dist	betapktrk1toll	p	1	1
SCTG04	15	15	1	-1	0.00025	1	1	0	-0.275	-1.77	-0.01	betapktrk1time	betapktrk1dist	betapktrk1toll	p	1	1
SCTG05	300	300	1	-1	3.07E-05	1	1	0	-0.275	-1.25	-0.01	betapktrk1time	betapktrk1dist	betapktrk1toll	p	1	1
SCTG06	90	90	1	-1	5.53E-05	1	1	0	-0.275	-1.2	-0.01	betapktrk1time	betapktrk1dist	betapktrk1toll	p	1	1
SCTG07	100	100	1	-1	7.60E-05	1	1	0	-0.275	-1.25	-0.01	betapktrk1time	betapktrk1dist	betapktrk1toll	p	1	1
SCTG08	60	60	1	-1	7.02E-05	1	1	0	-0.275	-1.2	-0.01	betapktrk1time	betapktrk1dist	betapktrk1toll	p	1	1
SCTG09	150	150	1	-1	8.00E-05	1	1	0	-0.275	-2.15	-0.01	betapktrk1time	betapktrk1dist	betapktrk1toll	p	1	1
SCTG10	20	20	1	-1	0.000435	1	1	0	-0.275	-1.34	-0.01	betapktrk1time	betapktrk1dist	betapktrk1toll	p	1	1
SCTG11	2.32	2.32	1	-1	0.005261	1	1	0	-0.275	-1.34	-0.01	betapktrk1time	betapktrk1dist	betapktrk1toll	p	1	1
SCTG12	5	5	1	-1	0.010323	1	1	0	-0.275	-1.34	-0.01	betapktrk1time	betapktrk1dist	betapktrk1toll	p	1	1
SCTG13	20.4	20.4	1	-1	0.001683	1	1	0	-0.275	-1.24	-0.01	betapktrk1time	betapktrk1dist	betapktrk1toll	p	1	1
SCTG14	17.41	17.41	1	-1	0.000595	1	1	0	-0.275	-1.21	-0.01	betapktrk1time	betapktrk1dist	betapktrk1toll	p	1	1
SCTG15	5	5	1	-1	0.004548	1	1	0	-0.275	-1.05	-0.01	betapktrk1time	betapktrk1dist	betapktrk1toll	p	1	1
SCTG16	290	290	1	-1	0.000116	1	1	0	-0.275	-2.17	-0.01	betapktrk1time	betapktrk1dist	betapktrk1toll	p	1	1
SCTG17	300	300	1	-1	0.000117	1	1	0	-0.275	-2.14	-0.01	betapktrk1time	betapktrk1dist	betapktrk1toll	p	1	1
SCTG18	300	300	1	-1	0.000188	1	1	0	-0.275	-2.14	-0.01	betapktrk1time	betapktrk1dist	betapktrk1toll	p	1	1
SCTG19	40	40	1	-1	0.000296	1	1	0	-0.275	-2.14	-0.01	betapktrk1time	betapktrk1dist	betapktrk1toll	p	1	1
SCTG20	80	80	1	-1	0.000108	1	1	0	-0.275	-1.72	-0.01	betapktrk1time	betapktrk1dist	betapktrk1toll	p	1	1
SCTG21	200	200	1	-1	8.00E-05	1	1	0	-0.275	-1.72	-0.01	betapktrk1time	betapktrk1dist	betapktrk1toll	p	1	1
SCTG22	35	35	1	-1	0.000227	1	1	0	-0.275	-1.72	-0.01	betapktrk1time	betapktrk1dist	betapktrk1toll	p	1	1
SCTG23	300	300	1	-1	1.94E-05	1	1	0	-0.275	-1.72	-0.01	betapktrk1time	betapktrk1dist	betapktrk1toll	p	1	1
SCTG24	150	150	1	-1	2.56E-05	1	1	0	-0.275	-1.51	-0.01	betapktrk1time	betapktrk1dist	betapktrk1toll	p	1	1
SCTG25	6.49	6.49	1	-1	0.000542	1	1	0	-0.275	-2.08	-0.01	betapktrk1time	betapktrk1dist	betapktrk1toll	p	1	1
SCTG26	75	75	1	-1	0.000173	1	1	0	-0.275	-1.69	-0.01	betapktrk1time	betapktrk1dist	betapktrk1toll	p	1	1
SCTG27	50	50	1	-1	0.000104	1	1	0	-0.275	-1.92	-0.01	betapktrk1time	betapktrk1dist	betapktrk1toll	p	1	1
SCTG28	100	100	1	-1	4.50E-05	1	1	0	-0.275	-1.72	-0.01	betapktrk1time	betapktrk1dist	betapktrk1toll	p	1	1
SCTG29	300	300	1	-1	1.70E-05	1	1	0	-0.275	-1.36	-0.01	betapktrk1time	betapktrk1dist	betapktrk1toll	p	1	1
SCTG30	100	100	1	-1	8.00E-05	1	1	0	-0.275	-0.994	-0.01	betapktrk1time	betapktrk1dist	betapktrk1toll	p	1	1
SCTG31	10	10	1	-1	0.000587	1	1	0	-0.275	-1.33	-0.01	betapktrk1time	betapktrk1dist	betapktrk1toll	p	1	1
SCTG32	32	32	1	-1	8.25E-05	1	1	0	-0.275	-1.57	-0.01	betapktrk1time	betapktrk1dist	betapktrk1toll	p	1	1
SCTG33	300	300	1	-1	2.06E-05	1	1	0	-0.275	-1.63	-0.01	betapktrk1time	betapktrk1dist	betapktrk1toll	p	1	1
SCTG34	150	150	1	-1	1.00E-05	1	1	0	-0.275	-1.66	-0.01	betapktrk1time	betapktrk1dist	betapktrk1toll	p	1	1
SCTG35	100	100	1	-1	1.00E-05	1	1	0	-0.275	-1.69	-0.01	betapktrk1time	betapktrk1dist	betapktrk1toll	p	1	1
SCTG36	300	300	1	-1	6.70E-06	1	1	0	-0.275	-1.21	-0.01	betapktrk1time	betapktrk1dist	betapktrk1toll	p	1	1
SCTG37	150	150	1	-1	1.71E-05	1	1	0	-0.275	-1.17	-0.01	betapktrk1time	betapktrk1dist	betapktrk1toll	p	1	1
SCTG38	300	300	1	-1	1.00E-05	1	1	0	-0.275	-0.91	-0.01	betapktrk1time	betapktrk1dist	betapktrk1toll	p	1	1
SCTG39	300	300	1	-1	1.38E-05	1	1	0	-0.275	-1.44	-0.01	betapktrk1time	betapktrk1dist	betapktrk1toll	p	1	1
SCTG40	300	300	1	-1	1.63E-05	1	1	0	-0.275	-1.22	-0.01	betapktrk1time	betapktrk1dist	betapktrk1toll	p	1	1
SCTG41	17	17	1	-1	0.000345	1	1	0	-0.275	-1.56	-0.01	betapktrk1time	betapktrk1dist	betapktrk1toll	p	1	1
MONEY AND UNCLASSIFIED	90	90	1	-1	0.000107	1	1	0	-0.275	-1.47	-0.01	betapktrk1time	betapktrk1dist	betapktrk1toll	p	1	1
2_PstSec	7.703079	7.703079	1	-1	0	1	1	0.0621	3.57	0	0	w7mcls_beta			c	1	1
4_OthP&T	7.751946	7.751946	1	-1	0	1	1	0.0595	2.5	0	0	w4mcls_beta			c	1	1
5_RetSls	8.52031	8.52031	1	-1	0	1	1	0.07	1.82	0	0	w1mcls_beta			c	1	1
1a_Health	10.2	10.2	1	-1	0	1	1	0.0445	3.57	0	0	w7mcls_beta			c	1	1
1_ManPro	9.440721	9.440721	1	-1	0	1	1	0.0466	3.57	0	0	w7mcls_beta			c	1	1
7_NonOfc	9.55	9.55	1	-1	0	1	1	0.07	1.82	0	0	w1mcls_beta			c	1	1
3_OthTchr	7.9	7.9	1	-1	0	1	1	0.0668	2.5	0	0	w4mcls_beta			c	1	1
6_OthR&C	8.75	8.75	1	-1	0	1	1	0.07	1.82	0	0	w1mcls_beta			c	1	1
RETAIL TRADE	20	20	1	-1	0.0197	1	1	0	1.67	0	0	s4mcls_beta			p	1	1
TRANSPORT	30	30	1	-1	0.0135	1	1	0	-0.0755	-0.0977	-0.01	betapkautotime	betapkautodist	betapkautotoll	p	1	1
WHOLESALE TRADE	30	30	1	-1	0.0135	1	1	0	-0.118	-0.0977	-0.01	betapkautotime	betapkautodist	betapkautotoll	p	1	1
CONSTRUCTION	30	30	1	-1	0	1	1	0.0135	-0.0716	-0.0977	-0.01	betapkautotime	betapkautodist	betapkautotoll	c	1	1
LOWER EDUCATION	20	20	1	-1	0.1	1	1	0	1.79	0	0	c4mcls_beta			p	1	1
PERSONAL AND OTHER SER	20	20	1	-1	0.0792	1	1	0	0.935	0	0	b5mcls_beta			p	1	1
INTERNAL SERVICES	60	60	1	-1	0	1	1	0.0135	0.935	0	0	b8mcls_beta			c	1	1
HOMEBASED SERVICES	15	15	1	-1	0	1	1	0.0135	1.67	0	0	o4mcls_beta			c	1	1
HIGHER EDUCATION	30	30	1	-1	0.03	1	1	0	1.79	0	0	c4mcls_beta			p	1	1
HEALTH SERVICES	30	30	1	-1	0.0212	1	1	0	1.67	0	0	o4mcls_beta			p	1	1
FIRE BUSINESS AND PROFE	30	30	1	-1	0	1	1	0.0135	-0.119	-0.0977	-0.01	betapkautotime	betapkautodist	betapkautotoll	c	1	1
COMMUNICATIONS AND U	10	10	1	-1	0.0135	1	1	0	-0.102	-0.0977	-0.01	betapkautotime	betapkautodist	betapkautotoll	p	1	1
ACCOMMODATIONS	15	15	1	-1	0.0135	1	1	0	-0.0993	-0.0977	-0.01	betapkautotime	betapkautodist	betapkautotoll	p	1	1
GOVERNMENT ADMINISTR	30	30	1	-1	0.0212	1	1	0	0.935	0	0	b4mcls_beta			p	1	1
Import	160	160	1	-1	0	1	1	0	0	0	0	betapktrk1time	betapktrk1dist	betapktrk1toll	n	1	1
Export	160	160	1	-1	0	1	1	0	0	0	0	betapktrk1time	betapktrk1dist	betapktrk1toll	n	1	1

Source: [CommoditiesI.csv]

6.5.4. Imports and Exports Model Parameters

Table 6.10 identifies the estimated parameters of the PI imports and exports model including floorspace imports, discussed in Section 6.3.3 and 6.3.4. The values of the parameters are discussed in the remainder of this section.

Table 6.10. PI Imports and Exports Model Parameters

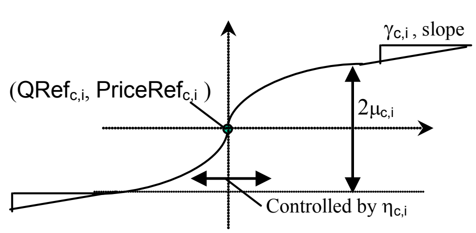
Parameter	Description	
$PriceRef_{c,i}$	Reference price per unit for import of commodity c	S1
$PriceRef_{c,e}$	Reference price per unit for export of commodity c	S1
$QRef_{c,i}$	Quantity of commodity c imported to exchange location when the unit exchange price for commodity c in exchange zone k is at its import reference level $PriceRef_{c,i}$	S2
$QRef_{c,e}$	Quantity of commodity c exported from exchange location when the unit exchange price for commodity c in exchange zone k is at its export reference level $PriceRef_{c,e}$	S2
$\gamma_{c,I}$	Function coefficient for the rate of increase in imports of commodity c for slope term	S2
$\gamma_{c,e}$	Function coefficient for the rate of increase in exports of commodity c for slope term	S2
$\mu_{c,I}$	Function coefficient for the rate of increase in imports of commodity c for linear term	S2
$\mu_{c,e}$	Function coefficient for the rate of increase in exports of commodity c for linear term	S2
$\eta_{c,I}$	Function coefficient for sensitivity to difference in exchange price for commodity c concerning increase in imports of commodity c for exponent term	S2
$\eta_{c,e}$	Function coefficient for sensitivity to difference in exchange price for commodity c concerning increase in exports of commodity c for exponent term	S2
F0Price	Reference price per unit for floorspace	S2
FMidpoint	Quantity of floorspace supplied when the unit exchange price for floorspace in exchange zone k is at its reference level *F0Price*	S2
FDelta	Function coefficient for the rate of increase in imports of floorspace for slope term	S1
FSlope	Function coefficient for the rate of increase in imports of floorspace for linear term	S2
FEta	Function coefficient for sensitivity to difference in exchange price for floorspace concerning increase in floorspace supply for exponent term	S2

<u>Import and export function parameters – Labor & Services</u>

Import and export parameters allow variation in external production and consumption so the market can clear for each commodity in each exchange zone. Import and export reference price per unit of import of each commodity c ($PriceRef_{c,i,}$ $PriceRef_{c,e}$) are currently set to 1 for all non-floorspace commodities in all zones, so PI thus operates in terms of relative prices with respect to the 1998 IMPLAN baseyear prices. The reference quantity represents the baseyear equilibrium quantity ($QRef_{c,i}$ $QRef_{c,e,}$) of each commodity imported/exported in each exchange zone when the exchange price ($PriceRef_{c,i}$, $PriceRef_{c,e}$) is set to 1.

The remaining coefficients regulate the response of import/export quantity in any zone to price changes. These parameters include a linear term ($\mu_{c,i,}$□$\mu_{c,e}$), a exponent slope term ($\gamma_{c,i}$□□ $\gamma_{c,e}$), and a coefficient for the sensitivity to exchange zone price differences ($\eta_{c,i}$, $\eta_{c,e}$). T he impact of these terms on the reference quantity and price can be seen graphically in Figure 6.3.

Figure 6.3. Import Function Parameters



Labor, was not available as an import or export, which implies no commuting across the study area boundary. All beta zones were allowed to serve as exchange zones for service commodities and selected goods (fuel, SCTGs 16-18). These commodities' import/export parameter values have been set as shown in Table 6.11. The reference quantities of services in each zone was calculated by dividing modelwide import and export commodity flows from 1998 IMPLAN data equally among all exchange zones. (see Section 5.3.1 regarding initial processing of IMPLAN data). $Qref_{c,i}$ is said to be the total use, while $Qref_{c,e}$ is the total make divided by the number of exchange zones. The slope terms were set at 10 percent of the reference quantities (negative export slope), and the exponent at 20 percent, except for floorspace.

Table 6.11. PI Import/Export Function Parameters

Commodity Categories	Import Coefficients					Export Coefficients				
	$QRef_{c,i}$	$\gamma_{c,i}$	$\eta_{c,i}$	$\mu_{c,i}$	$PriceRef_{c,i}$	$QRef_{c,e}$	$\gamma_{c,e}$	$\eta_{c,e}$	$\mu_{c,e}$	$PriceRef_{c,e}$
Labor	0	0	2	0.1 of $QRef_{c,i}$	1	0	0	2	-0.1 of $QRef_{c,e}$	1
Services	IMPLAN/ #Zones	0.9 of $QRef_{c,i}$	2	0.1 of $QRef_{c,i}$	1	IMPLAN/ #Zones	0.2 of $QRef_{c,e}$	2	-0.1 of $QRef_{c,e}$	1
Goods – World Market Zones	MktShare *IMPLAN	0	2	0.01* $QRef_{c,i}$	1	0	0	2	0	1
Goods – internal zones	0	0	2	10,000	1	0	0	2	0	1
Floorspace	0.9 of space	0	2	2000	1	0.9 of space	0	2	-20	1

Note: PriceRef values are S1 parameters (see section 4.2.4).
PI inputfile ExchangeImportExportsI.csv

Import and export function parameters – Goods

For the remaining goods commodities (all but fuel, SCTG16-18) import and export exchange zones are limited to the six World Markets. Thus goods must travel along the highway network to reach the import/export exchange location, representing the costs of transporting these physical goods to the external markets. For more discussion of these World Markets and associated assumptions see Section 6.6.5.

The goods commodities' import parameter values have been set as shown in Table 6.10. The commodity-specific import function for the relevant (non zero) World Market zones have a r eference quantity calculated by estimating the target annual Import quantity, effectively splitting up the IMPLAN modelwide imports among these World Market zones (see Section 5.3.1 regarding initial processing of IMPLAN data, and Section 6.6.5 for target allocation among World Markets) at the reference price ($PriceRef_{c,i}$) is 1.0 and a small slope is assumed. The small slope ($0.01*QRef_{c,i}$) approximates a horizontal curve, assuming the model area is a price setter for this commodity. When calibrated, this slope in the World Market zones will be increase to approximate a vertical curve, i.e., model area is a commodity price taker. For all other zones (ZoneNumber= -1), the import function is set to have 0 reference quantity, and negligible slope (10,000). Export function parameters in all zones are set at negligible levels, as they are constrained elsewhere (see discussion below).

The export parameters for the goods commodities are defined separately. An "SCTGXX Exporter" activity is defined for each commodity to consume the target amount of exports of that commodity (ActivitiesI.csv "Size"). The capacity of the export market is set by specifying the discretionary use rate (in MakeUseI.csv). A value of 10 is used, allowing up to 10 times the target baseyear exports (set in ActivitiesI.csv).

To obtain the target share of total exports by market, the Initial quantity and Zone Constant are adjusted in ActivitiesZonalValuesI.csv. The target exports consumed by the "exporter" activity ("initial quantity" in ActivitiesZonalValuesI.csv) is set to 0 for all internal zones and as the target annual export quantity elsewhere, by World Market zone. The "ZoneConstant" for all internal zones is set to infinity to discourage the exporter from consuming exports from anywhere except the World Market zones. The World Market "ZoneConstant" results from a constrained run, where the zonal activity targets are the target export quantities by zone (0 for internal zones, target World Market quantities elsewhere, in ActivityConstraintsI.csv).[19]

Floorspace import parameters

The import function has specific parameters to calculate the import of floorspace, as discussed in Section 6.3.5. The following parameters, present in the pi.properties file, are used to generate import function curves shaped like Figure 6.1 from the floorspace inventory from the ALD module, and the expected price of floorspace in the commodity input file ([CommodityI.csv] [ExpectedPrice]).

Table 6.12. PI Floorspace Import Parameters

Parameter	Field name in [pi.properties]	Parameter Value
F0Price	pi.floorspaceP0	0.5
FMidpoint	pi.floorspaceMidpoint	0.45
FDelta	pi.floorspaceDelta	0.5
FEta	pi.floorspaceEta	5
FSlope	pi.floorspaceSlope	0.07

6.6. Inputs and Outputs

The inputs and output of the PI module are listed in Table 6.13 and 6.14. The remainder of this section discusses in more detail, selected PI inputs, and processing to generate baseyear input data. When PI looks for previous year prices, it first looks for ExchangeResultsI.csv in the current year directory, and if not found, ExchangeResults.csv output from the previous year is used.

PI has an option to produce trip length/time histograms on request. To do so, the HistogramI.csv input file must be specified with the following column fields: commodity name, skim (distance/time matrix), the upper bound of up to 100 trip length or time bands (typically miles/minutes). All commodities must have the same number of bands in the file, with 0s listed for any bands not used. Each listed commodity generates an output Histogram_*commodity*.csv file with buying/selling quantity (commodity value$) that falls within each band, as well as the average trip length/time value of each band. One more band than the number of upper bounds, as the last band is values exceeding the uppermost band.

[19] Note that this constrained run target is actually an activity quantity, and as such, must be adjusted for the quantity of import commodity consumed per "exporter" unit activity ("coefficient" in output ZonalMakeUseI.csv).

Table 6.13. PI Inputs

Data Element	Source
Modelwide total production quantity of activity a (TW_a) [ActivityDollarDataForPI.csv] [householdsByHHCategory.csv]	ED (industry$) SPG1(HHs)
Quantities of total floorspace inventory by alpha zone [FloorspaceI.csv]	ALD
Increments of total floorspace change in past year by alpha zone [Increments.csv]	ALD
Fixed constant-production rate agricultural and forest lands by zone [PIAgForestFloorspace.csv] (used only in PI, replaces FloorspaceI.csv actual acreages)	exog
Mode choice composite utility for commodity c between beta zones k and z ($MSLogSum_{c,k,z}$) [###betals.zip]	PT
Auto and commercial vehicle times and distances traveled by commodity c between beta zones k and z ($Time_{c,k,z}$, $Dist_{c,k,z}$) [betapkdist.zip, betapktime.zip]	TS
Proportion of modelwide quantity of production activity a in zone z in the previous time period ($PrevW_{a,z}$) [ActivitesZonalValues.csv]	Prev year PI
Unit prices for commodities by beta zones ($Price_{c,k}$) [ExchangeResults.csv] (floorspace) [*commodity*_ExchangeResults.csv] (non-floorspace commodities)	Prev year PI
Production size terms by zone z and activity a ($Size_{a,z}$) [ActivitySizeTermsI.csv]	exog
Residential floorspace exchange location buying/selling, size term ($Size_{s,c,k}$, $Size_{b,c,k}$) [FloorspaceBuyingSizeTermsI.csv]	exog
Aggregate activities definitions/parameters [ActivitiesI.csv]	exog
Transportation-based cost coefficients by commodity [CommoditiesI.csv]	exog
Other modelwide coefficients (including floorspace constants) [MetaParameters.csv]	exog
Minimum/discretionary industry-commodity make coefficients [MakeUseI.csv]	exog
Minimum/discretionary institution (HHs/government)-commodity use coefficients [MakeUseI.csv]	exog
Import/export function coefficients by beta zone [ExchangeImportExportI.csv]	exog
List of alpha zones and beta zones [FloorspaceZonesI.csv][PECASZonesI.csv]	exog
List of alpha zones by beta zone [alpha2beta.csv]	exog
Trip length/time distribution input [HistogramI.csv] (optional)	exog

PI produces the following working files pulling data from other modules, as listed above and discussed with the PI p-processor in Section 6.3.7:

- **[ActivitiesW.csv]** from [ActivitiesI.csv], [ActivityDollarDataForPI.csv], [householdsByHHCategory.csv], [ImportShareByCommodity.csv], and [MakeUseI.csv]
- **[FloorspaceW.csv]** from [PIAgForestFloorspace.csv] and [FloorspaceI.csv]
- **[ActivitiesZonalValuesW.csv]** from [ActivitiesZonalValuesI.csv], [Increments.csv] and [ActivityLocations.csv]
- **[MakeUseW.csv]** from [MakeUseI.csv] and [LaborUseScalingFactors.csv]

Table 6.14. PI Outputs

Data Element	Users
PI Working files [ActivitiesW.csv][ActivitiesZonalValueW.csv][FloorspaceW.csv]	PI
Internal commodity dollar flows (goods, services, labor) between beta zones [buying_*commodity*.zipMatrix][selling_*commodity*.zipMatrix]	PT (selling labor) CT (goods)
Labor dollar production by occupation and household category and consumption by occupation and industry expanded to alpha zones [laborDollarProduction.csv][laborDollarConsumption.csv]	SPG2 (production)
Labor dollar production and consumption by occupation category expanded to alpha zones [laborDollarProductionSum.csv][laborDollarConsumptionSum.csv]	PT
Activity quantities and composite utilities for beta zones [ActivityLocations.csv] and alpha zones [ActivityLocations2.csv]	SPG2 (alpha zones) Next yr PI (beta zones)

Occupied quantities and unit prices for floorspace in beta zones [ExchangeResults.csv]	Next yr ALD
Import/export quantities of commodities ($ flows) to beta zones [ExchangeResults.csv]	ET (future)
Commodity quantities make and use by alpha zone [FloorspaceZoneTotalMakeUse.csv] [FloorspaceZoneTotalMakeUse.bin] (binary)	CT (future)
Modelwide composite utilities of production by activity [ActivitySummary.csv]	Next yr ED (future)
Solved beta zone industry-commodity production and consumption technical coefficients [ZonalMakeUse.csv] [ZonalMakeUse.bin] (binary)	diagnostics
Commodity beta zone composite utilities [CommodityZUtilities.csv]	diagnostics
Trip Length distribution histogram output [histograms.csv]	diagnostics

6.6.1. Modelwide Industrial and Government Activity by Category

Each period, PI allocates modelwide production activity, TW_a output from the ED module, among beta zones. The previous period's allocation by zone, $PrevW_{a,z}$, influences the outcome of the current year. Industry and government activity come from the ED module, while household counts come from the SPG1 module.

Table 6.15 shows the value of model area production (demargined make) by activity in 1990 dollars used for TW_a in the baseyear. The industry data comes from 1998 IMPLAN data, as discussed in Section 6.5.1.

Table 6.15. Baseyear 1998 Modelwide Activity (1990$ or household counts)-includesReno

PI Activity	MakeForRegion	MakeForExport	Total Production
ACCOMMODATIONS	1,496,369,510	1,261,694,667	2,758,064,176
AGRICULTURE AND MINING-Agriculture	3,457,998,908	5,617,927,423	9,075,926,330
AGRICULTURE AND MINING-Office	1,082,068	0	1,082,068
COMMUNICATIONS AND UTILITIES-Light Industry	8,692,140,397	2,656,706,579	11,348,846,975
COMMUNICATIONS AND UTILITIES-Office	1,043,392,653	41,451,228	1,084,843,881
CONSTRUCTION	19,243,332,027	3,208,837,287	22,452,169,315
ELECTRONICS AND INSTRUMENTS-Light Industry	4,803,177,983	9,754,985,952	14,558,163,935
ELECTRONICS AND INSTRUMENTS-Office	1,372,781,301	1,207,879	1,373,989,179
FIRE BUSINESS AND PROFESSIONAL SERVICES	38,472,894,604	5,168,787,030	43,641,681,633
FOOD PRODUCTS-Heavy Industry	2,108,512,931	4,624,499,504	6,733,012,435
FOOD PRODUCTS-Light Industry	1,471,552,279	1,817,497,395	3,289,049,674
FOOD PRODUCTS-Office	229,298,703	0	229,298,703
FORESTRY AND LOGGING	1,714,613,764	1,517,553,412	3,232,167,176
GOVERNMENT ADMINISTRATION-Government Support	11,757,615,422	118,334,781	11,875,950,203
GOVERNMENT ADMINISTRATION-Office	1,038,435,531	252,421	1,038,687,952
HEALTH SERVICES-Hospital	4,607,808,979	3,718,761	4,611,527,740
HEALTH SERVICES-Institutional	1,022,124,983	0	1,022,124,983
HEALTH SERVICES-Office	6,341,968,254	772,400,627	7,114,368,881
HIGHER EDUCATION	2,702,997,860	2,274,637	2,705,272,497
HOMEBASED SERVICES	156,478,846	0	156,478,846
LOWER EDUCATION-Grade School	4,217,628,436	23,086,457	4,240,714,893
LOWER EDUCATION-Office	170,348,197	0	170,348,197
LUMBER AND WOOD PRODUCTS-Heavy Industry	2,290,819,329	6,987,669,314	9,278,488,643
LUMBER AND WOOD PRODUCTS-Office	224,531,758	0	224,531,758
OTHER DURABLES-Heavy Industry	2,931,082,246	11,193,090,016	14,124,172,262
OTHER DURABLES-Light Industry	1,918,234,053	3,012,107,306	4,930,341,359
OTHER DURABLES-Office	1,266,108,247	4,446,375	1,270,554,622
OTHER NON-DURABLES-Heavy Industry	1,410,712,953	2,071,597,348	3,482,310,301
OTHER NON-DURABLES-Light Industry	1,442,666,326	1,101,408,398	2,544,074,724
OTHER NON-DURABLES-Office	531,385,252	25,258,781	556,644,034
PERSONAL AND OTHER SERVICES AND AMUSEMENTS	9,615,000,917	3,641,756,370	13,256,757,288
PULP AND PAPER-Heavy Industry	420,887,533	4,643,862,017	5,064,749,550
PULP AND PAPER-Office	161,942,535	0	161,942,535
RETAIL TRADE-Office	316,548,957	0	316,548,957
RETAIL TRADE-Retail	50,948,582,603	6,200,604,426	57,149,187,029
TRANSPORT-Depot	6,809,081,354	2,500,970,187	9,310,051,542
TRANSPORT-Office	784,002,323	0	784,002,323
WHOLESALE TRADE-Office	2,554,184,477	0	2,554,184,477
WHOLESALE TRADE-Warehouse	43,773,938,935	2,553,533,573	46,327,472,508
GOVERNMENT INSTITUTIONS	2,192,296,328	0	2,192,296,328
CAPITALISTS	549,588,125	0	549,588,125
HH0to5k1to2	714,840	0	714,840
HH0to5k3plus	134,068	0	134,068
HH5to10k1to2	1,370,299	0	1,370,299
HH5to10k3plus	457,153	0	457,153
HH10to15k1to2	2,099,584	0	2,099,584
HH10to15k3plus	878,666	0	878,666
HH15to20k1to2	2,270,330	0	2,270,330
HH15to20k3plus	1,183,773	0	1,183,773
HH20to30k1to2	5,544,097	0	5,544,097
HH20to30k3plus	4,486,663	0	4,486,663
HH30to40k1to2	4,049,356	0	4,049,356
HH30to40k3plus	5,013,985	0	5,013,985
HH40to50k1to2	2,643,690	0	2,643,690
HH40to50k3plus	4,415,002	0	4,415,002
HH50to70k1to2	3,324,119	0	3,324,119
HH50to70k3plus	6,294,348	0	6,294,348
HH70kUp1to2	1,809,606	0	1,809,606
HH70kUp3plus	3,110,904	0	3,110,904

6.6.2. Household Quantities by Category

The number of households by income and household size categories is used as the measure of residential activity and as a size term, in the allocation of labor ($Size_{a,z,}$) and the location of construction activity. Modelwide household counts used as activity totals in PI were obtained from the current year SPG1 module output. The zone-specific size terms, were taken from previous year PI output. For the baseyear, a synthetic population database of household and person data was generated from 1990 US Census counts, essentially a special SPG module run. The baseyear values are shown in Table 6.15.

6.6.3. Floorspace Quantities by Category by Zone

Floorspace is an important PI input. It establishes the available exchange locations for production activities. It is received as a fixed amount of space, from the ALD module. For the baseyear, floorspace quantities by industry and zone (alpha zone, aggregated to beta zones for use in PI) were generated synthetically for ALD. The development of the baseyear floorspace estimate is discussed in Section 5.6.1 under the ALD module.

In PI agriculture and logging lands were treated slightly differently than in ALD. Because PI requires a consistent use of floorspace per employee per year in a given industry, only a subset of the full 'FLR Agriculture' and 'FLR Logging' lands were used. Annual timber harvests assumed 2 percent of total timberlands modelwide. A single acres per employee usage rate (Table 6.16) was assumed for each industry, representing the most intensive acres per agriculture employee of the 75 modeled counties (Del Norte County, CA). Table 6.16 also identifies the resulting modelwide annual timber harvest acres per IMPLAN forestry employee used in PI.

Table 6.16. Assumed Agriculture/Logging Acres Per Employee

PI Industry	Acres Per Employee
AGRICULTURE AND MINING-Agriculture	9.1 acres/employee
FORESTRY AND LOGGING	50.1 acres/employee

These lands (quantity and location) are assumed to be fixed for the duration of the model. In the future, a more sophisticated submodel would be required to address the different land use intensities of agriculture and timberlands, as well as annually rotate timber harvests to un-cut timberland.

ALD will operate on the original full agriculture and timberlands inventory, however, the PI-p-processor will create a PI floorspace inventory file that includes the employee-based annual FLR Agriculture and FLR logging lands, as discussed above. This requires applying a fixed set of factors by alpha zone to reduce the full agriculture/forestry land area coverage into the employee-based single year lands. These fixed factors are based on relationships from the baseyear floorspace data (discussed in section 5.6.1). It should be noted that ALD in the Oregon Statewide Integrated Model (SWIM2) will initially assume that productive agriculture and logging lands are fixed in quantity and location over time. As a result, these factors will only be applied in the baseyear.

6.6.4. Road Network Travel Conditions

PI location decisions are influenced by transport costs and times to obtain factor inputs and reach markets. In addition the composite utility of personal travel across all modes is used in PI, calculated for the previous year in the PT module.

AM peak period (7-9AM) auto travel times and costs (both outbound and return) are used for goods and selected service commodities. As discussed in Section 6.6.5, identification of the imports/exports of goods commodities requires the TS networks to include travel conditions to/from the World Market zones (6000 zones). Commercial Vehicle skims will be used for selected goods commodities when they become available, allowing industry response to weight restrictions, i.e., increased heavy truck transport costs influence industry location decisions. PT-generated peak mode choice composite utility values, based on time and cost across all modes of travel, are used to represent the travel conditions for labor flows and selected personal services. The assumed travel skims are listed in Table 6.17 for all commodities (PI input CommoditiesI.csv)

These PT and TS outputs are in a compressed OD matrix format, 'squeezed' from Alpha-to beta zones for use in the PI module. Initial values were provided by loading the model networks used in the TS and PT modules. The baseyear employs preliminary output developed from metro area data.

Table 6.17. Assumed Network Travel Conditions by Commodity

Commodity	TS Travel Skim(s)
Goods Commodities	
All SCTG goods commodities	betapktrk1time, betapktrk1dist, betapktrk1toll
Occupation Labor Commodities	
1_ManPro	w7mcls_beta
1a_Health	w7mcls _beta
2_PstSec	w7mcls _beta
3_OthTchr	w4mcls_beta
4_OthP&T	w4mcls _beta
5_RetSls	w1mcls_beta
6_OthR&C	w1mcls _beta
7_NonOfc	w1mcls _beta
Service Commodities	
RETAIL TRADE	s4mcls_beta
HIGHER EDUCATION	c4mcls_beta
LOWER EDUCATION	c4mcls_beta
GOVERNMENT ADMINISTRATION	b4mcls_beta
PERSONAL AND OTHER SERVICES AND AMUSEMENTS	b5mcls_beta
INTERNAL SERVICES	b8mcls_beta
HOMEBASED SERVICES	o4mcls_beta
HEALTH SERVICES	o4mcls_beta
COMMUNICATIONS AND UTILITIES	betapkautotime, betapkautodist, beetapkautotoll
ACCOMMODATIONS	betapkautotime, betapkautodist, beetapkautotoll
TRANSPORT	betapkautotime, betapkautodist, beetapkautotoll
WHOLESALE TRADE	betapkautotime, betapkautodist, beetapkautotoll
CONSTRUCTION	betapkautotime, betapkautodist, beetapkautotoll

Where:
Peak period (7-9AM) auto network distance between beta zones [betapkdist.zip]
Peak period (7-9AM) auto network travel time between beta zones [betapktime.zip]
Mode choice logsum for Work trips, < $15K income, number of autos=0 [w1betals.zip]
Mode choice logsum for Work trips, $15K -$30K income, number of autos < household size [w4betals.zip]
Mode choice logsum for Work trips, ≥ $30K income, number of autos < household size [w7betals.zip]
Mode choice logsum for Work-based trips, $15K -$30K income, number of autos < household size [b4betals.zip]
Mode choice logsum for Work-based trips, $15K -$30K income, number of autos ≥ household size [b5betals.zip]
Mode choice logsum for Work-based trips, ≥ $30K income, number of autos ≥ household size [b8betals.zip]
Mode choice logsum for School trips, $15K -$30K income, number of autos < household size [c4betals.zip]
Mode choice logsum for Shopping trips, $15K -$30K income, number of autos<household size [s4betals.zip]
Mode choice logsum for Other trips, $15K -$30K income, number of autos<household size [o4betals.zip]

6.6.5. Import and Export Assumptions

PI Import and Export of goods commodities were constrained to flow through selected "gateways". That is, the costs faced to import/export goods commodities reflected travel across the model network and assumed distances to various World Markets. Additionally modelwide import and exports target quantities were identified for each World market. These assumptions are detailed below.

The other key PI import/export assumption is the target market share of each commodity's imports and exports among these world markets. The 1998 total modelwide imports and exports target values (for all World Markets combined) were calculated as a share of PI target modelwide consumption (or use). This share was derived from IMPLAN data indicating the portion of all modelwide consumption from imports for each commodity.[20] This was applied to total consumption generated from PI use rates by commodity estimated for other PI inputs (MakeUseI.csv "Minimum" use rate multiplied by overall 1998 Industry Activity in 1990$ units from ActivitiesI.csv). Exports for each commodity were then calculated to preserve the net Imports (Imports-Exports, set when MakeUseI.csv make and use rates were developed).

The total modelwide imports and exports were broken into domestic and foreign components using IMPLAN exports (make for foreign use) and imports (Use from foreign make) share data. Information on the shares of imports/exports going to each World Market was identified from two main sources: the ODOT Commodity Flow forecast[21] for domestic flows, and TradeStats Express website data for international flows.[22] The international source only covered imports, which was applied as shares to both foreign import and export totals.

The 1998 baseyear Local World Market share was removed from the other World Markets (non-Ocean) share based on expert judgment and 1997 and 2002 US Commodity flow average trip lengths by commodity. Those with large LOCAL market shares were typically low value-to-weight commodities with shorter average trip lengths.

The imports for fuel commodities (SCTG16-18) were modeled differently. These commodities are almost entirely imported with negligible exports. They are imported by pipeline to various locations in the state and trucked from these locations to their final demand location. Thus they are simplistically modeled with imports/exports directly available (at no additional cost) at each beta zone. In the future, the specific zonal locations of the pipelines could be identified and linked to the appropriate World Market (Canada is the source of nearly all Oregon fuels), and then PI fuel imports/exports could be configured as is done with the other goods commodities, discussed above.

The resulting World Market shares by commodity are shown in Table 6.18 and 6.19, and graphically in Figures 6.7 and 6.8. As you can see, for many commodities, imports and/or exports are negligible.

[20] 1998 IMPLAN model area estimation of imports and exports serve as both a target and the starting value for the PI S2 parameter reference quantities (QRefc,i and QRefc,e discussed in Section 5.4.3).

[21] ODOT Commodity Flow Forecast regions differ slightly from those used here. ODOT CFF NE region includes ID, WY, NE, IA and ODOT CFF S region includes parts of NV and AZ.

[22] http://tse.export.gov/tse/tsehome.aspx

Table 6.18. Assumed Share of Imports from the World Markets

SCTG	Description	World Market Import Share (sums to 100%) N 6001	NE 6002	E 6003	S 6004	Port 6005	Local 6006
SCTG01	Live animals and live fish	10.1	2.4	32.3	48.9	1.3	5.0
SCTG02	Cereal grains	4.9	1.8	27.1	35.5	25.7	5.0
SCTG03	Other agricultural products	5.0	2.0	28.9	39.5	19.7	5.0
SCTG04	Animal feed and products of animal origin, n.e.c.	7.6	4.7	33.2	46.2	3.3	5.0
SCTG05	Meat, fish, seafood, and their preparations	38.5	8.6	19.9	21.6	6.4	5.0
SCTG06	Milled grain products and preparations, and bakery products	18.3	12.9	29.8	29.6	4.3	5.0
SCTG07	Other prepared foodstuffs and fats and oils	16.9	11.3	29.5	31.1	6.2	5.0
SCTG08	Alcoholic beverages	19.4	13.0	30.5	29.8	2.3	5.0
SCTG09	Tobacco products	56.3	3.9	8.6	26.3	0.0	5.0
SCTG10	Monumental or building stone	11.5	10.5	2.2	39.8	1.0	35.0
SCTG11	Natural sands	8.7	7.8	1.6	29.7	2.2	50.0
SCTG12	Gravel and crushed stone	8.7	7.8	1.6	29.7	2.2	50.0
SCTG13	Nonmetallic minerals, n.e.c.	13.2	9.5	2.6	36.6	18.2	20.0
SCTG14	Metallic ores and concentrates	4.2	0.0	0.9	0.0	60.0	35.0
SCTG15	Coal	71.4	0.0	3.3	0.0	20.3	5.0
SCTG19	Coal and petroleum products, n.e.c.	88.2	0.0	0.7	0.4	5.6	5.0
SCTG20	Basic chemicals	17.0	0.0	7.8	0.9	69.3	5.0
SCTG21	Pharmaceutical products	16.8	0.0	7.7	0.8	69.6	5.0
SCTG22	Fertilizers	35.2	6.9	22.4	12.3	18.3	5.0
SCTG23	Chemical products and preparations, n.e.c.	36.4	7.3	23.3	13.0	14.9	5.0
SCTG24	Plastics and rubber	49.6	11.5	13.2	17.5	3.3	5.0
SCTG25	Logs and other wood in the rough	10.0	2.3	30.6	45.6	6.5	5.0
SCTG26	Wood products	13.3	4.1	29.2	43.2	5.2	5.0
SCTG27	Pulp, newsprint, paper, and paperboard	44.7	1.2	9.5	17.1	22.5	5.0
SCTG28	Paper or paperboard articles	23.1	2.6	21.3	43.1	4.8	5.0
SCTG29	Printed products	26.9	7.1	18.3	40.3	2.4	5.0
SCTG30	Textiles, leather, articles of textiles or leather	41.0	1.7	12.0	5.9	34.4	5.0
SCTG31	Nonmetallic mineral products	17.6	14.5	3.7	55.6	3.6	5.0
SCTG32	Base metal in primary or semi-finished forms and in finished basic shapes	16.6	1.1	27.3	39.0	11.0	5.0
SCTG33	Articles of base metal	9.5	6.3	60.0	15.7	3.4	5.0
SCTG34	Machinery	15.8	3.1	36.2	24.6	15.4	5.0
SCTG35	Electronic and other electrical equipment and components, and office equipment	9.5	1.7	17.3	9.5	57.0	5.0
SCTG36	Motorized and other vehicles (including parts)	19.4	1.3	54.5	18.3	1.5	5.0
SCTG37	Transportation equipment, n.e.c.	25.5	0.9	45.2	20.5	3.0	5.0
SCTG38	Precision instruments and apparatus	21.7	1.3	23.0	23.2	25.8	5.0
SCTG39	Furniture, mattresses and mattress supports, lamps, lighting fittings, and illuminated signs	24.0	1.9	23.9	39.5	5.7	5.0
SCTG40	Miscellaneous manufactured products	73.8	0.4	7.3	3.0	10.5	5.0
SCTG41	Waste and scrap	4.9	0.0	1.3	0.6	43.2	50.0

Sources: ODOT Commodity Flow forecast (domestic); TradeStats Express website data (international), plus US CFS and expert judgment estimation of Local 6006 share.

Table 6.19. Assumed Share of Exports to the World Markets

		World Market Export Share (sum to 100%)					
SCTG	**Description**	**N 6001**	**NE 6002**	**E 6003**	**S 6004**	**Port 6005**	**Local 6006**
SCTG01	Live animals and live fish	26.0	6.0	4.4	57.7	0.8	5.0
SCTG02	Cereal grains	23.4	6.3	4.7	59.8	0.9	5.0
SCTG03	Other agricultural products	19.2	4.9	6.1	46.5	18.3	5.0
SCTG04	Animal feed and products of animal origin, n.e.c.	23.5	13.8	10.1	46.9	0.8	5.0
SCTG05	Meat, fish, seafood, and their preparations	31.6	27.9	20.3	12.5	2.7	5.0
SCTG06	Milled grain products and preparations, and bakery products	23.6	32.2	23.5	13.6	2.1	5.0
SCTG07	Other prepared foodstuffs and fats and oils	23.5	29.4	21.6	17.1	3.4	5.0
SCTG08	Alcoholic beverages	26.6	27.4	22.3	11.5	7.1	5.0
SCTG09	Tobacco products	62.0	4.9	26.7	1.0	0.4	5.0
SCTG10	Monumental or building stone	37.3	8.5	11.7	6.3	1.1	35.0
SCTG11	Natural sands	29.1	6.6	9.2	5.0	0.1	50.0
SCTG12	Gravel and crushed stone	29.1	6.6	9.2	5.0	0.1	50.0
SCTG13	Nonmetallic minerals, n.e.c.	37.0	7.9	11.1	5.8	18.3	20.0
SCTG14	Metallic ores and concentrates	4.2	0.0	0.9	0.0	60.0	35.0
SCTG15	Coal	90.1	0.0	3.9	0.0	1.1	5.0
SCTG16	Gasoline and aviation turbine fuel	80.0	6.7	6.9	1.4	0.0	5.0
SCTG17	Gasoline and aviation turbine fuel	38.1	11.2	10.3	35.4	0.0	5.0
SCTG18	Fuel oils	38.1	11.2	10.3	35.4	0.0	5.0
SCTG19	Coal and petroleum products, n.e.c.	36.2	11.4	10.6	36.1	0.7	5.0
SCTG20	Basic chemicals	18.4	22.5	30.6	11.4	12.1	5.0
SCTG21	Pharmaceutical products	18.5	22.9	31.0	11.6	11.1	5.0
SCTG22	Fertilizers	18.5	23.3	31.5	11.8	9.9	5.0
SCTG23	Chemical products and preparations, n.e.c.	18.7	25.9	34.1	13.0	3.2	5.0
SCTG24	Plastics and rubber	34.0	2.4	35.4	19.9	3.3	5.0
SCTG25	Logs and other wood in the rough	26.6	5.4	4.3	51.2	7.5	5.0
SCTG26	Wood products	76.5	4.0	5.3	4.3	4.9	5.0
SCTG27	Pulp, newsprint, paper, and paperboard	38.1	6.5	12.2	21.2	17.0	5.0
SCTG28	Paper or paperboard articles	57.7	3.4	22.4	7.3	4.2	5.0
SCTG29	Printed products	20.6	7.0	55.0	11.0	1.4	5.0
SCTG30	Textiles, leather, articles of textiles or leather	55.3	0.5	4.7	1.7	32.8	5.0
SCTG31	Nonmetallic mineral products	51.7	11.2	16.5	8.7	6.9	5.0
SCTG32	Base metal in primary or semi-finished forms and in finished basic shapes	18.3	2.9	51.3	13.8	8.7	5.0
SCTG33	Articles of base metal	26.8	3.7	49.9	11.4	3.2	5.0
SCTG34	Machinery	35.0	4.4	36.0	12.0	7.5	5.0
SCTG35	Electronic and other electrical equipment and components, and office equipment	30.9	6.0	18.8	8.2	31.0	5.0
SCTG36	Motorized and other vehicles (including parts)	37.5	5.7	36.7	12.8	2.3	5.0
SCTG37	Transportation equipment, n.e.c.	34.6	6.8	42.2	10.2	1.2	5.0
SCTG38	Precision instruments and apparatus	30.3	4.6	37.4	15.5	7.2	5.0
SCTG39	Furniture, mattresses and mattress supports, lamps, lighting fittings, and illuminated signs	28.2	6.1	29.4	26.6	4.8	5.0
SCTG40	Miscellaneous manufactured products	37.0	3.6	24.2	10.9	19.3	5.0
SCTG41	Waste and scrap	28.9	2.2	2.1	0.2	16.6	50.0

Sources: ODOT Commodity Flow forecast (domestic); TradeStats Express website data (international), plus US CFS and expert judgment estimation of Local 6006 share.

Figure 6.4. Assumed World Market Imports Market Share

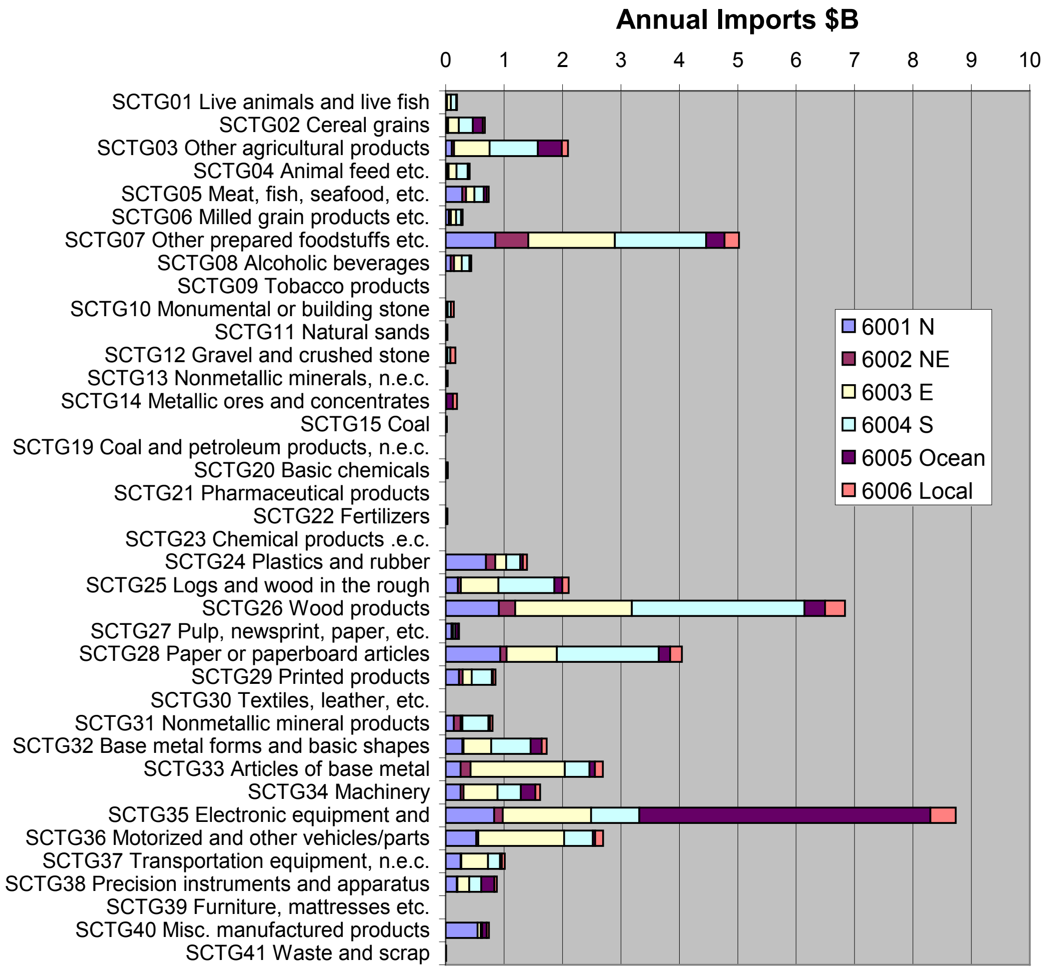
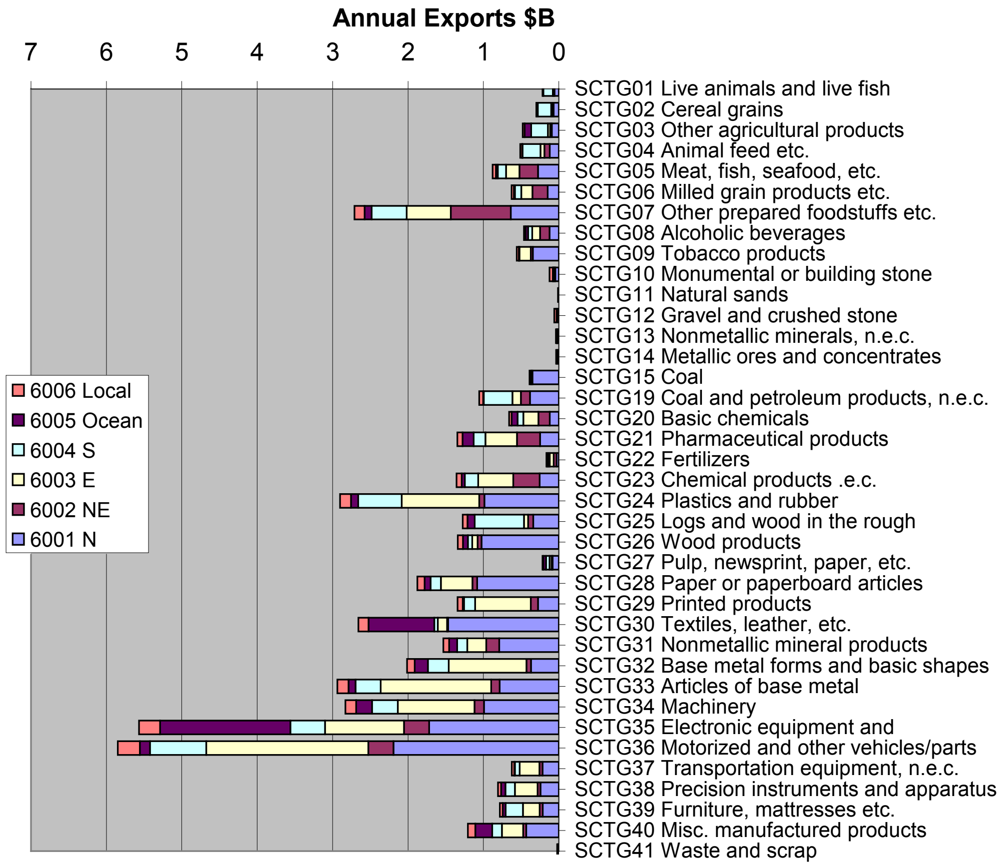


Figure 6.5. Assumed World Market Exports Market Share



6.7. Calibration Targets

PI has many avenues for calibration. The six formal PI calibration targets are listed in the top of Table 6.20. These will be used to formally assess PI calibration efforts. Additional targets to be reviewed are listed in the bottom of Table 6.20. Section 6.8 discusses a tier-based approach to using these targets to calibrate PI over time, achieving the most important performance earlier in the project schedule. The remainder of this section discusses the listed data sources in more detail.

Table 6.20. PI Calibration Targets

Source	Year	SWIM2 Target
Official Targets		
IMPLAN County Employment data	1998	Employment by industry/occupation
IMPLAN Activity data	1998	Modelwide imports/exports ($) by commodity
US Commodity Flow Survey	1993 and 1997	Average trip length by goods commodity
Oregon Travel Behavior Surveys	1994/1996	Personal trip length distributions by purpose/occupation
		Personal service trip length distributions
Ohio Establishment Survey	2003	Average trip lengths by Business Services
Urban Real Estate Reports (Bend-Redmond, Eugene-Springfield, Medford, Portland-Vancouver)	1998/1999	Average Home Sales and Apartment Rents and Office, Retail, and Industry floorspace rates by Real Estate Area
		Vacancy Rates by floorspace type by Real Estate Area
Census Housing Vacancy survey	1990-2004	Oregon statewide annual rent/own vacancy rates
Census Transportation Planning Package (CTPP)	1990, 2000	County-County Labor Flows County employment by occupation
Oregon Statewide Commodity Flow Survey	2004	County-County goods flows ($) among 12 statewide ACT zones
Ohio Establishment Surveys	2000	Business service trip length distributions
Additional Targets		
US census population changes	1990, 2000	Change in households by HHincome-size) by beta zone
Census (PUMS) Employment	1990, 2000	Occupation by HHincome x PUMA
Census (PUMS) Household Space	1990, 2000	Residential Floorspace by type by HHincome by PUMA
US BLS OES Survey Wage rates for selected MSAs	2000	Average Wage rates by Occupation x beta zone (in Portland-Vancouver, Salem, Corvallis, Eugene-Springfield, Medford-Ashland MSAs)
Portland Metro/Port of Portland Commodity Flow Forecasts	1997-2030	Forecast flows between Portland and aggregated state/external regions by commodity
Oregon ES202 Wage rates	1990, 1995	Average wage rates by industry and beta zone
Oregon Employment Department (OLMIS) Wage rates	1976-2000 (annual/quarterly)	Average wage rates by industry and county
Oregon Employment Department (OLMIS) Covered Employment	1990-2003 (annual/monthly)	Change in employment (by place of employment) by industry and county

6.7.1. Employment Data

Employment estimates provide a target for PI industry activity outputs. In the PI module formulation this is the consumption of the labor 'commodity' by category in each zone.

Employment by Industry

1998 Employment estimates by alpha zone and PI industry were primarily derived from 1998 IMPLAN county employment data. This data is more complete than ES202 data (covered employment only) and is consistent with the 1998 IMPLAN data also used in PI.

IMPLAN employment was obtained for the 75 counties in the study area and aggregated to match 26 PI industries (all except office support sectors). County employment estimates by industry were then allocated to alpha zones. ES202 data was used in Oregon and Clark County, WA, augmented with more comprehensive Oregon Economic

Department (OED) 1997 Pulp and Paper, 2002 Higher Education, and 2002 Hospital employees. These data aggregated employment into PI industries, using 2- and 4-digit SIC codes. In Oregon sectors lacking sufficient data and in the Halo counties, 1990 US Census STF3 tables of employment by industry by block group were used to inform the zonal allocation, after mapping block groups to alpha zones. The Census data is by place of residence, not employment, which was reasonable for most industries in the larger halo zones. The Census categories, mapped to PI industry categories are shown in Table 6.21.

Table 6.21. Equivalent SWIM2-Census Industry Categories

Category	SWIM2	1990 Census (STF3)
Ind1:	Agriculture, forestry, and mining	Agriculture, forestry, and fisheries (000-039) Mining (040-059)
Ind2:	Construction	Construction (060-099)
Ind3D:	Food products Pulp and Paper Other Non-Durables	Manufacturing, nondurable goods (100-229)
Ind3ND	Electronics and instruments Lumber and Wood products Other Durables	Manufacturing, durable goods (230-399)
Ind4:	Communications and Utilities Transport	Transportation (400-439) Communications and other public utilities (440-499)
Ind5:	Wholesale Trade	Wholesale trade (500-579)
Ind6:	Retail Trade	Retail trade (580-699)
Ind7:	FIRE, Business and Professional Services	Finance, insurance, and real estate (700-720) Business and repair services (721-760) Other professional and related services (841, 861-899)
Ind8:	Home-based services Personal and other services and amusements Accommodations	Personal services (761-799) Entertainment and recreation services (800-811)
Ind9:	Health Services	Health services (812-840)
Ind10:	Higher Education Lower Education	Educational services (842-860)
Ind11:	Government Administration	Public administration (900-939)

Industry management that occurs in office space was then separated from line industry employment. The estimated share of each industry in office space utilized 1990 PUMS PUMA-level employment by industry and occupation, and engineering judgment of percent non-office in each industry. This was dependent upon each zone's land use intensity, effectively ranging from CBD to rural type intensities. Land use intensity (LUI) in any zone is calculated as a logged scale of combined population and employment per unit area.

$$LUI_z = \ln[(2.5*Employment_z + Population_z)/Total\ Acres_z] \qquad (6.36)$$

where:
VeryHigh (CBD): $LUI \geq 3.5$
High (Urban): $2.0 \geq LUI > 3.5$
Medium (Suburban): $1.0 \geq LUI > 2.0$
Low (Rural): $LUI < 1.0$

This approach allows the share of management support workers to vary by industry-occupation combination and land use intensity. Table 6.22 identifies the assumed percent office support by industry and LU intensity used in the update.

Table 6.22. Assumed Baseyear Percent Office by Industry, Occupation, and LU Intensity

		Census Occupation						
Land Use Intensity	PI Industry	1 ManPro	2 PstSec	3 OthTch	4 OthP&T	5 RetSls	6 OthR&C	7 NonOfc
VeryHigh	AGRICULTURE AND MINING	100%	100%	100%	100%	100%	100%	100%
VeryHigh	COMMUNICATIONS AND UTILITIES	100%	100%	100%	100%	100%	100%	100%
VeryHigh	ELECTRONICS AND INSTRUMENTS	100%	100%	100%	100%	100%	100%	100%
VeryHigh	FOOD PRODUCTS-Heavy Industry	100%	100%	100%	100%	100%	100%	100%
VeryHigh	FOOD PRODUCTS-Light Industry	100%	100%	100%	100%	100%	100%	100%
VeryHigh	GOVERNMENT ADMINISTRATION	40%	40%	40%	40%	40%	40%	0%
VeryHigh	HIGHER EDUCATION	10%	10%	10%	10%	10%	10%	10%
VeryHigh	LOWER EDUCATION	10%	10%	10%	10%	10%	10%	0%
VeryHigh	LUMBER AND WOOD PRODUCTS-Forest	100%	100%	100%	100%	100%	100%	100%
VeryHigh	OTHER DURABLES-Heavy Industry	100%	100%	100%	100%	100%	100%	100%
VeryHigh	OTHER DURABLES-Light Industry	100%	100%	100%	100%	100%	100%	100%
VeryHigh	OTHER NON-DURABLES-Heavy Industry	100%	100%	100%	100%	100%	100%	100%
VeryHigh	OTHER NON-DURABLES-Light Industry	100%	100%	100%	100%	100%	100%	100%
VeryHigh	PULP AND PAPER	100%	100%	100%	100%	100%	100%	100%
VeryHigh	RETAIL TRADE	10%	10%	10%	10%	0%	10%	10%
VeryHigh	TRANSPORT	100%	100%	100%	100%	100%	100%	90%
VeryHigh	WHOLESALE TRADE	90%	100%	100%	100%	100%	100%	90%
High	AGRICULTURE AND MINING	100%	100%	100%	100%	100%	100%	0%
High	COMMUNICATIONS AND UTILITIES	100%	100%	100%	100%	100%	100%	0%
High	ELECTRONICS AND INSTRUMENTS	25%	25%	25%	25%	25%	25%	0%
High	FOOD PRODUCTS-Heavy Industry	75%	75%	75%	75%	75%	75%	0%
High	FOOD PRODUCTS-Light Industry	75%	75%	75%	75%	75%	75%	0%
High	GOVERNMENT ADMINISTRATION	25%	25%	25%	25%	25%	25%	0%
High	HIGHER EDUCATION	10%	10%	10%	10%	10%	10%	10%
High	LOWER EDUCATION	10%	10%	10%	10%	10%	10%	0%
High	LUMBER AND WOOD PRODUCTS-Forest	100%	100%	100%	100%	100%	100%	100%
High	OTHER DURABLES-Heavy Industry	75%	75%	75%	75%	75%	75%	0%
High	OTHER DURABLES-Light Industry	75%	75%	75%	75%	75%	75%	0%
High	OTHER NON-DURABLES-Heavy Industry	75%	75%	75%	75%	75%	75%	0%
High	OTHER NON-DURABLES-Light Industry	75%	75%	75%	75%	75%	75%	0%
High	PULP AND PAPER	50%	50%	50%	50%	50%	50%	0%
High	RETAIL TRADE	10%	10%	10%	10%	0%	10%	10%
High	TRANSPORT	90%	90%	90%	90%	90%	90%	0%
High	WHOLESALE TRADE	90%	90%	90%	90%	90%	90%	0%
Medium	AGRICULTURE AND MINING	100%	100%	100%	100%	100%	100%	0%
Medium	COMMUNICATIONS AND UTILITIES	100%	100%	100%	100%	100%	100%	0%
Medium	ELECTRONICS AND INSTRUMENTS	25%	25%	25%	25%	25%	25%	0%
Medium	FOOD PRODUCTS-Heavy Industry	75%	75%	75%	75%	75%	75%	0%

Medium	FOOD PRODUCTS-Light Industry	75%	75%	75%	75%	75%	75%	0%
Medium	GOVERNMENT ADMINISTRATION	0%	0%	0%	0%	0%	0%	0%
Medium	HIGHER EDUCATION	10%	10%	10%	10%	10%	10%	10%
Medium	LOWER EDUCATION	10%	10%	10%	10%	10%	10%	0%
Medium	LUMBER AND WOOD PRODUCTS-Forest	100%	100%	100%	100%	100%	100%	0%
Medium	OTHER DURABLES-Heavy Industry	50%	50%	50%	50%	50%	50%	0%
Medium	OTHER DURABLES-Light Industry	50%	50%	50%	50%	50%	50%	0%
Medium	OTHER NON-DURABLES-Heavy Industry	50%	50%	50%	50%	50%	50%	0%
Medium	OTHER NON-DURABLES-Light Industry	50%	50%	50%	50%	50%	50%	0%
Medium	PULP AND PAPER	50%	50%	50%	50%	50%	50%	0%
Medium	RETAIL TRADE	0%	0%	0%	0%	0%	0%	0%
Medium	TRANSPORT	50%	50%	50%	50%	50%	50%	0%
Medium	WHOLESALE TRADE	50%	50%	50%	50%	50%	50%	0%
Low	AGRICULTURE AND MINING	0%	0%	0%	0%	0%	0%	0%
Low	COMMUNICATIONS AND UTILITIES	0%	0%	0%	0%	0%	0%	0%
Low	ELECTRONICS AND INSTRUMENTS	0%	0%	0%	0%	0%	0%	0%
Low	FOOD PRODUCTS-Heavy Industry	0%	0%	0%	0%	0%	0%	0%
Low	FOOD PRODUCTS-Light Industry	0%	0%	0%	0%	0%	0%	0%
Low	GOVERNMENT ADMINISTRATION	0%	0%	0%	0%	0%	0%	0%
Low	HIGHER EDUCATION	0%	0%	0%	0%	0%	0%	0%
Low	LOWER EDUCATION	0%	0%	0%	0%	0%	0%	0%
Low	LUMBER AND WOOD PRODUCTS-Forest	0%	0%	0%	0%	0%	0%	0%
Low	OTHER DURABLES-Heavy Industry	0%	0%	0%	0%	0%	0%	0%
Low	OTHER DURABLES-Light Industry	0%	0%	0%	0%	0%	0%	0%
Low	OTHER NON-DURABLES-Heavy Industry	0%	0%	0%	0%	0%	0%	0%
Low	OTHER NON-DURABLES-Light Industry	0%	0%	0%	0%	0%	0%	0%
Low	PULP AND PAPER	0%	0%	0%	0%	0%	0%	0%
Low	RETAIL TRADE	0%	0%	0%	0%	0%	0%	0%
Low	TRANSPORT	0%	0%	0%	0%	0%	0%	0%
Low	WHOLESALE TRADE	0%	0%	0%	0%	0%	0%	0%

Employment for the two land-based industries (Agriculture and Mining, Forestry and Logging), was first split into office and non-office employment and then allocated to alpha zones. Office was assumed to be 10.5 percent and 12 percent[23] of modelwide employment in Agriculture and Forestry industries, and allocated to counties according to the office-based employment of all other industries ('office' + FIRE), not to exceed total Agriculture/forestry employment in any county. These employees were then allocated to alpha zones also using overall office-based employment. Forestry 'office' employees were added to the 'Lumber and Wood Products-office' industry. The remaining non-office agriculture/forestry employees in each county were allocated to alpha zones, using grid-based existing land cover data, a 30mx30m GIS gridded land coverage data of the study area, which assumes no agriculture or logging lands within urban boundaries. [10]

CTPP Employment data

The Census long form data is culled to produce the standard Census Transportation Planning Package (CTPP). 1990 and 2000 CTPP Oregon data were processed to arrive at

[23] Modelwide, the percent of office employees in the Agriculture and Forestry industry was originally based on 1990 PUMS of 12 and 27 percent respectively, but county limits resulted in 10.5 and 12 percent, respectively. All agriculture/forestry employment in the following counties were assumed to be office employees: Malheur, Multnomah, Washington, OR; Benton, Clark, Franklin, WA; Ada, Canyon, Elmore, Payette, ID; Washoe, NV.

total labor dollar flows between Oregon Counties in dollars. This involved iterative proportionate fit (IPF) processing to obtain employee flows among counties, applying CTPP average home county wage rates, and summing the labor dollars. Employment flows were segregated by worker earnings class to better estimate wages. A more complete description of the processing of the CTPP data follows:

1) Develop Employee County-County Flows Iterative Proportionate Fit (IPF)

Marginals:

- Number of workers by Residence County and Worker Earnings class,
- Number of workers by Work County and Worker Earnings Class.

(External counties included as county = -1)

Seed: County-County flow of workers within Oregon (external counties grouped as -1)

2) Apply home county Worker Earnings Rate, using classes and earnings shown in Table 6.23

Table 6.23 Assumed CTPP Worker Earnings classes

CTPP	Assumed Annual Earnings*
< $5K or loss	$2,500
5K to 9999	$7,500
10K to 14999	$12,500
15K to 19999	$17,500
20K to 24999	$22,500
25K to 29999	$27,500
30K to 34999	$32,500
35K to 49999	$42,500
50K to 74999	$62,500
75K or more	$8,500

* Current year dollars. Once summed, converted to 1990$ by applying a factor of 0.82144 to the 2000 CTPP.

3) Sum all worker earning categories to arrive at single labor dollar flow between each county and deflate to 1990$ using USGSP deflators from the ED module. (Flows to/from non-Oregon counties were excluded).

6.7.2. Demographic Data

Household income and size data is available from US Census PUMS data for the years 1990 and 2000. PUMS data is available by PUMA which will be tied to one or several beta zones in PI.

Cross-tabulations from the PUMS data will be used to calibrate PI to reflect specific behavioral patterns by household income group. These include occupations of workers and residential housing type within each household income/size group.

6.7.3. Floorspace Prices and Vacancies

Observed prices were collected for key locations within the study area to compare with PI commodity price outputs. Floorspace prices were obtained from quarterly Real Estate

Market reports for selected Oregon urban areas. These values provide general targets to assess residential and commercial floorspace rates PI outputs by beta zone.

Figures 6.5 and 6.6 plot recent market rates for selected commercial floorspace categories. Most data is for Portland metro area. Observed residential rents and home sales prices are shown in Figure 6.6. For comparison with PI outputs, the prices are in units of amortized annual prices ($/sqft) in current dollars. The residential data assumed 1800 and 800 sqft for homes and rentals, respectively, and a 30-year, 7 percent loan for home sales.

Vacancy data for various residential and nonresidential floorspace types from these same Real Estate Market reports. Additionally, the Census Housing Vacancy survey provides annual statewide vacancy data for the period 1990 to 2004, shown in Table 6.24.

Figure 6.6. Office Floorspace Rates

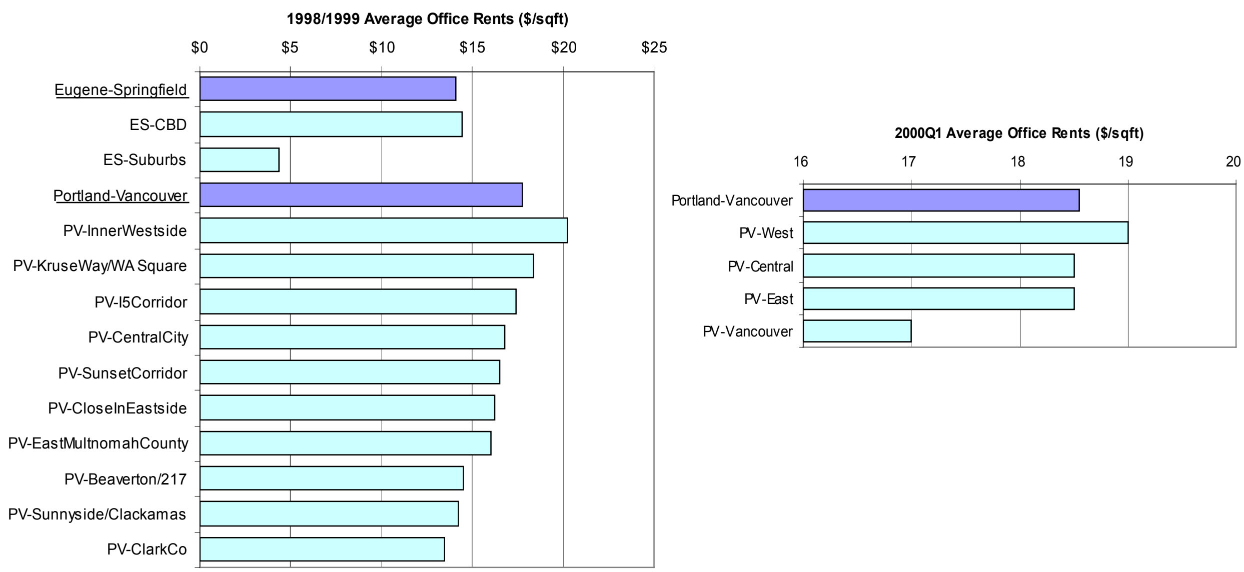


Figure 6.7. Retail and Industry Floorspace Rates

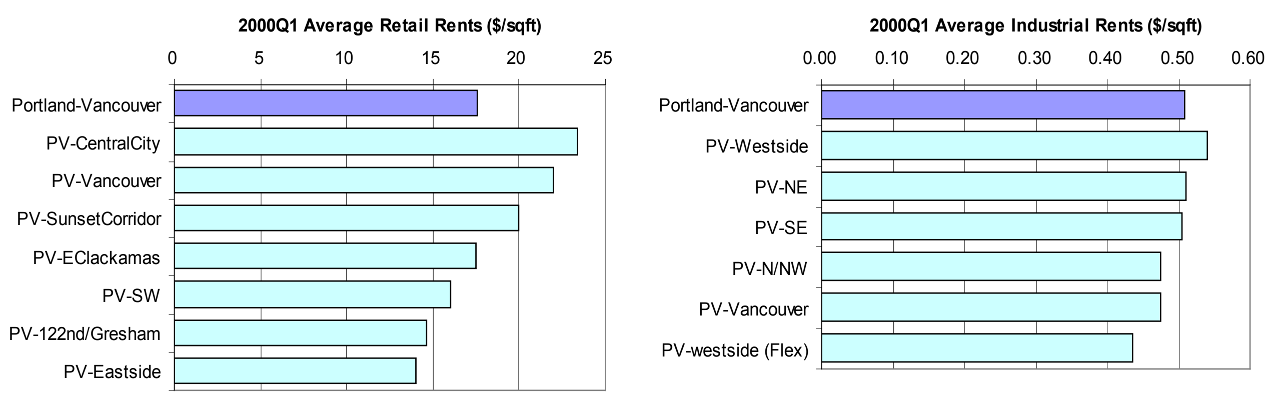


Figure 6.8. 1998 Average Home Sales & Apartment Rents in Selected Oregon Urban Areas

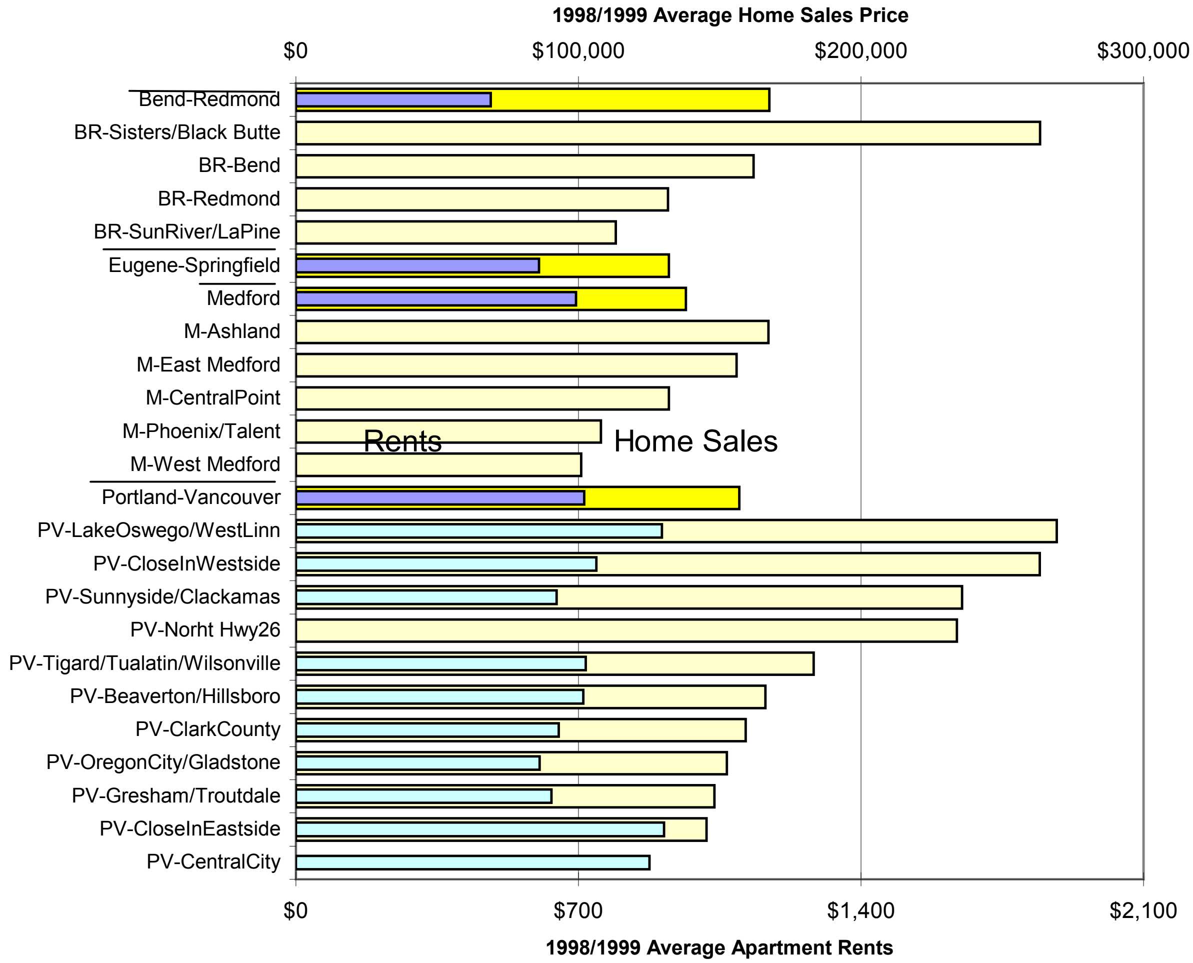


Table 6.24. Census Annual Housing Vacancy Rates for Oregon

	Oregon Annual Vacancy Rate	
Year	Rentals	Homeowners
1990	3.3%	0.8%
1991	5.1%	0.8%
1992	4.9%	0.8%
1993\r	5.6%	0.4%
1994	3.9%	1.0%
1995	4.0%	0.8%
1996	5.9%	1.4%
1997	5.4%	1.8%
1998	7.7%	2.0%
1999	7.6%	2.2%
2000	6.8%	2.4%
2001	6.8%	2.6%
2002\r	8.4%	1.9%
2003	9.9%	1.8%
2004	11.8%	1.7%

\r Census revised values

6.7.4. Trip Lengths

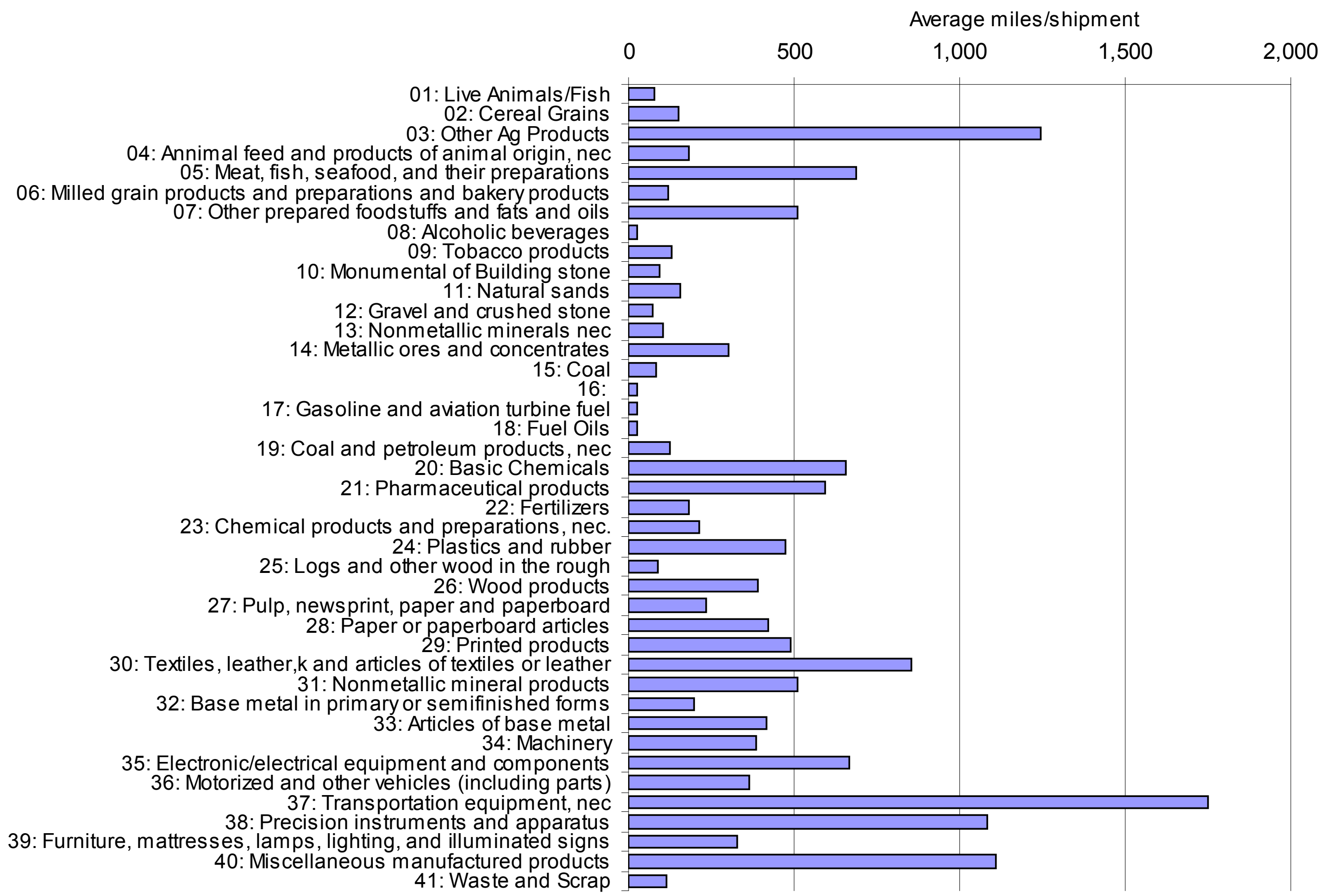
Observed flows and distances are being collected to compare with PI commodity flow outputs.

Commodity Trip Distances

For freight, the US Commodity Flow Survey (CFS) provides state-level average distances by SCTG commodity, as shown in Figure 6.9. Because CFS primarily addresses long-distance travel and average distances vary significantly between survey years, additional data is needed. Additionally, it is most important to calibrate the trips internal to the model area, excluding imports and exports where trip lengths are simplistic and less accurate. US CFS does not allow separation of internal trips.

The 2000 Oregon statewide commodity flow survey (ODOT CFS) [42] provides data on county-county flows and trip length distributions of commodity movements within the state. ODOT CFS commodities are in STCC, and thus must be converted to SWIM2 model's SCTG categories, and the PI output tons are converted into value.

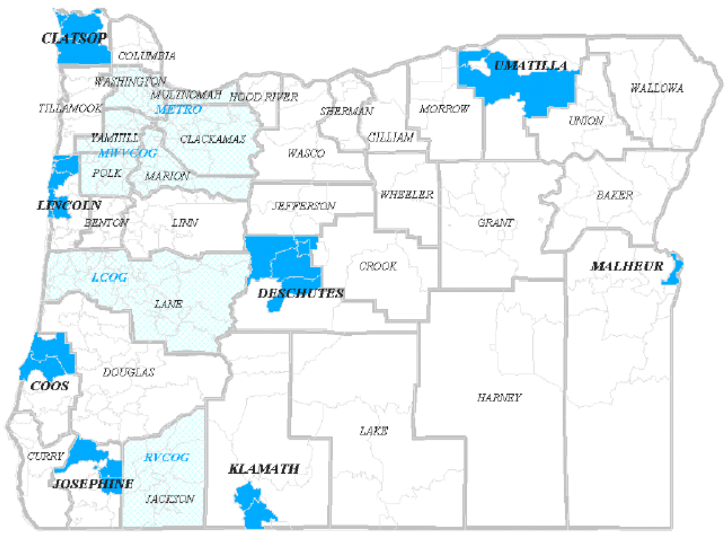
Figure 6.9. US CFS Average Commodity Trip Distance in Oregon



6.7.6. Person Trip distance distribution

The combined 1994 and 1996 Oregon Travel Behavior Surveys collected household activity data from the four Oregon MPO areas (Metro, M-WVCOG, LCOG and RVCOG) and eight additional rural Oregon counties (Clatsop, Coos, Deschutes, Josephine, Klamath, Lincoln, Malheur, and Umatilla) as shown in Figure 6.10. Eighty percent of the sampled trips were by auto.

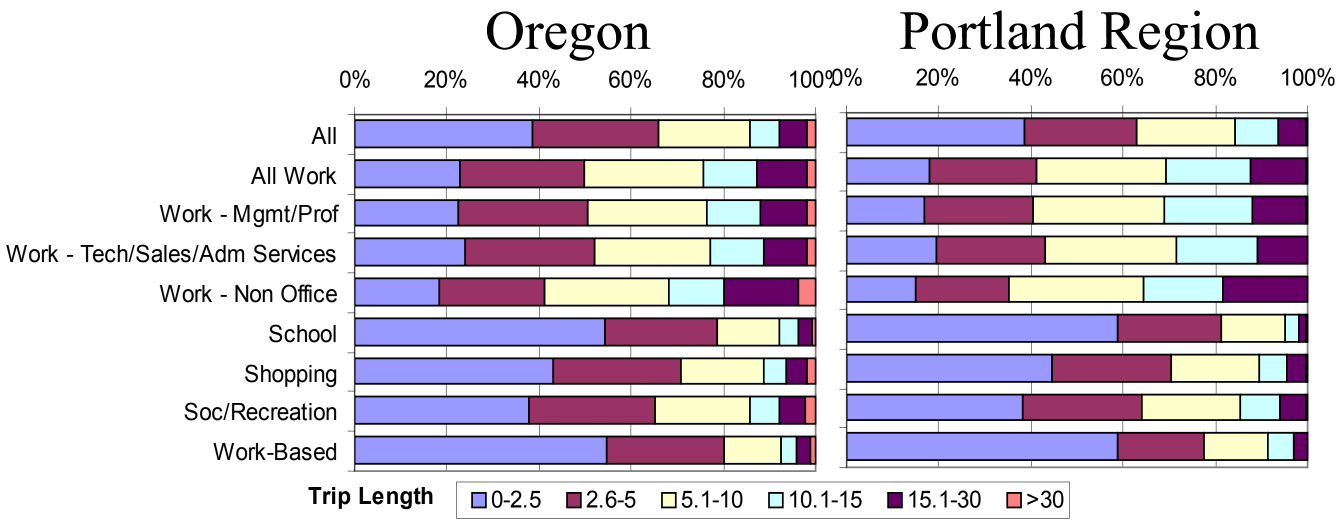
Figure 6.10. Oregon Travel Behavior Survey - Map of Surveyed Areas



These observed trip lengths will be used to assess PI person flow outputs. Survey data on the first link of each trip tours is broken out by purpose with work trips further delineated by occupation. These will be compared to work commute and personal services trip distances, output from the PI module. Services are broken into personal and business categories, based on their primary activity, as shown in Table 2.4. The personal distance distributions are shown in Figure 6.11. The figure indicates that most Oregon person tips are less than 5 miles. Work trips are the shortest in length. Portland has less of the shortest work trips (less than 2.5 miles). This concurs with a separate source, Portland DOT fact sheet that reports an average (home-based) work trip of 6.6 mile in Portland.

Average business-related service trip lengths will be generated by combining the 1994/1996 Oregon household survey data with Ohio Business Establishment survey data. Business-related service trips were isolated from the Oregon data by industry, and will be checked against Ohio data.

Figure 6.11. Oregon Travel Behavior Survey Person Trip Lengths



6.7.7. Import and Export Quantities

Import and export quantities for sub-domestic regions are difficult to find and definitions of import/export regions varies. As a result, 1998 IMPLAN model area estimation of imports and exports serve as both a target and the starting value for the PI S2 parameter reference quantities ($QRef_{c,i}$ and $QRef_{c,e}$ discussed in Section 5.4.3). For goods, this includes the import and export quantity targets by World Market, previously discussed in Section 6.6.5, which incorporates the ODOT Commodity Flow survey. Other potential sources for import/export targets are the US Commodity flow survey and Port of Portland commodity flow survey.

6.8. Initial Calibration

The strategy for assessing the fit of the PI module in the second stage (S2) of the calibration process is described below. A four tier calibration strategy is envisioned, as summarized below. The official and additional calibration targets that will be used to assess the model fit during calibration were previously listed in Table 6.20. Tier 1 ensures reasonable values for floorspace and labor prices, trip lengths, and a rough match with baseyear activity by beta zone, to ensure convergence and model stability. Tier 2 calibrates labor and residential floorspace relationships (labor made and floorspace used by type by various household categories), and matches modelwide import and export targets. Tier 3 builds on Tier1 by fine-tuning zonal constants to match zonal household counts and worker activity dollars. Tier 4 works on matching floorspace prices and vacancies in conjunction with the LD module.

Currently, the PI calibration results indicate:

- PI was roughly calibrated to prices, as needed, for convergence.
- PI was calibrated to trip lengths, including average person trip lengths from the Oregon Travel Behavior Survey (primarily intrazonal trips typically less than 5 miles); business service trip lengths from the Ohio Establishment survey; and average trip lengths for goods commodities from the US Commodity Flow survey (average of 1993, 1997, 2003 surveys). A maximum goods trip length target of 180 miles was

used, since the comparable PI output only includes trips internal to the study area (no imports/exports). In all cases, adjustments were made to the Buying/Selling Dispersion Parameters ($\lambda_{b,c}$ and $\lambda_{s,c}$).

- PI was calibrated to match 1990 Census modelwide household income-based consumption of various floorspace types and residential vacancy rates. Census rooms were assumed proportional to floorspace quantities. The initial negative vacancy rates for multi-family housing and large positive single-family housing were adjusted by changing household utility offset constants ($UBuyRef_{c,a}$). Although overall consumption was low and vacancy rates were negative in selected zones, the resulting modelwide vacancy rates were positive and floorspace usage trends by income were replicated. Valid modelwide vacancy rates are important for ALD operations.
- PI was calibrated to match employment by occupation and household income based production of various labor occupations. All PI labor outputs are in dollars. Adjustments were made to the household utility offset constants ($USellRef_{c,a}$). Utility function dispersion parameter was also adjusted for allocation of input substitutes (also referred to as the Consumption Substitution Nesting parameter $\lambda_{u,a}$) to rein in the model's tendency to consume labor in lieu of non-residential floorspace.
- PI is nearly finished calibrating to match key imports/export quantities (all services and top 10 goods) using the 1998 IMPLAN quantities as targets. There is a reasonable match for the goods commodities, with final adjustment being made to match the services import/export targets. Adjustments were made to the import/export reference quantity (also referred to as the Import/Export function midpoint, $QRef_{c,i}$ and $QRef_{c,e}$).
- PI was calibrated to match the Census distribution of household counts and industry dollars (modelwide allocated based on employment) by beta zone. Adjustments were made to zonal alternative specific constants ($Constant_{a,z}$).

Comments:

- Target trip lengths for business services and goods movement proved problematic. Business service trip lengths were too short from the Oregon Household Survey, so trip average lengths for these services were borrowed from an Ohio Establishment survey (roughly increased trip lengths from 5 to 20 mile averages). The US Commodity Flow Survey provides commodity which includes only intercity flows that do not match the full internal-internal (no import/exports) flows output by PI. Additionally, the 1993, 1997 and 2002 US Commodity Flow trip lengths reveal significant variation over time. Thus limited stock will be placed on the US CFS average trip length target data, instead relying on the Oregon commodity flow data.
- The census rooms by development type data implies a fairly large consumption of floorspace by the lowest income small households (HH0to5K1to2). This is under investigation.
- The current 1990 labor consumption targets seem inconsistent with the 1998 IMPLAN labor consumption values used to construction the technical coefficients. This was taken to be an increase in labor productivity per household over this 8-year period, possibly reflecting real productivity increases and the increasing participation of women in the workforce. It now seems that the implied increase in labor/household between 1990 and 1998 is just too large overall, and the 1990 targets

and 1998 technical coefficients need to be re-examined. This is causing problems in the overall business consumption functions (including labor), affecting the consumption of non-residential floorspace (vacancy rates), and delaying the integrated calibration of ALD and PI.

Future:

- Calibrate to Oregon Commodity Flow Survey, flows dollars among 12 statewide ACT regions. T his should improve the model's commodity flow output, given limitations in the goods trip length target data.
- Automate PI calibration to fine-tune household consumption of floorspace and production of employment by occupation at the Census PUMA level (modelwide already complete).
- Calibrate to floorspace prices and vacancy rates in selected urban areas. A lthough floorspace prices are reasonable, there is limited variation across the study area. Additionally, although modelwide vacancy rates are reasonable, overall vacancy rates are too high, and variation by beta zone needs attention. These calibrations will allow us to establish values for dispersion parameters which, for now, have been set to simply the right order of magnitude based on judgment and simple scenarios.
- Calibrate to household change (income/size category) and base year employment by β-zone
- Other calibration targets available include BLS OES wage rates by occupation in selected urban areas.

6.9. S3 Parameters

When the full SWIM2 model is undergoing calibration, the following parameters may be adjusted to improve PI and overall model performance

- Inertia parameters for activity location by activity type αinertia and InertiaConsta
- Floorspace import function parameters (for calculating floorspace import functions based on floorspace inventory)
- Multipliers for the influence of specific commodity buying and selling utility values on production location utility ($\phi_{b,c,a}$ and $\phi_{s,c,a}$)
- Affect of production utility and consumption utility on l ocation utility ($\alpha_{prod,a}$ and $\alpha_{cons.a}$)
- Utility of non-modeled production and non-modeled consumption (U_{nmc} and U_{nmp})
- Utility function dispersion parameter for allocation of by-product substitutes and input substitutes made and used by each activity ($\lambda_{m,a}$ and $\lambda_{u,a}$)

7.0 PT Module

The Person Transport (PT) module generates travel for all households resident in Oregon and the halo region. Work trips are based on labor flows from the PI module and influenced by travel times, distances, and costs by all modes of transport from the TS module, and intermediate accessibilities calculated by PT. PT consists of two jointly run sub-components: Short Distance Transport (SDT) which predicts all regular work commutes regardless of length and non-commute travel patterns less than or equal to 50 miles in length; and Long Distance Transport (LDT) which predicts non-commute travel patterns greater than 50 miles. PT returns a list of short- and long-distance trips with attributes including origin and destination alpha zone, start time, duration and mode. PT also provides zone-to-zone O-D matrices for person auto and (inter- and intra-city) transit trips by time period, and short distance tour mode choice and destination choice logsums by household category.

7.1. Theoretical Basis

For inspiration in designing the PT SDT module for modeling the sequence and timing of activities, we looked to tour-based micro-simulation model development work completed in Portland, Oregon [18], San Francisco, California [19], the Ohio Statewide Model [33], the Mid-Ohio Regional Planning Commission (MORPC) model [34], and work under development in Sacramento [35]. The Portland, San Francisco, and Sacramento model systems are based on the day-pattern modeling approach developed by John Bowman and Moshe Ben-Akiva at MIT [20]. The model imposes a hierarchical system of activity typology, with work and school tours at the top of the typology, followed by shop, social/recreational, and other activities. The day-pattern model consists of a large multinomial logit model (114 alternatives total) that predicts the primary activity type (as defined by the hierarchical structure) and its nominal location (at-home versus out-of-home), the number of intermediate stops on the primary tour, and the number and purpose of 'secondary' tours. These secondary tours were further defined (i.e., number of stops on secondary tours, and number of secondary tours if 2+ tours) by Monte Carlo sampling according to observed distributions. In the San Francisco and Portland models time periods are discretely defined (five total) and determined by another series of logit models. Tour mode and 'primary' destination are determined simultaneously, and intermediate stop locations are determined using the additional or 'out-of-direction' distance, that the intermediate stop incurs between the tour origin (home or work) and primary destination.

The PT module in the Oregon Statewide Integrated Model (SWIM2) departs from previous work in Portland, San Francisco, and Sacramento in primarily three significant ways. The day-pattern model uses observed patterns as alternatives in a multinomial logit framework. The model parameters interact with the characteristics of the person/household and the characteristics of the pattern to determine the utility for each observed pattern. The model is segmented by person type, which achieves the two-fold goal of reducing the number of alternatives for each sub-model and eliminates irrelevant choices given a person's work and student status.

Secondly, trip mode choice occurs at two stages within the Oregon Statewide Integrated Model system. At the first stage, trips are allocated to drive-alone, shared-ride 2, shared-ride 3+, walk, bike, transit walk or transit drive mode. Another layer of trip mode choice occurs on-the-fly within path-building for transit trips; a transit trip can either walk all the way, or use some combination of transit modes. Trip mode choice is restricted by the primary mode of the tour, and is probabilistic according to the characteristics of the person choosing the mode, the level of service characteristics of the modes allowed for the tour mode, and the characteristics of the tour and day-pattern.

Thirdly, time in the Oregon Statewide Integrated Model in SWIM2 was originally treated as a logit time-of-day choice model. Developments in the MORPC tour-based models and the Sacramento model design blend hazard-based duration models within a logit framework, offering the best of both worlds; a model that can be sensitive to level-of-service matrices within specific time periods, while offering a fairly detailed representation of time. In operation, the hazard duration model had limitations and was replaced with a discrete choice framework.[24] The Oregon models operate at a one-hour time resolution level.

A long-distance transport model (PT LDT) was developed, based on Ohio Statewide Model (OSMP) framework and the Ohio long distance travel survey. LDT leverages the tour-based methods of the SDT model with some simplifying assumptions. In the long-distance models, all tours are assumed to start at home, and in cases where multiple stops are chained together, the farthest stop is considered the primary destination, and all intermediate stops are ignored. For example, if a business tour is actually anchored at work, the model treats the home location as the tour origin. This convention was adopted partly due to data limitations. The Ohio long-distance survey only collected travel over 50 miles; so short trips such as travel between home and work were not included in the survey, and would have to be synthesized without a gain in overall model value – particularly since distance from home to work is typically short relative to the length of the trip. Additionally, the location of intermediate stops were not specifically gathered as part of the survey effort, thought it is likely that many additional stops are incidental stops for gas or food at highway exits, and have little effect on mode choice or route choice. The case of additional substantive stops, such as combining a trip to visit relatives with a vacation to a second city is a consideration for future improvements. The model chooses which component of the full trip will occur on the actual simulation day.

Enhancements to the Oregon PT model design have come from common software code used in both Oregon and Ohio statewide models. Ohio enhancements now employed in Oregon include the Long Distance Transport (LDT) module, and specifically within SDT include the logit time-of-day choice model (which replaces the initially-estimated hazard-based activity duration model), additional market segmentation and some generalization of the pattern choice model. These enhancements ensure a consistent representation of travel in Oregon while providing the opportunity for efficiencies in model calibration and application.

[24] PT SDT initially used hazard-based duration models treating time as a continuous variable, providing opportunities to overcome differences in peak period definitions for different urban areas throughout Oregon, and allowed for long distance travel to occur throughout multiple time periods in the day. However, the models do not provide for a convenient way to represent congestion effects on schedule, and their use in Oregon uncovered limitations due to the assumption of parametric baseline hazards which led to their replacement with a discrete choice model framework.

7.2. Quantity Definitions and Categories

The PT SDT module operates strictly at the alpha zone level, while the PT LDT module operates at the alpha zone level internally, while external destinations are assigned to one of the 12 External Station zones at the edge of the model area (zones 5000-5012), shown previously in Table 2.1 and Figure 2.2.[25]

PT SDT uses categories shown in Tables 7.1 through 7.6 as well as the occupation fields of Table 2.5 to define activities, modes, workers, households, and persons. PT LDT uses the categories shown in Table 7.7. Table 7.1 shows the 7 person trip activity definitions used in the SDT travel patterns of the Day-Pattern and Tour time-of-day models. Additionally, these codes (minus home) serve as the primary destination, or trip purpose, used in the PT Tour Primary Destination Choice model. The PT tour and trip Mode Choice model assumes the mode options shown in Tables 7.2 and 7.3, respectively. Table 7.4 identifies the various combinations of modes that can make up a trip. The PT Workplace Location Choice model uses the occupations, previously defined in Table 2.5 and the market segments of Table 7.5. The PT Tour Mode Choice also uses the Table 7.5 market segments. The PT day pattern model uses the SDT person types of Table 7.6.

It is useful to define several terms as they are used in PT such as day pattern, tour, intermediate stop, and primary destination and tour mode.

The activity **day pattern** consists of a sequence of characters (referred to as a 'word') that fully describes a person's activities during the forecast day. The number of tours, their sequence, their purpose, and the number, type, and sequence of stops on each tour can be determined from the word pattern.

Each character in the pattern represents an activity at a nominal location, implying that a trip is required for every activity with the exception of the first at-home activity of the day. The activity pattern consists of **tours**, which are sequences of activities that start and end at home. For example, the activity pattern word 'howhrh' consists of two tours for the following sequence of activities:

Tour 1: Home->other->work->home
Tour 2: Home->recreate->home

Note that intermediate at-home activities serve as breakpoints between tours, and that multiple at-home activities are modeled as a single activity.

A sequence of activities that starts and ends at work is known as a **work subtour or work-based tour**. In the pattern model these subtours are identified with a 'b', and are fully contained within a home-based tour. For example, the activity pattern 'hbhoh' consists of the following tours and activities:

Tour 1: Home->Work-based->Home
Tour 2: Work->Other-Work
Tour 3: Home->Other->Home

[25] PT SDT does not assign any trips to the External Stations.

Each tour contains a **primary destination**, which was selected from among all tour destinations according to the following hierarchical structure and which defines the purpose of the tour:

- Work
- School
- Shop
- Social/Recreational
- Other

For students, the highest priority activity is School, followed by Work. When a tour includes multiple high priority activities of the same type, the one with the longest duration was chosen as the primary activity. Therefore, the purpose of a stop cannot be of higher priority than the tour primary destination.

Each tour is allowed to include at most one **intermediate stop** between home and the primary tour activity (the outbound leg), and at most one intermediate stop between this activity and home (the inbound leg). In order to reduce VMT loss when estimating and calibrating the models, the tour retains from the survey data the intermediate stop requiring the largest distance deviation between home and the primary destination. Stops are allowed to choose destinations further away from home than the primary destination, but like primary destinations they are restricted to be within 50 miles of home.

The **tour mode** is the mode used to reach the primary destination, and is chosen before the location of the intermediate stops is known. The mode(s) for trips within a person's tour can be different from the tour mode, but they are consistent with it. For example, if the tour mode is passenger, none of the **trip modes** can be drive alone.

Table 7.1. PT SDT Activity/Tour Primary Destination Definitions

code	Description
	Short Distance Travel (SDT)
H	Home
W	Work (including second job), without a Work-Based sub-tour
B	Work (including second job), with a Work-Based sub-tour
C	School
S	Shop
R	Social/Recreation
O	Other (including Pickup/Drop-off Activity)

Table 7.2. PT SDT Tour Mode Categories

Tour Mode	Description
Auto Driver	Any trip on tour is auto driver, no trips are school bus
Auto Passenger	All trips on tour are passenger or non-motorized (including school bus for school tours)
Passenger – Transit	Any trip outbound is auto passenger and any trip inbound is walk transit
Transit – Passenger	Any trip outbound is walk transit and any trip inbound is auto passenger
Walk	Only walk trips on tour
Bike	Bike trips on tour, no motorized trips
Walk Access Transit	Walk transit trip on tour, no drive transit trips on tour. Includes tours with passenger and transit on same half tour
Drive Access Transit	Any trip on tour is drive transit

Table 7.3. PT Trip Mode Categories

Trip Code	SDT	LDT	Trip Mode	Trip Mode Definition
DA	X	X	Drive-Alone	Single-occupant auto
SR2	X	X	Shared-Ride 2	2 person occupant auto
SR3P	X	X	Shared-Ride 3+	3+ person occupant auto
WALK (1)	X		Walk	Walk
BIKE (1)	X		Bicycle	Bicycle
TRANSIT_WALK		X	Walk-Transit	Walk-Access Transit
TRANSIT_DRIVE		X	Drive-Transit	Auto-Access Transit
SCHOOL_BUS (1)	X		School bus	School bus (not assigned to the network)
AIR		X	Drive-Air	Drive-Access Air travel within the model area
HSR_DRIVE		X	Walk-HSR	Drive-Access intercity Rail
HSR_WALK		X	Drive-HSR	Walk-Access intercity Rail

(1) School Bus and non-motorized modes (walk and bicycle) are not assigned to the network.

Table 7.4. PT SDT Allowable Trip Modes Within Tour Mode (X indicates allowed)

		Trip Modes						
		Drive-Alone	Shared-Ride 2	Shared-Ride 3+	Walk	Bicycle	Walk-Transit	Drive-Transit
Tour Mode	Auto Driver	X	X	X				
	Auto Passenger		X	X	X			
	Walk				X			
	Bicycle					X		
	Walk-Transit				X		X	
	Transit-Passenger		X (return only)	X (return only)	X		X (outbound only)	
	Passenger-Transit		X (outbound only)	X (outbound only)	X		X (return only)	
	Drive-Transit				X		X	X

Table 7.5. PT SDT Market Segments (in $2000)[26]

Code	Market Segment
0	HHincome < 30,000, autos = 0
1	HHincome < 30,000, autos < HHWorkers
2	HHincome < 30,000, autos ≥ HHWorkers
3	30,000 ≤ HHincome <60,000, autos = 0
4	30,000 ≤ HHincome <60,000, autos < HHWorkers
5	30,000 ≤ HHincome <60,000, autos ≥ HHWorkers
6	HHincome ≥ 60,000, autos = 0
7	HHincome ≥ 60,000, autos < HHWorkers
8	HHincome ≥ 60,000, autos ≥ HHWorkers

Table 7.6. SDT Person Types

Code	Person Type	Definition
0	Pre-school	All persons less than 6 years old.
1	Grade/High School	All persons older than 5 and younger than 18
2	Worker	All students older than 17 and not students
3	College student	All persons older than 17
4	Non-worker	All persons older than 17 and not students nor workers

Table 7.7. LDT Trip Purposes and Patterns

Trip Purpose	Description
Household	Travel in which entire household participates
Work-Related	Individual business travel
Other	Individual travel for non-work purposes
Trip Pattern	**Description**
Complete Tour	Entire tour is complete on simulation day,
Begin Tour	Tour departs on the simulation day,
End Tour	Tour returns on the simulation day,
Away	Person is out-of-town on the simulation day, and
No Tour	Travel occurs on a different day.

It should be noted that PT was originally developed in Oregon, then applied in Ohio where it was further enhanced, and then re-instated back to Oregon to achieve the advancements in the Ohio version. As such, SWIM2 is estimated primarily with Ohio long distance and short distance travel survey data, supplemented with Oregon household survey data (see section 7.5). Additionally unlike the rest of SWIM2, Ohio uses 2000 dollars and cents monetary units. As such, the 1990 dollars of all SWIM2 inputs are translated to 2000 units for use in PT, and then translated again, if needed to produce SWIM2 outputs in 1990$ consistent with the rest of the model.

7.3. Component Models

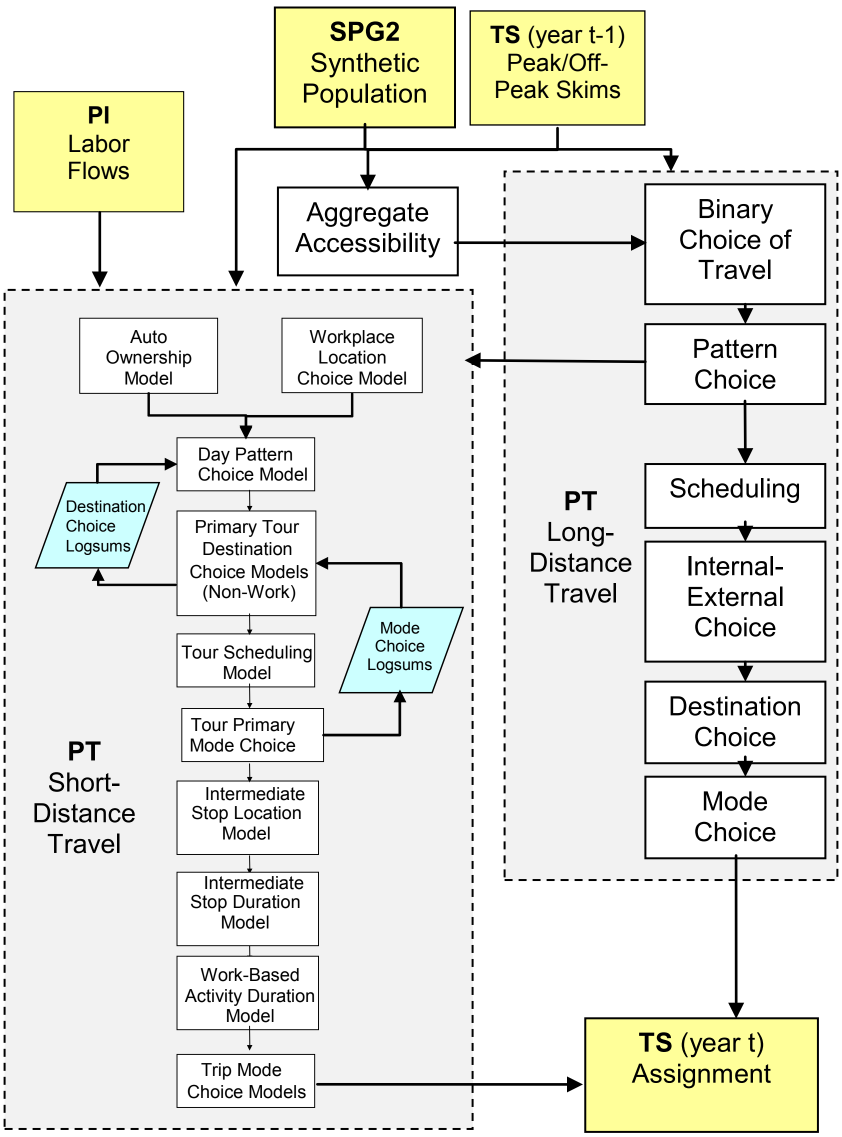
Figure 7.1 provides an overview of the PT SDT and LDT models. Both operate in a micro-simulation framework and rely on the attributes of the synthetic population (from SPG), and travel skims (from TS). The SDT model also uses work flows (in 1990$) from the PI module.

The SDT model generates mode choice and destination choice logsums as a measure of accessibility for use by the LDT model (and PI module). This allows for a lower

[26] PT properties files contains a factor to convert costs in 1990$ used in other modules into 2000$ for use within PT. This is done to be consistent with estimated coefficients within the Ohio statewide model.

probability of long-distance travel if the short-distance destinations are more attractive. In turn, the LDT choice of whether or not to engage in long-distance travel is fed back to the SDT models. Persons who are traveling out-of-town are assumed to not engage in short-distance travel (LDT only) while the remainder are assumed to travel typical short-distance travel patterns (SDT only).

Figure 7.1. Person Transport Model Flow Diagram



Short-distance and commute travel (SDT) consist of a series of (mostly) discrete choice models, which represent the trip-making decision as a sequential process, in the following order: auto ownership, work place location, activity day pattern, primary non-work activity location, work-based activity location, tour schedule, tour mode, intermediate stop location, intermediate stop duration, work-based activity duration, and trip mode.

The behavior of long-distance travel (LDT) is modeled in six steps. First, each eligible traveler is given the choice of whether or not to engage in long-distance travel during a two-week period. For those who travel during the two-week period, the pattern model predicts the type of travel that occurs on the actual simulation day. Third, the tours are scheduled to a time-of-day. Next, each tour is evaluated to determine whether the destination will be internal or external to the model area boundary. Finally, a specific destination and then a mode are chosen.

The resulting trips from both models are assigned together in the TS module to the same networks, although intra-city transit networks are used for SDT trips and inter-city transit networks for LDT trips. PT SDT also outputs prior period mode choice and destination choice logsums based on the prior period's travel costs (skims, 3 year lag) for use in the current year by the PT and the PI module. PT also produces current year synthetic population attributes regarding auto ownership and work alpha zone.

These PT SDT and LDT components are detailed in the remainder of this section.

7.3.1. SDT Aggregate Accessibilities

Initial aggregate accessibilities are calculated and used by both SDT and LDT components. Tour mode choice logsums and tour destination choice logsums are used as measures of travel accessibility by the LDT and the SDT components of the PT module as well as the PI module. The destination choice logsum represents the overall ability of travelers to access any destination. The logsums are important to PT LDT because they allow the models to capture the effect that people who have access to many destinations within a short distance are less likely to need to make long distance trips. Within SDT, these accessibilities influence the day pattern model, the auto ownership model, the tour destination choice model and the tour scheduling model. They are referred to as 'aggregate' accessibilities because they are a function of the origin and destination zone attributes only. The logsums are calculated in the same fashion as the utilities for the SDT tour mode choice and destination choice model, but excluding all terms that are person-related. The mode choice logsums are however segmented by household market. Refer to Section 7.3.8 and 7.3.10 for a detailed description of the PT SDT tour mode choice and destination choice models.

7.3.2. LDT Binary Choice of Travel

Urban modelers often complain that travel is difficult to predict because it planned on a time scale longer than one day. This is especially true of long-distance travel. To capture this longer-term planning, long-distance tours in LDT are generated over a two-week period, rather than over a single day. The binary choice of travel model, predicts the probability of engaging in each type of long-distance travel during a two-week period. Note that the binary choice of travel model predicts the presence of travel for each purpose (Table 7.7) during the time window, not the quantity. The presence could be part of a tour (i.e. departing during the travel window, and returning at a later date), it could be a complete tour, or it could be multiple tours. Also, an individual can have travel for multiple purposes occur during the two-week window. Given the presence of travel, the LDT tour pattern model will determine what actually happens on the model day. The variables in the linear utility for the binary choice of travel for each purpose include the following:

- Household attributes (workers, autos, household size, household income, presence of students, single family home)
- Person attributes (worker occupation, student, sex, age)
- Accessibility (SDT destination logsums)
- Constant.

7.3.3. SDT Auto Ownership Model

The PT SDT tour mode choice model requires the number of autos owned by each household. Since the SPG module does not output (not controlled for) auto ownership information in the synthetic population (from SPG2), the PT SDT auto ownership model predicts the total number of vehicles owned by each household. It is a discrete choice multinomial logit model applied to each resident household in the synthetic population. The resulting auto count is output with the household ID for future analysis in addition to other SPG-produced synthetic population attributes.

In the auto ownership model the household is assigned one of the following values regarding number of automobiles owned:

- 0 (base alternative)
- 1
- 2
- 3 or more.

A logit model is used to assign probabilities to the alternative categories for the Monte Carlo process to use in setting this attribute for an individual household. The utility function includes the following variables:

- household attributes of composition and wealth (household size, number of employed persons, household income)
- accessibility from the home location to the rest of the model area
- aggregate destination choice logsum (see Section 7.3.1)

The destination choice logsum is calculated as follows, where p denotes an origin zone and q a destination zone.

$$DCLogsum_p = \sum_q \exp\left(a * Dist_{pq} + b * Time_{pq} + \log(Emp_q)\right) \qquad (7.01)$$

where:

$DCLogsum_p$ = destination Choice logsum for home zone p to all destination zones
$Dist_{pq}$ = distance from zone p to zone q
$Time_{pq}$ = peak period travel time from zone p to zone q
Emp_q = total employment in destination zone q
a, b = parameters to be estimated

PT outputs the resulting auto ownership assignment (number of autos) in the household data file, which contains one record per household, as in the synthetic population.

7.3.4. SDT Workplace Location Choice Model

This model assigns a workplace location for every worker, by sampling from the labor flow probability matrices developed by the PI module. If a work tour is generated for the worker, the work alpha zone chosen through this method will become the primary destination of the work tour, and serve as the anchor location for any work-based tours. The workplace location model is applied to each employed person in the synthetic population.

The workplace location (alpha zone) choice for each worker is based on the following factors:

- Labor dollar flows by occupation between beta zones
- Quantity of labor produced and consumed in each alpha zone
- Mode choice logsums, as a measure of travel cost, between alpha zones

The model applies a matrix expansion process to convert labor dollar flows by occupation between beta zones to flows between alpha zones. T he formula for this conversion is as follows:

$$F_{\alpha_{mn}} = F_{\beta_{ij}} * \frac{QL_m}{\sum_{m \in M(i)} QL_m} * \frac{QL_n}{\sum_{n \in N(j)} QL_n} * \frac{\exp^{\lambda LS_{mn}}}{\sum_{m \in M(i)} \sum_{n \in N(j)} \exp^{\lambda LS_{mn}}} \tag{7.02}$$

where:

m	=	origin zones in the alpha zone system,
n	=	destination zones in the alpha zone system,
i	=	origin zones in the beta zone system,
j	=	destination zones in the beta zone system,
$M(i)$	=	set of all alpha zones contained within a specific beta zone i,
$N(j)$	=	set of all alpha zones contained within a specific beta zone j,
$F\alpha_{mn}$	=	labor flow from alpha zone m to alpha zone n,
$F\beta_{ij}$	=	labor flow from beta zone i to beta zone j,
QL_m	=	total labor produced at each alpha zone m,
QL_n	=	total labor consumed at each alpha zone n,
LS_{mn}	=	mode choice logsum between alpha zone m and alpha zone n, and
λ	=	dispersion parameter.

The process applies the above formula to each *ij* interchange in the activity allocation matrix of labor flows among beta zones, distributing the flow quantity among the corresponding set of *mn* interchanges.

The flow quantities between alpha zones are used to compute flow probabilities for all alpha zone pairs:

$$P_{mn} = \frac{F_{\alpha_{mn}}}{\sum_{n \in N} F_{\alpha_{mn}}} \tag{7.03}$$

The workplace location model uses these probabilities as the likelihood that a worker residing in alpha zone *m* (a synthetic population attribute) will work in alpha zone *n*. A Monte Carlo process chooses the workplace location based on these flow probabilities.

7.3.5. SDT Day-Pattern Model

The SDT day pattern models predict the number, purpose and sequence of activities for a given person in the synthetic population generated by SPG2. The following sections discuss the day pattern choice set as well as the various Day Pattern models.

Day Pattern Choice Set

As used in PT, a day pattern consists of a sequence of characters, where each character represents an activity. There is one activity per location, implying that a trip is required between each pair of activities in the pattern. The activity purposes handled by the pattern models are described in Table 7.1. The models are segmented by person type, using the five types defined in Table 7.6.

The choice set for each day pattern model consists of the unique day patterns observed for each person type. This choice set was developed from the Ohio Home Interview Survey data. As shown in Table 7.8, approximately one-half of the observed day patterns are observed only once – see the columns labeled 'Full Day Patterns'. As expected, the most complex day patterns – those comprising many tours and intermediate stops – are observed only once or twice. While the models need to be able to reproduce day pattern complexity, including in the choice set a large number of patterns that are chosen only once significantly increases the size of the estimation problem without adding much new information to the models, and it is unlikely that the models will be able to uniquely identify each of these patterns.

Table 7.8. Day Pattern Model Choice Set Size

Person Type	Full Day Patterns			Generalized Day Patterns		
	Unique Patterns	Unique Patterns Observed Once		Unique Patterns	Unique Patterns Observed Once	
		Freq.	Pct.		Freq.	Pct.
Pre-School	309	168	54%	177	47	27%
Grade/High School	426	235	55%	196	51	26%
College	759	525	69%	383	151	39%
Worker	2,103	1,361	65%	442	84	19%
Non Worker	942	539	57%	193	21	11%

Source: Ohio Statewide Household Interview Survey, used in PT estimation. Percentages used in Oregon would be similar.

In order to decrease the number of unique day patterns, and in particular of those observed only once, day patterns were generalized as follows:

- If the day pattern consists of one tour, the full specification of the day pattern is retained in the choice set.
- If the day pattern consists of two tours, the purpose of the intermediate stops is not retained; instead, they are generalized to be of purpose 'Other' within the pattern choice model; an actual purpose is chosen for each activity in a subsequent model.

- If the day pattern consists of three or more tours, all intermediate stops are dropped from the pattern specification within the pattern choice model; the actual number of stops is chosen in a subsequent model.

These generalizations reduce the choice set as shown in the right half of Table 7.8. In order to retain the ability to predict patterns as complex as those observed in the data, a full day pattern is reconstructed for the cases where the pattern was simplified. Therefore, the activity day pattern models in fact consist of four sets of models:

- The generalized day pattern models
- The intermediate stop pattern choice models (assigns number of intermediate stops for 3+ tour patterns)
- The intermediate stop purpose models (assigns purpose to 2 and 3+ tour patterns)

Generalized Day Pattern Model

The generalized day pattern models are discrete choice multinomial logit models. Five models were estimated, one for each person type. The estimation file for each model was constructed by including the full choice set as alternatives for each person in the person type set; therefore the number of alternatives for each observation in the estimation size varies with person type, and is given by the number of unique patterns (observed in the Ohio statewide data). The base alternative for all the models is the 'Stay-At-Home' (H) pattern.

Each of the alternative patterns has an associated identifiable utility consisting of an activity component, a traveler component, and a transport component.

- The **activity component** includes variables identifying the number and purpose of activities in the pattern, the sequence of activities or tours in the pattern, the number and purpose of tours in the pattern, and the number, purpose and presence/absence of intermediate stops in the pattern.
- The **traveler component** includes variables that describe the person making the activity day pattern choice, such as age and gender, and variables that describe the person's household, such as household size, number of workers, auto ownership, income and presence of young children. Note that worker status and student status are primarily considered via the model segmentation into person types, although they are also used for the person types that allow both conditions (grade/high school students and college students).
- The **transport component** includes distance between home and work (for workers) and the destination choice logsum for each tour purpose (the natural log of the denominator of Equation 7.04). The traveler and transport component appear in the models interacted with the activity components.

7.3.6. SDT Stop Pattern Model

The SDT Stop Pattern Model component assigns the number of intermediate stops to each tour on t he generalized day patterns with 3+ tours. It is a discrete choice multinomial logit model, with a choice set that consists of four alternatives:

- no stops (the base alternative),
- outbound stop only,
- inbound stop only,
- both one outbound and one inbound stop.

Five models were estimated, one for each tour purpose listed in Table 7.1, with work and work-based purposes combined. The utility of each stop alternative includes the following attributes:

- tour and day-pattern composition variables
- traveler attribute variables.

Since none of the explanatory variables are alternative-specific, they were entered in the utility function with a different coefficient for each alternative; that is, there are no generic coefficients in these models.

7.3.7. SDT Intermediate Stop Purpose Model

The SDT Intermediate Stop Purpose model assigns an activity purpose to the intermediate stops of 2-tour pattern tours and 3+ tour pattern tours. The purpose model component consists of an empirical distribution of activity purposes, derived from home interview survey data. The stop purpose probabilities are based on expanded data. For forecasting, activity purposes are assigned using Monte Carlo simulation.

The 2-tour pattern distributions are conditional on the following attributes:

- person type,
- tour purpose,
- tour number (first or second), and
- stop position (outbound leg or inbound leg).

The 3+ tour pattern distributions are conditional on the following attributes:

- person type,
- tour purpose and
- tour position (first, middle or last).

7.3.8. SDT Primary Tour Destination Choice Model

This model chooses the location (alpha zone) of the primary destination of a tour, given the known location of the traveler's home. It is a discrete choice multinomial logit model. The choice set for each alternative is the full set of available zonal alternatives, depending on the tour purpose and the type of activities (size term) of the destination TAZ. Destination choice models are very similar to mode choice models in that both are based on the logit discrete choice model. As applied to destination choice models, the logit formulation is:

$$P_i(k) = \frac{\exp(U_{k|i})}{\sum_{j \in D} \exp(U_{j|i})} \qquad (7.04)$$

where:

$P_i(k)$ = probability of selecting destination zone k, given origin zone i
$j \in D$ = the unique alternatives (destinations) in the selection set
U_j = utility of selecting a destination zone, given the origin zone

The equation states that given an origin zone i, the probability of selecting a destination zone k is a function of the exponential utility of selecting k over the sum of exponential utilities of all attractions zones in the choice set. The larger the utility of travel between origin zone i and destination zone j, the greater the probability of travel between the zones.

The utility for a selecting a particular alternative (U_k) is a linear function of the attributes that describe the alternative. In a destination choice model, the attributes that describe the selection of a zone include its accessibility, other variables that describe the quality of the choice, and variables that describe the quantity of activity in the destination zone:

$$U_{j|i} = \beta_0 \times \beta_1 \times accessibility_{j|i} + \beta_2 \times quality_{j|i} + \ln(\beta_3 \times quantity_{j|i}) \qquad (7.05)$$

Utility functions for destination choice look different from the comparable functions for mode choice models due to the logarithmic term. This term is referred to as the size term. The SDT Primary Tour Destination Choice Model uses mode choice logsums as a measure of impedance, which has a special interpretation. The destination and mode choice models can be interpreted as sequentially estimated nested models. Mode choice becomes a nested choice under the choice of destination. The coefficient estimated on the mode choice logsum is interpreted as a nesting coefficient. Thus the coefficient must range be between 0 and 1. A value of 1 implies that there is no nesting. A value greater than 1 implies that the nesting order is incorrect.

7.3.9. SDT Primary Tour Scheduling Model

This SDT model forecasts simultaneously departure-from-home time and arrival-back-home time for all home-based tours, with a time-of-day resolution of 1 hour. It is a discrete choice multinomial logit model, where the choice set consists of 190 possible schedules: all possible combinations of 19 departure hours and 19 arrival hours, with the arrival time always greater or equal to the departure time. Early departures or arrivals (before 5:00 AM) are considered a single choice, as are very late departures or arrivals (after 11:00 PM). The base alternative is the most frequent alternative and therefore varies with the tour purpose; it is identified by a zero departure time constant and zero duration constant. The utility function is based on continuous departure time and tour duration shift variables, where departure time is expressed in hours relative to midnight (assigned 0 departure time), and duration is expressed in hours. Three main types of explanatory variables are interacted with the departure time and duration shift variables:

- tour and day pattern variables,
- traveler attribute variables,
- travel condition variables, and
- constant term consisting of the sum of a departure time term and a duration term.

The model is applied to all tours in a day pattern, according to a pre-determined tour priority: w ork and school tours are scheduled first, followed by shop tours, then recreational tours, and finishing with other tours. Time windows that have been filled with higher priority tours are not available for lower priority tours. Also, if a low priority tour (for example, shop), occurs earlier in the day than a high priority tour (for example, work), then all time windows after the beginning of the work tour are unavailable for the shop tour. When the pattern includes tours of the same priority, they are scheduled sequentially.

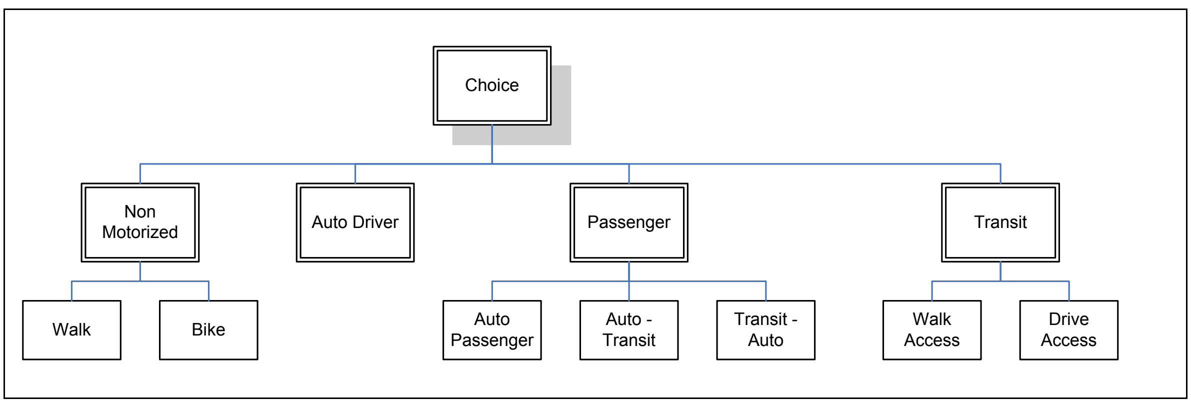
7.3.10. SDT Tour Mode Choice Models

The SDT Tour Mode Choice model assigns a primary mode to the entire tour. It uses a generalized definition of mode, which allows a combination of modes for all the trips in the tour. It is a discrete choice nested logit model. Figure 7.2 shows the nested structure of the model and its choice set. A description of the tour mode choice alternatives was given previously in Table 7.2.

The utility associated with any given tour mode choice is a function of the following attributes:

- level-of-service components describing the mode for the tour origin and primary destination (e.g., round trip time and cost attributes for origin and primary destination only since intermediate stops not known when this model is applied),
- characteristics of the tour (i.e., number of stops), and
- characteristics of the person choosing the mode.

Figure 7.2. Tour Mode Choice Nesting Structure



7.3.11. SDT Intermediate Stop Location Models

The PT SDT Intermediate Stop Location model chooses an alpha zone location for each intermediate stop on a tour. It is a discrete choice multinomial logit model, whose utilities are a function of the following attributes:

- origin and primary destination of the tour,
- tour purpose,
- tour mode, and

- characteristics of each alternative alpha zone location for the stop.

The model is structured so that the probability of selecting a TAZ as an intermediate stop destination is inversely related to the out-of-direction travel between the tour origin and its primary destination imposed by its selection. Note this does not preclude intermediate stops to be located farther away from home than the primary destination. The amount of out-of-direction travel is the additional travel time required to reach the intermediate stop using the tour's primary mode; that is, travel time in excess of the time required to travel directly between the tour origin and primary destination. For transit tours, a generalized travel time function is used, to account for out-of-vehicle travel time, as follows:

$$TravelTime_{Transit} = In - VehicleTime + 1.5 * FirstWaitTime + 2.5 * TransferWaitTime + 3.0 * WalkTime \quad (7.07)$$

Zones that are not reachable by transit (except for the intrazonal alpha zone) are not considered as alternatives for stops on tours whose primary mode is transit.

7.3.12. SDT Intermediate Stop Duration Models

The PT SDT intermediate stop duration models predicts the duration of intermediate stops on tours. It is a discrete choice multinomial logit model, where the choice set has a resolution of one hour and includes a total of twelve possible activity durations, ranging from 0-1 hour, 1-2 hours, etc. , up to 11 hours or longer. The base alternative is stop duration of one hour or less. The choice set is constrained by the total duration of the tour; that is, alternatives longer than the tour duration are not allowed. The utility function includes the following attributes:

- daily activity pattern attributes,
- traveler attributes, and
- stop attributes.

7.3.13. SDT Trip Mode Choice Models

The trip mode choice model predicts trip mode, contingent on the previously determined tour mode. The choice set for each trip is determined by the tour mode, as previously shown in Table 7.4, and summarized below:

- If the tour mode is walk, all trips on the tour are walk trips
- If the tour mode is bike, all trips on the tour are bike trips
- If the tour mode is auto driver, the available trip mode choices are drive-alone, shared ride 2 and shared ride 3+.
- If the tour mode is auto passenger or the auto passenger leg of a passenger/transit tour, the available trip mode choices are shared ride 2, shared ride 3+ and walk.
- If the tour mode is walk access transit, or the transit leg of a passenger/transit tour, the available trip mode choices are walk to transit and walk. The transit assignment selects the best transit path for this trip.
- If the tour mode is drive access transit, the first and last trips on the tour are drive to transit trips; other trips are passed to the transit path builder to determine whether the trip mode is walk to transit or walk.

Where the trip mode is not uniquely defined by the tour mode nor determined by the transit path builder, the model uses a multinomial discrete choice logit model, with the following attributes:

- level of service (in vehicle time, operating cost including parking costs)
- household attributes (e.g., household size and income), and
- alternative specific constants, stratified by tour mode.

7.3.14. SDT Work-Based Activity Duration Model

This model forecasts the duration of the three activities that comprise a work based subtour:

- first at-work activity,
- primary activity, and
- last at-work activity.

The duration of each individual activity is determined by applying Monte Carlo sampling from a set of empirical distribution functions based on Home Interview data. Two functions describing activity durations were calculated: the proportion of the total tour duration spent at the primary activity, and the proportion of the total work activity spent at the first at-work activity. Each of these is described below.

The duration of the primary activity of the work-based subtour is constrained by the total duration of the tour, as follows:

$$PctDuration_{primary} = \frac{Duration_{primary}}{Duration_{tour}} \tag{7.08}$$

The duration of the first at-work activity duration is constrained by the total duration of the work activity, as follows:

$$PctDuration_{first\ at-work} = \frac{Duration_{first\ at-work}}{Duration_{work}} \tag{7.09}$$

PT SDT samples from the frequency tables to obtain the percent duration of the primary and first at-work activities. Given that the duration of the tour is known (exclusive of intermediate stop durations, if present), then the primary and first-at work durations are obtained by solving the equations above, and the second at-work duration is obtained as:

$$Duration_{second\ at-work} = Duration_{tour} - Duration_{primary} - Duration_{first\ at-work} \tag{7.10}$$

7.3.15. LDT Tour Pattern Model

Given the initial LDT long-term choice of travel (LDT rather than SDT, see 7.3.1), LDT next determines if travel occurs on the simulation day and if so what type. The five possible patterns of long distance travel were defined previously in Table 7.7. The decision-making agent for household travel is the household, and the decision making agent for work-related and other travel purposes is the person.

Because so few travelers (1 percent in the Ohio long-distance surveys) take more than one long-distance tour in a single day, the tour pattern model does not allow for multiple long-distance tours on the model day. It is not uncommon, however, for travelers to make multiple long-distance tours during the two-week travel window (see section 7.3.1), making it more likely that some travel will occur on the model day. Travelers making multiple long-distance tours were included when the tour pattern choice frequencies were developed, such that they implicitly reflect this scenario.

Since the long-distance travel model predicts behavior on a typical weekday, Monday through Thursday, there are no explanatory variables to logically sample among different "typical weekdays". Thus, the LDT tour pattern model draws from the observed frequency of each pattern type from a long distance travel survey.

7.3.16. LDT Scheduling Model

LDT Tours are scheduled to a time-of-day with a one-hour resolution. Beginning tours are given a departure time, ending tours are given an arrival time, and complete tours are given a departure time and duration to fully define their schedule. As with the tour pattern model, the scheduling model draws from observed frequency distributions found in a long distance travel survey.

For complete tours, the schedule is determined using a constants-only logit model, with constants on the departure time and duration. This strategy was applied to smooth the outcomes because observed data was found to have high unexplained variability when viewed in both dimensions.

7.3.17. LDT Internal-External Choice Model

The LDT internal-external choice model is a binary choice model predicting whether a tour will have a destination within the model area or beyond the bounds of the model area. All model coefficients are applied to the utility of leaving the model area. The linear utility function contains the following variables:

- household attributes (i.e., income)
- person attributes (i.e., occupation, worker binary, age)
- complete travel in 1 day
- auto travel time to external station)
- constant.

7.3.18. LDT Destination Choice Model

The LDT destination choice models are applied separately for internal versus external destinations. The internal destination choice uses a logit model with utility variables, as specified below:

- mode choice logsum
- auto travel time (if complete travel in 1 day)
- various size terms (i.e., households, employees, hotel employment, higher education employment, government employment, employment in worker's own industry)
- distance flags

LDT external destinations cannot be modeled in the same way as internal destination because detailed level-of-service and socioeconomic information are not available outside the model area. Because SWIM2 does not maintain a national network and associated extensive external zone system to associate detailed trip origins and destination, SWIM2 trips are assigned to the selected set of External Stations at the edge of the model area (zones numbered in 5000s). Trips are then distributed to the External Stations using a simple logit destination choice model with the following utility variables:

- Highway travel time (as impedance),
- Traffic volumes at the station (as the size term).

7.3.19. LDT Mode Choice Model

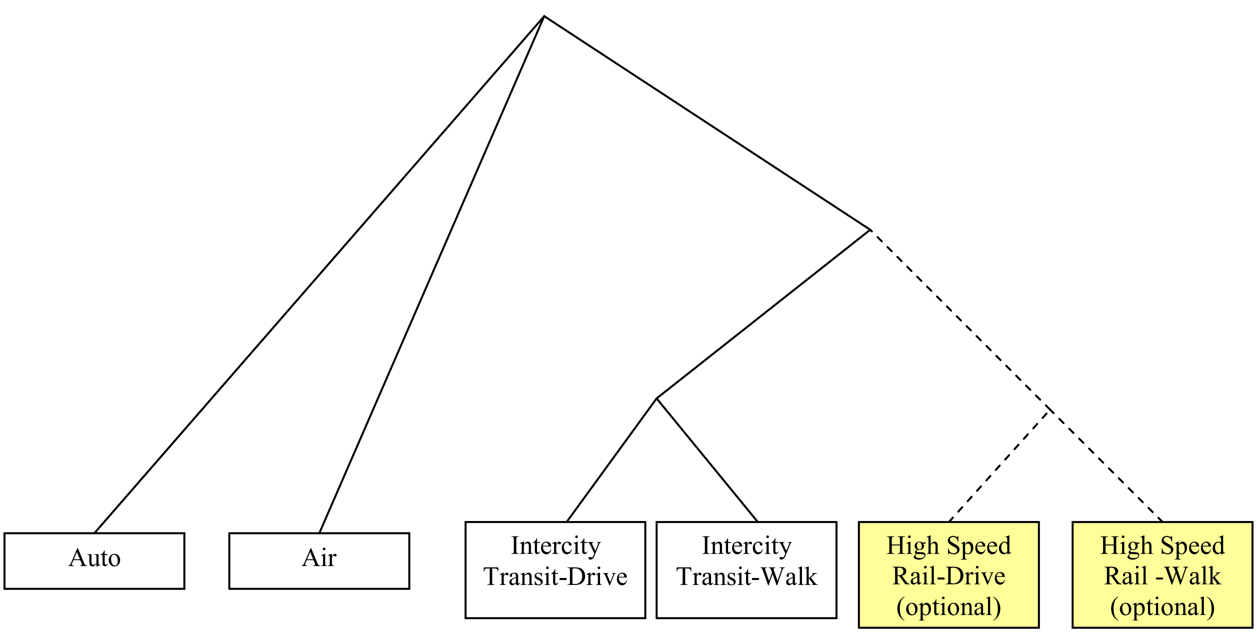
The LDT mode choice models include four alternatives in the base year and two optional future year transit options, as previously shown in Figure 7.3. T he base year transit alternatives include walk-to-transit and drive-to-transit alternatives, which cover the existing intercity Greyhound. Amtrak intercity rail service is a separate choice coded as High Speed Rail (hsr, name carried over from Ohio model).

Internal model choice model uses a nested logit equation with the following utility variables:

- travel/wait time for each trip segment
- travel cost as a function of household income
- transit nesting coefficients
- modal constants.

As with other LDT modules, a simplified mode choice model is applied for trips with destinations outside the model area. In this case, fixed mode splits are applied.

Figure 7.3 Mode Choice Model Nesting Structure



7.3.20. Integration

PT mode choice and destination choice logsums are created at the alpha zone level in compressed zip matrix format. Once PT produces skims at the alpha zone level, it also performs a 'squeeze' function to produce selected logsum skims at the more disaggregate β -zone level for use in PI. This function will be set to average the component alpha zone values in each beta zone. A weighted average using trip ends will be used once PT is calibrated.

7.4. Software Implementation

PT is implemented in java code. To reduce run times, PT is run in a distributed environment across a cluster of computers.

A description of the sequence of PT sub-models implementation process follows:

- Create aggregate Mode Choice Logsums matrices
- Create aggregate Destination Choice Logsums matrices
- Run auto ownership model for all households
- Run workplace location model for all employed persons
- Generate a daily pattern of activities for each person by choosing an activity pattern; each activity implies a nominal location; each pattern implies a sequence of activities. Three models are applied to fully specify the day pattern: the generalized pattern model, the stop pattern choice model and the stop purpose model
- For each tour in the pattern for each person:
  - Choose the tour schedule. The tour scheduling model for the appropriate tour purpose is applied to select the tour home departure time and the tour duration
  - Choose a primary destination for the tour. Do not choose a destination for work if a location has already been determined in the workplace location model. The tour primary destination choice model for the appropriate tour primary activity is applied to choose a location alpha zone
  - Choose a primary mode for the tour
  - Choose a location for each intermediate stop on the tour. The intermediate stop location is a function of the tour primary mode and the location of the tour origin and primary destination
  - Choose a duration for each intermediate stop on the tour
  - Choose a trip mode if the tour primary mode is not transit nor the transit leg of a transit-passenger or passenger-transit tour
- If the tour includes work-based subtours, then for each subtour :
  - Calculate the durations of the three activities that make up the work-based tour, conditional on the duration of the work activity
    - Calculate the percent of time at the primary destination of the tour
    - Calculate the percent of the at-work portion of the total tour duration that is the first at-work activity
    - Calculate the duration of the three subtour activities

7.4.1. PT Distributed Processing

Because of the computational requirements of the PT module to micro-simulate a full weekday of activities and travel for several million people within the model area, PT was built to run on a distributed application framework (DAF). The PT-DAF software implementation consists of the following tasks:

- PTMasterTask
- MCLogsumCalculatorTask
- DCLogsumCalculatorTask
- WorkplaceLocationWorkerTask
- MicroSimulationWorkerTask
- LongDistanceTask
- and several file writer tasks

The PTMasterTask, the LongDistanceTask and the file writer tasks each occupy their own node while the remaining 5 nodes each have an MC and a DCLogusmCalculator task and multiple MicroSimulationWorkerTasks running on them.

The PTMasterTask first instructs the MCLogsumCalculatorTasks to calculate a matrix of aggregate mode choice logsums. Although the full mode choice model is applied later, PT pre-calculates an aggregate set of mode choice logsums, which only depend on the activity purpose and market segment. The PTMasterTask sends an activity purpose (Table 7.1) and a market segment (Table 7.5) to each CalculatorTask. The CalculatorTask calculates the logsums for each alpha zone and stores the values in a matrix. The matrices are then passed to the MCWriterTask, which writes the mode choice logsums out to disk in compressed matrix format (Figure 7.5) for use later by PT (α -zone) as well as by the PI module (beta zone).

Next the MasterTask assigns each MicroSimulationWorkerTask a set of households to apply the AutoOwnership model to. The full set of households is divided evenly amongst the set of worker tasks. The results are returned to the MasterTask via an array indexed by household Id number.

Once all the households have been processed, the full array of auto-ownership results is sent back to the Workers so that it can be used in the workplace location model. For this model, the MasterTask assigns each MicroSimulationWorkerTask a set of persons to apply the workplace location model to. The results are sent back to the MasterTask as a mapping between the hhId_personId (key) and the workplace taz (value). In addition, each worker task sends back a summary of its persons' employment by occupation by zone to the MasterTask where it is tabulated and written to disk as Employment.csv.

After the workplace location model is finished, the destination choice logsums can be calculated. The work is divided up into segments (there are 9) so that each DCLogsumCalculatorTask does at least 1 segment. Before beginning the calculation, each CalculatorTask reads in the latest Employment.csv file and updates their Taz objects that are used in the size term calculations. The results are sent to the DCWriterTask which creates a table and when the work is completed is written out to disk to be used in future calculations [dclogsums.csv].

Once the destination choice logsums are complete, the MasterTask again divides the households evenly amongst the MicroSimulationWorkerTask so the remaining models can be applied. The first set of models in the sequence relate to the long-distance models. Each household decides if the entire household or specific members of the household will make a long distance tour on the model day (long-distance binary choice and long distance pattern choice model). If long-distance tours do occur, Tour objects are formed and sent to the LongDistanceWorkerTask for processing (see LongDistanceWorkerTask description below). The next set of models applied relate to the short-distance travel models. For each household (that doesn't make a long-distance tour), then for each person (that doesn't make a long-distance tour), the workers execute the day pattern model, calculating the weekday pattern that determines the person's weekday tours. The workers then loop through each tour and calculates the activity duration, the tour primary destination, tour primary mode choice, intermediate stop destinations, trip mode choice, and secondary work-based tour characteristics (duration, destination, and mode).

Once all the members of a household have been processed the worker task sends the Household object (that now contains Person objects that contain Tour objects) to the PTResultsWriterTask where a sequence of files are written to. The outputs written include a Household file [HouseholdData.csv], a Pattern file [WeekdayPattern.csv], a Tour file [WeekdayTour.csv], and most importantly a Trip file [weekdayTrip.csv]. The Trip file is used by TS to compile trip matrices by time period for assignment to the network.

Long-DistanceWorkerTask: The long-distance worker applies all of the long-distance models to the tours that were produced by the earlier binary choice models. This includes the scheduling model, the internal/external model, the internal mode and destination choice models, the external mode and destination choice models and the auto details model. Once the tours have been processed, the results are sent to the PTResultsWriterTask which adds the results to LDT specific output files. These include a PersonTour file [ldTours.csv] and a PersonTrips file [ldTrips.csv]. The trips file is used by TS in the assignment procedure.

Figure 7.4. PT-DAF Process to Create Mode Choice Logsums

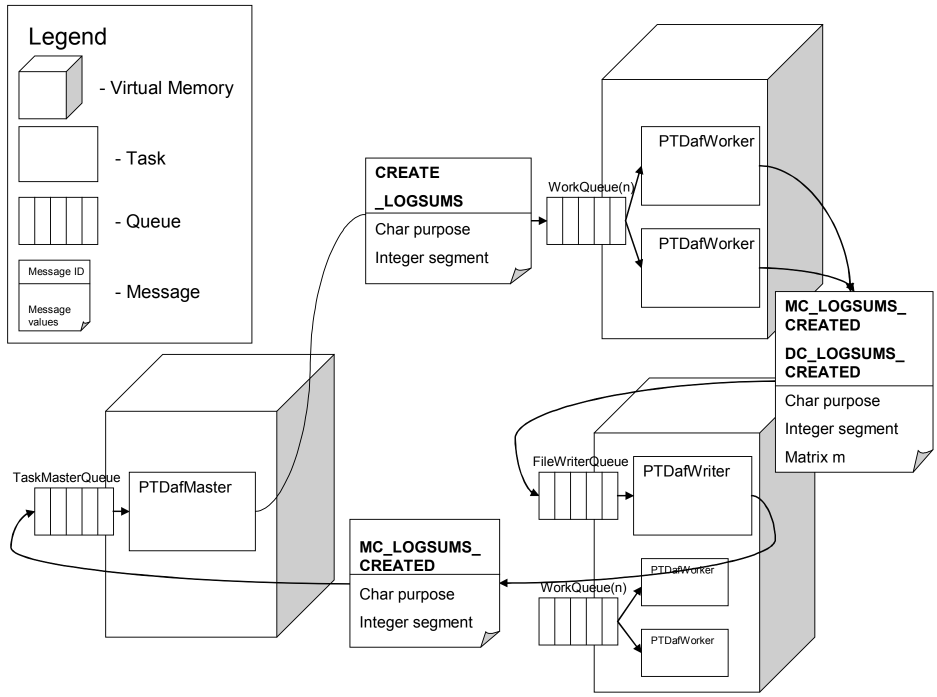
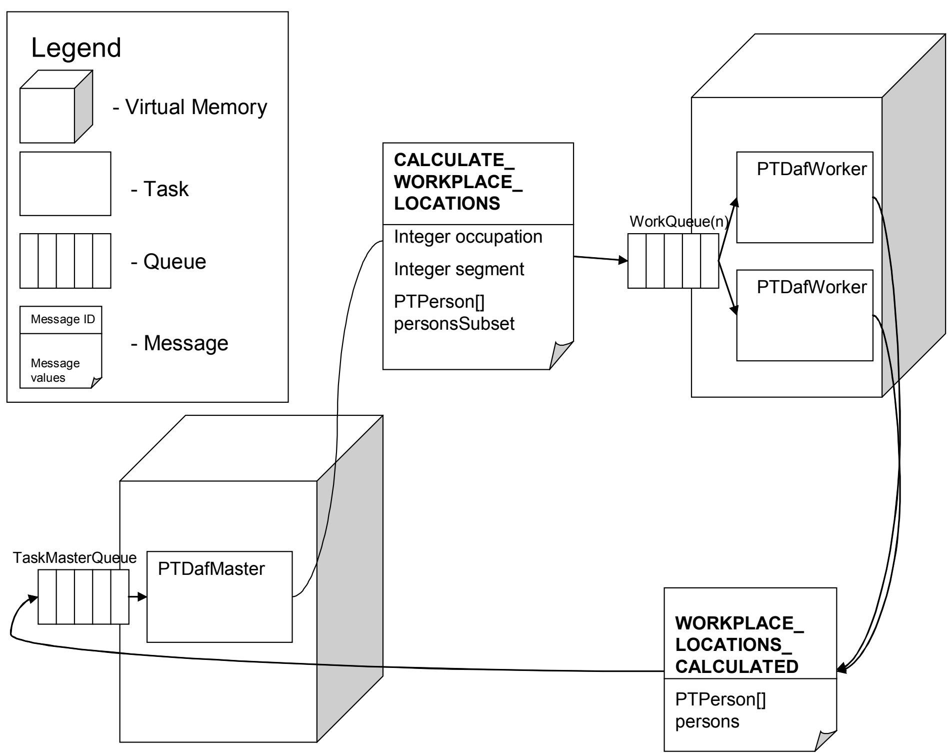


Figure 7.5. PT-DAF Process to Calculate Workplace Locations



7.5. S1 and S2 Module Parameters

The PT module requires a series of parameters, discussed below by sub-module. Many of the SDT utility function coefficients were originally estimated with the 1995/2000 Ohio Household Survey data, using maximum likelihood methods. In cases, particularly in LDT where the data are unavailable, explanatory variables are insignificant, or budget constraints limit analysis, the model components draw from static frequency distributions. LDT estimation was also based on the Ohio Long Distance Travel Survey. These SDT and LDT parameters were adopted in Oregon, adjusting only the utility constants during calibration to Oregon-specific data. In later stages of calibration, mode choice and destination log sums are updated and downstream parameters recalibrated iteratively, until minimal change occurs in this cycle.

Ohio Travel behavior data for the estimation and calibration of the PT SDT models, later transferred to Oregon, were obtained from four home interview surveys and from the 2000 Census. The SWIM2 PT module utility constants were adjusted to match Oregon data:

- The Ohio Statewide Home Interview Survey, conducted in 2002
- The OKI Regional Council Home Interview Survey, conducted in 1995
- The MORPC Home Interview Survey, conducted in 1995
- The NOACA Home Interview Survey, conducted in 1994
- 2000 Census Transportation Planning Package

These four surveys comprise a total sample of 26,200 households. The OKI, MORPC and NOACA surveys were re-weighted and re-expanded using Census 2000 data. The surveys were processed to eliminate missing or illogical information, as well as to conform to a unique coding scheme of household, person and trip/activity attributes.

LDT parameter estimation was done for the 2000 Ohio statewide model using the 2002-2003 Ohio Long distance travel survey. These LDT parameters were adopted in Oregon, adjusting only the utility constants during calibration to Oregon-specific data.

7.5.1. SDT Aggregate Accessibilities Model Estimation

The aggregate accessibilities used for “feed-up” of lower level models to upper level models are mode choice logsums and destination choice logsums. Mode choice logsums are the natural log of the denominator of the mode choice model, which is equivalent to a composite utility of travel across all modes of transportation, weighted by the probability of selection of each mode. Mode choice logsums are created for each household segment and tour purpose, and are stored in matrices by origin and destination alpha zone. Destination choice logsums are the natural log of the denominator of the destination choice model, which is equivalent to a composite utility of accessibility across all possible destination zones, weighted by the probability of selection for each TAZ. Since the destination choice model relies on mode choice logsums as the measure of accessibility, the accessibility is based on a consideration of all modes of travel to each zone. Parameters used to produce the PT SDT aggregate accessibilities are the same as those used in the disaggregate SDT tour primary destination choice and tour mode choice components; see section 7.5.8 and 7.5.10, respectively. However, since the aggregate accessibilities are pre-computed, certain situational variables, such as number of stops on tour, are not available and are "turned off" when computing aggregate accessibilities for upper level components.

7.5.2. LDT Binary Choice of Travel Model Estimation

The LDT binary choice of travel model predicts if a person will engage in any long distance travel of each purpose during a two-week period. All model coefficients are applied to the utility of traveling. Table 7.9 indicates the coefficients calibrated to match targets for each purpose derived from the Ohio Statewide survey data, but scaled to match total trips from the Oregon element of the 1995 American Travel Survey [36]. The significant descriptive variables are primarily demographic characteristics: households with more workers and larger households are less likely to travel probably because there are more family ties keeping them home. Households with more autos and higher incomes are more likely to travel due to a higher mobility level and a greater ability to absorb the cost. Certain occupations are more or less likely to travel long-distances, as would be expected. Men are more likely to go on business trips, probably because they tend to have fewer child-care responsibilities. As the short-distance destination choice logsum coefficients indicate, long-distance travel is less necessary if there are more attractive destinations within 50 miles. Finally, individuals who travel with their entire household are less likely to travel on their own.

Table 7.9. LDT Binary Choice of Travel Model Parameters

Variable		Household Coefficients	Work Related Coefficients	Other Coefficients
Constant		-1.14618	-6.61398	-2.06888
Household Workers	1	-0.3364		
	2	-0.3476	-0.2928	
	3+	-1.1494	-0.3462	
Household Autos	1			0.419
	2			0.606
	3+			0.846
Household Size	2			-1.149
	3	-1.1637		-0.898
	4+	-1.4137		-0.809
Household Income	$20-40k	0.387		0.289
	$40-60k	0.746		0.417
	$60k+	1.248	0.581	0.695
Single Family Dwelling		0.254		-0.161
Household Students	3+		0.276	
Occupation	Agriculture/Farming/Mining			-0.636
	Manufacturing	-0.297	-0.430	-0.474
	Transportation	-0.366		-0.372
	Wholesale		0.884	
	Finance		0.778	
	Other Services	-0.181		-0.101
	Professional	-0.3169		-0.1601
College Student		-0.242		0.455
Male			0.806	
Age			0.100	0.051
Age Squared			-0.001	-0.001
Short-Distance Destination Choice Logsum		-0.182		-0.119
Household Long Distance Tour			-0.842	-0.324

7.5.3. SDT Auto Ownership Model Estimation

The final estimated SDT Auto Ownership model discussed in Section 7.3.3 is shown in Table 7.10. All variables have significant and logical coefficients: the likelihood of higher auto ownership increases with household size, income and employed household members. Higher auto ownership decreases with increasing destination choice logsum, meaning that households tend to own fewer cars when they are located near places with high employment. In the destination choice logsum calculation of Eq. 7.01, the distance coefficient is -0.01835 and the time coefficient is -0.025, parameters a and b in the equation.

Table 7.10. PT SDT Auto Ownership Model Parameters

	Choice Alternatives					
	One Auto		*Two Autos*		*Three+ Autos*	
Variable	*Coeff.*	*t Stat.*	*Coeff.*	*t Stat.*	*Coeff.*	*t Stat.*
2 person household	0.473	5.3	2.845	29.8	2.611	23.2
3+ person household			2.523	44.7	2.868	35.3
Household Income = $20K - $40K	1.281	15.9	2.002	22.1	2.225	19.2
Household Income = $40K - $60K	1.576	12.5	2.995	22.7	3.519	23.6
Household Income = $60K+	1.658	8.1	3.824	18.5	4.549	20.9
1 household worker	1.068	13.1	1.226	14.0	1.530	15.2
2 household workers	0.501	3.0	1.723	10.3	2.204	12.6
3+ household workers					2.731	29.8
Destination choice logsum	-0.423	-6.3	-0.815	-11.3	-1.280	-16.8
Constant	5.811	7.1	7.904	9.1	11.508	12.9
Final Likelihood	-21650					
Rho-Squared wrt Zero	0.380					
Sample Size	25175					

Note: Estimation using Ohio statewide Home Interview survey. Constants adjusted in Oregon-specific calibration.

7.5.4. SDT Workplace Location Choice Model Estimation

The only parameter in the SDT Workplace Location Choice Model discussed in Section 7.3.4 is a gravity model dispersion parameter, λ. It retains the initial value set at 0.54, which was based on a work location choice model that was previously estimated using Oregon household survey data.

7.5.5. SDT Day-Pattern Model Estimation

The estimation results for the five Day Pattern models discussed in section 7.3.5 are shown in Tables 7.11 to 7.15 base on ???. Among the most powerful explanatory variables across all models are number of tours, presence and/or number of intermediate stops, and number of activities of each purpose. As expected, as the day pattern complexity increases, with complexity measured as either more tours, more activities or more intermediate stops on tours, the less likely the pattern is to be chosen. The models also show that people manage day pattern complexity by trading off number of intermediate stops against number of tours, as shown by the negative coefficients on the product of intermediate stops and tours (see Table 7.12 and Table 7.14), and the negative coefficient on the product of stops on work tours and number of non-work tours (see Table 7.15).

The tour sequence variables are also very significant. These variables explain the likelihood of engaging in shop, recreational and other activities before or after work or school, as well as the sequencing of work and school when both activities are part of the day pattern. All models show there is significantly less likelihood of making shop, recreational or other tours before either a school or work tour, with social/recreational tours being less likely to appear before work or school tours than shop tours.

Both pre-school and grade/high school students are very unlikely to have a day pattern that includes two or more home-based school tours. Grade/high school students are more likely to make a tour that includes both school and work than separate school and work tours. When a work tour is present in their day pattern, it is more likely to appear after the school tour than before. If they self-reported being workers, these students are less likely to choose a pattern that consists of one home-based school tour with no work stops than any other pattern. The likelihood of choosing a day-pattern that includes a work activity is higher for students between 15-17 years old than for younger students. If a school tour has stops, it is most likely to be an inbound stop.

College students are very likely to have a day pattern that is either just a home-based work tour or a home-based school tour without work stops. Patterns that include both school and work tours are also more likely than staying at home, with work after school being the most likely sequence. Patterns with a tour that includes both school and work activities are also more likely than staying at home. And when the day pattern does not include school or work, it is likely to consist of three or more tours, suggesting that the most complex trip-making behavior is left for (or possible on) days that do not include long-duration mandatory activities. Similarly, tours that include both work and school activities are unlikely to have additional stops on it, suggesting limited ability to engage in non-mandatory activities. Outbound stops on work or school tours are very unlikely, while work and school tours with both inbound and outbound stops are more likely than tours with no stops, or with only inbound or outbound stops. The same behavior is observed for patterns that include both work and school

For workers, the most likely pattern consists of a single home-based work tour (no stops) followed by a pattern that includes one work tour (no stops) among other tours. If there are stops on the work tours, inbound stops are more likely than outbound stops. Work-based tours are relatively rare; work-based tours with stops are more likely than work-based tours without stops.

For non-workers the most likely pattern is to stay at home, followed by a single home-based other tour. Their day-pattern is more likely than not to include a recreation tour. When both shop and recreation tours are present in the pattern, the recreation tour is more likely to occur after the shop tour, rather than before. As observed for the other person types, tours with outbound stops are less likely than tours with inbound stops or no stops at all.

The models show multiple, significant and logical effects when the traveler components (age, gender, auto ownership, etc.) are interacted with the activity components:

- The oldest preschoolers are more likely to engage in out-of-home recreational activities than the youngest children;
- The likelihood of a school tour increases with preschooler age;

- Preschoolers are more likely to stay at home if there's a non-working adult in the household or if it is a low income household;
- Multiple tours or stops on tours are less likely when the household is car-insufficient (owns no cars or owns less cars than adults or workers);
- Recreational activities (tours or stops) are more likely for persons in high income households;
- Shopping activities are more likely for persons in high income households;
- Grade/high school students are less likely to make stops for shop, recreational or other purposes when there's a non-working adult in the household, but more likely to do so when there's only one adult in the household, suggesting sharing of household responsibilities;
- Grade/high school students are more likely to perform shop tours if they are old enough to drive and there's more cars than adults in their household;
- Female adults are more likely than male adults to engage in shopping activities;
- When compared against adults 18 to 25 years old, the likelihood of participating in social/recreational activities decreases with age;
- The youngest adults (18 to 25 years old) are the most likely to stay at home, regardless of whether they are college students, workers or non-workers;
- Adults with pre-school children at the most likely to stay at home;
- A worker is less likely to participate in recreational activities if he/she lives in a multiple adult household or if he/she has children;
- A workers is more likely to have shopping activities if he/she is single and has children;

The estimation results for variables that interact accessibility variables with day-pattern composition variables are also significant and logical:

- For workers and college students, the likelihood of a multiple tour pattern decreases with increasing home-to-work distance;
- For college students, the likelihood of making multiple stops on work tours decreases with home to work distance, except when the home is more than 25 miles away from work. Workers are more likely to make stops on their work tours if their home-to-work separation is more than 50 miles. Together, these two results suggest that people tend to decrease stops as their trip length increases, until they reach a distance threshold such that their only way to fulfill their activity needs/desires is by making stops (rather than by performing additional tours).
- As the destination choice logsum increases (meaning higher accessibility), people are more likely to make more tours and less likely to make stops. They are also less likely to stay at home.

For calibration, the Day-Pattern Model parameters controlling for choice of pattern with respect to specific pattern attributes (i.e. numbers and types of activities on pattern) are considered S2 parameters, the others are S1 parameters.

Table 7.11. Pre-School Person Day Pattern Model

Day Pattern Variable	Coefficient	t Statistic
Number of tours is 1	-1.3445	-10.3
Number of tours is 2	-3.8465	-13.4
Number of tours is 3	-6.1119	-14.4
Number of tours is 4	-8.5593	-16.5
Number of tours is 5 or more	-9.1605	-11.3
Number of Work Tours	-	
Number of School Tours	-0.5883	
Number of Shop Tours	0.3400	
Number of Recreation Tours	0.3563	
Number of Other Tours	0.1002	
More than 1 school tour dummy	-2.0807	-4.9
Presence of recreation tours dummy	0.2290	1.5
Presence of other tours dummy	-0.1556	-1.3
Shop tours present before school	-1.4791	-3.6
Recreation tours present before school	-1.5875	-4.4
Other tours present, before school	-1.6172	-6.8
One shop activity	-1.2556	-8.6
Two or more shop activities	-1.6746	-7.3
One recreation activity	-0.3685	-2.5
Two or more recreation activities	-0.5304	-2.3
One other activity	0.4257	3.6
Two or more other activities	1.2264	6.6
Outbound stops > inbound stops	0.1074	1.1
Outbound stops < inbound stops	-0.2560	-2.3
Outbound stops = inbound stops & > 0	-1.0574	-6.4
Presence of stops on shop tours	-1.0245	-6.2
Presence of stops on recreation tours	-2.2336	-13.1
One stop on other tours	-2.0968	-10.9
Two or more stops on other tours	-2.0253	-7.9
Two or more tours dummy if 0 < autos < adults or autos = 0	-0.6432	-2.8
Presence of stops on tours if 0 < autos < adults or autos = 0	-0.3665	-0.9
School tour present if age <=1	-1.2753	-6.4
School tour present if age = 2	-0.6885	-3.7
School tour present if age = 3	0.2856	1.8
School tour present if age = 4	0.8874	5.8
School tour present if age = 5	2.0747	13.8
School tour present if high income	0.2896	3.0
School tour present if non working adult in HH	-0.2831	-2.7
Presence of shop tours or stops if high income	0.3394	3.4
Presence of shop tours or stops if non-working adult in HH	0.7941	7.8
Presence of shop tours or stops if there is only 1 adult in the H	0.2766	1.6

Table 7.11. (cont) Pre-School Person Day-Pattern Model

Day Pattern Variable	Coefficient	t Statistic
Presence of recreation tours or stops if age = 4	0.4419	4.2
Presence of recreation tours or stops if age = 5	0.3544	3.2
Presence of other tours or stops if low income	-0.3589	-2.1
Presence of other tours or stops if high income	0.1962	2.5
Presence of other tours or stops if non-working adult in HH	0.1710	1.9
Presence of other tours or stops if there is only 1 adult in HH	0.5890	4.3
Stay at home if age <=1	0.1580	1.9
Stay at home if low income household	0.4045	2.7
Stay at home if non-working adult in HH	0.6345	5.9
Number of shop tours * Destination choice logsum of same purpose	0.0618	(a)
Number of recreation & other tours * Destination choice logsum of sar	0.0432	(a)
Number of stops per tour * Destination choice logsum of same purpos	-0.0617	(a)
Final Likelihood	-11046	
Rho-Squared wrt Zero	0.4274	

(a) Asserted coefficients, based on Non-Worker Day Pattern Model

Table 7.12. Grade/High School Student Day Pattern Model

Day Pattern Variable	Coefficient	t Statistic
Number of tours is 1	-1.7357	-14.6
Number of tours is 2	-3.8320	-15.7
Number of tours is 3	-6.9132	-18.9
Number of tours is 4	-10.0489	-19.2
Number of tours is 5 or more	-10.6381	-15.6
Number of Work Tours	1.4975	
Number of School Tours	-0.0619	
Number of Shop Tours	0.2365	
Number of Recreation Tours	0.3442	
Number of Other Tours	-0.6715	
School tour only, with no work stops	3.4623	27.5
School tour, then work/work-based tour, with no work stops	3.3813	15.6
School and work on same tour	2.8941	11.7
More than 1 school tour dummy	-1.6339	-10.9
Presence of work based tours	-2.8126	-2.8
Pattern is home-school-home	0.5030	7.5
Presence of shop tours dummy	0.4483	2.3
Presence of recreation tours dummy	0.4940	3.2
Shop tours present before school	-2.4615	-4.2
Recreation tours present before school	-4.5474	-14.3
Other tours present, before school	-3.0084	-18.0
One shop activity	-1.7167	-12.4
Two or more shop activities	-1.9551	-8.4
One other activity	0.3248	3.8
Two or more other activities	0.8942	6.0
Number of intermediate stops * number of tours	-0.3313	-7.2
Dummy if school tour has outbound stop but no inbound stop	-3.3763	-27.2
Dummy if school tour has inbound stop but no outbound stop	-1.9685	-15.8
Dummy if school tour has both inbound and outbound stops	-3.7069	-22.2
Dummy if work tour has outbound stop but no inbound stop	-2.6337	-5.0
Dummy if work tour has inbound stop but no outbound stop	-2.7072	-6.6
Presence of stops on shop tours	-1.1337	-7.7
Presence of stops on recreation tours	-1.9097	-15.4
One stop on other tours	-1.9291	-11.4
Two stops on other tours	-2.6619	-8.6
Three or more stops on other tours	-2.6619	-8.6
Presence of shop, rec & other tours if autos = 0	-0.8283	-4.0
Presence of stops for shop, rec & other if cars < workers (cars > 0)	0.5318	5.4
Presence of stops for shop, rec or other if non-working adult in HH	-0.3140	-5.6
Presence of stops for shop, rec & other if only 1 adult in HH	0.4173	5.6
School tour only, with no work stops, if worker	-0.2598	-2.1
Presence of work tour or stop for 15 years old	1.5066	3.7
Presence of work tour or stop for 16 years old	1.5037	5.7
Presence of work tour or stop for 17 years old	1.7472	7.0

Table 7.12. (cont.): Grade/High School Student Day Pattern Model

Day Pattern Variable	Coefficient	t Statistic
Presence of shop tours or stops if age 16-17 & cars > adults	0.3784	3.4
Presence of shop tours or stops if non-working adult in HH	0.2903	3.8
Presence of shop tours or stops if there is only 1 adult in the HH	0.2077	2.0
Presence of recreation tours or stops if high income	0.3768	7.6
Presence of other tours or stops if age 11-13	-0.1175	-4.2
Presence of other tours or stops if age 14-15	-0.1434	-4.4
Presence of other tours or stops if age 16-17 & cars > adults	0.2528	3.2
Presence of other tours or stops if low income	-0.1794	-3.9
Stay at home if non-working adult in HH	0.4592	3.2
Number of shop tours * Destination choice logsum of same purpose	0.0664	3.5
Number of recreation/other tours * Destination choice logsum of same purpos	0.0123	1.1
Number of stops per tour * Destination choice logsum of same purpose	-0.0414	-4.9
Final Likelihood	-27249	
Rho-Squared wrt Zero	0.4702	

Table 7.13. College Student Day Pattern Model

Day Pattern Variable	Coefficient	t Statistic
Number of tours is 1	-0.0078	-14.0
Number of tours is 2	-2.5715	-13.9
Number of tours is 3	-4.8843	-12.4
Number of tours is 4	-6.7774	-11.9
Number of tours is 5 or more	-9.2249	-10.3
Number of Work Tours	0.7670	
Number of School Tours	0.3224	
Number of Shop Tours	0.6446	
Number of Recreation Tours	0.9575	
Number of Other Tours	0.3192	
School tour only, with no work stops	1.6808	17.5
Work/work-based tour only	1.9143	19.7
School tour, then work/work-based tour, with no work stops	2.6411	17.6
Work/work-based tour, then school tour, with no work stops	1.7879	10.8
School and work on same tour	1.8795	10.2
Two or more work/work-based tours, no stops	-1.3615	-8.3
Two or more work/work-based tours, with stops	-1.3615	-8.3
More than 1 school tour dummy	-0.3734	-3.3
Presence of work based tours	-1.8463	-17.0
If no primary tour, there are 3+ secondary tours	0.6666	4.4
Presence of recreation tours dummy	0.1023	1.0
Presence of other tours dummy	-0.4498	-4.9
Shop before work dummy	-1.1409	-7.2
Recreation before work dummy	-1.5949	-7.7
Other before work dummy	-0.9438	-9.3
Shop tours present before school	-1.1409	-7.2
Recreatio tours present before school	-1.5949	-7.7
Other tours present, before school	-0.9438	-9.3
One shop activity	-0.2811	-3.5
Two or more shop activities	-0.4740	-3.9
One other activity	0.4739	5.8
Two other activities	1.2181	9.5
Three or more other activities	1.9471	9.4
If work or school, there are outbound stops on it	-1.7468	-10.9
If work or school, there are inbound stops on it	-0.9021	-6.1
If work or school, there are inbound & oubound stops on it	0.6752	4.2
If school & work tours, there are outbound stops on the first	-1.8009	-6.1
If school & work tours, there are inbound stops on the first	-1.4269	-5.5
If school & work tours, there are oubound & inbound stops on the first	1.1068	2.4
If school & work tours, there are outbound stops on the second	-2.3554	-6.5
If school & work tours, there are inbound stops on the second	-1.4837	-5.9
If school & work tours, there are oubound & inbound stops on the second	1.0298	1.8
If school and work on same tour, there are additional stops on it	-1.5109	-6.8
Presence of stops on shop tours	-0.2581	-1.3

Table 7.13. (cont.) College Student Day Pattern Model

Day Pattern Variable	Coefficient	t Statistic
Presence of stops on work or school if two+ adults, no children	-0.2411	-2.1
Presence of stops on work or school if two+ adults, 1+ children, no pı	-0.3799	-2.8
Presence of stops on work or school if two+ adults, 1+ children, 1+ pı	-0.2158	-1.4
Presence of stops on shop, rec or other if one adult, 1+ children	-0.9811	-2.4
Presence of stops on shop, rec or other if two+ adults, no children	-0.6151	-3.7
Presence of stops on shop, rec or other if two+ adults, 1+ children	-0.7039	-3.7
School tour only, with no work stops, if worker	-0.2193	-2.6
Presence of shop tours or stops if female	0.6226	6.2
Presence of shop tours or stops if one adult, 1+ children	-0.4628	-1.4
Presence of shop tours or stops if two+ adults, 1+ children, no presch	-0.6124	-3.4
Presence of shop tours or stops if two+ adults, no children	-0.4745	-3.1
Presence of shop tours or stops if two+ adults, 1+ children, 1+ presch	-0.3079	-1.5
Presence of recreation tours or stops if age 25-35 yrs	-0.3528	-2.8
Presence of recreation tours or stops if age 35-45 yrs	-0.5585	-3.8
Presence of recreation tours or stops if age 45-55 yrs	-0.5788	-3.2
Presense of recreation tours or stops if low income	-0.2824	-2.0
Presence of recreation tours or stops if high income	0.2394	2.3
Presence of recreation tours or stops if 2+ adults in HH	-0.2646	-2.7
Presence of other tours or stops if one adult, 1+ children	0.9370	4.1
Presence of other tours or stops if two+ adults, 1+ children	0.3796	4.3
Stay at home if age 25-35 yrs	-0.2884	-1.9
Stay at home if age 35-45 yrs	-0.4218	-2.2
Stay at home if age 45+ yrs	-0.3197	-2.2
Stay at Home if 1+ children, 1+ preschooler	0.3051	1.7
Stay at Home if 1+ children, no preschooler	-0.2743	-1.7
Number of tours if home to work distance is 1.0 - 5.0 miles	0.2725	2.3
Number of tours if home to work distance is 5.0 - 10.0 miles	0.2861	3.0
Number of tours if home to work distance is 10.0+ miles	-0.4516	-2.9
Number of stops on work tours if home to work distance is 1 - 2.5 mile	0.7542	4.2
Number of stops on work tours if home to work distance is 2.5 - 5.0 m	0.7542	4.2
Number of stops on work tours if home to work distance is 5.0 - 10.0 ı	0.6227	6.3
Number of stops on work tours if home to work distance is 10.0 - 25.0	0.3295	2.4
Number of stops on work tours if home to work distance is 25.0+ mile	0.5255	1.9
Number of stops on all tours if home to work distance is 1.0 - 2.5 mile	-0.7168	-3.5
Number of stops on all tours if home to work distance is 2.5 - 5.0 mile	-0.4793	-2.3
Number of stops on all tours if home to work distance is 5.0 - 10.0 mil	-0.4780	-3.7
Number of stops on all tours if home to work distance is 10.0 - 25.0 m	-0.3038	-2.1
Number of stops on all tours if home to work distance is 25.0 - 50.0 m	-0.3727	-1.5
Number of stops on all tours if home to work distance is 50.0+ miles	-0.7443	-1.5
Number of tours * Destination choice logsum (college)	0.0173	1.2
Number of stops per tour * Destination choice logsum (college)	-0.0646	-5.2
Final Likelihood	15496	
Rho-Squared wrt Zero	0.2780	

Table 7.14. Worker Day Pattern Model

Number of Work Tours	-0.4478	
Number of School Tours		
Number of Shop Tours	-0.0989	
Number of Recreation Tours	0.0107	
Number of Other Tours	0.3192	
One work/work-based tour only, no stops	1.6703	27.6
One work/work-based tour, no stops	1.0760	17.9
One work/work-based tour only, with outbound stop only	-0.1862	-3.8
One work/work-based tour only, with inbound stop only	0.9002	22.0
One work/work-based tour, with outbound stop only	-0.1980	-3.2
One work/work-based tour, with inbound stop only	0.3507	6.6
Two or more work/work-based tours, no stops	-0.4302	-3.5
Two or more work/work-based tours, with stops	-2.1309	-21.2
Number of work-based tours	-1.9030	-72.9
Presence of recreation tours dummy	0.7924	7.4
Presence of other tours dummy	-0.0658	-1.5
Shop before work dummy	-1.6990	-24.7
Recreation before work dummy	-2.2490	-22.8
Other before work dummy	-1.4246	-30.4
One shop activity	-1.7571	-19.0
Two shop activities	-3.1036	-20.0
Three shop activities	-3.7773	-14.4
Four or more shop activities	-4.1507	-6.4
One recreation activity	-1.9385	-16.0
Two recreation activities	-3.5854	-19.1
Three or more recreation activities	-4.4960	-10.9
One other activity	-0.9023	-12.8
Two other activities	-1.0429	-8.7
Three other activities	-1.3145	-7.7
Four or more other activities	-1.5610	-6.6
Number of stops on work tours * Number of non-work tours	-0.0073	-0.2
Presence of stops on work tours * Number of stops on non-	-0.1712	-3.5
Presence of stops on work-based tours	0.6037	12.8
Presence of stops on shop tours	-0.2885	-5.8
Presence of stops on recreation tours	-1.3233	-20.7
One stop on other tours	-1.3026	-23.2
Two stops on other tours	-1.8580	-17.7
Three or more stops on other tours	-2.7974	-7.5
Two or more tours dummy if autos = 0	-1.0000	-6.4
Presence of stops on work tours if autos = 0	-0.6028	-3.3
Presence of stops on work based tours if autos = 0	-1.1349	-2.2

Table 7.14. (cont.) Worker Day Pattern Model

Day Pattern Variable	Coefficient	t Statistic
Presence of shop stops on work tours if female	0.1958	2.9
Presence of shop tours or stops if female	0.3496	10.0
Presence of shop tours or stops if age less than 25 yrs old	-0.2534	-3.2
Presence of shop tours or stops if age 55+ yrs	0.2009	4.9
Presence of shop tours or stops if high income	0.0464	1.4
Presence of shop tours or stops if one adult worker, 1+ children	0.1933	1.9
Presence of shop tours or stops if 1+ preschoolers in household	-0.1625	-3.2
Presence of recreation tours or stops if age less than 25 yrs	0.3214	4.2
Presence of recreation tours of stops if age 55+ yrs	0.1241	2.6
Presence of recreation tours or stops if high income	0.2020	5.3
Presence of recreation tours or stops if one adult, worker, 1+ children	-0.2837	-2.1
Presence of recreation tours or stops if two+ adults, no children	-0.2766	-6.7
Presence of recreation tours or stops if two+ adults, 1+ children, 1+ pı	-0.3358	-5.5
Presence of other tours or stops if female	0.2903	10.8
Presence of other tours or stops if age less than 25 yrs old	-0.3946	-6.4
Presence of other tours or stops if age 55+ yrs	0.2038	5.6
Presence of other tours or stops if high income	0.0689	2.5
Other tours or stops if one adult, worker, 1+ children, no preschooler	1.2888	10.7
Other tours or stops if one adult, worker, 1+ children, 1+ preschooler	1.4168	6.9
Other tours or stops if two+ adults, workers=adults, 1+ children, no pr	0.5952	14.7
Other tours or stops if two+ adults, workers=adults, 1+ children, 1+ pr	0.6991	14.2
Other tours or stops if two+ adults, workers<adults, 1+ children, no pr	0.3828	5.7
Other tours or stops if two+ adults, workers<adults, 1+ children, 1+ pr	0.1340	1.9
Stay at home if age 35-55 yrs	-0.3413	-6.9
Stay at home if age 55+ yrs	-0.1926	-2.9
Stay at Home if one adult, worker, 1+ children, no preschooler	0.4168	1.8
Stay at Home if one adult, worker, 1+ children, 1+ preschooler	1.1450	4.0
Stay at Home if two+ adults, workers=adults, no children	0.2133	2.9
Stay at Home if two+ adults, workers=adults, 1+ children, no preschoo	0.2255	2.5
Stay at Home if two+ adults, workers=adults, 1+ children, 1+ preschoo	0.4599	4.8
Stay at Home if two+ adults, workers<adults, no children	0.3816	4.9
Stay at Home if two+ adults, workers<adults, 1+ children, no preschoo	0.3128	2.6
Stay at Home if two+ adults, workers<adults, 1+ children, 1+ preschoo	0.1383	1.2
Number of tours if home to work distance is 1.0 - 2.5 miles	0.2968	6.3
Number of tours if home to work distance is 2.5 - 5.0 miles	0.1622	3.7
Number of tours if home to work distance is 5.0 - 10.0 miles	0.1137	4.8
Number of tours if home to work distance is 10.0 - 25.0 miles	-0.4009	-7.1
Number of tours if home to work distance is 25.0 - 50.0 miles	-0.4657	-6.6
Number of tours if home to work distance is 50.0+ miles	-0.4139	-3.8
Number of stops on work tours if home to work distance is 50.0+ mile	0.8827	2.9
Number of stops on all tours if home to work distance is 1.0 - 2.5 mile	-0.1853	-2.6
Number of stops on all tours if home to work distance is 2.5 - 5.0 mile	-0.0796	-1.3
Number of stops on all tours if home to work distance is 5.0 - 10.0 mil	-0.1034	-2.2
Number of stops on all tours if home to work distance is 10.0 - 25.0 m	-0.0939	-1.9
Number of stops on all tours if home to work distance is 25.0 - 50.0 m	-0.1349	-2.0
Number of stops on all tours if home to work distance is 50.0+ miles	-0.9854	-3.4

Table 7.14. (cont.) Worker Day Pattern Model

Day Pattern Variable	Coefficient	t Statistic
Number of shop tours * Destination choice logsum of same purpose	0.0562	6.6
Number of recreation & other tours * Destination choice logsum of sa	0.0205	3.9
Number of stops per tour * Destination choice logsum of same purpos	-0.0141	-2.2
Final Likelihood	-97414	
Rho-Squared wrt Zero	0.3939	

Table 7.15. Non Worker Person Day Pattern Model

Day Pattern Variables	Coefficient	t Statistic
Number of tours is 1	-1.5586	-13.2
Number of tours is 2	-3.2758	-17.8
Number of tours is 3	-4.8754	-22.5
Number of tours is 4	-7.3472	-28.2
Number of tours is 5 or more	-8.6109	-29.4
Number of Work Tours		
Number of School Tours		
Number of Shop Tours	0.2584	
Number of Recreation Tours	0.3874	
Number of Other Tours	-0.3899	
If only 1 tour, purpose other	0.5825	9.1
If multiple tours, all shop	-0.2938	-3.1
If multiple tours, all other	0.5463	6.3
Recreation tours occur prior to shop tours	-0.5608	-7.8
One shop activity	-1.0228	-5.7
Two or more shop activities	-1.5783	-8.0
One recreation activity	-0.2203	-1.2
Two or more recreation activities	-1.0573	-5.1
Two ore more other activities	0.3097	3.0
Number of intermediate stops * Number of tours	-0.2634	-11.6
Outbound stops > inbound stops	-0.3508	-9.2
Outbound stops = inbound stops & > 0	-0.5863	-11.2
Presence of stops on shop tours	-0.1225	-1.9
Presence of stops on recreation tours	-0.9874	-12.2
One stop on other tours	-1.0584	-15.8
Two stops on other tours	-1.4269	-13.0
Three or more stops on other tours	-1.6095	-5.5
Two or more tours dummy if autos = 0	-1.7639	-11.5
Two or more tours dummy if 0 < autos < adults	-0.2395	-4.6
Presence of stops on tours if 0 < autos < adults or autos = (	-0.3285	-6.2
Presence of shop tours or stops if female	0.2732	6.4
Presence of shop tours or stops if age 25-35	0.4516	2.7
Presence of shop tours or stops if age 35-45	0.4516	2.7
Presence of shop tours or stops if age 45-55 yrs	0.5767	3.4
Presence of shop tours or stops if age 55-65 yrs	0.6198	3.8
Presence of shop tours or stops if age 65+ yrs	0.4720	3.0
Presence of shop tours or stops if low income	-0.1284	-2.6
Presence of shop tours or stops if high income	0.0961	2.0
Presence of recreation tours or stops if age 25-65 yrs	-0.2988	-1.9
Presence of recreation tours or stops if age 65+ yrs	-0.3828	-2.4
Presense of recreation tours or stops if low income	-0.1550	-2.7
Presence of recreation tours or stops if high income	0.2286	4.3
Presence of recreation tours or stops if 2+ adults in HH	-0.1735	-3.1

Table 7.15. (cont'd) Non Worker Person Day Pattern Model

Day Pattern Variable	Coefficient	t Statistic
Presence of other tours or stops if age 65+ yrs	-0.1310	-2.4
Presence of other tours or stops if low income	-0.2624	-5.6
Presence of other tours or stops if high income	0.1866	3.9
Presence of other tours or stops if 1+ children, 1+ preschooler	0.1897	2.3
Presence of other tours or stops if two+ adults, no children	-0.1240	-2.1
Presence of other tours or stops if 1+ children, no preschooler	0.5103	6.5
Stay at home if female	0.2429	5.8
Stay at home if age 25-45 yrs	-0.4206	-2.8
Stay at home if age 45-55 yrs	-0.3545	-2.3
Stay at home if age 55-65 yrs	-0.4521	-3.0
Stay at home if age 65+ yrs	-0.4414	-2.9
Stay at home if autos = 0	1.0486	10.7
Stay at home if 0 < autos < adults	0.3424	6.8
Stay at Home if two+ adults, no workers, no children	-0.1943	-3.6
Number of shop tours * Destination choice logsum of same purpose	0.0618	8.7
Number of recreation & other tours * Destination choice logsum of sa	0.0432	10.6
Number of stops per tour * Destination choice logsum of same purpos	-0.0617	-10.7
Final Likelihood	-97414	
Rho-Squared wrt Zero	0.3939	

7.5.6. SDT Stop Pattern Model Estimation

The SDT Stop Pattern Choice Model was estimated with the Intermediate Stop Purpose Models, as discussed in the next section.

7.5.7. SDT Intermediate Stop Purpose Model Estimation

The SDT Intermediate Stop Pattern Models include distributions for identification of stop purpose for tours in 2+ tour patterns, and a multinomial model for number of intermediate stops for those with 3+ tour patterns by activity type. The trip purpose distributions were derived from Oregon Home Interview Survey data and are shown in Tables 7.16 to 7.20 for 2 tour patterns, and Tables 7.21 to 7.23 for 3+ tour patterns. The stop purpose probabilities are based on expanded data. The distributions are conditional on person type, tour purpose, tour position (3+ tours only), tour number (2 tours only), and tour position (3+ tours only) and stop position (2 tours only).

Tables 7.24 through 7.26 shows the estimation results for the Stop Choice model, estimated for each tour purpose, based on the Oregon Home Interview Survey. As discussed in Section 7.3.6, it is discrete choice multinomial logit model with four alternatives. Since none of the explanatory variables are alternative-specific, they were entered in the utility function with a different coefficient for each alternative; that is, there are no generic coefficients in these models. A wide range of tour and day-pattern composition variables were tried in all models; only those that resulted in significant coefficients were retained. When a coefficient was made generic across two alternatives, the t-statistic is reported only on one of the alternatives, but the coefficient is reported for both.

Table 7.16. Two Tour Intermediate Stop Purpose Model, Pre-School Persons

Number of Observations

	Tour 1						**Tour 2**					
Tour	*Outbound Stop*			*Inbound Stop*			*Outbound Stop*			*Inbound Stop*		
Purpose	*S*	*R*	*O*	*S*	*R*	*O*	*S*	*R*	*O*	*S*	*R*	*O*
W												
B												
C	1	5	26	9	9	29	0	0	2	0	0	6
S	9	9	50	5	7	26	12	15	31	3	8	23
R		2	15			14		6	23			22
O			27			5			25			5

Stop Purpose Probabilities

	Tour 1						**Tour 2**					
Tour	*Outbound Stop*			*Inbound Stop*			*Outbound Stop*			*Inbound Stop*		
Purpose	*S*	*R*	*O*	*S*	*R*	*O*	*S*	*R*	*O*	*S*	*R*	*O*
W												
B												
C	0.006	0.245	0.748	0.172	0.244	0.584	0.000	0.000	1.000	0.000	0.000	1.000
S	0.114	0.097	0.788	0.107	0.161	0.732	0.211	0.302	0.487	0.122	0.159	0.719
R		0.022	0.978		0.000	1.000		0.197	0.803		0.000	1.000
O			1.000			1.000			1.000			1.000

Note: Trip purposes are W=work, B=work-based, C=school, S=shopping, R=recreation, O=other

Table 7.17. Two Tour Intermediate Stop Purpose Model, Grade/High School Persons

Number of Observations

	Tour 1						**Tour 2**					
Tour	*Outbound Stop*			*Inbound Stop*			*Outbound Stop*			*Inbound Stop*		
Purpose	*S*	*R*	*O*	*S*	*R*	*O*	*S*	*R*	*O*	*S*	*R*	*O*
W	0	0	0	0	0	0	0	1	2	1	1	6
B	0	0	0	0	0	0	0	0	0	0	0	0
C	7	33	162	22	110	209	0	3	7	4	5	15
S	8	7	18	3	3	13	26	73	87	10	33	74
R		3	6		1	12		47	97		6	143
O			14			3			57			10

Stop Purpose Probabilities

	Tour 1						**Tour 2**					
Tour	*Outbound Stop*			*Inbound Stop*			*Outbound Stop*			*Inbound Stop*		
Purpose	*S*	*R*	*O*	*S*	*R*	*O*	*S*	*R*	*O*	*S*	*R*	*O*
W	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.831	0.169	0.046	0.073	0.881
B	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
C	0.022	0.177	0.802	0.051	0.334	0.615	0.000	0.172	0.828	0.084	0.247	0.669
S	0.309	0.277	0.414	0.118	0.294	0.588	0.115	0.371	0.515	0.066	0.261	0.673
R		0.144	0.856		0.039	0.961		0.300	0.700		0.051	0.949
O			1.000			1.000			1.000			1.000

Note: Trip purposes are W=work, B=work-based, C=school, S=shopping, R=recreation, O=other

Table 7.18. Two Tour Intermediate Stop Purpose Model, College Persons

Number of Observations

	Tour 1						Tour 2					
Tour	Outbound Stop			Inbound Stop			Outbound Stop			Inbound Stop		
Purpose	S	R	O	S	R	O	S	R	O	S	R	O
W	5	1	31	10	5	42	1	3	13	5	6	17
B	4	0	4	1	2	7	0	1	0	0	0	2
C	0	5	52	34	10	69	5	2	11	9	13	21
S	11	5	24	3	2	22	8	10	35	3	16	24
R			10			9		17	34		2	30
O			16			3			39			6

Stop Purpose Probabilities

	Tour 1						Tour 2					
Tour	Outbound Stop			Inbound Stop			Outbound Stop			Inbound Stop		
Purpose	S	R	O	S	R	O	S	R	O	S	R	O
W	0.138	0.017	0.845	0.110	0.174	0.715	0.114	0.267	0.619	0.244	0.221	0.534
B	0.334	0.000	0.666	0.045	0.095	0.860	0.000	1.000	0.000	0.000	0.000	1.000
C	0.000	0.049	0.951	0.262	0.050	0.688	0.165	0.235	0.601	0.226	0.225	0.549
S	0.277	0.092	0.631	0.074	0.044	0.882	0.128	0.178	0.694	0.037	0.343	0.619
R		0.000	1.000		0.000	1.000		0.253	0.747		0.091	0.909
O			1.000			1.000			1.000			1.000

Note: Trip purposes are W=work, B=work-based, C=school, S=shopping, R=recreation, O=other

Table 7.19. Two Tour Intermediate Stop Purpose Model, Workers

Number of Observations

	Tour 1						Tour 2					
Tour	Outbound Stop			Inbound Stop			Outbound Stop			Inbound Stop		
Purpose	S	R	O	S	R	O	S	R	O	S	R	O
W	65	26	589	202	91	720	26	12	113	55	29	136
B	11	6	130	46	18	111	3	1	7	3	3	14
C												
S	51	28	287	41	19	149	105	102	396	32	92	260
R		5	42		4	39		58	194		7	191
O			231			60			251			37

Stop Purpose Probabilities

	Tour 1						Tour 2					
Tour	Outbound Stop			Inbound Stop			Outbound Stop			Inbound Stop		
Purpose	S	R	O	S	R	O	S	R	O	S	R	O
W	0.074	0.038	0.888	0.153	0.102	0.745	0.170	0.096	0.734	0.235	0.115	0.650
B	0.056	0.035	0.908	0.294	0.080	0.626	0.157	0.019	0.824	0.095	0.090	0.815
C												
S	0.126	0.088	0.786	0.167	0.097	0.736	0.148	0.159	0.693	0.067	0.251	0.683
R		0.130	0.870		0.100	0.900		0.245	0.755		0.040	0.960
O			1.000			1.000			1.000			1.000

Note: Trip purposes are W=work, B=work-based, C=school, S=shopping, R=recreation, O=other

Table 7.20. Two Tour Intermediate Stop Purpose Model, Non Workers

Number of Observations

Tour Purpose	Tour 1 Outbound Stop S	R	O	Tour 1 Inbound Stop S	R	O	Tour 2 Outbound Stop S	R	O	Tour 2 Inbound Stop S	R	O
W												
B												
C												
S	111	99	526	62	36	266	81	56	248	26	35	143
R		24	94		4	87		27	104		6	120
O			231			51			164			46

Stop Purpose Probabilities

Tour Purpose	Tour 1 Outbound Stop S	R	O	Tour 1 Inbound Stop S	R	O	Tour 2 Outbound Stop S	R	O	Tour 2 Inbound Stop S	R	O
W												
B												
C												
S	0.149	0.137	0.713	0.160	0.128	0.712	0.191	0.177	0.632	0.132	0.193	0.675
R		0.255	0.745		0.042	0.958		0.271	0.729		0.096	0.904
O			1.000			1.000			1.000			1.000

Note: Trip purposes are W=work, B=work-based, C=school, S=shopping, R=recreation, O=other

Table 7.21. Three+ Tour Intermediate Stop Purpose Model, Student Person Types

Number of Observations

Tour Purpose	Pre-School Stop Purpose S	R	O	Grade/High School Stop Purpose S	R	O	College Stop Purpose S	R	O
W				1	2	9	4	6	46
B				0	0	0	0	0	3
C	2	5	12	9	18	78	18	14	77
S	14	8	86	19	25	104	19	16	75
R		2	30		10	70		11	58
O			45			55			64

Stop Purpose Probabilities

Tour Purpose	Pre-School Stop Purpose S	R	O	Grade/High School Stop Purpose S	R	O	College Stop Purpose S	R	O
W				0.300	0.085	0.615	0.078	0.083	0.840
B				0.000	0.000	0.000	0.000	0.000	1.000
C	0.065	0.088	0.847	0.065	0.120	0.815	0.141	0.121	0.737
S	0.139	0.122	0.739	0.063	0.167	0.770	0.129	0.178	0.692
R		0.029	0.971		0.227	0.773		0.154	0.846
O			1.000			1.000			1.000

Note: Trip purposes are W=work, B=work-based, C=school, S=shopping, R=recreation, O=other

Table 7.22. Three+ Tour Intermediate Stop Purpose Model, Workers

Number of Observations

Tour Purpose	First Tour Stop Purpose S	R	O	Middle Tour Stop Purpose S	R	O	Last Tour Stop Purpose S	R	O
W	67	24	328	44	21	207	9	5	40
B	12	1	42	2	0	14	0	0	0
C									
S	18	19	158	52	38	283	35	55	170
R		2	43		7	80		20	140
O			121			175			100

Stop Purpose Probabilities

Tour Purpose	First Tour Stop Purpose S	R	O	Middle Tour Stop Purpose S	R	O	Last Tour Stop Purpose S	R	O
W	0.171	0.061	0.768	0.132	0.057	0.810	0.076	0.122	0.802
B	0.205	0.051	0.744	0.058	0.000	0.942	0.000	0.000	0.000
C									
S	0.081	0.086	0.834	0.087	0.104	0.809	0.181	0.178	0.641
R		0.046	0.954		0.079	0.921		0.079	0.921
O			1.000			1.000			1.000

Note: Trip purposes are W=work, B=work-based, C=school, S=shopping, R=recreation, O=other

Table 7.23. Three+ Tour Intermediate Stop Purpose Model, Non Workers

Number of Observations

Tour Purpose	First Tour Stop Purpose S	R	O	Middle Tour Stop Purpose S	R	O	Last Tour Stop Purpose S	R	O
W									
B									
C									
S	52	29	257	57	67	318	27	33	127
R		5	75		5	82		10	94
O			120			156			73

Stop Purpose Probabilities

Tour Purpose	First Tour Stop Purpose S	R	O	Middle Tour Stop Purpose S	R	O	Last Tour Stop Purpose S	R	O
W									
B									
C									
S	0.139	0.082	0.779	0.113	0.172	0.715	0.165	0.137	0.698
R		0.062	0.938		0.052	0.948		0.186	0.814
O			1.000			1.000			1.000

Note: Trip purposes are W=work, B=work-based, C=school, S=shopping, R=recreation, O=other

Table 7.24. Intermediate Stop Number Model for Work Tours

	Choice Alternatives					
	Outbound		*Inbound*		*Both*	
Tour Stop Variable	*Coeff.*	*t Stat.*	*Coeff.*	*t Stat.*	*Coeff.*	*t Stat.*
Workbased tour dummy	0.400	3.2			0.406	2.8
Tour is first work tour in day pattern			0.386	3.2	0.386	
Presence of children < 5 yrs old	0.922	5.5			0.936	4.7
Presence of children btw 5-15 yrs old	0.609	4.4	0.171	1.6	0.837	5.4
Grade/high school person type	-0.342	-0.9	-0.342		-1.280	
College person type	-0.584	-2.1	-0.579	-2.8		
Constant	-2.601	-19.9	-1.235	-12.5	-2.348	-18.3
Final Likelihood	-2971					
Rho-Squred wrt Zero	0.240					
Sample Size	2818					

Table 7.25. Intermediate Stop Number Model for School Tours

	Choice Alternatives					
	Outbound		*Inbound*		*Both*	
Tour Stop Variable	*Coeff.*	*t Stat.*	*Coeff.*	*t Stat.*	*Coeff.*	*t Stat.*
Four or more tours in daypattern			-0.481	-1.6	-1.076	-1.4
First school tour in the daypattern	0.856	1.6			1.961	1.9
Presence of shop tours					-0.820	-1.8
Pre-school person type			0.705	2.1	0.705	
College person type	0.890	2.9	0.728	3.6	0.788	2.2
Constant	5.000	-6.6	-1.200	-12.8	-3.643	-4.6
Final Likelihood	-650					
Rho-Squred wrt Zero	0.433					
Sample Size	827					

Table 7.26. Intermediate Stop Number Model for Shop Tours

	Choice Alternatives					
	Outbound		*Inbound*		*Both*	
Tour Stop Variable	*Coeff.*	*t Stat.*	*Coeff.*	*t Stat.*	*Coeff.*	*t Stat.*
Four or more tours in daypattern	-0.179	-2.1	-0.459	-3.7	-0.179	
Presence of other shop tours	-0.137	-1.6			-0.442	-3.9
Presence of other tours			0.251	2.2		
Presence of work or school tours	-0.488	-4.8	-0.199	-1.8	-0.948	-7.2
Low income household	-0.437	-2.8	-0.214	-1.4		
Zero car household					-1.501	-1.5
Presence of children < 15 yrs old	0.408	5.0			0.465	4.3
Worker person type	0.181	2.1				
Constant	-1.138	-4.6	-1.062	-10.4	-1.121	-8.6
Final Likelihood	-4183					
Rho-Squred wrt Zero	0.108					
Sample Size	3382					

Table 7.27. Intermediate Stop Number Model for Social/Recreational Tours

	Choice Alternatives					
	Outbound		*Inbound*		*Both*	
Tour Stop Variable	*Coeff.*	*t Stat.*	*Coeff.*	*t Stat.*	*Coeff.*	*t Stat.*
Four or more tours in daypattern			-0.513	-3.0		
Presence of shop tours	-0.341	-2.7			-0.341	
Presence of other tours	0.238	1.9	-0.217	-1.6	0.238	
Presence of work or school tours	-0.556	-3.8	-0.323	-2.2	-0.510	-2.6
Presence of children < 5 yrs old	0.458	2.5	0.358	2.1	0.365	1.6
Preschool person type	-0.853	-2.0				
College person type			0.735	3.2		
Worker person type			0.397	2.6		
Constant	-1.981	-11.8	-1.990	-13.7	-3.108	-14.5
Final Likelihood	-2153					
Rho-Squred wrt Zero	0.413					
Sample Size	2644					

Table 7.28. Intermediate Stop Number Model for Other Tours

Four or more tours in daypattern					-0.778	-3.7
Presence of shop tours					0.596	1.8
Presence of other 'other' tours					0.759	3.1
Presence of work or school tours	-1.044	-7.0	-0.970	-6.6	-0.929	-4.1
Presence of children < 5 yrs old	0.337	3.4	0.337			
Presence of children 5-15 yrs old					-0.430	-2.1
Grade/high school person type	0.701	2.4	0.843	3.4	0.801	1.8
College person type	0.475	1.8	0.424	1.7	0.992	3.0
Worker person type	0.528	3.7	0.162	1.2	0.427	2.0
Constant	-2.917	-30.9	-1.770	-31.5	-3.969	-15.8
Final Likelihood	-3262					
Rho-Squred wrt Zero	0.676					
Sample Size	7254					

7.5.8. SDT Primary Tour Destination Choice Model Estimation

The estimation results for the SDT Tour Primary Destination Choice Model discussed in section 7.38, including utility expression of Eq. 7.05, are shown in Tables 7.29 and7.30. All models were estimated using either time and mode choice logsum or distance and mode choice logsums; the latter specification resulted in more logical estimates. The coefficient estimated on the mode choice logsum can be interpreted as a nesting coefficient. Thus the coefficient must range be between 0 and 1. A value of 1 implies that there is no nesting. A value greater than 1 implies that the nesting order is incorrect. Logsum coefficients higher than 1.0 in estimation were assigned a value lower than 1.0. T he distance variable was stratified by number of tours on the day pattern and by number of stops on tours. The results show that distance decreases with the number of tours, but increases with the number of stops on the tour.

Table 7.29. School Tours and Work-Based Sub-Tours Primary Destination Choice Models

	College Education		K12 Education		Work-Based Subtours	
Variable	*Coeff.*	*t Stat.*	*Coeff.*	*t Stat.*	*Coeff.*	*t Stat.*
Distance	-0.188	-12.1	-0.698	-41.0	-0.198	-1.8
if 2 tours	-0.027	-2.2	-0.004	-0.4	-0.043	-0.4
if 3+ tours	-0.111	-5.2	-0.068	-2.8	-0.063	-0.5
if stops on tour	0.008	0.7	0.038	3.6		
if preschooler						
Intrazonal Indicator	-1.067	8.2	-0.544	31.3	-1.014	13.7
Mode Choice Logsum	0.443	4.7	0.453	16.7	0.800 (a)	
Size Terms						
Retail					1.000	
Other Services					0.183	-13.2
Households					0.208	-11.7
Health					0.059	-5.8
Transp. & Handling					0.254	-3.0
Other Employment					0.005	-1.9
High Ed. Employment	1.000					
K12 Ed. Employment			1.000			
Intrarural Indicator	-1.690		-4.270		-5.824	
Rho-Squared wrt Zero	0.13		0.14		0.17	
Sample Size	1173		6808		2167	

(a) Asserted coefficient.

Table 7.30. Shop, Social/Recreation and Other Tours Primary Destination Choice Models

	Shop		Social/Recreation		Other	
Variable	*Coeff.*	*t Stat.*	*Coeff.*	*t Stat.*	*Coeff.*	*t Stat.*
Distance	-0.292	-48.6	-0.197	-44.7	-0.262	-57.0
if 2 tours	-0.010	-2.2	-0.036	-7.0	-0.028	-6.2
if 3+ tours	-0.040	-6.7	-0.049	-7.9	-0.076	-14.8
if one stop on tour	0.059	11.3	0.043	8.7	0.114	23.1
if two stops on tour	0.115	19.1	0.065	8.0	0.169	20.5
if preschooler at home	0.021	3.7				
Intrazonal Indicator	-0.686	17.5	-0.249	24.1	-0.628	39.8
Mode Choice Logsum	0.991	20.0	0.760 (a)		0.880	20.9
Size Terms						
Retail	1.000		1.000		1.000	
Other Services	0.038	-30.5	1.755	2.7	0.214	-9.7
Households			4.616	8.3	1.019	0.3
Government					0.300	-6.5
Other Employment						
Intrarural Indicator	-4.697		-2.515		-3.474	
Rho-Squared wrt Zero	0.13		0.11		0.15	
Sample Size	11479		8582		15621	

(a) Asserted coefficient.

7.5.9. SDT Primary Tour Scheduling Model Estimation

Estimation results for the SDT Tour Scheduling Models discussed in Section 7.3.9 are shown in Tables 7.31 to 7.36 . The day pattern, traveler attribute and travel condition variables were typically interacted with both departure time shift and duration shift variables; variables were kept if they showed logical estimates for both shift variables, and significant estimates for at least one of them.

The constant terms for all models show the expected result: increasingly negative departure time or duration constant with decreasing observed departure time or duration frequencies. Among the day-pattern composition variables, those that describe the place of the tour in the pattern sequence relative to the length of the pattern (in tours) are very powerful and have logical signs. The departure time shifts essentially indicate that how early or late, relative to a one-tour pattern, the tour occurs. Note that a non-significant estimate simply means that the tour tends to occur at about the same time as the one-tour pattern. The duration shifts indicates that first tours tend to be the longest tours, followed by second tours, etc. This trend was observed in the data. Note as well that the duration shift variables are negative, indicating that tours in multiple tour patterns are shorter than tours in single tour patterns.

The other day pattern composition variables included in the models are dummy variables to indicate the presence of tours of a given purpose in the pattern, and dummy variables to flag the presence of inbound and/or outbound stops in the tour. The models show many significant effects related to these variables, both for tour departure time and for tour duration. For example, the presence of multiple work tours in the day pattern tends to shift work tour departure times early, and to shorten the duration of the tour. The presence of tours of any other purpose tends to shift the work tour departure time late, and to lengthen the duration of the work tour. Note that this is after controlling for the number of tours in the pattern. The result is logical because it is essentially comparing a work tour coupled with another work tour vs. a work tour coupled with a non-work tour; the work tour in the latter case is expected to be longer than the work tour in the former case. The presence of intermediate stops on the tour tends to increase the duration of the tour. However, tours with both inbound and outbound stops are on average shorter than tours with either just one inbound or just one outbound stop (one or the other, depending on purpose), suggesting that when multiple stops occur on a tour they tend to be of short duration.

The models also show multiple significant effects related to the traveler attribute variables. Among these are:

- Female workers tend to have later work departures and shorter work tours than male workers;
- The youngest workers (less or equal to 25 years old) tend to have the latest work departures, while the oldest workers (55 years old or older) tend to have the shortest work tours;
- Workers in the following industries have significantly later departure times for work than workers in all other industries: arts & recreation, accommodations & food, and real estate. Workers in the latter two industries also have the shortest work tours;
- Persons in worker households tend to make later shop tours than those in no-worker households;

- Workers and students make longer shop tours than non-workers; women make longer shop tours than men;
- Workers are more likely to depart late for recreation tours than non-workers or students, but students make the longest recreation tours.

The only travel condition variable estimated was tour distance, due to the unavailability of mode choice logsums when the models were estimated. The models show longer tour distance associated with earlier departure times and with longer tours. However, the structure of the models places the scheduling models before the destination choice models for all purposes other than work. Therefore the distance variable can only be used for work tours; for other tour purposes, the distance variable is set to 0.

Table 7.31. Work Tour Scheduling Model

Variable	Coeff.	t-Stat
Departure Time Shift / Day Pattern Composition Effects		
One or more other work tours	-0.2211	-10.1
Presence of school tours		
Presence of shop tours	0.1080	6.0
Presence of recreation tours	0.0425	2.3
Presence of other tours	0.0945	4.8
Inbound stop only on tour	-0.0751	-4.5
Outbound stop only on tour	0.1095	5.2
Inbound & outbound stop on tour	-0.0014	-0.1
First tour of the day if 2 tour pattern	-0.2177	-11.3
Second tour of the day if 2 tour pattern	0.3860	17.3
First tour of the day if 3 tour pattern	-0.2658	-8.5
Second tour of the day if 3 tour pattern	-0.0032	-0.1
Third tour of the day if 3 tour pattern	0.5888	12.9
First tour of the day if 4+ tour pattern	-0.3469	-8.0
Second tour of the day if 4+ tour pattern	-0.1143	-2.4
Third tour of the day if 4+ tour pattern	0.1208	2.1
Fourth tour of the day if 4+ tour pattern	0.6810	8.4
Presence of a work-based sub-tour	0.0706	4.5
Departure Time Shift / Traveler Attribute Effects		
Grade/High school student	-0.1320	-2.8
College student	0.0134	0.8
High income household	-0.0023	-0.3
Zero car household	0.0763	2.6
Female	0.0592	7.5
Children 5 years old or younger in hhld	-0.0154	-1.3
Children 6-15 years old in hhld	-0.0281	-2.8
Non working adult in hhld	0.0236	1.9
Multiple, all working adult hhld	0.0071	0.6
Age greater than 55 years old	-0.1580	-10.4
Age between 26 & 35 years old	-0.1101	-7.8
Age between 36 & 55 years old	-0.2007	-15.4
Retail occupation or industry	0.2438	14.2
Public Administration occupation or industry (not retail)	0.0725	3.4
Arts/Recreation industry (not retail, not public administration)	0.3118	8.3
Accommodations/Food industry (not retail, not public admin.)	0.2723	11.2
Real Estate industry (not retail, not public administration)	0.2563	5.3
Office industry or occupation (not retail, not public administration)	0.1170	8.4
Departure Time Shift / Travel Condition Effects		
Home to work distance	-0.0034	-7.6

Table 7.31. (cont) Work Tour Scheduling Model

Variable	Coeff.	t-Stat
Duration Shift / Day Pattern Composition Effects		
One or more other work tours	-0.4085	-25.2
Presence of shop tours	0.0363	2.5
Presence of recreation tours	0.0471	3.2
Presence of other tours	0.0536	3.4
Inbound stop only on tour	0.2429	19.6
Outbound stop only on tour	0.0194	1.0
Inbound & outbound stop on tour	0.0903	4.8
First tour of the day if 2 tour pattern	-0.2463	-16.2
Second tour of the day if 2 tour pattern	-0.2706	-14.2
First tour of the day if 3 tour pattern	-0.4506	-18.6
Second tour of the day if 3 tour pattern	-0.5840	-20.1
Third tour of the day if 3 tour pattern	-0.3474	-8.0
First tour of the day if 4+ tour pattern	-0.5822	-18.1
Second tour of the day if 4+ tour pattern	-0.7676	-19.3
Third tour of the day if 4+ tour pattern	-0.6505	-11.4
Fourth tour of the day if 4+ tour pattern	-0.5674	-6.4
Presence of a work-based sub-tour	0.3357	26.5
Duration Shift / Traveler Attribute Effects		
Grade/High school student	-0.1251	-3.1
College student	0.0031	0.2
High income household	0.0373	5.5
Zero car household	-0.0875	-2.9
Female	-0.0780	-11.8
Children 5 years old or younger in hhld	-0.0079	-0.8
Children 6-15 years old in hhld	-0.0082	-1.0
Non working adult in hhld	-0.0310	-2.9
Multiple, all working adult hhld	-0.0448	-4.7
Age greater than 55 years old	-0.0807	-5.6
Age between 26 & 35 years old	0.0281	2.0
Age between 36 & 55 years old	0.0255	2.0
Retail occupation or industry	-0.0573	-4.2
Public Administration occupation or industry (not retail)	-0.0378	-2.6
Education occupation or industry (not retail or public admin.)	-0.0928	-6.7
Arts/Recreation industry (not retail or public administration)	-0.0828	-2.2
Accommodations/Food industry (not retail, public admin. or gov.)	-0.1313	-5.6
Real Estate industry (not retail, government or education)	-0.1736	-3.8
Office industry (not education)	-0.0216	-2.2
Duration Shift / Travel Condition Effects		
Home to work distance	0.0030	11.1

Table 7.31. (cont) Work Tour Scheduling Model

Variable	Coeff.	t-Stat
Constants		
Departure at 5:00 AM	-1.3387	-30.7
Departure at 6:00 AM	-0.8122	-20.2
Departure at 7:00 AM	0	
Departure at 8:00 AM	-0.358917	-21.7
Departure at 9:00 AM	-1.397865	-33.9
Departure at 10:00 AM	-2.251444	-32.3
Departure at 11:00 AM	-2.263423	-28.5
Departure at 12:00 PM	-2.343676	-22.1
Departure at 1:00 PM	-2.334848	-19.1
Departure at 2:00 PM	-2.424048	-15.6
Departure at 3:00 PM	-2.635354	-15.8
Departure at 4:00 PM	-3.692009	-16.2
Departure at 5:00 PM	-5.547199	-18.0
Departure at 6:00 PM	-9.493763	-18.8
Departure at 7:00 PM	-12.22604	-18.9
Departure at 8:00 PM	-18.03557	-17.6
Departure at 9:00 PM	-18.19125	-15.9
Departure at 10:00 PM	-18.54397	-14.2
Departure at 11:00 PM	-35.63242	-10.8
Duration is less than 1 hour	-7.532179	-40.9
Duration is 1 hours	-6.025114	-38.9
Duration is 2 hours	-4.838914	-38.0
Duration is 3 hours	-4.060941	-35.9
Duration is 4 hours	-3.216657	-32.9
Duration is 5 hours	-2.76608	-31.4
Duration is 6 hours	-2.624259	-35.1
Duration is 7 hours	-2.201011	-36.7
Duration is 8 hours	-0.961754	-33.8
Duration is 9 hours	0	-11.8
Duration is 10 hours	-0.173743	
Duration is 11 hours	-0.738126	-13.2
Duration is 12 hours	-1.378917	-23.4
Duration is 13 hours	-2.115609	-26.0
Duration is 14 hours	-2.699061	-25.9
Duration is 15 hours	-3.494024	-26.3
Duration is 16 hours	-4.166394	-24.2
Duration is 17 hours	-3.712391	-18.7
Duration is 18 hours	-2.588843	-12.8
Final likelihood	-81685	
ρ^2 w.r.t. zero	0.2571	

Table 7.32. School Tour Scheduling Model

Variable	Coeff.	t-Stat
Departure Time Shift / Day Pattern Composition Effects		
Presence of other school tours	0.0140	0.4
Presence of work tours	-0.1228	-3.0
Presence of shop tours	0.0584	1.8
Presence of recreation tours	-0.0205	-0.7
Inbound stop only on tour	0.0349	1.1
Outbound stop only on tour	-0.0672	-1.3
Inbound & outbound stop on tour	-0.0230	-0.4
First tour of the day if 2 tour pattern	-0.0333	-1.3
Second tour of the day if 2 tour pattern	0.6171	15.6
First tour of the day if 3 tour pattern	-0.0534	-1.2
Second tour of the day if 3 tour pattern	0.3620	7.2
Third tour of the day if 3 tour pattern	0.8878	10.4
First tour of the day if 4+ tour pattern	-0.1112	-1.1
Second tour of the day if 4+ tour pattern	0.1884	2.1
Third tour of the day if 4+ tour pattern	0.4049	4.2
Fourth tour of the day if 4+ tour pattern	0.8137	6.1
Departure Time Shift / Traveler Attribute Effects		
Grade/High school student	-0.7183	-17.5
College student	0.0326	1.1
High income & preschooler	-0.0830	-2.1
High income & grade/high school student	-0.0675	-2.6
High income & college student	-0.0427	-1.5
Zero car household & college student	0.0750	1.2
Insufficient auto/worker household & preschooler	-0.3753	-2.1
Insufficient auto/worker hhld & grade/high school student	-0.2887	-5.1
Female	-0.0321	-2.0
Grade/high school student in multiple adult hhld, no preschoolers	0.2020	5.8
Grade/high school student in multiple adult hhld, with preschoolers	0.3807	9.4
Grade/high school student in one adult, worker, with children hhld	-0.2627	-2.2
College student in 2+adults, workers=adults, with children hhld	-0.1318	-3.0
College student in 2+ adults, workers<adults, with children hhld	-0.1250	-3.4
Departure Time Shift Variables / Travel Conditions Effects		
Home to school distance	-0.0025	-1.6

Table 7.32. (cont.) School Tour Scheduling Model

Variable	Coeff.	t-Stat
Duration Shift / Day Pattern Composition Effects		
Presence of other school tours	-0.3018	-12.5
Presence of work tours	-0.2661	-10.5
Presence of shop tours	-0.0402	-1.9
Presence of recreation tours	0.0143	0.8
Inbound stop only on tour	0.4680	25.7
Outbound stop only on tour	0.3559	11.2
Inbound & outbound stop on tour	0.1828	5.0
First tour of the day if 2 tour pattern	-0.1696	-10.7
Second tour of the day if 2 tour pattern	-0.4447	-13.9
First tour of the day if 3 tour pattern	-0.3163	-11.8
Second tour of the day if 3 tour pattern	-0.5492	-12.3
Third tour of the day if 3 tour pattern	-0.4535	-5.9
First tour of the day if 4+ tour pattern	-0.4473	-8.2
Second tour of the day if 4+ tour pattern	-0.6754	-8.5
Third tour of the day if 4+ tour pattern	-0.4338	-4.0
Fourth tour of the day if 4+ tour pattern	-0.6996	-4.2
Duration Shift / Traveler Attribute Effects		
Grade/High school student	0.6340	22.0
College student	0.2826	7.0
High income & preschooler	0.0568	1.7
High income & grade/high school student	0.0515	4.4
High income & college student	0.0175	0.8
Zero car household & college student	-0.1203	-2.0
Insufficient auto/worker household & preschooler	0.0975	1.0
Insufficient auto/worker household & grade/high school student	0.0936	4.3
Insufficient auto/worker household & college student		
Female	-0.0123	-1.3
Preschooler in hhld with 1 adult, worker	0.6721	11.0
Preschooler in hhld with 2+ adults, workers=adults	0.4025	12.2
Grade/high school student in multiple adult hhld, no preschoolers	-0.0822	-5.9
Grade/high school student in multiple adult hhld, with preschooler:	-0.1480	-8.1
College student in hhld with workers and no children	0.1978	5.7
College std. in hhld with workers=adults, children no preschooler	0.1638	3.5
College std. in hhld with workers=adults, children with preschooler	0.2581	4.3
College std. in hhld with workers<adults, children no preschooler	0.2137	4.7
College std. in hhld with workers<adults, children with preschooler	-0.0796	-1.4
Duration Shift Variables / Travel Conditions Effects		
Home to school distance	0.0104	10.8

Table 7.32. (cont.) School Tour Scheduling Model

Variable	Coeff.	t-Stat
Constants		
Departure at 5:00 AM	-6.9129	-38.6
Departure at 6:00 AM	-3.8426	-46.6
Departure at 7:00 AM	-0.8515	
Departure at 8:00 AM	0	0.2
Departure at 9:00 AM	-1.238676	-22.9
Departure at 10:00 AM	-2.212767	-20.8
Departure at 11:00 AM	-1.954914	-16.6
Departure at 12:00 PM	-1.459406	-12.6
Departure at 1:00 PM	-2.033209	-15.2
Departure at 2:00 PM	-2.113252	-15.1
Departure at 3:00 PM	-1.59844	-15.3
Departure at 4:00 PM	-2.256468	-14.8
Departure at 5:00 PM	-1.682207	-12.8
Departure at 6:00 PM	-1.412488	-13.1
Departure at 7:00 PM	-4.043403	-15.0
Departure at 8:00 PM	-5.312312	-14.6
Departure at 9:00 PM	-6.050756	-13.1
Departure at 10:00 PM	-6.050756	
Departure at 11:00 PM	-6.050756	
Duration is less than 1 hour	-1.067682	-8.4
Duration is 1 hours	-0.584327	-5.6
Duration is 2 hours	0.2026952	-4.2
Duration is 3 hours	0.4552437	-0.6
Duration is 4 hours	-0.378817	-4.2
Duration is 5 hours	-1.026156	-11.4
Duration is 6 hours	-0.131637	-15.6
Duration is 7 hours	0	9.7
Duration is 8 hours	-1.576106	
Duration is 9 hours	-2.833978	-34.4
Duration is 10 hours	-4.152021	-37.2
Duration is 11 hours	-5.798814	-38.8
Duration is 12 hours	-7.715536	-38.1
Duration is 13 hours	-8.910467	-37.3
Duration is 14 hours	-10.76757	-36.6
Duration is 15 hours	-14.0361	-35.8
Duration is 16 hours	-14.40143	-33.1
Duration is 17 hours	-14.74348	-22.4
Duration is 18 hours	-14.74348	
Final likelihood	-35633	
Rho-Squared w.r.t. zero	0.3643	

Table 7.33. Shop Tour Scheduling Model

Variable	Coeff.	t Stat.
Duration Shift / Day Pattern Composition Effects		
Inbound stop only on tour	0.3903	26.4
Outbound stop only on tour	0.3629	26.6
Inbound & outbound stop on tour	0.2306	21.4
School tours present	-0.0769	-2.3
Work tours present	-0.1459	-6.9
Other shop tours present	-0.0892	-5.6
First tour of the day if 2 tour pattern	-0.1150	-8.6
Second tour of the day if 2 tour pattern	-0.1761	-10.3
First tour of the day if 3 tour pattern	-0.2664	-9.6
Second tour of the day if 3 tour pattern	-0.2758	-11.5
Third tour of the day if 3 tour pattern	-0.2836	-9.0
First tour of the day if 4+ tour pattern	-0.4671	-7.6
Second tour of the day if 4+ tour pattern	-0.3754	-9.0
Third tour of the day if 4+ tour pattern	-0.4896	-9.5
Fourth tour of the day if 4+ tour pattern	-0.4884	-8.2
Duration Shift / Traveler Attribute Effects		
Grade/High school student	0.1229	4.8
College student	0.0861	3.3
Zero car household	0.0908	2.8
Female	0.0205	2.1
Worker adult age 18 to 25	0.2287	5.9
Worker adult age 25 to 55	0.1126	9.0
Worker adult age 55+	0.0672	3.6
One adult worker households	0.1181	6.2
Duration Shift / Travel Condition Effects		
Tour distance (miles)	0.0161	22.7

Table 7.33. (cont.) Shop Tour Scheduling Model

Variable	Coeff.	t Stat.
Constants		
Departure at 5:00 AM	-4.9492	-26.9
Departure at 6:00 AM	-4.0498	-29.9
Departure at 7:00 AM	-2.0967	-27.2
Departure at 8:00 AM	-0.80735	-16.1
Departure at 9:00 AM	-0.35685	-6.5
Departure at 10:00 AM	0	
Departure at 11:00 AM	-0.05986	-3.0
Departure at 12:00 PM	-0.07659	-5.1
Departure at 1:00 PM	-0.0747	-3.8
Departure at 2:00 PM	-0.26435	-6.4
Departure at 3:00 PM	-0.45217	-9.1
Departure at 4:00 PM	-0.74872	-9.8
Departure at 5:00 PM	-1.01774	-11.2
Departure at 6:00 PM	-1.39267	-11.8
Departure at 7:00 PM	-2.1994	-15.6
Departure at 8:00 PM	-3.77419	-21.5
Departure at 9:00 PM	-6.32509	-24.8
Departure at 10:00 PM	-17.4962	-23.3
Departure at 11:00 PM	-23.437	-18.0
Duration is less than 1 hour	-0.76555	-32.6
Duration is 1 hour	0	
Duration is 2 hours	-0.43399	-9.1
Duration is 3 hours	-1.12793	-20.2
Duration is 4 hours	-1.81708	-28.7
Duration is 5 hours	-2.61849	-32.9
Duration is 6 hours	-3.31414	-34.6
Duration is 7 hours	-4.11732	-35.4
Duration is 8 hours	-5.08052	-35.3
Duration is 9 hours	-5.62617	-34.9
Duration is 10 hours	-6.52062	-34.7
Duration is 11 hours	-7.66603	-33.9
Duration is 12 hours	-8.67471	-32.8
Duration is 13 hours	-9.57311	-30.5
Duration is 14 hours	-10.5284	-28.8
Duration is 15 hours	-10.8817	-20.7
Duration is 16 hours	-10.4847	-16.7
Duration is 17 hours	-10.8817	
Duration is 18 hours	-10.8817	
Final likelihood	-50945	
Rho-Squared w.r.t. zero	0.1743	

Table 7.34. Social/Recreation Tour Scheduling Model

Variable	Coeff.	t Stat.
Departure Time Shift / Day Pattern Composition Effects		
Inbound stop only on tour	-0.0837	-3.4
Outbound stop only on tour	-0.0816	-3.1
Inbound & outbound stop on tour	-0.0593	-1.9
School tours present	-0.1898	-8.1
Additional recreation tours present	-0.1326	-8.8
First tour of the day if 2 tour pattern	-0.1313	-8.5
Second tour of the day if 2 tour pattern	0.2856	20.3
First tour of the day if 3 tour pattern	-0.1960	-6.8
Second tour of the day if 3 tour pattern	0.0223	1.1
Third tour of the day if 3 tour pattern	0.4658	19.0
First tour of the day if 4+ tour pattern	-0.3405	-6.1
Second tour of the day if 4+ tour pattern	-0.1163	-2.8
Third tour of the day if 4+ tour pattern	0.1450	3.6
Fourth+ tour of the day if 4+ tour pattern	0.4867	12.4
Departure Time Shift / Traveler Attribute Effects		
Worker	0.0620	4.7
Preschooler	-0.0713	-3.8
Grade/High school student	0.0346	1.7
College student	0.0499	1.9
High income	-0.0272	-2.7
Female	0.0153	1.7
Age between 18 & 25 years old	0.2131	8.5
Age is 55+ years old	-0.0703	-5.3
In household with 1+ children, no preschooler	-0.0831	-4.3
In household with 1+ children, 1+ preschooler	0.0762	4.5
Departure Time Shift / Travel Condition Effects		
Tour distance (miles)	0.0015	2.1

Table 7.34 (cont.) Social/Recreational Tour Scheduling Model

Variable	Coeff.	t Stat.
Duration Shift / Day Pattern Composition Effects		
Inbound stop only on tour	0.2214	9.5
Outbound stop only on tour	0.2615	10.5
Inbound & outbound stop on tour	0.1009	3.4
School tours present	-0.1880	-6.9
Work tours present	-0.0325	-1.4
Shop tours present	0.0654	3.2
Additional recreation tours present	-0.0461	-2.3
First tour of the day if 2 tour pattern	-0.2031	-9.9
Second tour of the day if 2 tour pattern	-0.1732	-9.1
First tour of the day if 3 tour pattern	-0.4294	-9.8
Second tour of the day if 3 tour pattern	-0.3868	-12.2
Third tour of the day if 3 tour pattern	-0.1466	-5.0
First tour of the day if 4+ tour pattern	-0.6964	-7.5
Second tour of the day if 4+ tour pattern	-0.5633	-8.5
Third tour of the day if 4+ tour pattern	-0.5109	-7.8
Fourth tour of the day if 4+ tour pattern	-0.3830	-7.7
Duration Shift / Traveler Attribute Effects		
Worker	0.0930	5.3
Preschooler	0.2037	9.2
Grade/High school student	0.1488	5.9
College student	0.1090	3.7
Female	-0.0248	-2.3
Age between 18 & 25 years old	0.1807	6.4
Age is 55+ years old	-0.0419	-2.6
Two+ adults household	-0.0358	-2.8
In household with 1+ children, no preschooler	0.1311	5.3
In household with 1+ children, 1+ preschooler	-0.1495	-6.8
Duration Shift / Travel Condition Effects		
Tour distance (miles)	0.0143	18.8

Table 7.35. (cont.) Social/Recreational Tour Scheduling Model

Variable	Coeff.	t Stat.
Constants		
Departure at 5:00 AM	-3.0404	-11.3
Departure at 6:00 AM	-2.7299	-8.6
Departure at 7:00 AM	-1.6589	-3.6
Departure at 8:00 AM	-1.00047	-0.5
Departure at 9:00 AM	-0.7717	0.0
Departure at 10:00 AM	-0.92467	-0.9
Departure at 11:00 AM	-0.81376	-0.6
Departure at 12:00 PM	-0.86746	-1.5
Departure at 1:00 PM	-0.96729	-3.7
Departure at 2:00 PM	-0.93966	-6.1
Departure at 3:00 PM	-0.59808	-4.5
Departure at 4:00 PM	-0.4731	-4.1
Departure at 5:00 PM	-0.25844	0.7
Departure at 6:00 PM	0	
Departure at 7:00 PM	-1.0793	-22.7
Departure at 8:00 PM	-4.16826	-31.3
Departure at 9:00 PM	-8.9682	-28.1
Departure at 10:00 PM	-18.6813	-21.3
Departure at 11:00 PM	-33.0667	-11.9
Duration is less than 1 hour	-3.71544	-33.8
Duration is 1 hour	-0.43521	-15.8
Duration is 2 hours	0	
Duration is 3 hours	-0.16591	-2.7
Duration is 4 hours	-0.56386	-7.9
Duration is 5 hours	-1.03798	-9.4
Duration is 6 hours	-1.13591	-10.7
Duration is 7 hours	-1.29262	-10.2
Duration is 8 hours	-1.47528	-9.5
Duration is 9 hours	-1.63116	-9.6
Duration is 10 hours	-1.84664	-8.6
Duration is 11 hours	-2.61975	-10.1
Duration is 12 hours	-2.90168	-10.3
Duration is 13 hours	-4.1108	-11.3
Duration is 14 hours	-3.7682	-10.9
Duration is 15 hours	-4.90808	-10.4
Duration is 16 hours	-4.98961	-8.2
Duration is 17 hours	-5.32706	-6.6
Duration is 18 hours	-4.87059	-4.7
Final likelihood	-36679	
Rho-Squared w.r.t. zero	0.1351	

Table 7.36. Other Tour Scheduling Model

Variable	Coeff.	t Stat.
Departure Time Shift / Day Pattern Composition Effects		
Inbound stop only on tour	-0.0800	-3.4
Outbound stop only on tour	-0.2000	-12.5
Inbound & outbound stop on tour	-0.1024	-2.6
School tours present	0.1021	4.9
Work tours present	0.1411	10.3
Shop tours present	0.1264	12.2
Recreation tours present	0.1139	9.8
First tour of the day if 2 tour pattern	-0.1284	-13.4
Second tour of the day if 2 tour pattern	0.0793	6.9
First tour of the day if 3 tour pattern	-0.2620	-15.9
Second tour of the day if 3 tour pattern	-0.1274	-8.2
Third tour of the day if 3 tour pattern	0.0846	4.2
First tour of the day if 4+ tour pattern	-0.3812	-14.3
Second tour of the day if 4+ tour pattern	-0.3208	-12.0
Third tour of the day if 4+ tour pattern	-0.1965	-7.6
Fourth+ tour of the day if 4+ tour pattern	-0.0048	-0.2
Departure Time Shift / Traveler Attribute Effects		
Worker	0.0190	2.4
Grade/High school student	0.0587	3.6
High income household	-0.0125	-1.7
Female	0.0176	2.7
Age between 18 & 25 years old	0.0825	5.0
In 1 adult, 1+ children (any age) household	-0.0492	-2.6
In 2+ adults, 1+ children (any age) household	-0.0296	-4.2
Departure Time Shift / Travel Condition Effects		
Tour distance (miles)		

Table 7.36. (cont.) Other Tour Scheduling Model

Variable	Coeff.	t Stat.
Duration Shift / Day Pattern Composition Effects		
Inbound stop only on tour	0.2589	14.4
Outbound stop only on tour	0.3322	27.4
Inbound & outbound stop on tour	0.1208	4.9
Work tours present	0.0333	2.2
Shop tours present	0.1168	9.0
Recreation tours present	0.1838	13.8
First tour of the day if 2 tour pattern	-0.1650	-15.7
Second tour of the day if 2 tour pattern	-0.2593	-20.8
First tour of the day if 3 tour pattern	-0.3838	-17.9
Second tour of the day if 3 tour pattern	-0.4058	-19.9
Third tour of the day if 3 tour pattern	-0.3545	-15.6
First tour of the day if 4+ tour pattern	-0.6809	-15.9
Second tour of the day if 4+ tour pattern	-0.5763	-15.1
Third tour of the day if 4+ tour pattern	-0.6327	-16.7
Fourth tour of the day if 4+ tour pattern	-0.5413	-14.8
Duration Shift / Traveler Attribute Effects		
Worker	0.1455	15.6
Preschooler	0.1953	13.6
Grade/High school student	0.2811	17.7
College student	0.1452	8.0
Female	-0.0242	-3.4
Age between 18 & 25 years old	0.0670	3.7
In 2+ adults, no children household	-0.0311	-2.9
In 1 adult, 1+ children (any age) household	-0.0492	-2.6
In 2+ adults, 1+ children (any age) household	-0.0296	-4.2
Duration Shift / Travel Condition Effects		
Tour distance (miles)	0.0117	22.3

Table 7.36. (cont.) Other Tour Scheduling Model

Variable	Coeff.	t Stat.
Constants		
Departure at 5:00 AM	-2.1348	-31.3
Departure at 6:00 AM	-1.8446	-25.1
Departure at 7:00 AM	-0.4953	
Departure at 8:00 AM	0	6.7
Departure at 9:00 AM	-0.56007	-1.7
Departure at 10:00 AM	-0.7611	-5.2
Departure at 11:00 AM	-0.73762	-3.9
Departure at 12:00 PM	-0.92869	-7.9
Departure at 1:00 PM	-1.14172	-9.8
Departure at 2:00 PM	-0.81887	-4.6
Departure at 3:00 PM	-0.95116	-8.0
Departure at 4:00 PM	-1.53289	-11.5
Departure at 5:00 PM	-1.74265	-11.2
Departure at 6:00 PM	-2.21472	-11.2
Departure at 7:00 PM	-3.85831	-18.8
Departure at 8:00 PM	-7.46323	-27.4
Departure at 9:00 PM	-11.6513	-29.1
Departure at 10:00 PM	-16.9722	-28.3
Departure at 11:00 PM	-35.6522	-22.4
Duration is less than 1 hour	0	
Duration is 1 hour	0.153267	28.0
Duration is 2 hours	-0.38561	9.3
Duration is 3 hours	-1.04271	-2.7
Duration is 4 hours	-1.51356	-9.4
Duration is 5 hours	-1.82574	-13.5
Duration is 6 hours	-2.20751	-14.6
Duration is 7 hours	-2.22032	-13.2
Duration is 8 hours	-1.73542	-12.3
Duration is 9 hours	-0.92428	-10.4
Duration is 10 hours	-1.24112	-10.7
Duration is 11 hours	-1.88473	-13.9
Duration is 12 hours	-2.50139	-16.0
Duration is 13 hours	-3.32077	-18.1
Duration is 14 hours	-3.76004	-18.1
Duration is 15 hours	-3.63226	-17.9
Duration is 16 hours	-4.36376	-15.8
Duration is 17 hours	-2.83868	-11.3
Duration is 18 hours	-1.7519	-8.7
Final likelihood	-66907	
Rho-Squared w.r.t. zero	0.1244	

7.5.10. SDT Tour Mode Choice Model Estimation

The SDT Tour Mode Choice Model final parameters were asserted not estimated (in both Ohio and Oregon). An initial set of mode choice model parameters were estimated with the Oregon data. These showed reasonable and significant in-vehicle and out-of-vehicle parameters, but with implied low values of time. Also significant were the number of stops on the tour, showing a direct relationship between the number of stops and the propensity to choose auto driver. To define the final parameters asserted for these models, the in-vehicle time coefficients were set at values consistent with accepted practice, the cost coefficients were set to yield reasonable values of time, and other coefficients were adjusted to exhibit similar internal relationships shown by the estimated parameters.

The final parameters are shown in Table 7.37. All parameter values are given for the mode at the multinomial level. The auto driver mode is the base alternative for each model. Additionally, sets of descriptive statistics are provided, including the implied value of time (cost parameters are in 2000 cents and time parameters are in minutes), and ratios of in-vehicle time to various out-of-vehicle time parameters. All models have cost parameters stratified by three household income groups.

The level of service variables, such as time and cost, represent round trip travel characteristics; that is, they are the sum of the level of service attributes for the outbound and the inbound legs of the tour. Level of service variables are based on the tour origin TAZ and the tour primary destination TAZ; they do not include trips made to intermediate stops on the tour, since the location of these stops is not known when the tour mode choice model is applied.

For calibration, the tour primary mode choice model alternative specific constants are considered S2 parameters, while the others are S1 parameters.

Table 7.37. Tour Mode Choice Model Parameters

Parameter	Tour Purpose: Work & College	School	Shop	Recreate	Other	Work Based
In-Vehicle Time	-0.0250	-0.0172	-0.0150	-0.0150	-0.0150	-0.0200
Cost (cents)						
Low Income (<$30k)	-1.0400	-1.0733	-0.9360	-0.9360	-0.9360	-1.2480
Med Income ($30-$60k)	-0.2600	-0.2683	-0.2340	-0.2340	-0.2340	-0.3120
Hi Income (>$60k)	-0.1300	-0.1342	-0.1170	-0.1170	-0.1170	-0.1560
First Wait Time (2.0)	-0.0500	-0.0344	-0.0300	-0.0300	-0.0300	-0.0400
Xfer Wait Time (2.5)	-0.0625	-0.0430	-0.0375	-0.0375	-0.0375	-0.0500
Walk Time (2.5)	-0.0625	-0.0430	-0.0375	-0.0375	-0.0375	-0.0500
Drive Time (2.5)	-0.0625	-0.0430	-0.0375	-0.0375	-0.0375	-0.0500
Walk Mode Time (3.5)	-0.0875	-0.0602	-0.0525	-0.0525	-0.0525	-0.0700
Bike Mode Time (4)	-0.1000	-0.0688	-0.0600	-0.0600	-0.0600	-0.0800
Value of Time						
Low Income (<$30k)	1.4423	0.9615	0.9615	0.9615	0.9615	0.9615
Med Income ($30-$60	5.7692	3.8462	3.8462	3.8462	3.8462	3.8462
Hi Income (>$60k)	11.5385	7.6923	7.6923	7.6923	7.6923	7.6923
Number of Stops						
Passenger	-0.6380	-0.3843	-0.0867	-0.1897	-0.0867	
Walk	-1.6196	-1.7860	-1.2873	-1.2962	-1.2873	
Bike	-1.1752	-1.7846	-0.7714	-0.8953	-0.7714	
Walk-Transit	-0.9393	-0.9790	-0.2273	-0.6367	-0.2273	
Transit-Passenger	-0.1724	-0.2749	0.3845	-1.5006	0.3845	
Passenger-Transit	-0.6503	-0.2749	0.1511		0.1511	
Drive-Transit	-2.1832					
Passenger, HHSize=1	-0.7148		-1.1303	-1.1917	-1.1303	
Passenger, HHSize=2		0.8440				
Passenger, HHSize=3		1.4159				
Nesting Coefficient	0.7659	0.7659	0.7659	0.7659	0.7659	0.7659

TS uses the implied value of time in 1990$ (per [globalTemplate.properties]) as follows:

```
userClass.pk.vot = 0.0945 (High Income (>$60K) work purpose)
userClass.op.vot = 0.0632 (High Income (>$60K) non-work purposes)
```

Table 7.37 (cont.) Tour Mode Choice Model Parameters

	Tour Purpose						
Constants	Work	School	College	Shop	Recreate	Other	Work Subtour
Passenger	0	0	0	0	0	0	-2.5142
Auto=0	0	0	0	0	0	0	0
Auto<Workers	-0.806051	-0.79661	-0.12926	-0.65097	-0.31053	-1.49818	0
Auto>=Workers	-2.934108	-4.70402	-1.26957	-1.542	-1.2627	-1.75402	0
Walk	0	0	0	0	0	0	2.608697
Auto=0	12.062177	3.33675	8.361619	3.420239	3.662585	3.045379	0
Auto<Workers	5.1458602	3.137561	5.613197	1.738815	2.245663	1.367355	0
Auto>=Workers	0.8115956	-1.23361	3.158006	-0.06181	1.235951	0.197923	0
Bike	0	0	0	0	0	0	-1.08563
Auto=0	5.6388445	1.237569	3.124373	-0.13321	0.452455	0.239558	0
Auto<Workers	1.0647373	-0.51173	1.696912	-1.13319	0.03291	-1.69701	0
Auto>=Workers	-1.865153	-4.41389	-0.28726	-3.29519	-1.9874	-3.15621	0
Walk-Transit							-1.17112
Auto=0	10.603633	5.162211	5.493234	2.452804	2.602145	2.672183	
Auto<Workers	2.1450629	1.120495	3.450026	-0.94705	-1.57024	-0.28757	
Auto>=Workers	-0.426422	-4.24694	1.004008	-3.67795	-2.96557	-2.86711	
Transit-Passenger							
Auto=0	4.3400123	-3.37959	0.636015	-1.8702	0.08749	-0.98882	
Auto<Workers	-0.671269	-2.15801	-4.60097	-3.24972	-1.50009	-4.13164	
Auto>=Workers	-3.506976	-8.08546	-1.89834	-8.62422	-4.17891	-4.27614	
Passenger-Transit							
Auto=0	2.0174573	-3.77849	1.997484	-1.49839	-4.87509	-1.73966	
Auto<Workers	-0.72721	-1.72759	-5.20397	-3.88507	-3.17212	-3.2258	
Auto>=Workers	-3.114368	-6.27993	-1.12847	-14.8902	-4.39391	-4.05825	
Drive-Transit							
Auto=0	-999						
Auto<Workers	1.3964068						
Auto>=Workers	-0.049115						

7.5.11. SDT Intermediate Stop Location Model Estimation

This model was estimated with Oregon data. To construct the estimation file, each alpha zone in the Oregon statewide network was placed into one of 39 districts based on the additional travel time imposed for the alternative zone and the tour origin and primary destination zones, such that an equal number of zones were placed into each district. One alpha zone was then randomly selected within each district, for a total of 39 alternatives plus one chosen alternative. Estimation results for the intermediate stop destination choice models are given in Table 7.38.

For calibration, the intermediate stop destination choice model's level-of-service parameters (i.e., out-of-direction time and intrazonal dummies) for all modes are considered S2 parameters, while the others are S1 parameters.

Table 7.38. SDT Intermediate Stop Location Model Estimation Results

Tour Purpose - First Stop							
Variable	*Work*	*School*	*College*	*Shop*	*Recreation*	*Other*	*Work Based*
Out of Direction Time							
Auto	-0.08967	-0.14046	-0.09395	-0.120719	-0.13726	-0.17555	-0.12479
Walk	-0.04091	0	0	-0.037825	-0.09983	-0.4924	-0.0579
Bike	-0.19564	-1.02944	-0.14012	-1.09156	0.099633	-2.69683	-0.09872
Transit	0	0	0	0	-0.05632	0	0
Intrazonal Indicator Origin							
Auto	1.065499	0.661837	0.474727	0.8968893	1.012551	1.349375	0.91891
Non Motorized	0.229814	1.289337	1.499788	1.4046721	0.569464	-1.06557	-1.79138
Transit	2.364683	4.65924	2.375588	5	4.001458	3.340845	1.94735
Intrazonal Indicator Destination							
Auto	-1.28097	-0.58235	-0.80467	-0.461725	-0.0779	0.032978	-0.45498
Non Motorized	0.253672	0.242551	-1.12018	0.3671809	0.541895	0.733409	-0.41145
Transit	0.901022	1.183129	1.499669	5	2.772157	3.40153	1.90908
Size Term							
Retail LU, All Industries	1.0000	0.0000	1	1.0000	1.0000	1.0000	1
Retail LU, Retail Industry	0.0000	1.0000	1	0.0000	0.0000	0.0000	0
Retail LU, Non Retail Industry	0.0000	0.4842	0.4842	0.0000	0.0000	0.0000	0
Non Retail	0.0000	0.0000	0	0.0000	0.0000	0.0913	0
Grade School	1.2000	0.7194	0.7194	0.8382	0.0000	0.0000	1.2
Households	0.0000	0.3421	0.3421	0.0000	0.2892	0.3507	0

Tour Purpose - Intermediate Stop							
Variable	*Work*	*School*	*College*	*Shop*	*Recreation*	*Other*	*Work Based*
Out of Direction Time							
Auto	-0.1085	-0.2129	-0.1195	-0.1135	-0.1101	-0.1458	-0.2109
Walk	-0.0409	0.0000	0.0000	-0.0378	-0.0998	-0.4924	-0.0579
Bike	-0.1956	-1.0294	-0.1401	-1.0916	0.0996	-2.6968	-0.0987
Transit	0.0000	0.0000	0.0000	0.0000	-0.0563	0.0000	0.0000
Intrazonal Indicator Origin							
Auto	0.5678	0.0126	-1.2581	0.7744	0.2059	0.3363	0.2301
Non Motorized	0.2298	1.2893	1.4998	1.4047	0.5695	-1.0656	-1.7914
Transit	2.3647	4.6592	2.3756	5.0000	4.0015	3.3408	1.9473
Intrazonal Indicator Destination							
Auto	-0.1916	-0.1272	0.1235	0.3893	1.1531	1.0928	0.3295
Non Motorized	0.2537	0.2426	-1.1202	0.3672	0.5419	0.7334	-0.4115
Transit	0.9010	1.1831	1.4997	5.0000	2.7722	3.4015	1.9091
Size Term							
Retail LU, All Industries	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Retail LU, Retail Industry	0.0000	1.0000	1.0000	0.0000	0.0000	0.0000	0.0000
Retail LU, Non Retail Industry	0.0000	0.4842	0.4842	0.0000	0.0000	0.0000	0.0000
Non Retail	0.0000	0.0000	0.0000	0.0000	0.0000	0.0913	0.0000
Grade School	1.2000	0.7194	0.7194	0.8382	0.0000	0.0000	1.2000
Households	0.0000	0.3421	0.3421	0.0000	0.2892	0.3507	0.0000

7.5.12. SDT Intermediate Stop Duration Model Estimation

The estimated model parameters for the SDT Intermediate Stop Duration Model discussed in Section 7.3.12 are shown in Table 7.39. The results show that stop duration increases with deviation distance from the tour anchors; that is, the longer it takes to reach a given stop, the longer the duration of that stop. Stops on shop tours that take place in the morning tend to be longer than stops at any other time of day. Stop duration decreases with increasing number of tours and activities in the daily activity pattern, consistent with the necessary tradeoff of number of activities and activity duration given fixed time budgets. A work tour is highly unlikely to have an intermediate stop longer than 6 hours, which is also consistent with the notion of fixed time budgets, given the typical long duration of work activities. Note that stops of very long duration (up to 10 hours) may occur for school tours; these are likely to be work activities. The estimation also shows that outbound stops tend to be shorter than inbound stops, and that shop stops tend to be shorter than stops for other purposes.

For calibration, the alternative-specific constants and the outbound stop indicator (dummy) variable are considered S2 parameters; all others are S1 parameters.

Table 7.39. Intermediate Stop Duration Model Parameters

	Tour Purpose						
Variable	*Work*	*School*	*College*	*Shop*	*ecreation*	*Other*	Work Based
Outbound	-0.8000	-1.2100	-0.6700	0.0900	-0.0900	0.0200	-1.0300
Tours sta	-0.6233			0.1520			-0.6233
Adult worker dumm		0.3260	0.3260				
Number of daily tours							
Two		-0.2562	-0.2562		-0.2240		
Three				-0.2124	-0.4060		
Three or more		-0.4674	-0.4674				
Four or more				-0.4403	-0.7580		
Number of daily stops is 2+				-0.2975			
Number of daily activities							
Six or s	-0.1358						-0.1358
Six or more						-0.2231	
Eight or	-0.1640						
Presence	-0.4323	-0.5873	-0.5873	-0.1710			-0.4323
Deviation	0.0086	0.0067	0.0067	0.0069	0.0086	0.0099	0.0086
Constants							
Less th	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
One hou	-0.1818	-0.4166	-0.8757	-1.0337	-0.4518	-1.4266	-0.2276
Two hou	-0.0734	-0.4016	-0.5255	-1.4073	-1.2283	-2.2712	-0.1220
Three h	0.1225	-1.1849	-1.3305	-1.7416	-1.8994	-2.6793	0.0413
Four ho	0.5384	-1.8436	-1.7802	-1.8483	-2.6073	-3.1561	-0.0673
Five hou	0.2393	-2.0865	-3.2447	-1.4063	-3.9223	-5.1640	-0.3256
Six hou	1.1194	-2.0855	-1.9475	-1.6598	-1.7697	-8.3657	-0.6957
Seven h	0.7000	-2.2855	-2.1475	-1.8598	-1.9697	-8.8657	-0.8957
Eight h	0.6000	-2.4855	-2.3475	-2.0598	-2.1697	-9.3657	-1.0957
Nine ho	0.5000	-2.6855	-2.5475	-2.2598	-2.3697	-9.8657	-1.2957
Ten hou	0.2000	-2.8855	-2.7475	-2.4598	-2.5697	-10.3657	-1.4957
Eleven	0.1000	-3.0855	-2.9475	-2.6598	-2.7697	-10.8657	-1.6957
Sample Size							
Rho-squared wrt Zero							

7.5.13. SDT Trip Mode Choice Model Estimation

The estimation of the PT SDT Trip Mode Choice Model discussed in section 7.3.13 includes the values in Table 7.40. The alternative-specific constants in the trip mode choice model are stratified by tour mode. If the tour mode is auto driver, the available trip mode choices are drive-alone, shared-ride 2, and shared-ride 3+. If the tour mode is auto passenger (or the auto passenger leg of a transit/auto passenger tour), the available trip modes are shared-ride 2, shared-ride 3+ and walk. Additionally, there are trip mode choice parameters on travel time, cost (both auto operating and parking), and household size.

For calibration, the trip mode choice model's alternative-specific constants are considered S2 parameters, while the others are S1 parameters.

Table 7.40. SDT Trip mode choice model parameters

	Tour Purpose						
Variable	*Work*	*School*	*College*	*Shop*	*Recreation*	*Other*	*Work Subtour*
In Vehicle Time	-0.0137	-0.0107	-0.0107	-0.0134	-0.0214	-0.0134	-0.0182
Operating Cost if Auto Driver							
Low Income (<$30k)	-0.4200	-0.3700	-0.3700	-0.6300	-0.9500	-0.6300	-1.1200
Med Income ($30-$60k)	-0.3000	-0.3700	-0.3700	-0.6000	-0.9500	-0.6000	-0.8000
High Income (>$60k)	-0.2100	-0.3700	-0.3700	-0.5800	-0.9500	-0.5800	-0.5600
Operating Cost if Auto Pass.	-0.2300	-0.6900	-0.6900	-0.6000	-0.9500	-0.6000	-0.6111
Parking Cost if Auto Driver							
Low Income (<$30k)	-0.6200	-0.6600	-0.6600	-0.8400	-0.9500	-0.8400	-1.6473
Med Income ($30-$60k)	-0.4900	-0.6600	-0.6600	-0.7900	-0.9500	-0.7900	-1.3019
High Income (>$60k)	-0.4900	-0.6600	-0.6600	-0.7900	-0.9500	-0.7900	-1.3019
Shared Ride 2, HH Size = 2	1.7719	1.6602	1.6602	1.5226	1.4822	1.5226	0.7499
Shared Ride 3+, HH Size = 3+	2.1331	1.9640	1.9640	1.6402	1.4257	1.6402	0.7499
Shared Ride 3+, HH Size = 3+	2.1331	2.1682	2.1682	2.8041	2.4071	2.8041	0.2275
Constant if Auto Driver							
Shared Ride 2	-3.5095	-2.6527	-2.8170	-1.9775	-1.8861	-1.9552	-2.6337
Shared Ride 3+	-3.9442	-3.3369	-3.3901	-3.1940	-2.8310	-3.1801	-2.7937
Constant if Auto Passenger							
Shared Ride 3+	-0.7093	0.1201	-0.5113	-0.6926	-0.4785	-0.6580	-0.1991
SchoolBus	0.0000	1.9567	0.0000	0.0000	0.0000	0.0000	0.0000
Walk	1.7979	2.1166	1.3720	-0.2075	0.7490	-0.6879	-1.8716
Transit Shared Ride 2	1.4592	4.6664	-0.3533	-2.4378	-4.5688	-2.0684	0.0000
Transit Shared Ride 3+	0.4644	4.8050	-0.7468	-5.1960	-7.1283	-3.1550	0.0000
Constant if Transit Rider							
Walk	-0.6680	-2.1328	-1.8953	-2.3142	-1.7179	-1.3735	-0.7441
Transit Shared Ride 2	1.2708	1.0859	15.5969	7.5896	2.7324	-0.8788	0.0000
Transit Shared Ride 3+	0.6348	2.6636	15.0114	6.5134	2.1380	-2.8206	0.0000

7.5.14. SDT Work-based Activity Duration Model Estimation

The empirical distributions computed for the SDT Work-based Activity Duration Model functions described by Equations 7.08 and 7.09 in Section 7.3.13 are shown below. These functions were obtained from the distribution of activity durations observed in the Oregon Home Interview Survey data. Figures 7.6 and 7.7 show the primary work activity observed frequency distribution ($PctDuration_{primary}$) and its observed cumulative distribution functions, respectively. Figures 7.8 and 7.9 provide the corresponding plots for the first at-work activity ($PctDuration_{first\ at\text{-}work}$,).

Figure 7.6. Observed Frequency Distribution for the Work-Based Primary Activity Percent Duration

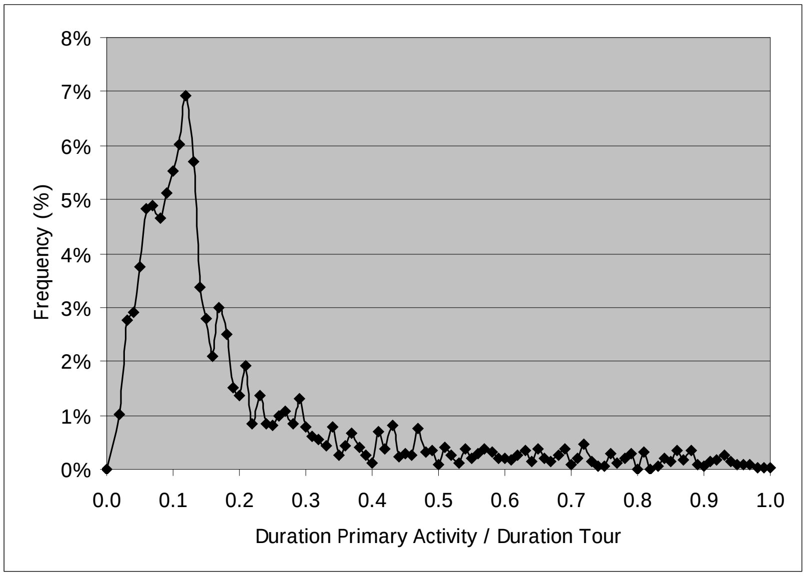


Figure 7.7. Observed Cumulative Distributions for the Work-Based Primary Activity Percent Duration

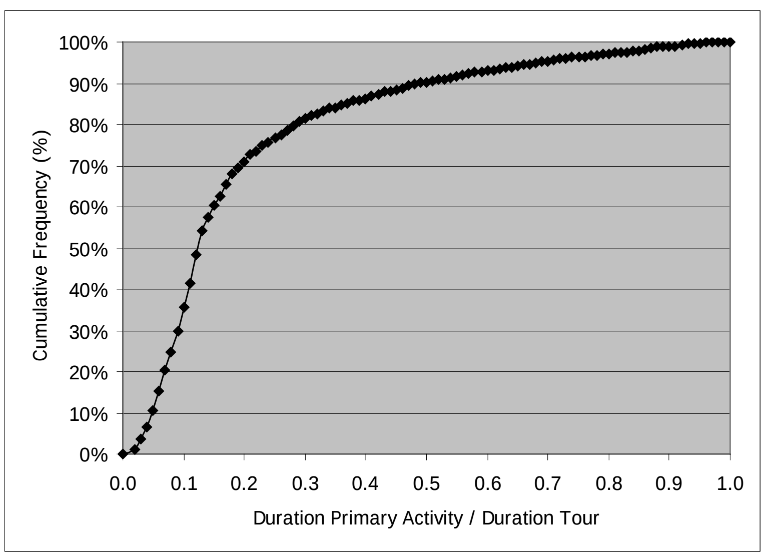


Figure 7.8. Observed Frequency Distribution for the First At-Work Activity Percent Duration

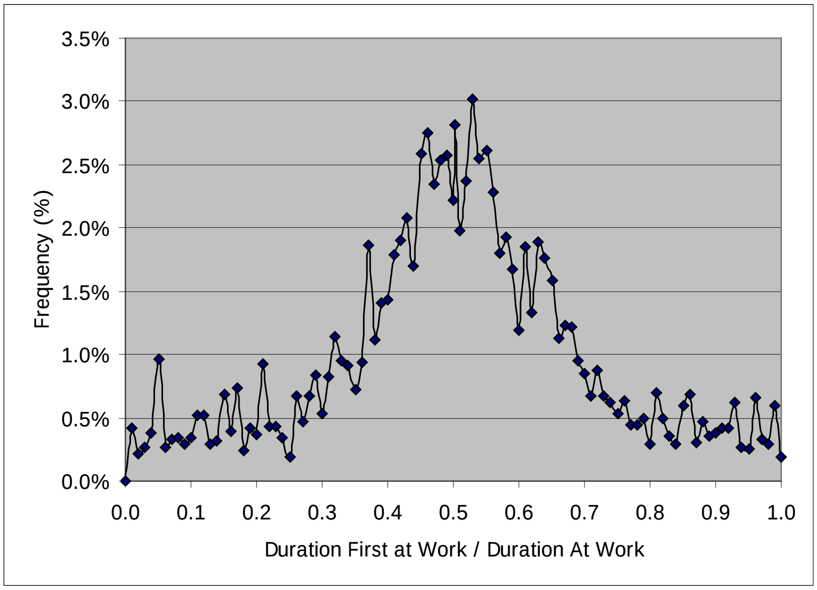


Figure 7.9. Observed Cumulative Distributions for the First At-Work Activity Percent Duration

7.5.15. LDT Tour Pattern Model Frequencies

The LDT Tour Pattern Model discussed in Section 7.3.15 predicts the type of long-distance travel that occurs on the simulation day, if any. The model applies a set of factors, by purpose, derived from the Ohio survey data, and assumed to be of the same pattern for Oregon. No further calibration is required.

The Ohio survey-based tour pattern model observed frequency of each pattern type is shown in Table 7.41. Because the model predicts typical weekday (Monday-Thursday) the weekends are excluded and thus work related travel is more likely to occur than household or other travel. Even with Fridays excluded, there are still more travelers departing during the week than returning.

Table 7.41 LDT Tour Pattern Choice Frequencies

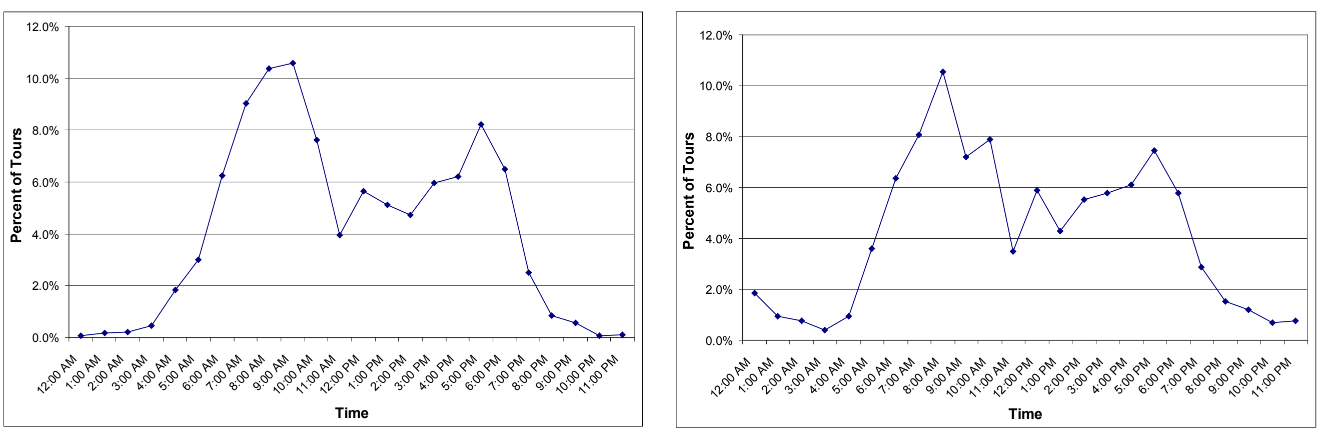
Pattern Type	Household	Work Related	Other
Complete Tour	2.48%	6.95%	2.86%
Begin Tour	2.37%	4.72%	2.11%
End Tour	2.03%	3.36%	1.71%
Away	7.90%	11.26%	5.43%
No Tour	85.21%	73.71%	87.88%

Source: Ohio Statewide Model Program, LDT model estimation

7.5.16. LDT Scheduling Frequencies

LDT Tours are scheduled to a time-of-day with a one-hour resolution. Beginning tours are given a departure time, ending tours are given an arrival time, and complete tours are given a departure time and duration to fully define their schedule. As with the LDT tour pattern model, the scheduling model draws from observed frequency distributions from the Ohio Long Distance Survey data. Figure 7.10 shows these Ohio-based departure time distribution for beginning tours, and arrival time distribution for ending tours, respectively.

Figure 7.10 LDT Departure **Times for Beginning Tours & Arrival Times for Ending Tours**



For complete tours, the schedule is determined using a constants-only logit model, with constants on the departure time and duration. This strategy was applied to smooth the outcomes because the observed data had high unexplained variability when viewed in both dimensions. The choice set is restricted such that trips cannot depart before 5 AM or after 7 PM, and all trips must return by 12 AM. The minimum duration is 2 hours, and the maximum duration is 17 hours. Some changes were made to the model during calibration to better fit the observed departure time, arrival time and duration distributions. Table 7.42 shows the final model coefficients. They are estimated such that sequential two-hour periods have the same coefficient, to avoid high variability in the coefficient values. Mornings are popular departure times. The time periods after 3 pm have higher coefficients because the choice set is restricted such that those periods have fewer possible alternatives that can return by 12 AM.

Table 7.42 LDT Complete Tour Scheduling Model Coefficients

Variable	Coefficient
Duration Constant	
2 Hours	0.959
3 Hours	1.609
4 Hours	2.544
5 Hours	2.898
6 Hours	3.278
7 Hours 8 Hours	3.518
9 Hours 10 Hours	2.696
11 Hours 12 Hours	3.767
13 Hours 14 Hours	2.874
15 Hours 16 Hours	2.964
17 Hours	
Departure Time Constant	
5:00 AM 6:00 AM	0.000
7:00 AM	1.033
8:00 AM	1.944
9:00 AM	2.216
10:00 AM	1.459
11:00 AM 12:00 PM	1.423
1:00 PM 2:00 PM	1.392
3:00 PM 4:00 PM	2.457
5:00 PM 6:00 PM	3.027
Arrival Time Constant	
9:00 PM	-1.174
10:00 PM	-1.457
11:00 PM	-2.440

7.5.17. LDT Internal-External Choice Model Parameters

The LDT Internal-External Choice Model, as discussed in Section 7.3.17 is a binary choice model predicting whether a tour will have a destination within the model area or beyond the bounds of the model area. All model coefficients are applied to the utility of leaving the model area. The models were calibrated to match the in-state versus out-of-state shares found in the Oregon section of the 1995 American Travel Survey (ATS) for trips longer than 100 miles.

Table 7.43 LDT Internal-External Model Estimated Coefficients

Variable		Household Coefficients	Work Related Coefficients	Other Coefficients
Constant		1.6456	2.006	0.837
Income	<20k			
	$20-40k			
	$40-60k			
	$60k+	0.441		0.462
Occupation	Construction		-2.892	
	Finance, insurance & real estate		-0.566	
	Public administration		-1.683	
	Education		-1.426	
	Medical		-1.383	
Person is a Worker				-0.189
Age	<25			-0.319
	55+			0.436
	65+		-1.155	0.436
Complete Travel in One Day		-2.084	-2.707	-1.458
Time to Nearest External Station		-0.0084		-0.0125

7.5.18. LDT Destination Choice Model parameters

The LDT Destination Choice Models are applied separately for internal versus external destinations. Table 7.44 shows the internal destination choice model parameters calibrated to Ohio trip length data, in the absence of Oregon long distance trip data. Trips are distributed to external destinations through External Stations (5000 zones) using a simple destination choice model, which uses the highway travel time as the impedance, and the traffic volume at the station as the size term. These model coefficients are shown in Table 7.45.

Table 7.44 LDT Internal Destination Choice Model Estimated Coefficients

Variable		Household Coefficients	Work Related Coefficients	Other Coefficients
Mode Choice Logsum		0.936	0.612	1.000
Time, if complete tour in one day		-0.016	-0.012	-0.011
Size Terms	Total Households*	2.793		1.958
	Total employment	1.000	1.000	1.000
	Hotel--if overnight trip*	264.365	228.321	55.571
	Higher Ed—if age 18+ & student*			80.434
	Government employment*		7.057	
	Employment in worker's industry*		3.671	
Flag for distance < 60 miles		-0.167	0.286	-1.514
Flag for distance 60-70 miles		0.738	1.026	-0.940
Flag for distance 70-150 miles				-0.349

*Coefficient for application is exponential of reported coefficient.

Table 7.45 LDT External Destination Choice Model Estimated Coefficients

Variable		Household Coefficients	Work Related Coefficients	Other Coefficients
Time		-0.0075	-0.0075	-0.0075
Size Term	Traffic Volume	1	1	1

7.5.19. LDT Mode Choice Model parameters

The LDT Mode Choice Model includes six alternatives. (Amtrak occupies the high speed rail choices in Oregon, a carry over from the Ohio model terminology) As with destination choice, a simplified mode choice model is applied for trips with destinations outside the model area. In this case, fixed mode splits are applied, as derived from the Oregon segment of the 1995 American Travel Survey (ATS) data.

Table 7.46 LDT Internal Mode Choice Model Estimated Coefficients

Variable		Household Coefficients	Work-Related Coefficients	Other Coefficients
In-Vehicle Time		-0.005	-0.010	-0.005
Walk-Access Time		-0.010	-0.020	-0.010
Drive-Access Time		-0.010	-0.020	-0.010
Wait Time	Up to 30 minutes	-0.010	-0.020	-0.010
	In excess of 30 minutes	-0.0025	-0.005	-0.0025
Cost (cents)	Income $0-20k	-0. 080	-0. 080	-0. 080
	Income $20-60k	-0. 030	-0. 030	-0. 030
	Income $60k+	-0. 012	-0. 012	-0. 012
Transit-High Speed Rail Nest		0.650	0.650	0.650
Transit Walk-Drive Nest		0.500	0.500	0.500
High Speed Rail Walk-Drive Nest		0.500	0.500	0.500
Air Constant		-3.18698	-1.03798	-2.30198
Transit-Walk Access Constant		-2.79729	-2.79729	-2.79729
Transit-Drive Access Constant		-2.7929	-2.7929	-2.7929
High Speed Rail-Walk Access Constant		-4.4422	-4.4422	-4.4422
High Speed Rail-Drive Access Constant		-4.4422	-4.4422	-4.4422

Note: "High Speed Rail" is the Amtrak intercity rail option in Oregon

7.6. Inputs and Outputs

The PT module inputs and outputs are listed in Tables 7.47 and 7.48. PT SDT inputs include the person and household attributes of the synthetic population generated by SPG, labor dollar flows from the PI module, travel attributes from the TS module, all in the current year. PT LDT inputs include External Station traffic counts. Additionally, PT SDT and LDT requires some exogenous data including an alpha-to-beta zone mapping file, alpha zone acres and parking costs (daily and hourly), as well as files containing the parameters for each PT model. Currently only the weekday model of PT is used.

The primary PT output is a list of SDT and LDT trip tours for network assignment in TS. LDT also prints out an initial output, prior to additional processing into the format used by TS for assignment. PT also outputs mode choice and destination choice logsums by alpha zone for its own use and selected beta zone logsums for PI, additional household and person attributes tied to the synthetic population (autos and work location), and an employment summary (based on work location).

Table 7.47. PT SDT and LDT Inputs

Data Element	Source
Lists (with attribute states) of modeled households resident in study area [SynPopH]	SPG
Lists (with attribute states) of modeled persons resident in study area [SynPopP]	SPG
Peak and off-peak auto times & distances for interchanges between alpha zones, Peak and off-peak walk-to/drive-to transit travel attributes [*.zmx] (see table 10.1 for filename coding)	TS
Labor production (home end) and consumption (work end) 1990$ by occupation in alpha zone [laborDollarProductionSum.csv][laborDollarConsumptionSum.csv]	PI
Labor selling flows by industry (work trip ends) [selling_*commodity*.csv]	PI
Solved beta zone industry-commodity production and consumption technical coefficients [ZonalMakeUse.csv]	PI
alpha zone acres and beta zones in alpha zones [alpha2beta.csv]	exog
Unit parking costs (work/nonwork) in alpha zones [alpha2beta.csv] fields “HourPark” and “DayPark”	exog
Size Term for LDT Destination Choice Model [ExternalStationVolumes.csv]	exog
SDT HH Survey observed activity patterns [weekdaypatterns.csv] [patternAttributes.csv]	exog
SDT Auto Ownership Model parameters [autoownershipparameters.csv] and [globalTemplate.properties](latter from distance and time parameters)	exog
SDT Day-Pattern Model parameters [weekdaypatternparameters.csv],[patternparameters.csv]	exog
SDT Intermediate Stop Purpose Model parameters, [stoppurpose2tparameters.csv], [stoppurpose3ptparameters.csv]	exog
SDT Primary Tour Scheduling Model parameters [TourScheduleParameters.csv]	exog
SDT Tour Mode Choice Model parameters [tourmodeparameters.csv]	exog
SDT Primary Tour Destination parameters [tourdestinationparameters.csv]	exog
SDT Intermediate Stop Model parameters [IntermediateStopChoiceParameters.csv], [stopdestinationparameters.csv], [firststopdestinationparameterss.csv], [secondstopdestiatinoparameters.csv]	exog
SDT Trip Mode Choice Model parameters [tripmodeparameters.csv]	exog
SDT Intermediate Stop Duration Model parameters [stopDurationParameters.csv]	exog
SDT Work Based Trip Duration Model parameters [PctWorkBasedDuration.csv]	exog
LDT Binary Choice of Travel model parameters [LDTourBinaryChoiceParameters.csv]	exog
LDT Tour Pattern Model parameters [LDPatternModelFrequencies.csv]	exog
LDT Scheduling Model parameters [LDTourScheduleFrequencies.csv],[LDTourScheduleParameters.csv]	exog
LDT Internal-External Choice Model parameters [LDInternalExternalParameters.csv],[LDExternalDestinationChoiceParameters.csv]	exog
LDT Destination Choice Model parameters [LDExternalDestinationFrequencies.csv],[LDInternalDestinationChoiceParameters.csv]	exog
LDT Mode Choice Model parameters [LDInternalModeChoiceParameters.csv], [LDExternalModeChoiceParameters.csv], [LDExternalModeShares.csv]	exog
LDT other inputs (rental car/taxi/airport parking costs, multi-day trip duration and auto occupancy by purpose) [globalTemplate.properties]	exog
SDT cost inputs (walk, bike and drive to transit speeds, auto operating cost, time of first wait segment, non-work parking cost factor) [globalTemplate.properties]	

PT generates the following working files for use in later PT submodels:

- Exponentiated travel utilities for alpha zones (destination choice utilities) [x##dceu.bin]
- Travel accessibilities for alpha zones (destination choice logsums) [x##dcls.bin]

- Mode travel utilities for interchanges between alpha zones (mode choice logsums) by alpha zone [x#ls.zip]

Table 7.48. PT SDT and LDT Outputs

Data Element	Users
Selected mode travel utilities by market segment for interchanges between alpha zones (mode choice logsums) [##mcls.zmx]	PT (current year)
Selected mode travel utilities by market segment for interchanges between beta zones (mode choice logsums) [##betamcls.zmx]	PI
Selected destination travel utilities for interchanges between alpha zones (destination choice logsums) [dcLogsums.zmx]	PT (current year)
Aggregate employment by industry and alpha zone [employment.csv]	PT (next year)
Additional Synthetic Population person attributes identified within PT (linked to SynPopP by hhID and personID) [personData.csv]	diagnostics
Additional Synthetic Population household attributes identified within PT (linked to SynPopH by hhID) [householdData.csv]	diagnostics
Alpha zone level summary of persons, household, workers [SynPop_Taz_Summary.csv]	diagnostics
SDT Daily Pattern details [Patterns_SDT.csv]	diagnostics
SDT Person Tour and Trip details [Trips_SDTPerson.csv]	TS
LDT Person Tour details [Tours_LDT.csv]	diagnostics
LDT Daily Vehicle trips [Trips_LDTVehicle.csv]	diagnostics
LDT Daily Person Trips [Trips_LDTPerson.csv]	TS

The PT person trip table output used by the TS module has the following attributes:

- Origin Alpha zone (or External Station)
- Destination Alpha zone (or External Station)
- Distance
- Origin Activity End Time (Trip start time)
- Primary Mode
- Trip Mode

7.6.1 Baseyear Time & Distance Interchange Matrices

PT uses time and distance interchange matrices (skims) output by the TS module, as listed below. During calibration, an exogenous baseyear set of skims was developed. The baseyear SWIM2 transit skims were assembled primarily from mid-1990s MPO network data in EMME/2. Peak period skims were created using congested travel times from MPO model runs in the MPO portions of the network, and free-flow travel times minus 5 mph in non-MPO areas. Off-peak skims used free-flow speeds. Once the statewide network was built, the skims were generated by EMME/2 using the MPO path-building parameters. See Reference [37] for description of baseyear MPO network data and processing.

- Peak Walk-Transit In-vehicle Time
- Peak Walk-Transit First Wait
- Peak Walk-Transit Total Wait
- Peak Walk-Transit Auxiliary Transit (WALK) Time
- Peak Walk-Transit Number Boardings

- Peak Walk-Transit Fare
- Off-Peak Walk-Transit In-vehicle Time
- Off-Peak Walk-Transit First Wait
- Off-Peak Walk-Transit Total Wait
- Off-Peak Walk-Transit Auxiliary Transit (WALK) Time
- Off-Peak Walk-Transit Number Boardings
- Off-Peak Walk-Transit Fare
- Peak Drive-Transit In-vehicle Time
- Peak Drive-Transit First Wait
- Peak Drive-Transit Total Wait
- Peak Drive-Transit Auxiliary Transit (WALK) Time
- Peak Drive-Transit Number Boardings
- Peak Drive-Transit Drive Time
- Off-Peak Drive-Transit In-vehicle Time
- Off-Peak Drive-Transit First Wait
- Off-Peak Drive-Transit Total Wait
- Off-Peak Drive-Transit Auxiliary Transit (WALK) Time
- Off-Peak Drive-Transit Number Boardings
- Off-Peak Drive- Drive Time

Once SWIM2 models are calibrated, the base year skims generated by the TS model replace the original baseyear inputs synthesized from MPO data. In application, all future year skims are output from TS and used in PT in the following (currently 3-year) period.

7.6.2 Other parameters

A series of exogenous inputs are provided exogenously in the [globalTemplate.properties] file, under the AO and PT sections. These include the following, including their source data.

- Auto Operating Cost. This value is shared by SDT and LDT. See Section 10.6.3 for further discussion.

- SDT speeds, wait time, parking factor. The following speeds and wait times were assumed:

  - Walk speed (mph): 3 mph
  - Bike Speed (mph): 12 mph
  - Drive to Transit Speed (mph): 25 mph
  - Time of first wait segment (minutes): 10 minutes
  - Non-work parking cost factor: 2.5

- LDT-specific Travel Cost Information. In addition to the transit costs associated with network skimming on the TS module (Section 10.6.3), the following long distance travel costs are assumed in LDT.

  - Daily Rental Car Costs (1990$): $47.17/day
  - Taxi rate (1990$): $1.42/minute
  - Daily Airport parking costs (1990$): $10.78/day

- LDT Average duration of a multi-day trip by purpose:

2.4, 4.6, and 2.6 hrs for Household, Work-related and Other purpose, respectively

- LDT Average Auto occupancy by purpose. Based on Ohio Long Distance Survey.

  2.81, 1.22, and 1.91 hrs for Household, Work-related and Other purpose, respectively

7.7. Calibration Targets

During initial calibration, the PT module was formally compared to five observed targets from the Oregon mid-1990s Household Travel Behavior Survey, as listed in Table 7.49. Supplemental calibration targets are also listed. Transit boarding data from the major transit agencies in the state (typically annual or monthly boardings system-wide and/or by route) were compared with daily transit trips output by PT and TS. Census Journey to Work data commute trips (at a sub-county geographic scale) were used by PT (and PI) to calibrate the PT generated work trips (and PI labor flows).

Table 7.49. PT Calibration Targets

Source	Year	SWIM2 Target
Official SDT Targets		
Oregon Travel Behavior Surveys	1994/1996	Average Tours by Purpose and MPO per Household day
		Frequency of Patterns by Number of Tours per Pattern and MPO
		Average Number of Trips per Household and MPO
		Frequency of Tour departure time and duration by hour and MPO
		Average Highway distance by tour purpose and MPO
Census Journey to Work Data	1990, 2000	Commute trip data
Official LDT Targets		
American Travel Survey, Oregon Element	1995	Number of trips greater than 100 miles made by Oregon residents
		Share of long distance trips remaining within Oregon
		Share of auto versus non-auto long distance trips
Additional SDT Targets		
Local Transit Boarding data (Tri-Met, Lane TD, Salem-Kaiser Transit, Rogue Valley Transit)	various	1990 monthly passenger boardings
		July87-Dec99 (-Aug98 by route) monthly passengers
		1987-96 average weekday boardings by route
		1991-99 Monthly ridership totals, 1993 service performance/ridership by route

7.8. Initial Calibration

The PT module was updated in fall 2006 to add the LDT component and update various SDT components enhanced in Ohio application. After code changes were made, both the SDT and LDT components completed a Stage 2 calibration, in isolation of other modules. This section discusses this S2 calibration.

7.8.1. SDT Calibration

The initial calibration of the SDT component of PT was based on a 5 percent population sample model estimates. The results were factored by the sampling rate so they are representative of the entire population. Once the model was well-calibrated, a 100 percent population run was completed and the results were compared to the target data.

Day-Pattern Choice Model

The PT Day-Pattern Choice model was calibrated to match the targets shown below. The PT parameters control for the choice of pattern with respect to specific pattern attributes (i.e., numbers and types of activities on pattern) for each person type.

Table 7.50 shows the calibration results for the distribution of patterns by the number of tours in the pattern, for all of Oregon plus Clark County in Washington. Tables 7.51 to 7.55 break down this summary by MPO region. The model matches the targets in terms of total patterns produced, statewide and by MPO region. It tends to over predict the longest patterns, which are also the least frequent ones.

Table 7.50. Patterns by Number of Tours per Pattern – Oregon & Clark County

	Target		Estimate		Error	
Number of Tours	*Freq.*	*Pct.*	*Freq.*	*Pct.*	*Freq.*	*Pct.*
0	641,444	16.8%	694,900	18.0%	8%	1.2%
1	1,852,901	48.5%	1,850,046	47.9%	0%	-0.6%
2	987,231	25.9%	978,941	25.4%	-1%	-0.5%
3	269,184	7.0%	268,052	6.9%	0%	-0.1%
4	53,012	1.4%	54,351	1.4%	3%	0.0%
5	12,364	0.3%	11,190	0.3%	-9%	0.0%
6	1,980	0.1%	2,727	0.1%	38%	0.0%
7	553	0.0%	863	0.0%	56%	0.0%
8	68	0.0%	279	0.0%	308%	0.0%
Total	3,818,738	100.0%	3,861,349	100.0%	1%	0.0%

Table 7.51. Patterns by Number of Tours per Pattern – Portland

	Target		Estimate		Error	
Number of Tours	*Freq.*	*Pct.*	*Freq.*	*Pct.*	*Freq.*	*Pct.*
0	242,312	14.0%	314,081	17.7%	30%	3.7%
1	865,862	49.9%	837,464	47.1%	-3%	-2.8%
2	483,257	27.9%	458,169	25.8%	-5%	-2.1%
3	116,676	6.7%	132,824	7.5%	14%	0.7%
4	20,567	1.2%	27,449	1.5%	33%	0.4%
5	5,104	0.3%	5,945	0.3%	16%	0.0%
6	565	0.0%	1,434	0.1%	154%	0.0%
7	331	0.0%	467	0.0%	41%	0.0%
8	44	0.0%	150	0.0%	238%	0.0%
Total	1,734,718	100.0%	1,777,983	100.0%	2%	0.0%

Table 7.52. Patterns by Number of Tours per Pattern – Salem

Number of Tours	Target Freq.	Target Pct.	Estimate Freq.	Estimate Pct.	Error Freq.	Error Pct.
0	29,407	14.3%	37,079	17.6%	26%	3.3%
1	97,526	47.4%	95,432	45.4%	-2%	-2.0%
2	57,230	27.8%	56,476	26.8%	-1%	-1.0%
3	17,600	8.6%	16,771	8.0%	-5%	-0.6%
4	3,051	1.5%	3,614	1.7%	18%	0.2%
5	735	0.4%	734	0.3%	0%	0.0%
6	84	0.0%	216	0.1%	159%	0.1%
7	96	0.0%	61	0.0%	-37%	0.0%
8	0	0.0%	24	0.0%	0%	0.0%
Total	205,728	100.0%	210,407	100.0%	2%	0.0%

Table 7.53. Patterns by Number of Tours per Pattern – Eugene

Number of Tours	Target Freq.	Target Pct.	Estimate Freq.	Estimate Pct.	Error Freq.	Error Pct.
0	37,235	14.2%	45,690	17.8%	23%	3.6%
1	120,499	46.0%	116,751	45.6%	-3%	-0.4%
2	74,094	28.3%	67,956	26.5%	-8%	-1.8%
3	24,166	9.2%	20,173	7.9%	-17%	-1.3%
4	4,793	1.8%	4,406	1.7%	-8%	-0.1%
5	867	0.3%	844	0.3%	-3%	0.0%
6	266	0.1%	237	0.1%	-11%	0.0%
7	63	0.0%	80	0.0%	27%	0.0%
8	0	0.0%	23	0.0%	0%	0.0%
Total	261,983	100.0%	256,160	100.0%	-2%	0.0%

Table 7.54. Patterns by Number of Tours per Pattern – Medford

Number of Tours	Target Freq.	Target Pct.	Estimate Freq.	Estimate Pct.	Error Freq.	Error Pct.
0	30,706	20.2%	27,509	17.7%	-10%	-2.5%
1	70,553	46.4%	71,496	46.1%	1%	-0.3%
2	36,393	23.9%	41,343	26.7%	14%	2.7%
3	11,642	7.7%	11,665	7.5%	0%	-0.1%
4	2,176	1.4%	2,415	1.6%	11%	0.1%
5	463	0.3%	492	0.3%	6%	0.0%
6	73	0.0%	114	0.1%	56%	0.0%
7	0	0.0%	48	0.0%	0%	0.0%
8	0	0.0%	11	0.0%	0%	0.0%
Total	152,006	100.0%	155,093	100.0%	2%	0.0%

Table 7.55. Patterns by Number of Tours per Pattern – Non MPO

Number of Tours	Target Freq.	Target Pct.	Estimate Freq.	Estimate Pct.	Error Freq.	Error Pct.
0	301,786	20.6%	270,541	18.5%	-10%	-2.1%
1	698,462	47.7%	728,903	49.9%	4%	2.2%
2	336,257	23.0%	354,997	24.3%	6%	1.3%
3	99,100	6.8%	86,619	5.9%	-13%	-0.8%
4	22,424	1.5%	16,467	1.1%	-27%	-0.4%
5	5,196	0.4%	3,175	0.2%	-39%	-0.1%
6	992	0.1%	726	0.0%	-27%	0.0%
7	63	0.0%	207	0.0%	228%	0.0%
8	24	0.0%	71	0.0%	195%	0.0%
Total	1,464,304	100.0%	1,461,706	100.0%	0%	0.0%

Frequency of Tours by Tour Purpose.

Table 7.56 shows the calibration results for the distribution of tours by tour purpose, for all of Oregon plus Clark County in Washington. Tables 7.57 to 7.61 break down this summary by MPO region. S tatewide the model is matching the number of work and school tours, overestimating shop and recreation tours and underestimating other tours. At the MPO level the most noticeable difference is the overestimation of work tours in Salem and Medford.

Table 7.56. Tours by Tour Purpose – All of Oregon & Clark County.

Tour Purpose	Target Freq.	Target Pct.	Estimate Freq.	Estimate Pct.	Error Freq.	Error Pct.
Work - no subtour	968,715	20.7%	1,046,260	22.4%	8%	1.7%
Work - w. subtour	235,073	5.0%	244,813	5.2%	4%	0.2%
School	643,757	13.8%	609,172	13.1%	-5%	-0.7%
Shop	64,398	1.4%	119,567	2.6%	86%	1.2%
Recreation	864,356	18.5%	904,497	19.4%	5%	0.9%
Other	889,425	19.0%	919,294	19.7%	3%	0.7%
Total	1,003,333	21.5%	821,657	17.6%	-18%	-3.9%

Table 7.57. Tours by Tour Purpose – Portland

Tour Purpose	Target Freq.	Target Pct.	Estimate Freq.	Estimate Pct.	Error Freq.	Error Pct.
Work - no subtour	477,814	21.7%	497,364	22.7%	4%	1.0%
Work - w. subtour	91,641	4.2%	114,353	5.2%	25%	1.1%
School	298,944	13.6%	274,332	12.5%	-8%	-1.1%
Shop	39,296	1.8%	55,869	2.6%	42%	0.8%
Recreation	405,532	18.4%	427,092	19.5%	5%	1.0%
Other	404,647	18.4%	429,622	19.6%	6%	1.2%
Total	480,163	21.8%	391,883	17.9%	-18%	-4.0%

Table 7.58. Tours by Tour Purpose – Salem

	Target		Estimate		Error	
Tour Purpose	*Freq.*	*Pct.*	*Freq.*	*Pct.*	*Freq.*	*Pct.*
Work - no subtour	42,914	16.2%	56,827	21.4%	32%	5.2%
Work - w. subtour	15,245	5.7%	13,005	4.9%	-15%	-0.8%
School	33,563	12.6%	33,451	12.6%	0%	0.0%
Shop	467	0.2%	6,448	2.4%	1280%	2.3%
Recreation	52,794	19.9%	53,071	20.0%	1%	0.1%
Other	58,710	22.1%	52,548	19.8%	-10%	-2.3%
Total	62,027	23.3%	50,383	19.0%	-19%	-4.4%

Table 7.59. Tours by Tour Purpose – Eugene

	Target		Estimate		Error	
Tour Purpose	*Freq.*	*Pct.*	*Freq.*	*Pct.*	*Freq.*	*Pct.*
Work - no subtour	67,389	19.6%	68,092	21.2%	1%	1.6%
Work - w. subtour	20,455	5.9%	15,556	4.8%	-24%	-1.1%
School	44,793	13.0%	37,877	11.8%	-15%	-1.2%
Shop	2,258	0.7%	8,661	2.7%	284%	2.0%
Recreation	71,614	20.8%	65,407	20.3%	-9%	-0.5%
Other	73,230	21.3%	64,717	20.1%	-12%	-1.2%
Total	64,526	18.7%	61,326	19.1%	-5%	0.3%

Table 7.60. Tours by Tour Purpose – Medford

	Target		Estimate		Error	
Tour Purpose	*Freq.*	*Pct.*	*Freq.*	*Pct.*	*Freq.*	*Pct.*
Work - no subtour	27,922	15.5%	40,682	21.1%	46%	5.6%
Work - w. subtour	8,619	4.8%	9,326	4.8%	8%	0.1%
School	21,294	11.8%	24,407	12.6%	15%	0.8%
Shop	1,652	0.9%	5,062	2.6%	206%	1.7%
Recreation	40,670	22.5%	39,022	20.2%	-4%	-2.3%
Other	40,370	22.4%	38,419	19.9%	-5%	-2.5%
Total	39,904	22.1%	36,161	18.7%	-9%	-3.4%

Table 7.61. Tours by Tour Purpose – Non MPO

	Target		Estimate		Error	
Tour Purpose	*Freq.*	*Pct.*	*Freq.*	*Pct.*	*Freq.*	*Pct.*
Work - no subtour	352,676	21.0%	383,295	22.6%	9%	1.6%
Work - w. subtour	99,114	5.9%	92,573	5.5%	-7%	-0.4%
School	245,164	14.6%	239,105	14.1%	-2%	-0.5%
Shop	20,724	1.2%	43,527	2.6%	110%	1.3%
Recreation	293,747	17.5%	319,905	18.9%	9%	1.4%
Other	312,468	18.6%	333,988	19.7%	7%	1.1%
Total	356,714	21.2%	281,904	16.6%	-21%	-4.6%

Frequency of Trips by Tour Purpose

Table 7.62 shows the calibration results for the distribution of trips by tour purpose, for all of Oregon plus Clark County in Washington. Tables 7.63 to 7.67 break down this summary by MPO region. Statewide the model overestimates the number of trips on work, shop and recreation tours, and underestimates the number of trips on school, other, and college tours. Together with the results for tours by tour purpose, this indicates that the model tends to over-select patterns with multiple stops on work tours and under-select patterns with multiple stops on school tours. The results for shop, recreation and other tours may be directly a result of the tour purpose distribution rather than related to the stops.

Table 7.62. Trips by Tour Purpose – Oregon & Clark County

	Target		Estimate		Error	
Tour Purpose	*Freq.*	*Pct.*	*Freq.*	*Pct.*	*Freq.*	*Pct.*
Work - no subtour	2,348,106	21.4%	2,483,861	22.4%	6%	1.0%
Work - w. subtour	597,642	5.4%	625,615	5.6%	5%	0.2%
School	1,525,040	13.9%	1,378,017	12.4%	0%	-1.5%
College	1,673,953	15.3%	308,150	2.8%	-82%	-12.5%
Shop	2,214,399	20.2%	2,284,009	20.6%	3%	0.4%
Recreation	1,984,808	18.1%	2,060,727	18.6%	4%	0.5%
Other	2,152,554	19.6%	1,960,045	17.7%	-9%	-2.0%
Total	10,971,462	100.0%	11,100,424	100.0%	1%	0.0%

Table 7.63. Trips by Tour Purpose – Portland

	Target		Estimate		Error	
Tour Purpose	*Freq.*	*Pct.*	*Freq.*	*Pct.*	*Freq.*	*Pct.*
Work - no subtour	1,169,683	22.7%	1,173,609	22.7%	0%	0.0%
Work - w. subtour	231,965	4.5%	290,627	5.6%	25%	1.1%
School	693,251	13.4%	615,207	11.9%	0%	-1.5%
College	784,907	15.2%	141,427	2.7%	-82%	-12.5%
Shop	1,031,815	20.0%	1,062,827	20.6%	3%	0.6%
Recreation	903,687	17.5%	955,544	18.5%	6%	1.0%
Other	1,035,536	20.1%	928,052	18.0%	-10%	-2.1%
Total	5,157,593	100.0%	5,167,293	100.0%	0%	0.0%

Table 7.64. Trips by Tour Purpose – Salem

	Target		Estimate		Error	
Tour Purpose	*Freq.*	*Pct.*	*Freq.*	*Pct.*	*Freq.*	*Pct.*
Work - no subtour	105,909	17.0%	133,777	21.4%	26%	4.5%
Work - w. subtour	39,872	6.4%	32,834	5.3%	-18%	-1.1%
School	77,325	12.4%	75,050	12.0%	0%	-0.4%
College	78,337	12.6%	16,256	2.6%	-79%	-10.0%
Shop	131,422	21.1%	131,718	21.1%	0%	0.0%
Recreation	134,626	21.6%	116,516	18.7%	-13%	-2.9%
Other	132,973	21.3%	117,620	18.9%	-12%	-2.5%
Total	623,139	100.0%	623,771	100.0%	0%	0.0%

Table 7.65. Trips by Tour Purpose – Eugene

	Target		Estimate		Error	
Tour Purpose	*Freq.*	*Pct.*	*Freq.*	*Pct.*	*Freq.*	*Pct.*
Work - no subtour	167,499	20.6%	160,779	21.2%	-4%	0.6%
Work - w. subtour	52,517	6.5%	39,370	5.2%	-25%	-1.3%
School	106,493	13.1%	84,817	11.2%	0%	-1.9%
College	112,133	13.8%	21,941	2.9%	-80%	-10.9%
Shop	182,001	22.4%	162,581	21.5%	-11%	-0.9%
Recreation	162,504	20.0%	143,713	19.0%	-12%	-1.0%
Other	136,363	16.8%	143,472	19.0%	5%	2.2%
Total	813,018	100.0%	756,673	100.0%	-7%	0.0%

Table 7.66. Trips by Tour Purpose – Medford

	Target		Estimate		Error	
Tour Purpose	*Freq.*	*Pct.*	*Freq.*	*Pct.*	*Freq.*	*Pct.*
Work - no subtour	68,051	16.1%	96,206	21.1%	41%	5.0%
Work - w. subtour	22,025	5.2%	23,834	5.2%	8%	0.0%
School	49,446	11.7%	54,865	12.0%	0%	0.3%
College	53,171	12.6%	12,983	2.8%	-76%	-9.7%
Shop	104,644	24.7%	97,901	21.4%	-6%	-3.3%
Recreation	90,122	21.3%	85,769	18.8%	-5%	-2.5%
Other	85,568	20.2%	85,079	18.6%	-1%	-1.6%
Total	423,581	100.0%	456,637	100.0%	8%	0.0%

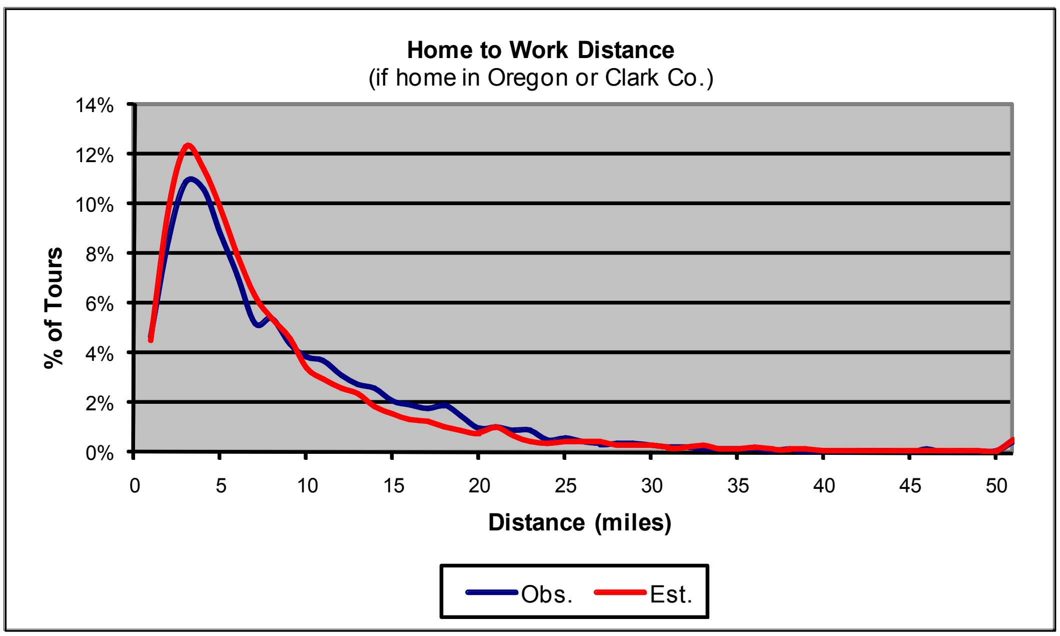
Table 7.67. Trips by Tour Purpose – Non MPO

Tour Purpose	Target Freq.	Target Pct.	Estimate Freq.	Estimate Pct.	Error Freq.	Error Pct.
Work - no subtour	836,965	21.2%	919,490	22.4%	10%	1.3%
Work - w. subtour	251,263	6.4%	238,950	5.8%	-5%	-0.5%
School	598,525	15.1%	548,078	13.4%	0%	-1.8%
College	645,404	16.3%	115,543	2.8%	-82%	-13.5%
Shop	764,517	19.3%	828,982	20.2%	8%	0.9%
Recreation	693,868	17.5%	759,185	18.5%	9%	1.0%
Other	762,114	19.3%	685,822	16.7%	-10%	-2.5%
Total	3,954,132	100.0%	4,096,050	100.0%	4%	0.0%

Workplace Location Model

Figure 7.11 shows the comparison of work tour lengths for all income groups. The model matches well the target tour length (home to work, one way) overall, but does not match well differences by income group. The income groups can be adjusted within the PI module, and that is a recommended next step for the model.

Figure 7.11. Calibration Results - Home to Work Distance



Tour Primary Destination Choice Model

This model has been calibrated to match average tour length by tour purpose, statewide, and the percent of intrazonal tours, also statewide. The calibration consists of adjusting the coefficients for tour distance and for the intrazonal indicator variable. The comparison to the target data is shown in Table 7.68.

Table 7.68. Average Tour Length and Percent Intrazonal Tours

	Average Tour Length (mi)			Percent Intrazonals		
Tour Purpose	*Target*	*Estimate*	*Error*	*Target*	*Estimate*	*Error*
School	9.5	9.4	-1%	16.3%	15.2%	-1%
College	15.6	16.8	8%	6.1%	5.5%	-1%
Shop	14.4	14.6	1%	6.5%	6.1%	0%
Recreation	12.8	13.7	7%	11.4%	10.9%	-1%
Other	11.0	11.0	0%	9.1%	8.3%	-1%
Subtours	8.1	8.3	2%	4.7%	8.1%	3%

Tour Schedule Choice Model

This model has been calibrated to match the distribution of departure time and duration by tour purpose, statewide. The calibration consisted of adjusting the alternative-specific constants. The comparison to the target data is shown in Figures 7.12 to 7.16 (departure time) and Figures 7.17 to 7.21 (duration).

Figure 7.12. Work Tour Departure Time

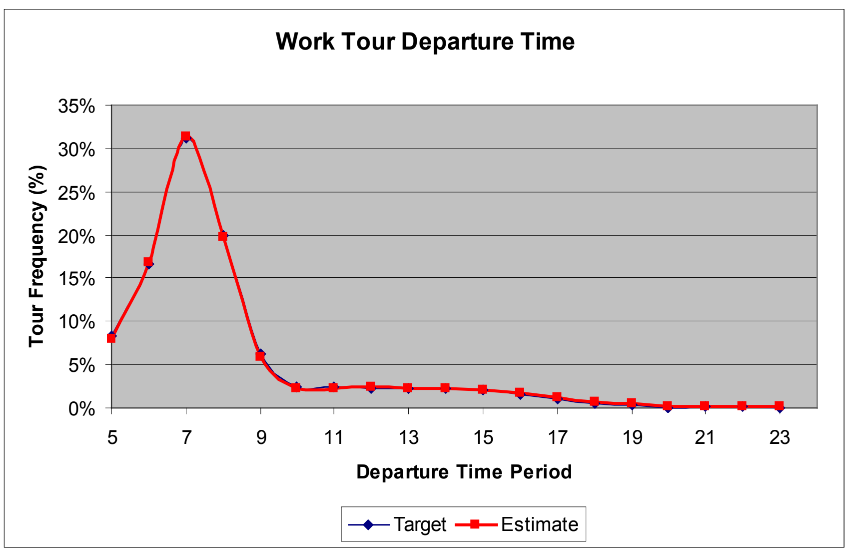


Figure 7.13. School Tour Departure Time

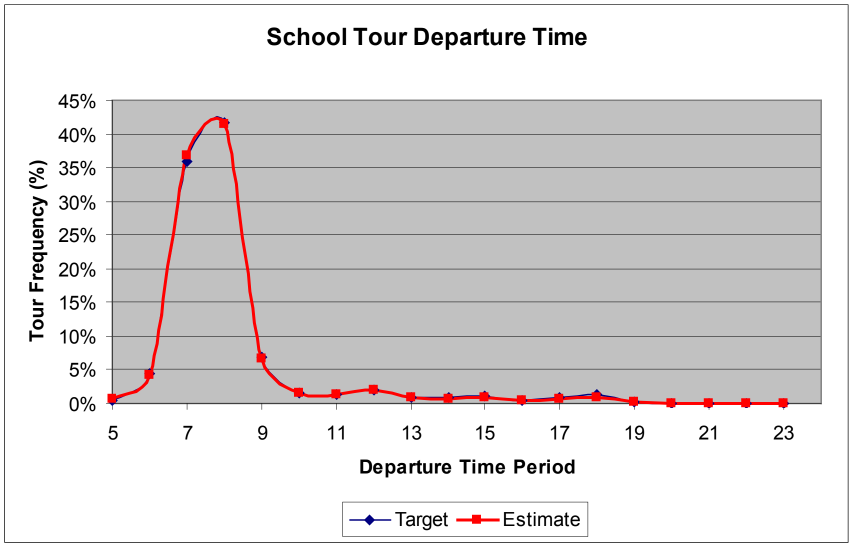


Figure 7.14. Shop Tour Departure Time

Figure 7.15. Recreation Tour Departure Time

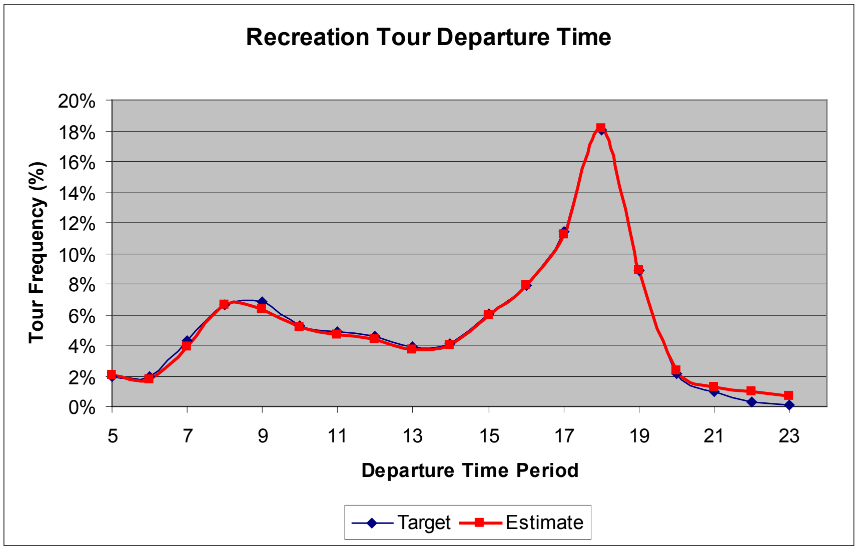


Figure 7.16. Other Tour Departure Time

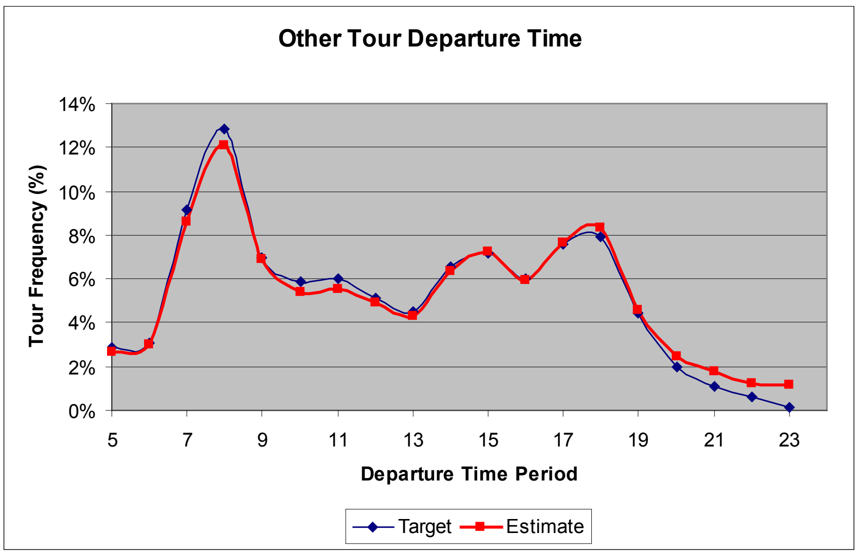


Figure 7.17. Work Tour Duration.

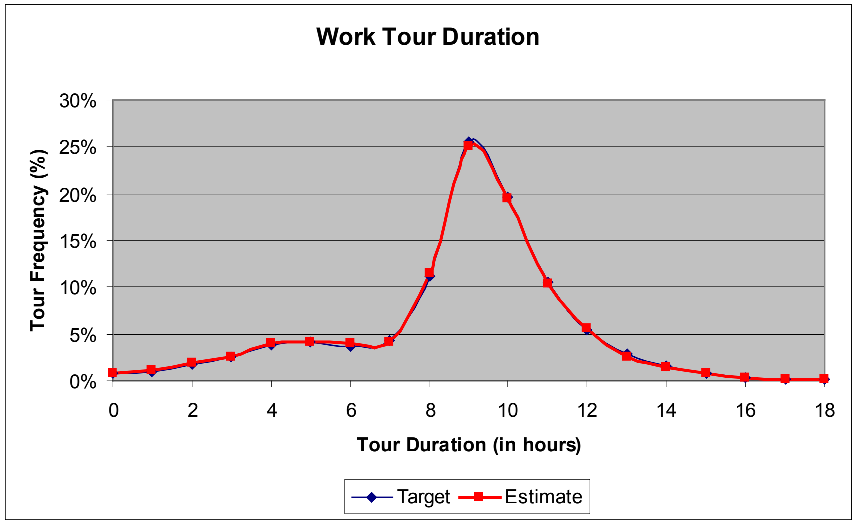


Figure 7.18. School Tour Duration.

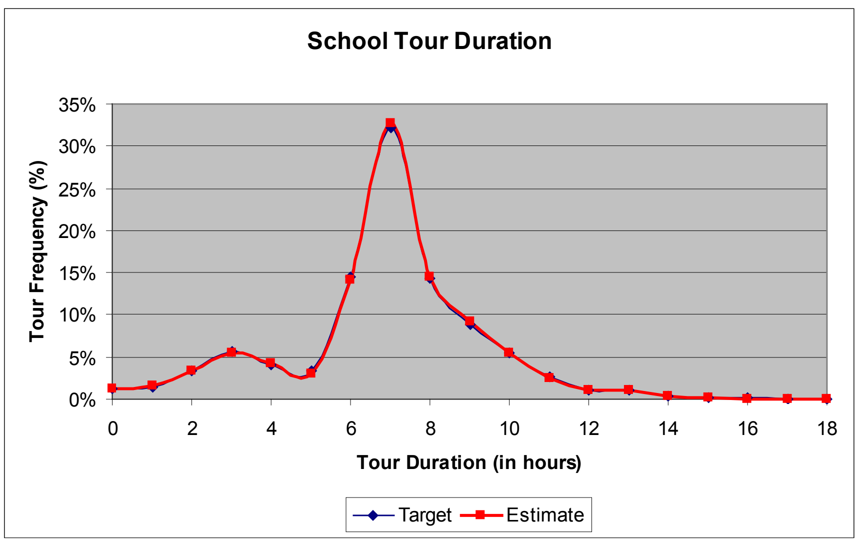


Figure 7.19. Shop Tour Duration

Figure 7.20. Recreation Tour Duration

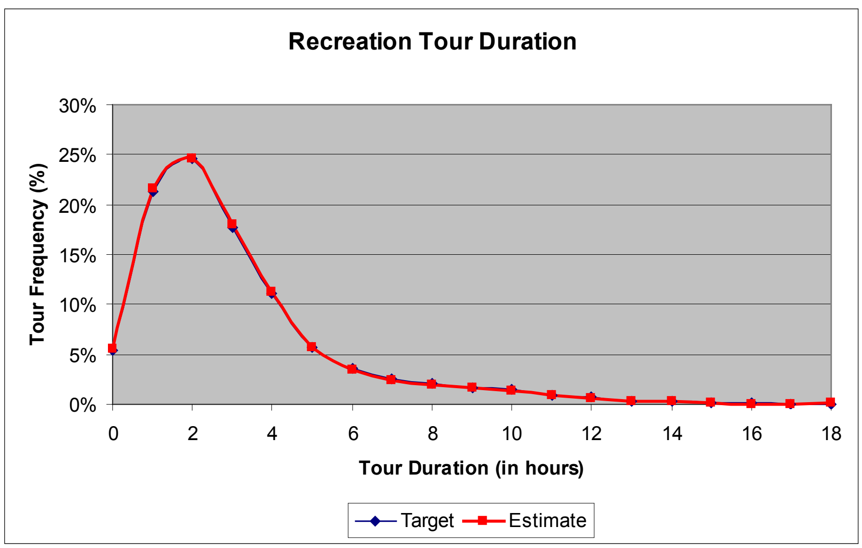
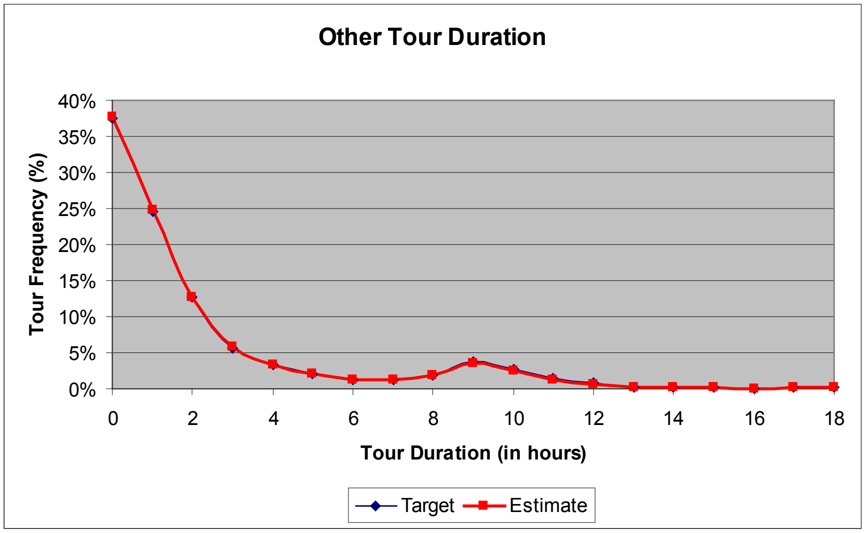


Figure 7.21. Other Tour Duration



Other Targets:

- The **Auto Ownership Model** was calibrated to match targets developed from the Oregon survey data. The number of households within the zero, one, two or three or more vehicles was matched within 2% of the target data statewide.
- The PT SDT **Intermediate Stop Location Model** was calibrated to match average deviation distance by mode, percent of stops in the home alpha zone by mode and percent of stops in the primary destination alpha zone by mode. The calibration consists of adjusting the coefficients on out-of-direction time and intrazonal indicator variables. An initial calibration showed that the model was not able to reproduce observed differences in trip length by inbound/outbound stop. The model has been modified so that the time and intrazonal variables are now segmented by stop position; further calibration of these segmented parameters is underway.
- The PT SDT **Intermediate Stop Duration Model** was calibrated to match the distribution of stop duration by tour purpose and stop position (outbound/inbound). The calibration consisted of adjusting the alternative-specific constants and the outbound stop indicator variable.
- The PT SDT **Tour Primary Mode Choice Model** was calibrated to the frequency of tours by market segment (car sufficiency). The calibration consists of adjusting the alternative-specific constants until each segment is within 10% of the target.
- The PT SDT **Trip Mode Choice Model** was calibrated to frequency of trips by primary mode. The calibration consists of adjusting the alternative-specific constants until each segment is within 10% of the target.

7.8.2. LDT Calibration

Binary Choice of Travel

Table 7.69 shows the results of the binary choice of travel model by purpose compared to the 1995 American Travel Survey calibration targets. Overall, the highest rate of travel is for other tours, at 33 percent, and the lowest is for work related tours, at 4 percent. According to the target data, the frequency of long distance travel is greater in Oregon than in Ohio, perhaps because of income and geographic differences.

Table 7.69. Percent of Persons Making a Long Distance Tour in a Two-Week Period

Observed	No	Yes	Total
Household	83.2%	16.8%	100.0%
Work Related	96.2%	3.8%	100.0%
Other	67.0%	33.0%	100.0%
Total	52.3%	47.7%	100.0%
Modeled	No	Yes	Total
Household	82.1%	17.9%	100.0%
Work Related	95.9%	4.1%	100.0%
Other	64.8%	35.2%	100.0%
Total	52.6%	47.4%	100.0%
Difference	No	Yes	Total
Household	-1.1%	1.1%	0.0%
Work Related	-0.3%	0.3%	0.0%
Other	-2.2%	2.2%	0.0%
Total	0.3%	-0.3%	0.0%

Tour Pattern

While the LDT tour pattern model itself requires no calibration, when combined with the binary choice of travel model, it results in the total trips generated. Table 7.70 shows the total number of long distance trips occurring on the travel day, and the subset of those that are greater than 100 miles, for comparison to the 1995 American Travel Survey (ATS).

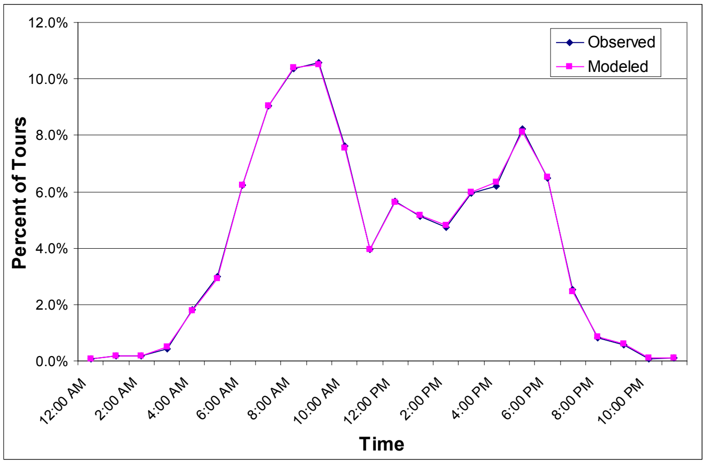
Table 7.70. Total Trips on Model Day

	Trips
Modeled > 50 miles	257,152
Modeled > 100 miles	157,684
Observed > 100 miles	157,272
Difference	412
% Difference	0%

Scheduling

The scheduling model draws from observed frequency distributions for beginning tours and ending tours, which is assumed to be the same in Oregon as in Ohio. No calibration was required for the departure time of beginning tours or the arrival time of ending tours, shown in Figure 7.13. Figures 7.22 through 7.24 show the modeled and observed departure times, arrival times and durations for the complete tour scheduling model.

Figure 7.22 Departure Time for Begin Tours & Arrival Time for End Tours



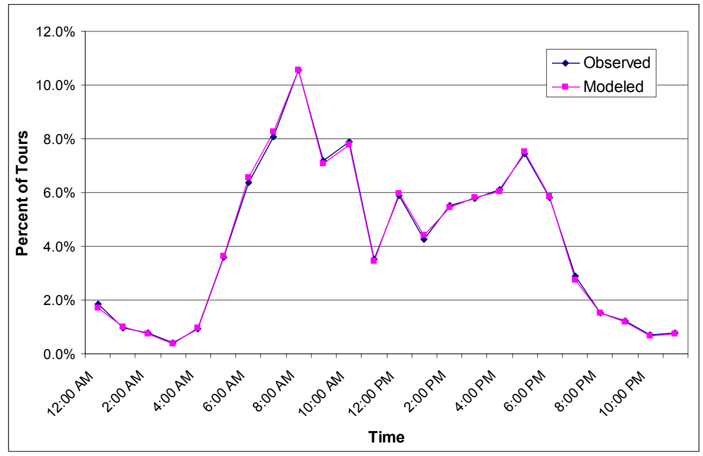
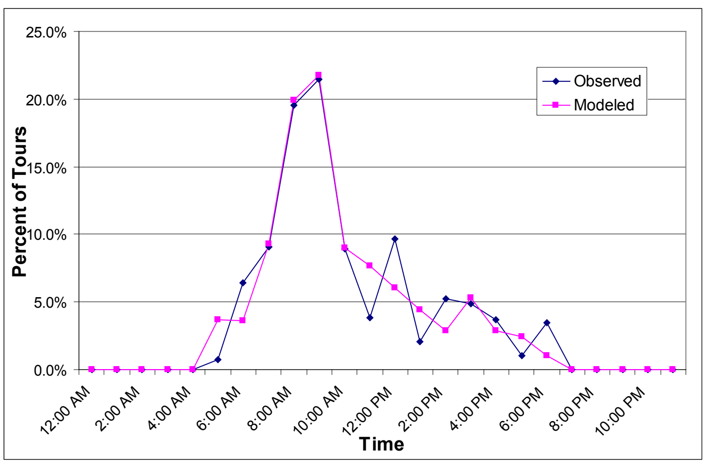


Figure 7.23 Departure Time for Complete Tours & Arrival Time for Complete Tours



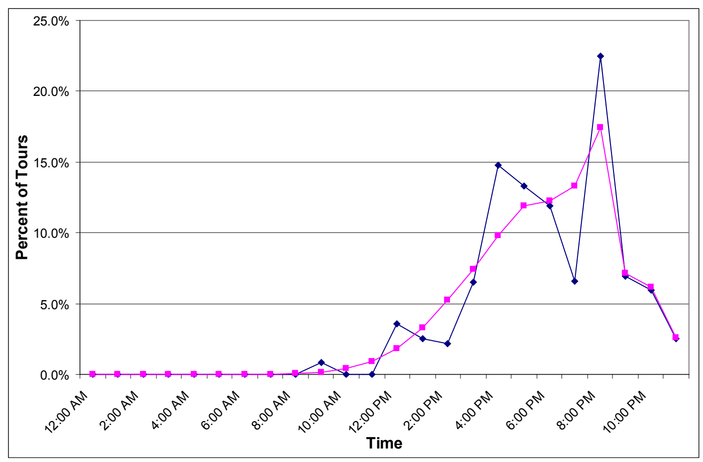
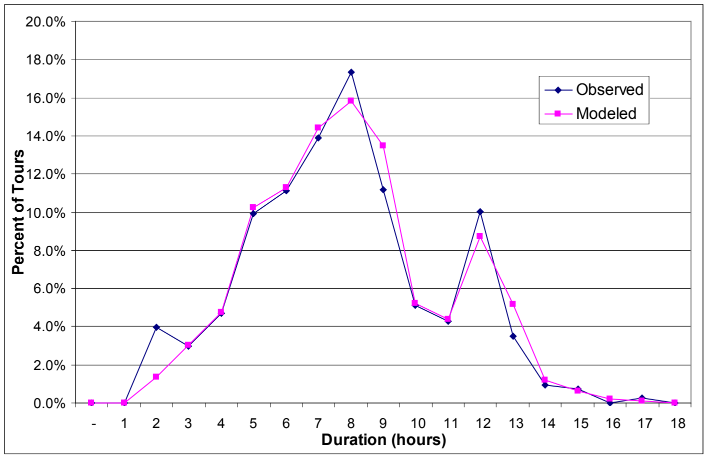


Figure 7.24 Duration for Complete Tours



Internal-External Choice

The LDT Internal-External choice models were calibrated to match the in-state versus out-of-state shares found in the 1995 American Travel Survey (ATS) for trips longer than 100 miles. Table 7.71 shows the model calibration results. Because the length of external trips is not known beyond the model area, all external trips are assumed to be longer than 100 miles for comparison to the ATS.

Table 7.71. Internal-External Model Calibration Results

Trips	Internal	External	Total
Modeled > 50 miles	185,323	90,402	275,725
Modeled > 100 miles	67,282	90,402	157,684
Observed > 100 miles	64,836	92,436	157,272
Difference	2,446	(2,034)	412
% Difference	4%	-2%	0%

Destination Choice

The LDT destination choice models are applied separately for internal versus external destinations. To calibrate the models, the distance flags were adjusted to properly match the number of trips in three distance bands: less than 60 miles, 60 to 70 miles, and 70 to 150 miles. The inclusion of these distance band constants allows the model to match the observed trip length distributions without modifying the mode choice logsum coefficients. The observed trip lengths and trip length distributions are taken from the Ohio data, because no such information is available in the ATS. If data becomes available that is specific to Oregon, these models can be recalibrated.

Table 7.72 shows the modeled and observed average trip lengths. Figures 7.25 and 7.26 show the modeled and observed trip length distributions by purpose. Due to relatively small sample sizes, the observed distributions are somewhat lumpy, but the models generally match those curves well.

Table 7.72. Average Trip Lengths of Tours with Internal Destinations

Household	Observed	Modeled	Difference
Begin & End Tours	131.4	165.0	33.6
Complete Tours	89.4	97.4	8.0
Total	101.3	116.5	15.2
Work Related	Observed	Modeled	Difference
Begin & End Tours	130.6	155.5	24.8
Complete Tours	90.8	98.9	8.1
Total	97.5	108.4	10.9
Other	Observed	Modeled	Difference
Begin & End Tours	126.8	114.0	-12.8
Complete Tours	92.1	92.7	0.6
Total	102.8	99.3	-3.5
All Trips	Observed	Modeled	Difference
Begin & End Tours	128.3	130.6	2.3
Complete Tours	91.2	94.9	3.8
Total	101.7	105.0	3.3

Figure 7.25 Trip Length Distribution of Household Tours with Internal Destinations

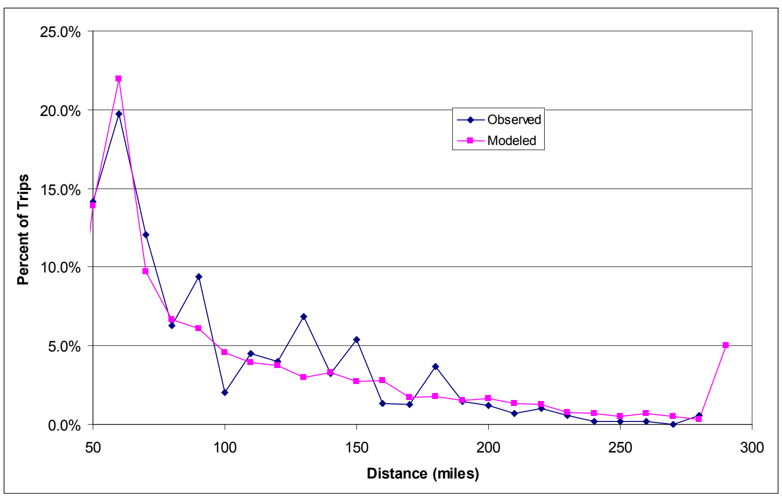
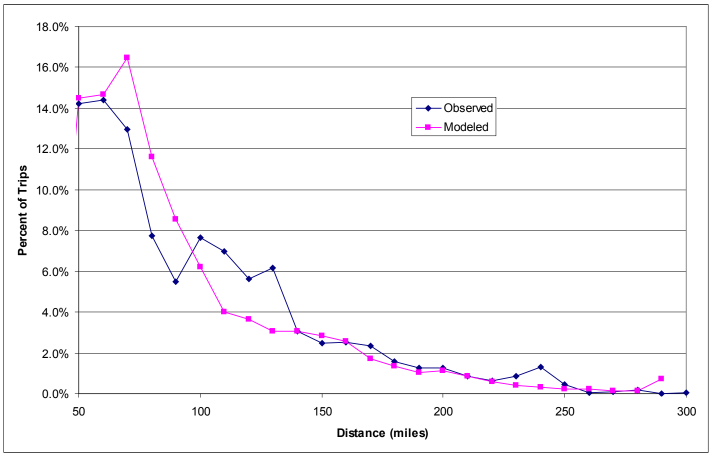
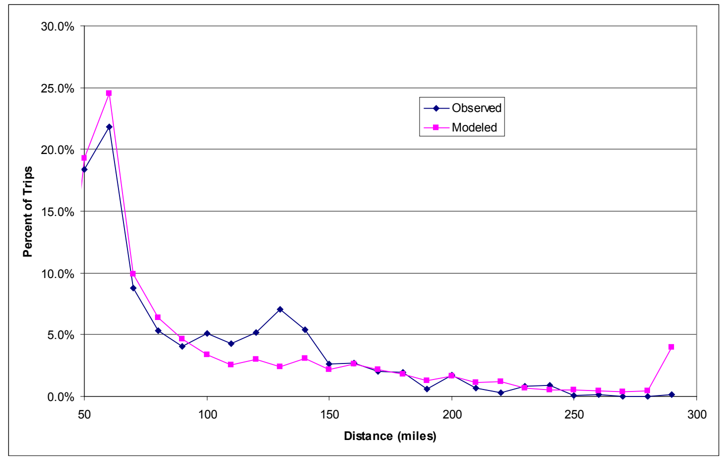


Figure 7.26 Trip Length Distribution of Work Related Tours with Internal & External Destinations





The modeled LDT external trips lengths do not compare well to the trip lengths observed in the Ohio survey, because they are truncated at the model boundary or External Station. Therefore, the average modeled trip lengths are shown in Table 7.73 with no evaluation against observed data.

Table 7.73. Average Modeled Trip Length for Tours with External Destinations

Household	Modeled
Begin & End Tours	172.0
Complete Tours	165.2
Total	170.2
Work Related	Modeled
Begin & End Tours	167.7
Complete Tours	167.2
Total	167.6
Other	Modeled
Begin & End Tours	160.5
Complete Tours	157.1
Total	159.2
All Trips	Modeled
Begin & End Tours	166.0
Complete Tours	160.9
Total	164.4

Mode Choice

The mode choice models were calibrated to match the auto versus non-auto shares observed in the 1995 American Travel Survey (ATS) for trips within Oregon. Unfortunately, inter-city transit and air skims are not available, so that calibration was not completed. For now, the air and transit alternatives are unavailable, such that all trips with internal destinations choose auto. This is a reasonable approximation because the observed data show 96% of long distance trips choosing auto. The current mode choice constants may change when the calibration is completed. Existing uncalibrated LDT mode choice outputs are shown in Table 7.74 by trip type.

Table 7.74. Mode Choice Calibration Results for Trips > 100 Miles

Observed	Internal	External	Total
Auto	62,256	51,652	113,908
Non-Auto	2,580	40,784	43,364
Total	64,836	92,436	157,272
Modeled	Internal	External	Total
Auto	67,282	50,458	117,740
Non-Auto	-	39,944	39,944
Total	67,282	90,402	157,684
Difference	Internal	External	Total
Auto	5,026	(1,194)	3,832
Non-Auto	(2,580)	(840)	(3,420)
Total	2,446	(2,034)	412
% Difference	Internal	External	Total
Auto	8%	-2%	3%
Non-Auto	-100%	-2%	-8%
Total	4%	-2%	0%

Auto Occupancy

During the calibration process, it was recognized as important to account for auto occupancy in order to get the number of auto vehicle trips correct. For work related and other tours, a simple model is applied to determine if an auto person trip becomes a vehicle trip by calculating the probability of being a vehicle trip as one divided by the average auto occupancy. For household tours, all household members travel together, so the auto occupancy is, by definition, the household size. Table 7.75 shows the modeled and observed auto occupancies. The modeled household tour auto occupancy is somewhat lower than the observed value, indicating that the average size of households traveling is lower in the model than in the survey data. This is not considered a major issue because the number of vehicle trips is still correct.

Table 7.75. Average Auto Occupancy

Observed	Internal	External	Total
Household	2.79	2.84	2.81
Work Related	1.21	1.27	1.22
Other	1.86	2.04	1.91
Modeled	Internal	External	Total
Household	2.24	2.26	2.25
Work Related	1.22	1.22	1.22
Other	1.91	1.91	1.91
Difference	Internal	External	Total
Household	-0.55	-0.58	-0.56
Work Related	0.01	-0.05	0.00
Other	0.05	-0.13	0.00

7.9. S3 Parameters

When the full Oregon Statewide Integrated Model (SWIM2) undergoes calibration, PT is largely assumed fixed. The one exception is the SDT Workplace Choice Model parameter, λ, which can be adjusted to reflect the calibrated PI labor flow inputs. Other parameters may be revisited, if warranted.

8.0 CT Module

The Commercial Transport (CT) module is a hybrid micro-simulation model of freight travel demand. Given commodity flow movements, the model attempts to replicate several freight travel choices made by different agents, especially trip linking and the use of intermediate distribution and warehousing centers. Inter-zonal flows (plus external zones) of production generated by the SWIM2 Production allocation and activity Interaction (PI) module are converted to discrete shipments by commodity and mode of transport. The shipments are further allocated to origins, destinations, intermediate stops, and vehicles. Vehicle tours are optimized to reduce total distance traveled.

The commercial transportation (CT) component translates the production and consumption flows into discrete shipments that can be assigned on a multimodal transportation network. The aggregate intersector commodity flows, output from the PI module, are expressed in constant 1990 annual dollar terms. The data produced by PI includes the transaction flows between different sectors (mapped to commodity) of the economy and final demand users. CT starts by decomposing the aggregate flows from the PI module into weekly flows by mode of transport, and from there into individual daily shipments. It then uses a micro simulation process to allocate them to individual vehicles for routing through the network. The program produces a list of truck tours by 5 vehicle types that can be read by the Transport Supply (TS) module for network assignment, as well as a summary of the annual truck ton flows and annual dollar flows by all modes. CT simulates individual shipments, which are allocated to explicit destinations. These shipments are grouped into tours on individual vehicles (either private or for-hire of various vehicle type), which are later assigned to a transportation network in the TS module.

The current implementation of this component is beset with several compromises. The lack of ideal data (or in some instances, any data) for model development required the synthesis of several parts. The current implementation assigns each economic flows a transport mode (truck, rail, air, water or pipeline) but only flows assigned to trucks are converted into weekly commodity flows, decomposed into discrete shipments, and organized into vehicle tours. Finally, the current implementation only addresses goods movement, leaving service and fleet travel for future work.

It should also be noted that CT currently allocates all internal flows and the bulk of inbound/outbound commodity flows generated by the PI module, resulting in a truck trip table for assignment in the TS module. The ET module (Section 9) adds through or external-external truck trips. However, one set of inbound/outbound PI commodity flows is not assigned in SWIM2. This is the trips to/from the local World Market 6006 (within 75 miles of the model area, see Figure 2.1). This market is estimated to cover roughly 4% of PI module's goods flows largely shipped by truck. If it is desirable to cover these flows in SWIM2, it is recommended that they be added to the CT module with a few adjustments (e.g., assuming truck mode only, skipping transshipment, and choosing the closest External Station).

8.1. Theoretical Basis

The literature on travel demand forecasting includes many approaches for the modeling of freight movements. Such models tend to fall into one of two categories: commodity flow models and truck travel models. The former have tended to be applied at the regional level, with explicit linkages to formal economic models. In almost all instances truck models have been applied at the urban scale, and formulated as analogues of the person travel models. While the four-step process used in truck models may still be viable for person travel forecasting, the case against them for freight models has long been evident to those who have tried to implement such models for urban goods movement. Several groups of actors influence freight transportation, many of whom have different goals and constraints: shippers, carriers, intermediaries, recipients, and regulators. [16] Attempting to model their different decision-making processes in a single aggregate treatment, often results in a poor approximation of each. Moreover, such models generally divide flows into different truck classes, and have no information about the commodities carried, and miss transshipment points and multiple delivery routing common in urban freight movement, particularly service trips. A journey or tour-based modeling approach is more appropriate for these complex trips.

Ideally the SWIM2 CT module will ultimately encompass both traditional goods movement and service trip types of freight movement. The current implementation of this component includes only goods movement. The framework however, can hopefully be extended in the future to include other trip purposes satisfied using commercial vehicles. A goal in the development of the SWIM2 CT module was to build upon the strengths of both commodity-based and truck trip models. An important secondary goal was to complement the level of detail associated with the person travel model, which is a micro simulation activity-based travel model. The approach described here is an unproven extension of more traditional uses of these techniques.

Micro simulation provides a tractable and accepted means of modeling behavioral patterns exhibiting high degrees of variability. It also excels at producing emergent behavior, which cannot be measured in the real world. The interaction between shippers and carriers is an excellent example of such emergent behavior, which are visualized as truck flows on the roadway network. Distributions of observed data from many different sources can be fused, even from different levels of spatial and temporal resolution, in order to produce robust simulations of freight activity. Combining these data into a single deterministic model would be difficult (if even possible) and would likely lead to unsatisfactory models. The implementation of CT described in this paper attempts to get around these limitations, making maximum use of scarce aggregate travel behavior data and simple decision rules.

8.2. Quantity Definitions and Categories

The CT module operates at two geographic levels within SWIM2. Alpha zones are the most detailed spatial representation, covering Oregon and the halo as well as 12 External Station zones that represent truck/rail "gateways" to the World Zones used by the PI module. In CT the alpha zones are used as the basis for assigning freight trip origin and destination locations. However, the PI module's inter-zonal commodity flows, input to the CT module, are at the more aggregate beta and World Zone level. The alpha and beta zones were previously shown in Figure 2.3, External Stations in Table 2.1 and Figure 2.2, and World Market Zones were previously defined in Table 2.2.

Freight commodities include 42 types of goods, based on Standard Classification of Transportable Goods (SCTG) classifications shown previously in Table 2.3 (as specified in [TransportableGoods.csv]). CT considers commercial goods transport on the freight modes previously shown in Table 2.7, although only truck movements are assigned to the transportation network. Table 8.1 shows attributes of the 5 truck categories currently in the CT module. Additionally, each simulated commercial vehicle tour is distinguished as either private, or for-hire.

Table 8.1. CT module Truck Categories and Attributes

Code	Truck Description	Gross Vehicle Weight (GVW)	Vehicle capacity (lbs)	Driver Shift Duration (min)	Pick-up Dwell Time (min)
TRK1	<34,000 lbs. (likely single-unit)	6,259	27,741	480	8.9
TRK2	34,000 -64,000 lbs.	17,427	46,573	660	10
TRK3	64,000 -80,000 lbs. (articulated)	20,785	59,215	660	45
TRK4	80,000 - 105,500 lbs. (articulated)	22,045	82,955	660	45
TRK5	>105,500 lbs. (articulated)	52,186	197,814	660	90

Note: Data in file VehicleTypeAttributes.csv
Note: ET considers TRK1-3 as Light and TRK4-5 as Heavy trucks.

8.3. Component Model Equations

The CT module is a multi-agent micro simulation of goods movement throughout the study area from the aggregate intersector annual dollar flows generated by the PI module. The incidence and extent of such flows are summarized by value and reported for five modes (Table 2.7), although only flows on truck mode are processed further. For trucks, the CT model generates converts annual dollar flows to weight (tons), and then into discrete daily shipments allocated to discrete vehicles of five weight-based types (Table 8.1) often in combination with other shipments. A portion of these shipments are simulated to flow through trans-shipment facilities, in effect splitting the shipment into two separate movements. An itinerary of the shipments for each vehicle are optimized (to include the final trip back to the origin), resulting in a daily tour that satisfies the operator and vehicle operating constraints (e.g., private vs. for hire, weight restrictions, driver shift durations, etc.). These ordered itineraries are converted to individual trips that are then assigned to the statewide network by the TS module.

The following Oregon Statewide Integrated Model (SWIM2) CT module components are detailed in the remainder of this section.

- Mode Choice (of annual commodity flow dollars)
- Value-density functions (1990$ to tons)
- Weekly Shipments
- Disaggregation of Trip Ends
- Attribution of trans-shipment location
- Truck itinerary generation and optimization
- Output Truck Trip File

8.3.1. Mode Choice

The goods flows output from the PI module are expressed in annual dollar flows between beta zone pairs; a separate matrix represents each commodity ([buying_SCTG##.zmx]) with production activities as origins and consumption activities as destinations.[27] CT first assigns a mode to the annual flow based on the type of commodity and the distance traveled. Annual flows traveling by truck are further condensed into daily shipments before beginning micro simulation. Mode choice is addressed first, followed by conversion from dollars to tons, as the value-density function (relationship of 1990$ per ton) varies considerably by mode.

The majority of zonal interchanges in the model are short (less than 20 miles) and thus are attributable to truck, the only mode able to efficiently serve these movements. A process for allocating longer shipments to alternate modes of transport was required. Because no disaggregate data are available to estimate a formal mode choice model, a Monte Carlo process was employed to allocate inter-zonal movements to specific modes.

The mode choice Monte Carlo sampling process draws heavily on commodity-specific mode distribution data from the 2002 Freight Analysis Framework (FAF2) summary tables. In the initial model development, the distribution data came from the 1997 US Commodity Flow Survey (CFS). In 2010, that data was replaced by FAF2, as it has Oregon-specific data. Although the underlying distribution of actual trip distances is unknown, most travel distributions for person or freight follow a log-normal distribution, such as a Gamma distribution. We used a triangular distribution approximation, constructed from the FAF2 data for each commodity. The parameters of the distribution are obtained from the FAF2 data or inferred from them. The minimum (a), maximum (b), and mean trip distances are found in the data, while the mode (c) is calculated from them. These parameters define the shape of the triangular distribution, which in most instances mimics the shape of a log-normal distribution. An example of how the triangular distributions were obtained for each mode and commodity is shown in Figure 8.1. This figure references the CFS since it was created for the initial design. The FAF2 update functions the same way. In some cases, particularly the air and water mode, the same distances were repeated multiple times in the dataset due to common origin/destination locations. In cases where the distance from the FAF2 was not reasonable (usually due to low observations), it was adjusted to match a similar commodity.

At this point flows in dollars by mode are optionally saved, one file per commodity ([DollarByModeFlow_SCTG##_mode.csv]).

In the future, it may be possible to utilize the mode split of the Oregon FHWA FAF dataset directly, rather than use a mode choice model. While this would provide more realistic mode choice in the reference run, it removes the limited distance-based sensitivity of the existing mode choice model formulation.

[27] Note that PI produces both selling and buying matrices representing flows from “producer” to an “exchange zone” (selling flows) and between the “exchange zone” and the “consumer” (buying flows). Ecause PI assumes tthat transport of goods is paid for by the buyer/consumer, the exchange zone is set to be the same as the seller/producer zone. Thus only the PI buying goods flows are used by CT. The selling flows (seller to exchange location) are simply intrazonal flows.

Figure 8.1. Modal Allocation Process

Mean trip distances by mode for each commodity are obtained from CFS

Known information from CFS97

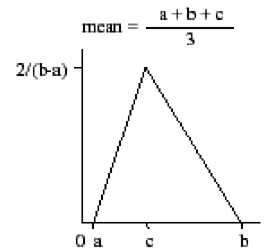
SCTG	Average trip distance (miles)			
	Truck	Rail	Air	Water
20 (Basic chemicals)	639	1641	2715	NS[a]

a. Not a significant share of the movements of this commodity.

With the mean as given (from Table above), the minimum and maximum distances are defined by the user. The mode of the distribution (c) is calculated.

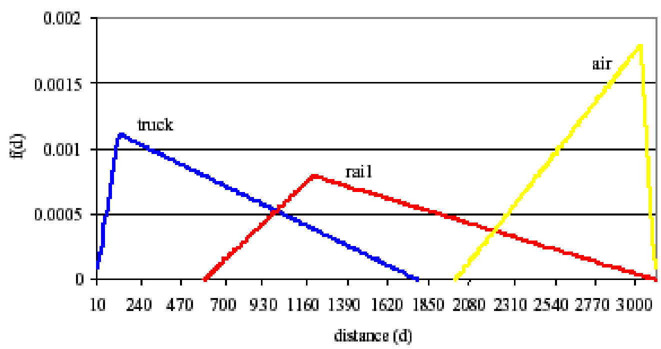
Synthesized distribution

Mode	a	b	mean	c
Truck	0	2700	639	125
Rail	600	3030	1641	1210
Air	2000	3030	2715	3030



The distributions from the center table are plotted. The height of the curve at any given distance is its relative probability of being chosen.

Overlaid distributions



8.3.2. Value-Density Functions

Once the mode has been chosen, the dollar flows from PI are translated into tonnages using value-density factors ([ValueDensityParameters.csv]). The value density factor was applied to the PI annual dollar flows to convert them into annual flows by weight (tonnage). The factor varied by direction of flow, allowing variation in the value of goods that flow inbound, outbound or internally within Oregon. This enables distinguishing a bit more finely less expensive raw materials from more expensive finished goods, although this is still diluted by the broad mix of goods within each SCTG commodity group. Additionally, as a result CT can be calibrated to overall commodity flows by direction.

Another component of the dollars to tons conversion is the use of a value-added factor. In addition to Value Density conversion, CT employs an additional factor to account for discrepancies between PI and CT commodity units. PI is based on BEA economic commodity information and the value of each commodity flow output by PT represents the price paid by the purchaser. As such, this price does not include mark-ups for wholesaling. As such, a ValueAdded factor by commodity was applied to expand the PI value to a market value flow. This factor also captures definitional differences and biases when comparing BEA-based PI economic flows to freight survey-based datasets (e.g., US CFS, FHWA FAF2 commodity flow).

8.3.3. Weekly Shipments

The annual tonnage flows are next translated into weekly flows by simply dividing the annual flows by 52 weeks. In the future, if warranted, a commodity-specific parameter could be used. The resulting three-dimensional matrix of weekly tonnage flows by origin, destination, and commodity for each mode are summarized and output in binary format for later use by the model [WeeklyDemand.bin].

The weekly tonnage flow matrix is adjusted to exclude extremely small flows. These very small flows are artifacts of the logit choice method employed in PI and exacerbated in the translation from annual dollars to weekly tons, but which are unlikely to occur in reality. All of the flows over a threshold value are retained and scaled upwards so that the resulting total matches the original matrix total for that commodity.

The weekly origin-destination flows are then translated into discrete weekly shipments by sampling from a distribution of observed shipment weights by commodity observed in previous ODOT truck surveys (specified in [CommodityProperties.csv]). Finally, each individual shipment is randomly assigned to ship on the model day or not. The flows that ship on the model day are carried forward for further processing by the model [DailyShipments.csv] in pounds. This list of individual daily truck shipments is the starting point for the micro simulation trip-building portion of the CT module.

8.3.4. Disaggregation of Trip Ends

CT truck trips are assigned to Alpha zone origins and destinations. Thus, the original internal Beta zone flows from the PI module must be allocated among the candidate internal Alpha zones within each Beta zone. In addition, the PI module produces flows between external World Market zones and internal Beta zones and vice versa. The allocation process is slightly different as the World Market zones are abstractions that represent large markets outside the model area. The flows going to/from these markets use the external stations surrounding the Oregon study area as access to the model area. Thus the flows to/from the World Market zones have one end that is assigned to one of the 12 External Station zones.

Internal Flows: The process for allocating the origin and destination zones for each commodity flow involves choosing an Alpha zone within each Beta zone based on the relative activity intensity of each Alpha zone for the industry group associated with that commodity. The initial implementation ignores the commodity-industry association and instead relies upon the land use intensities, a combined population/employment measure, defined in Section 6.7.1 [28]

The current land use intensity zonal attribute (from [alpha2beta.csv]) is translated into a numeric value and weighted by the Alpha zone area. This forms a mapping table (Alpha zone columns, Beta zone rows). This mapping is normalized within each Beta zone (row), calculating its cumulative value (i.e., the last non-zero entry equals 1.0). Then, each time an Alpha zone is requested, a random number is chosen to determine the Alpha zone within the cumulative Beta zone distribution to assign the specific shipment origin or destination.

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[28] Future implementations could use PI activity by sector and Alpha zone (using the primary sector producing each commodity in FloorspaceZoneTotalMakeUse.csv) to weight the intensity of the alpha zones within each Beta zone and thus identify an appropriate Alpha zone origin or destination for each commodity shipment.

Internal to/from World Market Flows: In the case of exported commodities, where the origin is an internal Beta zone and the destination is a World Market zone, the origin Alpha zone is chosen based on the internal flows procedure discussed above. The destination zone however is determined based on the shortest distance between that Alpha zone and the World Market zone through an External Station that connects to this market (i.e. Distance = Alpha zone-to-External Station + External Station-to-World Market zone.). The distance between Alpha zones and External Station zones is found by distance skims of the SWIM2 network, produced by the TS module, while the distance between the External Station zones and the World Market Zones is determined based on an exogenous table [WorldZoneExternalStationDistances.csv] used by multiple SWIM2 modules.

In the reverse import commodity situation (World Market to Internal Zone), in order to know which external station the shipment will arrive at, it is necessary to first know the Alpha zone destination. Therefore, the internal destination is chosen first using the internal flow procedure and then the External Station origin is determined based on the shortest distance from the Alpha zone to the World Market zone origin through the appropriate External Station.

8.3.5. Attribution of Trans-shipment Location

Many commercial goods shipments often have an intermediate stop at a trans-shipment facility (TF), such as a warehouse and distribution center, break-bulk and reload facility, or truck and inter-modal terminal. In the CT module, a stop at a trans-shipment point is generated for randomly selected trips. Distance limitations, imply that trans-shipment activity occurs primarily in the import/export commodity flows, with only limited transshipment occurring on internal model flows.

The probability of passing through a trans-shipment point is modeled as a function of the commodity and trip distance using the following equations:

$$P_{TF} = P_c * P_d \quad (8.01)$$

$$P_d = \tanh(0.01d) \quad (8.02)$$

where:

P_{TF} = Trans-shipment probability

P_c = Commodity-based trans-shipment probability component

P_d = Distance-based trans-shipment probability component

d = origin-destination shipment distance

The commodity-based probability component (P_c) and the hyperbolic tangent distance-based probability component (P_d) are exogenously supplied. When used as a multiplicative probability ($P_c \times P_d$) the effect of including P_d is simply to filter the trips eligible to make a TF stop. Each origin-destination commodity flow from the PI module is evaluated for trans-shipment. If the P_{TF} probability exceeds a randomly drawn number ($0 \leq r \leq 1$) a trans-shipment stop is made.

In instances where a TF stop is made the shipment is split into two independent shipments, with the first coded from the origin to the TF facility, and the second from TF facility to the destination. Thus there will be two records in the output file ([DailyShipments.csv]), the first showing the shipment from the origin zone to the trans-shipment facility's zone and the second showing the trip from the trans-shipment facility's zone to the destination zone.[29] The practical effect of splitting a shipment with a TF stop into two separate shipments is that it allows a change in vehicle and carrier type, which has been observed in the few published studies of TF operations applicable at this scale [15][28]

Lacking information about transshipment facility locations in the model area and moreover, which of these facilities would be more likely to handle any given commodity or vehicle type than another, the CT module chooses a transshipment location at the destination Beta zone, which may or may not match the destination Alpha Zone (see Section 8.3.4). Thus 2 trips are created, one from the origin to the destination Alpha zone, and a second more local trip between the transshipment and the destination Alpha zone, within the same Beta Zone.[30]

8.3.6. Truck Itinerary Generation and Optimization

The list of individual truck shipments by commodity are assembled into truck itineraries. Shipments are then sorted in origin, commodity, and destination order.

Carrier Type. All shipments from a given origin are first assigned a carrier type (private or for-hire) using a Monte Carlo process. The commodity-specific private carrier share is exogenously provided [CommodityProperties.csv]. All shipments for a given origin and commodity are assumed to have a consistent carrier type, i.e., private or for-hire. We assume that an Alpha zone contains one or more shippers of a given commodity whose choice of carrier and vehicle type are identical. This is a plausible approach because we do not know whether the employment within the zone comes from a single large establishment or many smaller ones. It would imply that two or more firms within an Alpha zone would be unlikely to have different transportation options available to them. Only for-hire carriers are required to return to their base at the end of the tour.

Vehicle Type. A vehicle type is then selected for the first shipment in the list based on the commodity type. Commodity specific vehicle type probabilities are exogenously provided ([CommodityProperties.csv]) and a Monte Carlo process is used to make this selection.

Truck Itinerary. At this point truck itineraries can begin to be assembled. The process for handling shipments on private trucks is simple. Shipments from each origin are loaded onto a truck until its average payload weight is reached, and onto additional trucks as needed. Average payload is provided exogenously.

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[29] In the case of an exported shipment traveling from inside the model area to a World Market through an External Station, many if not all of these shipments will be trans-shipped but the trans-shipment facility will be located at the destination end which is beyond the model area. Therefore in the trip file, although this record would be marked as trans-shipped there would only be a single record that records the internal origin and external destination.

[30] In the future, the candidate transshipment facility methodology could be more complex, such as constrained within a certain distance of the destination zone ([CommodityProperties.csv]), with further choice of transshipment zone based on the presences of a designated facility with the appropriate attributes (e.g., size/capacity, vehicles types and commodities served). Such data might be obtained from ODOT's Inter-modal Management System (IMS) augmented by further data collection (e.g., GIS aerial photo analysis). Such data and software changes would be required to implement such an approach.

The process for handling for-hire carriers is more complex, in that for-hire tours can accept shipments from more than one origin zone. At the first origin zone, for-hire trucks are loaded in the same manner described for private trucks. However, any for-hire truck not filled to capacity is tagged as 'available' and placed in a list of available partially filled trucks. For all subsequent for-hire shipments, the closest truck within a user-specified range (currently one mile) with capacity greater than or equal to the shipment size is selected for carriage. Shipments are added to this truck until all for-hire shipments from the origin are accommodated or until the vehicle reaches capacity. If the vehicle reaches capacity the search for another 'available' vehicle is repeated. In the event that a for-hire truck with adequate capacity is not found within the specified search radius a new empty for-hire truck is created and filled with the shipment(s), and placed in the 'available' list as appropriate.

The model also imposes an additional constraint on the for-hire vehicle selection. Each vehicle is only allowed to handle a **maximum number of pickups**. The result is that many do not fill to capacity before becoming ineligible to add additional shipments. This is a common occurrence in the LTL industry, making this plausible behavior to add to the model.

Before a shipment is added to a vehicle, the vehicle must not only be able to hold the total weight of the shipment(s), but also must not exceed the **driver shift duration limit**. A vehicle's travel time is updated with each shipment to include the travel time to the new shipment, the dwell time of the pickup activity, as well as the resulting travel time to the final destination. The travel times are estimated using the congested off-peak period travel time matrices for the previous model period, an output of the TS module.

Departure Time. At the end of this step all of the shipments are assigned to itineraries on specific vehicles. A departure time is assigned to the first departure, based upon a verage time-of-day distributions from various truck types provided exogenously. The departure times for subsequent legs in the itinerary are obtained by adding the dwell and travel times for that leg to the previous departure time. Note that this is not an attempt to replicate a true departure time choice model. Rather, it is a simple attempt to place each leg of the itinerary within an appropriate time period for assignment within the TS module.

Itinerary Optimization. The shipment list is next sorted by vehicle identifier (i.e., a specific truck itinerary). Each vehicle carries one or more shipments, each possibly having a different destination. Each destination is coded as a stop in a tour that will serve all destinations for that specific vehicle in sequence. For-hire trucks that pick up loads from more than one zone will also have stops coded for the additional origins.

The optimal itinerary that minimizes the total distance traveled is selected. A classical traveling salesman problem (TSP) algorithm is used to generate the solution, in which each stop is considered a city in the classical TSP literature. The algorithm employed in the model follows the traditional solution, in that it automatically returns all for-hire vehicles to the origin after the last stop, solving the problem of the empty backhaul. More complex routing methods, such as the vehicle routing problem with backhauls (VRPB) suggested by Mingozzi, et al. [24] were investigated but did not appear to offer significant advantages over the TSP solution.

At this point, the trips with their optimized itinerary and associated attributes are written to an output file [Trips_CTTruck.csv] used in TS assignment. The planned times and routing (distance) assumed in this file may be adjusted due to congestion or other issues during assignment to the network in the TS module.

8.4. Software Implementation

The CT module is implemented as a Java application. Separate classes are used for the different agents in the simulation: matrices, shipments, establishments (including trans-shipment facilities), vehicles, and itineraries. The program produces an ordered list of vehicle itineraries in a format that can be directly read by the TS module. Separate programs have been written in the R statistical language and Statistical Analysis System (SAS) to assist in the analysis and summarization of the itineraries. The current version of the program uses a geometric Traveling Salesman Problem solution algorithm described in Daellenbach, et al. [22]

The CT module runs after the PI module in each model year. When CT finishes, it feeds results to the TS module for network routing/assignment during that model year. Data appropriate to the model specification is read-in from current year data specified for CT, or from other modules. Estimates for the current model year are written to the tn output folder for use by other components and CT signals to the model controller (AO) when its operations are complete. All of the memory used by the CT component is then freed for use by other modules during the rest of the model year's computations. The work of program is accomplished primarily through three Java classes:

- Freight Demand3 – Reads PI annual commodity flow files, assigns demand to mode, converts annual truck dollars to tons, and creates weekly Beta zone flows. Outputs include annual flows by mode in dollars [DollarByModeFlow_SCTG##_{mode}.csv] and weekly shipments in tons [WeeklyDemand.bin].
- DiscreteShipments2 – Creates discrete truck shipments, allocates origins and destinations to alpha zones and External Stations, adds trans-shipment locations, and writes output in pounds [Daily Shipments.csv].
- TruckTours4 – Reads individual truck shipments, assigns carrier and truck type, adds shipments to fill vehicle capacity (subject to truck weight limit, driver shift duration, and maximum number of stops constraints), sorts and optimizes itineraries, and writes trip data in TS format, including payload weight in tons [Trips_CTTruck.csv]

8.5. S1 and S2 Module Parameters

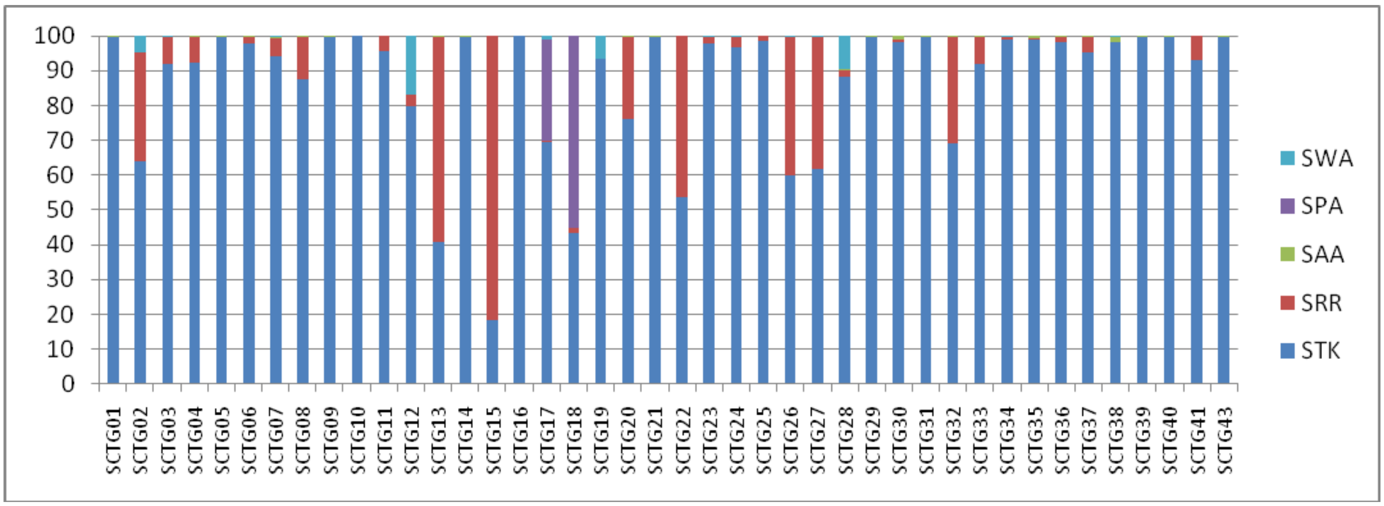
The CT module requires a set of parameters that are discussed in this section.

8.5.1. Modal Choice Parameters

The mode choice allocation for goods transport in the CT module employs a commodity-specific Monte Carlo sampling process. Initially summary trip length data tables from the 1997 US Commodity Flow Survey (CFS) were used. In 2010, these relationships were updated to utilize FHWA Freight Analysis Framework (FAF2), which provides a more comprehensive commodity O-D flow dataset. These relationships were used to define the mode choice distribution for sampling. Longer trips were generally more likely to travel by rail than by truck, although the distance at which rail began to capture a significant modal share varied widely by commodity. For trips that extend beyond the model area, a fixed distance to the PI World Market is assumed in addition to the internal distance traveled to reach the closest external station. As a result, the probability for non-truck modes increases for these longer trips.

As discussed in Section 8.3.1, a triangular distribution was used to approximate the likely relationship. The parameters of the distribution are much simpler to estimate, and yield intuitively sensible results. The distribution parameters are taken from the 2002 FAF2 data for Oregon (replacing initial use of 1997 US CFS Table 1a data). Table 8.2 shows how the distance distributions are applied (minimum and maximum are the a and b in Figure 8.1). The implied mode split using these data are shown in Figure 8.2.

Figure 8.2. Implied Commodity-specific Mode Split (percent)



Data specified in [ModalDistributionParameters.csv]
Source: 2002 FHWA FAF2 Oregon Commodity Flow data.

Table 8.2. Commodity-specific Mode Choice Parameters (Mean, Min, Max Distance)

	SAA			SPA			SRR			STK			SWA		
	mean	min	max	mean	min	max	mean	min	max	mean	min	max	mean	min	max
SCTG01	6003	1474	7000							96	0	1284			
SCTG02							761	168	1584	209	0	1126	4610	135	14000
SCTG03	6445	1474	7000				1213	138	2212	260	0	2529	168	168	168
SCTG04	6009	1474	7000	0	0	0	889	138	1036	227	0	2296	0	0	0
SCTG05	5919	1474	7000				0	0	0	658	0	2411	0	0	0
SCTG06	6298	1474	7000				1133	933	1845	255	0	2403	0	0	0
SCTG07	6254	1474	7000	0	0	0	853	136	2262	458	0	2529	499	499	499
SCTG08	6354	1474	7000				799	491	1848	277	0	2411	0	0	0
SCTG09	4967	1474	5405							167	0	2296	0	0	0
SCTG10	0	0	0				0	0	0	127	0	395			
SCTG11	0	0	0				630	275	2182	275	0	1668	0	0	0
SCTG12	0	0	0				681	9	1496	98	0	2200	171	9	224
SCTG13	6423	1474	7000	0	0	0	637	554	2146	324	0	2146	0	0	0
SCTG14	4968	1474	5405	0	0	0	0	0	0	775	0	1746	0	0	0
SCTG15				0	0	0	637	168	1794	379	0	2296	0	0	0
SCTG16	0	0	0				0	0	0	92	0	395	0	0	0
SCTG17	0	0	0	168	168	168	37	32	42	155	0	770	220	168	1700
SCTG18	0	0	0	148	9	224	1432	224	1608	117	0	1845	0	0	0
SCTG19	4967	1474	5405				0	0	0	100	0	395	9	9	9
SCTG20	6280	1474	7000				777	23	1974	373	0	2390	0	0	0
SCTG21	289	97	7000				0	0	0	339	0	2529	0	0	0
SCTG22	4967	1474	5405				1027	224	1538	363	0	1852	0	0	0
SCTG23	6115	1474	7000	0	0	0	1718	275	2411	339	0	2390	6854	1474	7000
SCTG24	5761	1474	7000				1696	1286	2155	876	0	2529	2463	2463	2463
SCTG25	0	0	0				225	224	2220	166	0	2155	0	0	0
SCTG26	5152	1474	7000				1143	14	2411	370	0	2403	1331	168	10000
SCTG27	4968	1474	5405				651	9	2287	445	0	2403	1359	9	7000
SCTG28	6207	1474	7000				927	325	2133	310	0	2529	1818	9	14000
SCTG29	6035	1474	7000				1628	1628	1628	782	0	2529	0	0	0
SCTG30	5818	97	7000				1882	1879	2162	676	0	2529	0	0	0
SCTG31	5276	1474	7000				1545	454	2213	112	0	2345	0	0	0
SCTG32	5229	1474	7000				940	9	2287	682	0	2390	0	0	0
SCTG33	6247	1474	7000				497	417	1384	356	0	2507	0	0	0
SCTG34	5478	97	7000				460	14	2232	382	0	2529	2516	2516	2516
SCTG35	5670	1474	7000				2132	2132	2132	743	0	2529	0	0	0
SCTG36	5009	97	7000				1332	468	1879	887	0	2464	0	0	0
SCTG37	5687	1474	7000				1600	1384	1626	300	0	2411	0	0	0
SCTG38	4838	97	7000				0	0	0	686	0	2529	728	728	728
SCTG39	6169	1474	7000				2057	2057	2057	586	0	2529	0	0	0
SCTG40	4490	97	7000				539	9	1894	507	0	2529	0	0	0

Data specified in [ModalDistributionParameters.csv]
Source: 2002 FHWA FAF2 Oregon Commodity Flow dataset (some adjustments due to data limitations).

8.5.2. Value-Density Parameters

Within CT, value density factors were used to convert annual dollar interzonal commodity flows, from the PI module, into tons of goods shipped. The value density factors, one for each mode-commodity combination, were derived from the 2002 FHWA FAF2 Oregon Commodity Flow dataset. These data report commodity flows between 114 US FAF zones (and 7 international zones) in value and weight of goods shipped for each of the SCTG commodities. As such, the data could be distinguished by direction of flow: inbound, outbound, and internal to Oregon. The value-density factors were calculated by dividing the FAF2 dollar flows by the FAF2 tonnage flows. Only flows that had at least one end in Oregon were used, and the factors are applied directionally. The calculated factors were then calibrated so that the CT tonnage flows in the calibration year would more closely align with the FAF2 flows.

The estimated value density factors by value are listed in Table 8.3. The first column shows the values calculated directly from the FAF2 Oregon data. These values were deflated to 1990 dollars using ED module US GDP deflators, to be consistent with other Oregon Statewide Integrated Model (SWIM2) components. The second column exhibits the values required in calibration to match the FHWA FAF2 flows by direction.

As noted in section 8.3.2, a Value-Added factor was also applied to the PI flows to convert from purchaser value to market value, as well as accommodate definitional issues and biases in the different PI-CT datasets. These values represent the conversion of from SWIM2 PI annual dollar flows by commodity (internal Oregon flows only) to values that match the FAF2 dataset. The value is applied to the PI flows before the value-density factor. These values represent the difference in value added, i.e., retail price versus SWIM2 purchaser price (some goods are marked up while others are sold at a discount), definitional issues between the BEA-based economic dataset in PI and the surveyed data sources in FAF, as well as the uncertainty introduced in trying to reconcile these two datasets (e.g., application of FAF mode split to PI data, and use of 2002 PI data, 4 years beyond the 1998 calibration year). The resulting Value Added factors are also shown in Table 8.3. Overall, these values show more variation that would be desirable. However, it does enable the resulting PI flows used in CT to match the FAF dataset.

SCTG41 in the SWIM model is a catchall for non-spatial monetary flows (e.g., farm subsidies, etc.). SCTG41 should not be used in the SWIM CT module since 33% of this commodity flow represents aspatial monetary flows.

Table 8.3. Truck Value Density Function (1990$/ton) and Value Added Factor

Commodity	Value Added Factor	VDF - Original FAF2			VDF - Calibrated		
		Outbound	Inbound	Internal	Outbound	Inbound	Internal
SCTG01	2.64	95	158	92	810	2,821	760
SCTG02	1.02	7	5	4	101	56	3
SCTG03	2.13	79	83	38	5,618	759	147
SCTG04	1.64	20	37	14	1,357	1,269	7
SCTG05	1.22	184	202	257	7,172	1,328	374
SCTG06	2.1	82	88	88	879	2,152	229
SCTG07	0.72	69	89	95	4,267	611	86
SCTG08	1.66	98	66	88	3,855	2,599	52
SCTG09	1.51	1,836	2,959	1,714	222	161,307	32
SCTG10	0.07	16	16	16	37	113	5
SCTG11	1.05	0	1	1	66	3	1
SCTG12	3.21	1	1	1	16	11	4
SCTG13	2.87	4	11	10	254	75	2
SCTG14	0.35	16	18	176	17,188	86	112
SCTG15	0.002	1	1	1	5	14	4
SCTG16	0.25	0	38	12	0.25	0.27	15
SCTG17	6.15	24	29	26	6	2	450
SCTG18	5.2	18	25	33	5	2	777
SCTG19	2.8	15	33	15	13	930	27
SCTG20	1.08	32	49	47	376	1,924	45
SCTG21	1.76	158	747	1,219	1,899	60,103	383
SCTG22	3.33	13	16	12	1,019	525	42
SCTG23	15.33	164	272	80	23,539	36,706	286
SCTG24	1.02	185	205	316	20,086	3,551	45
SCTG25	0.43	4	5	2	93	68	20
SCTG26	3.61	47	47	47	3,360	477	137
SCTG27	7.3	79	39	75	8,472	829	54
SCTG28	1.1	120	114	134	26,492	3,094	65
SCTG29	0.95	243	243	332	19,700	3,472	192
SCTG30	4.07	829	553	891	11,907	28,421	1,962
SCTG31	1.35	11	76	6	175	1,092	24
SCTG32	4.7	79	132	77	31,416	4,271	34
SCTG33	0.92	237	229	171	8,268	2,780	186
SCTG34	23.55	752	1027	511	115,473	37,288	9,148
SCTG35	0.44	1343	1106	3191	166,224	18,015	2,206
SCTG36	1.62	445	468	443	47,846	10,373	793
SCTG37	1.45	446	395	293	13,152	5,862	42
SCTG38	0.35	742	513	1169	87,736	10,320	5,175
SCTG39	1.36	105	196	292	1,070	4,132	564
SCTG40	1.66	296	423	175	8,136	6,139	54

Data specified in [ValueDensityParameters.csv]
VDF Source: 2002 FHWA FAF2 Oregon Commodity Flow dataset.
Value Added source: FAF2 and PI Flows for Oregon internal-internal flows. PI flows based on SCEN_**

8.5.3. Weekly Shipment Parameters

The annual truck tonnage flows are further condensed to weekly flows and ultimately to individual daily shipments. Weekly shipments are simply annual flows divided by 52 weeks. A cursory review of the Surface Transportation Board Rail Waybill Sample data for Class 1 rail shipments (including month of shipment) was made to assess underlying trends in seasonality. The review found that most commodities do not experience a significant peaking factor, with notable exceptions in agriculture, raw foods, and timber. And imports of these commodities during off seasons, dampens the seasonality for all but the raw producers. This factor will be monitored and may be adjusted during calibration.

In the scaling of less than threshold flows from the resulting weekly flow matrix, a minimum shipment size by commodity is specified, as shown in Table 8.3c. In calibration, a commodity specific factor (rather than an initial single value for all commodities) was found to be necessary. The 'original' values in Table 8.4 are primarily based on the analysis of the 2007 Port of Portland Truck Intercept and Terminal Survey and the Oregon 1997 truck intercept survey. During calibration, these values were adjusted to match the observed truck counts. The resulting calibrated shipment sizes are shown in the second column. In theory, truck trips within the urban area might be more likely to carry a smaller load and deliver smaller shipments to more destinations. For example, some commodities might be called out separately for lower minimum payload. Since there was no data to identify these commodities, nor to identify the alternative urban minimum shipment size value to use, this was not implemented, but could be considered should data become available in the future or issues surface with too few urban truck movements.

Table 8.4. Truck Minimum Shipment Size (tons)

Commodity	Original	Calibrated
SCTG01	0.100	3.375
SCTG02	0.100	3.375
SCTG03	0.100	3.375
SCTG04	0.100	3.375
SCTG05	0.100	3.375
SCTG06	0.100	3.375
SCTG07	0.100	3.375
SCTG08	0.100	3.375
SCTG09	0.100	2.667
SCTG10	0.100	3.375
SCTG11	0.100	3.375
SCTG12	0.100	3.375
SCTG13	0.200	6.75
SCTG14	0.225	7.594
SCTG15	0.225	7.594
SCTG16*	0.225	7.594
SCTG17	0.225	7.594
SCTG18	0.225	7.594
SCTG19	0.225	7.594
SCTG20	0.038	1.266
SCTG21	0.038	1.266

Commodity	Original	Calibrated
SCTG22	0.038	1.266
SCTG23	0.038	1.266
SCTG24	0.038	1.266
SCTG25	0.050	1.688
SCTG26	0.100	3.375
SCTG27	0.450	15.188
SCTG28	0.050	1.688
SCTG29	0.100	3.375
SCTG30	0.150	5.063
SCTG31	0.200	6.750
SCTG32	0.100	3.375
SCTG33	0.225	7.594
SCTG34	0.050	1.688
SCTG35	0.050	1.688
SCTG36	0.350	11.813
SCTG37	0.100	3.375
SCTG38	0.200	6.750
SCTG39	0.050	1.688
SCTG40	0.200	6.750

Data specified in [ValueDensityParameters.csv]

Source: 1997 ODOT Truck Intercept Survey, 2007 Port of Portland Truck Intercept and Terminal Survey

CT samples individual shipments sizes from commodity-specific shipment sizes distributions, defined (by average and maximum values) in Table 8.5. These values are derived from the 1997 CFS data for all states (Table 6 in the CFS summaries). The average size was adjusted in 2010 so that it is 2/3 of the CFS maximum. That is because in the model function, the maximum is calculated as 1.5 times the average. The averages were therefore adjusted up so that the maximum shipment size could be reached.

A weekly –to-daily factor by commodity is used to identify whether the individual shipment will occur on the modeled day. A threshold of 16.7% is assumed for all commodities as shown in Table 8.4.

Table 8.5. Individual Shipment Parameters

Commodity		Individual Shipment Size (lbs) Ave	Max	Threshold (%)	Private Carrier Prob (00%)	Trans-shipment P_c (00%)	Proximity (miles)
SCTG01	Animals+fish	20,441	30,662	0.167	0.406	0.398	5
SCTG02	Cereal grains	20,441	30,662	0.167	0.338	0.434	5
SCTG03	Other ag prod	20,441	30,662	0.167	0.313	0.398	5
SCTG04	Animal feed	20,441	30,662	0.167	0.870	0.398	5
SCTG05	Meat+seafood	55,888	83,832	0.167	0.850	0.249	5
SCTG06	Grain+bakery	55,888	83,832	0.167	0.881	0.249	5
SCTG07	Other foods	55,888	83,832	0.167	0.628	0.249	5
SCTG08	Alcoholic bev	55,888	83,832	0.167	0.669	0.249	5
SCTG09	Tobacco prod	5,333	8,000	0.167	0.742	0.249	5
SCTG10	Building stone	47,917	71,876	0.167	0.483	0.137	5
SCTG11	Natural sands	51,793	77,690	0.167	0.930	0.137	5
SCTG12	Gravel	51,793	77,690	0.167	0.775	0.137	5
SCTG13	Nonmet minerals	51,793	77,690	0.167	0.547	0.137	5
SCTG14	Metallic ores	25,968	38,952	0.167	0.143	0.249	5
SCTG15	Coal	23,433	35,150	0.167	0.219	0.192	5
SCTG16	Naural gas+crude	45,900	68,850	0.167	0.903	0.192	5
SCTG17	Gasoline+fuel	45,900	68,850	0.167	0.903	0.192	5
SCTG18	Fuel oils	45,900	68,850	0.167	0.923	0.192	5
SCTG19	Coal+petr prod	45,900	68,850	0.167	0.452	0.249	5
SCTG20	Basic chemicals	51,155	76,732	0.167	0.431	0.334	5
SCTG21	Pharmaceuticals	51,155	76,732	0.167	0.771	0.334	5
SCTG22	Fertilizers	51,155	76,732	0.167	0.843	0.334	5
SCTG23	Chemical prod	51,155	76,732	0.167	0.583	0.334	5
SCTG24	Plastics+rubber	43,751	65,627	0.167	0.365	0.249	5
SCTG25	Raw wood	56,063	84,094	0.167	0.445	0.240	5
SCTG26	Wood prod	56,063	84,094	0.167	0.196	0.240	5
SCTG27	Pulp+paper	51,960	77,940	0.167	0.141	0.249	5
SCTG28	Paper prod	51,960	77,940	0.167	0.313	0.249	5
SCTG29	Printed prod	38,388	57,582	0.167	0.561	0.199	5
SCTG30	Textile+leather	19,079	28,618	0.167	0.439	0.240	5
SCTG31	Nonmet min prod	51,793	77,690	0.167	0.867	0.249	5
SCTG32	Basic metals	43,911	65,867	0.167	0.392	0.212	5
SCTG33	Metal articles	44,565	66,848	0.167	0.340	0.212	5
SCTG34	Machinery	57,097	85,646	0.167	0.436	0.199	5
SCTG35	Electronics	45,621	68,432	0.167	0.487	0.199	5
SCTG36	Vehicles	46,433	69,650	0.167	0.390	0.199	5
SCTG37	Transport equip	46,433	69,650	0.167	0.334	0.199	5
SCTG38	Precision goods	46,311	69,467	0.167	0.050	0.199	5
SCTG39	Furniture+lights	38,967	58,450	0.167	0.427	0.284	5
SCTG40	Misc mfg prod	52,317	78,476	0.167	0.562	0.249	5
SCTG41	Waste+scrap	44,256	66,384	0.167	0.454	0.249	5
SCTG43**	Mixed freight	21,757	32,636	0.167	0.873	0.249	5

Data specified in [CommodityProperties.csv]
Sources: Transshipment -1999-2000 Canadian National Roadside Survey, else 1997 US CFS.
* SCTG16, unavailable in US CFS is assumed have the same attributes as SCTG17
** Not used in SWIM2, despite inclusion in US CFS

8.5.4. Disaggregation of Trip ends

Disaggregation of trip ends from Beta and World Zones to Alpha and External Station zones depends on inputs of Alpha Zone land use intensity attribute (see Section 8.6.4), distance skims and distance to world markets. No parameters are used.

8.5.5. Trans-shipment parameters

Trans-shipment probability in Equations 8.01 and 8.02 is exogenously provided. The commodity-specific probability of trans-shipment component (P_c) value is shown above in Table 8.5 (and file [CommodityProperties.csv]). The parameter was derived from the 1999-2000 Canadian National Roadside Survey (original data shown below in Table 8.6), [25] a nationwide intercept survey of trucks conducted at 243 locations across Canada, and ranges from 14 to 43 percent. The land use at the trip destination was coded, with terminals, warehousing, and distribution centers as some of the choices. The probabilities shown in Table 8.6 represent the percentage of trips in each commodity group destined for such facilities.

The distance-based term (P_d) is specified as a hyperbolic tangent, which results in a low probability of a TF stop for trips under 50 miles and a high probability for trips longer than that, with trips greater than 300 miles assigned a probability of 1.0.

Table 8.6. Facility type at the trip destination from the 1999 Canadian NRS[a]

SCTG group	Description	Percent of trip destinations[b]			
		Terminal[c]	Distribution center/ warehouse	Manufacturer or producer	All others
--	Empty	41.6	13.7	28.5	16.2
01-05	Agricultural products and fish	19.3	39.8	16.6	24.3
06-09	Grains, alcohol and tobacco	17.4	43.4	18.5	20.7
10-14	Stone, minerals and ores	14.1	13.7	29.9	42.3
15-20	Coal and petroleum products	20.6	19.2	32.2	28.0
21-24	Pharmaceutical and chemical products	21.6	33.4	27.9	17.1
25-30	Wood, textile, and leather products	21.2	24.0	34.4	20.4
31-34	Metal products and machinery	20.5	21.2	41.0	17.4
35-38	Electronics, vehicles, and precision goods	28.5	19.9	42.7	8.9
39-43	Furniture and miscellaneous products	16.8	28.4	20.9	33.8

a. Source: PBConsult analysis of 1999 Canadian National Roadside Study data (Parsons Brinckerhoff., 2002)
b. Percentages may not total exactly 100 percent due to rounding.
c. Includes truck terminals, marine ports, airports, rail terminals, and intermodal terminals. The vast majority of trips were to truck terminals.

A facility is chosen at random from all facilities within a specified radius of the destination, also shown in Tale 8.4 (and file [CommodityProperties.csv]). An original value of 1 mile used for all commodities was based on review by the Port of Portland Freight Advisory Committee on what was reasonable, and the assumption that CT would use point locations rather than zones. Upon further review, this seemed low given an urban area can span 30- 40 miles, and only 1 percent of the SWIM2 alpha zone intra-zonal distances are 1 mile or less.

Thus, the CT Transshipment proximity parameter was updated from 1 to 5 miles for all commodities equal to the average urban alpha zone intrazonal distance (Urban was defined as alpha zones not equal to “NonMPO” or “OOO” in alpha2beta.csv “MPOmodeled” field). This value could be increased to 8 or 10 miles without too much concern, if the transsshipment probability is still low in further validation.

8.5.6. Truck itinerary parameters

1997 US Commodity Flow Survey data was used to obtain commodity-specific **carrier type** probabilities. The share of the commodity shipped by private carrier vs. for-hire are shown previously in Table 8.5 and defined in [CommodityProperties.csv].

The model also imposes an additional constraint on the for-hire vehicle selection. Each vehicle is only allowed to handle a **maximum number of pickups**, initially set at 10 (within the code). The choice of ten origins is arbitrary, as no data are available to describe the true behavior of LTL carriers in this regard. It is unlikely that given driver shift constraints and zone size, that a tour would ever hit this limit, unless all stops were clustered in a single zone.

The probability of choosing a particular **vehicle types** for truck flows is defined in [CommodityVehicleTypes.csv]. This is taken from the 2002 Vehicle Inventory and Use Survey (VIUS). The definition of the truck vehicles including attributes of payload limits and driver shift duration are shown in Table 8.1 and found in file [VehicleTypeAttributes.csv].

In 2010 CT **driver shift parameters** were updated to reflect changes in regulations by the USDOT Motor Carrier Safety Administration (https://www.fmcsa.dot.gov/). Current regulations limit driving time to 11 hours, or less based on consecutive hours of duty. The CT duration parameters in the [VehicleTypeAttributes.txt] file were updated to be 11 hours for all but TRK1. This could be reduced further to account for breaks and meals, if desired. The smaller TRK1 was assumed to operate more locally based on an 8-hour work day.

The **average payload weights** by truck type (specified in [VehicleTypeAttributes.csv]) are derived from 1997 ODOT Truck Intercept Survey and Port of Portland Truck Intercept and Terminal Surveys and were shown previously in Table 8.5.

In setting the truck tour **departure time**, average time-of-day distribution by truck type is defined in the code based on 1994-2000 ODOT Automatic Traffic Recorder (ATR) hourly count data at 30 locations, and from the Quick Response Freight Manual [32].

8.6. Inputs and Outputs

The categories of inputs required for running the CT module are shown in Table 8.7. CT outputs are listed in Table 8.8.

Table 8.7. CT Inputs

Data Element	Source
Truck Distances between Alpha and Beta Zones [betapktrk1dist.zmx] [pktrk1dist.zmx] (per [globalTemplate.properties])	TS
Truck peak times between alpha zones [pktrk1dist.zmx] (per [globalTemplate.properties])	TS
Annual flows$ of goods commodities between beta zones [Buying_SCTG##.zmx] (optional)	PI
List of SCTG goods [TransportableGoods.csv]	exog
Alpha zone attributes (land use intensity) [alpha2beta.csv]	exog
Modal Allocation Process parameters by commodity (alpha, beta, mean distances and mode share) [ModalDistributionParameters.csv]	exog
Value Density Parameters by commodity (slope, intercept) [ValueDensityParameters.csv]	exog
Shipment properties by commodity type (shipment size, trans-shipment probabilities, private/for-hire probabilities, trans-shipment proximity) [CommodityProperties.csv]	exog
Vehicle type attributes (gvw, payload capacity (lbs), driver shift (min), dwell time (min)) [VehicleTypeAttributes.csv]	exog
Vehicle type capacities by commodity [CommodityVehicleTypes.csv]	exog

Table 8.8. CT Outputs

Data Element	Users
Annual beta zone dollar flows by mode and commodity [DollarByModeFlow_SCTG##_[mode].csv] (optional)	Diagnostic
Weekly beta zone tonnage flows by commodity [WeeklyDemand.bin]	CT
Daily truck alpha zone tonnage shipments (tons) by commodity [Dailyshipments.csv]	CT
Modeled truck trip lists by vehicle type link-to-link (1 record per trip) [Trips_CTTruck.csv]	TS

The CT module outputs an interzonal Alpha zone trip table by vehicle class and time of day from the modeled truck trip list. This output is assigned to the network in the TS module. Trucks are assigned to the roadway network which contains weight class restrictions (see TS discussion, Section 9.0). T he CT trip table output in the SWIM2 model implementation includes the following truck trip attributes. :

- origin (Alpha zone)
- Trip Start time (departure time)
- destination (alpha zone)
- tour mode (9 indicating STK, generic truck)
- trip mode (9 indicating STK, generic truck)
- Truck ID (unique vehicle id sequence)
- truck type (Table 8.1)
- carrier type (i.e., private or for-hire)
- commodity (two-digit SCTG commodity code) (Table 2.5)
- weight (payload in units of pounds)
- distance (between trip origin and destination)
- travel time (between trip origin and destination)
- dwell time (at trip destination)

Tour and trip mode are placeholders for future implementation that would include non-truck modes and intermodal freight trips.

The key limitation to developing the SWIM2 CT model, or indeed, any freight model, is the long-standing lack of suitable data for model development and application. None of the existing data reveal information about individual trips and legs within trip journeys. The origin-destination patterns reported in the data reflect groups of shipments, and do not include information about trans-shipment. Thus, it remains necessary to synthesize information about trip-making from the data, using data from secondary sources and intuition. The various data used in the development of the CT module are shown in Table 8.9.

The lack of freight data has been a function of two factors: the overall lack of travel demand data, and the high variability associated with the limited data that are available. The latter often reflects the highly variable nature of businesses, even at the level of detail handled in the SWIM2 model. However, the availability of data suitable for freight modeling is improving. There are a number of initiatives presently underway that will affect the quality and character of freight travel demand data available over the next several years, including the following:

- American Freight Survey - future successor to the US Commodity Flow Survey administered by the USDOT Bureau of Transportation Statistics.
- Vehicle Inventory and Use Survey (VIUS) – recent Census Bureau changes will make it more useful for modeling, including availability of Microdata.
- Oregon Department of Transportation and Port of Portland - conducting truck travel surveys at selected locations across the state.
- FHWA Freight Analysis Framework (FAF) dataset (FAF2 data used in 2010 C T update and re-calibration)

Table 8.9. Sources of CT Freight Travel Behavior Data

Source	Type	Year	Use(s)
Commodity Flow Surveys (CFS)	One and two-way summary tables	1993, 1997	Estimation of value-weight ratios, static mode shares by commodity, distribution of carrier type by commodity
Vehicle Inventory and Use Survey (VIUS)	Microdata	1997	Distributions of carrier and vehicle types by commodity, average vehicle and payload weight by commodity, and incidence of stop at trans-shipment point
Canadian National Roadside Survey (NRS)	Microdata	1999	
ODOT truck intercept survey	Microdata	1997	
Portland Metro/Port of Port-land freight inventory and forecasts	One and two-way summary tables	1994[a]	Control totals for goods shipped into and out of the Portland region
ODOT 24-hour average week-day truck counts	One-way summary tables	1994-2000	Validate replication of truck volumes at selected locations in the network

Additional detail on key CT inputs are discussed in the remainder of this section.

8.6.1. Truck Vehicle Operating Parameters

Truck vehicle attributes are user-defined inputs. The five weight-based truck types and their operating attributes are identified in Table 8.1 and stored in the file

[VehicleTypeAttributes.csv]. The choice of vehicle depends upon commodity-specific parameters, shown in Table 8.10 and stored in the file [CommodityVehicleType.csv]. To reduce run-time in the TS module when full truck weight restrictions are not needed, the CT truck categories may be grouped during assignment. The assignment classes are defined in the TS section of the [globalTemplate.properties] file.

Table 8.10. Truck Type Shares by Commodity (percent)

Commodity	Commodity Description	TRK1	TRK2	TRK3	TRK4	TRK5	Total
SCTG01	Animals+fish	62%	28%	10%	0%	0%	100%
SCTG02	Cereal grains	62%	28%	10%	0%	0%	100%
SCTG03	Other agricultural prod	62%	28%	10%	0%	0%	100%
SCTG04	Animal feed	62%	28%	10%	0%	0%	100%
SCTG05	Meat+seafood	62%	28%	10%	0%	0%	100%
SCTG06	Grain+bakery	62%	28%	10%	0%	0%	100%
SCTG07	Other foods	62%	28%	10%	0%	0%	100%
SCTG08	Alcoholic beverages	62%	28%	10%	0%	0%	100%
SCTG09	Tobacco products	62%	28%	10%	0%	0%	100%
SCTG10	Building stone	12%	46%	34%	7%	1%	100%
SCTG11	Natural sands	12%	46%	36%	6%	0%	100%
SCTG12	Gravel	12%	46%	36%	6%	0%	100%
SCTG13	Nonmetallic minerals	12%	46%	36%	6%	0%	100%
SCTG14	Metallic ores	12%	46%	36%	6%	0%	100%
SCTG16*	Natural Gas and crude oil	12%	50%	38%	0%	0%	100%
SCTG15	Coal	12%	50%	38%	0%	0%	100%
SCTG17	Gasoline+fuel	12%	50%	38%	0%	0%	100%
SCTG18	Fuel oils	12%	50%	38%	0%	0%	100%
SCTG19	Coal+petroleum products	49%	32%	19%	0%	0%	100%
SCTG20	Basic chemicals	49%	32%	19%	0%	0%	100%
SCTG21	Pharmaceuticals	49%	32%	19%	0%	0%	100%
SCTG22	Fertilizers	49%	32%	19%	0%	0%	100%
SCTG23	Chemical products	49%	32%	19%	0%	0%	100%
SCTG24	Plastics+rubber	49%	32%	19%	0%	0%	100%
SCTG25	Raw wood	9%	43%	45%	3%	0%	100%
SCTG26	Wood products	37%	35%	28%	0%	0%	100%
SCTG27	Pulp+paper	49%	32%	19%	0%	0%	100%
SCTG28	Paper products	49%	32%	19%	0%	0%	100%
SCTG29	Printed products	49%	32%	19%	0%	0%	100%
SCTG30	Textile+leather	37%	35%	28%	0%	0%	100%
SCTG31	Nonmetallic mineral products	49%	32%	19%	0%	0%	100%
SCTG32	Basic metals	37%	35%	28%	0%	0%	100%
SCTG33	Metal articles	37%	35%	28%	0%	0%	100%
SCTG34	Machinery	36%	34%	27%	2%	1%	100%
SCTG35	Electronics	37%	35%	28%	0%	0%	100%
SCTG36	Vehicles	36%	34%	27%	2%	1%	100%
SCTG37	Transport equipment	36%	34%	27%	2%	1%	100%
SCTG38	Precision goods	37%	35%	28%	0%	0%	100%
SCTG39	Furniture+lights	37%	35%	28%	0%	0%	100%
SCTG40	Misc manufacturing products	33%	33%	33%	1%	0%	100%
SCTG41	Waste+scrap	37%	35%	28%	0%	0%	100%
SCTG43**	Mixed freight	33%	33%	33%	1%	0%	100%

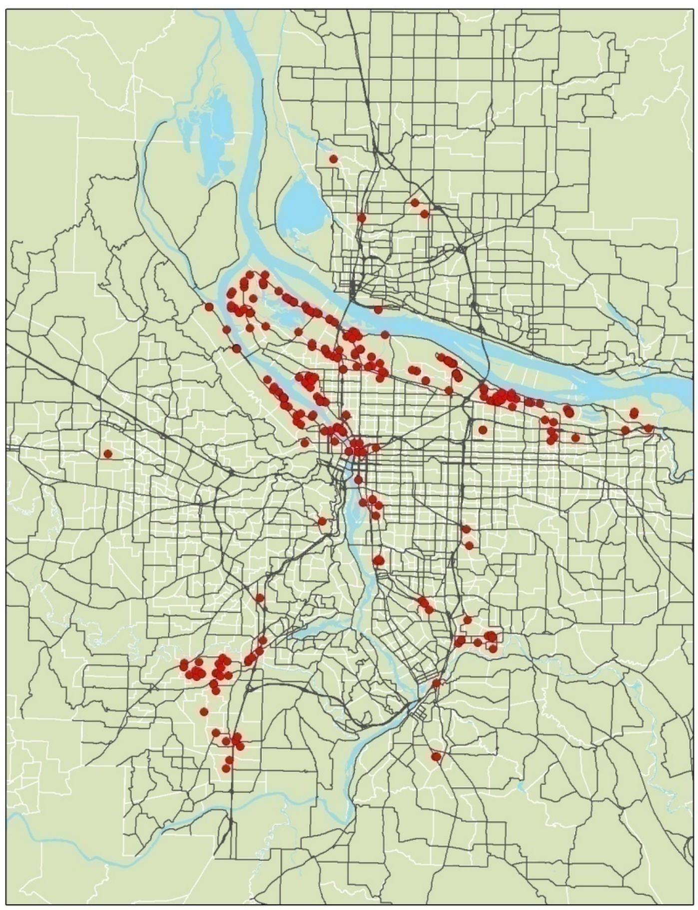
Note: Data in file CommodityVehicleTypes.csv
* SCTG16, unavailable in US CFS is assumed have the same attributes as SCTG17
** Not used in SWIM2, despite inclusion in US CFS

8.6.2. Trans-shipment Facilities

A key limitation of the trans-shipment approach used in the CT module is the limited inventory of distribution centers. Currently the code chooses the destination alpha zone as the transshipment, resulting in an intrazonal trip from the Transshipment facility to the end destination. When better transshipment data is available, the code can be adjusted to make use of it. The rest of this section documents the currently available transshipment data not currently utilized in the SWIM2 model.

Trans-shipment (TF) facilities are defined by the 1997 ODOT Intermodel Management System (IMS) and data collected on private facilities by the Port of Portland, as shown graphically in Figure 8.3. The database includes the name, location, and approximate size in square feet of approximately 300 facilities across the Portland Metro area. Several attempts to obtain data from individual TF operators in Oregon were unsuccessful. Many, and perhaps most, of the private distribution centers in the Portland area are not included in the IMS. Indeed, there are no regulatory or advertising reasons that would draw this information into public view. The development of the IMS was mandated by the ISTEA in 1991, but its requirement was dropped in 1996. Many of the states that developed them have discontinued them. The few remaining, including Oregon, do not appear to have adequate resources devoted to ensure their timely upkeep. Thus, this source of data will rapidly become obsolete, and is of questionable value in the SWIM2 Model.

Figure 8.3. ODOT/Port of Portland Trans-shipment Facility Locations



Alternatively, for-hire distribution facilities can be identified by looking at the location of employment in freight transportation and warehousing industry (e.g., SIC 42), or such activity as allocated within the PI module. However, employment data alone will not identify the location of private distribution centers, which form the majority of such facilities. This is an area requiring further development of the CT component, whose urgency will be determined during model validation. The literature on models for determining the location of industry-specific distribution centers is rather thin.

8.6.3. Travel Time Matrices

CT uses interzonal time and distance values produced by the TS module for the various truck types. The Beta zone distance matrix for Truck Type 1 [betapktrk1dist.zmx] is used in determining the trans-shipment probability. Later, the Alpha zone congested travel times by time period are used to determine truck tour travel times when building and optimizing itineraries [pktrk1time.zmx]. The congested Alpha zone distance matrix [pktrk1dist.zmx] in conjunction with the World Market zone-External zone distance table ([WorldZoneExternalStationDistances.csv] reflecting the distances shown in Table 2.2) is used to choose an appropriate External Station for shipments inbound/outbound from the model area. Note that there is a fixed association between Work Market and External Station Zones; Each World market links only to the closest 1 or 2 External Stations. The chosen time and distance skim files used by CT are defined in the [globalTemplate.properties] file.

8.6.4. Land Use Intensity

CT must allocate PI interzonal Beta zone flows to Alpha zone origin and destination zones. This allocation is currently based on ove rall activity intensity. Pre-calculated Alpha zone land use intensity values, a measure of population and employment per unit area (see Section 6.7.1), are currently used [alpha2beta.csv]. A more accurate measure might be the intensity of industry activity associated with each commodity. This could be obtained from PI output, which identifies the annual commodity dollars produced and consumed by Alpha zone [FloorspaceZoneMakeUse.csv]. This will be evaluated during model validation work.

8.7. Validation Targets

Few independent targets not used in model development exist for assessing the fit of the CT module in validation. The two formal validation targets to assess the CT model are listed in Table 8.11 in bold text, among other possible targets/validation. Anticipated future data sources such as the VIUS and ODOT/Port of Portland travel surveys or ODOT Oregon Special Truck Weightings data may provide future target values for these CT outputs. Additionally, CT will be tested to ensure that the output matches the input data sources, such as the share of for-hire and transshipped trips, and vehicle type and payload weights by commodity.

Additionally, SWIM2 CT truck trips across external stations can be combined with ET through (E-E) truck trips and compared to traffic counts observed at these locations. These traffic counts shown in Table 8.12 include AM, mid-day and ADT detail of for the counts used in ET data processing.

Table 8.11. CT Validation Targets (official targets in bold)

Source	Year	SWIM2 Target
No data source currently available		Frequency of Trips by Truck Vehicle Type
No data source currently available		Average Distance by Commodity by mode
US Commodity Flow Survey (CFS), Oregon summary tables	1997 (final) and 2003(preliminary)	**Average trip distance /distribution by commodity**
US Commodity Flow Survey (CFS), Oregon summary tables	1997 (final) and 2003(preliminary)	Value and tons by commodity and mode
US Commodity Flow Survey (CFS), Oregon summary tables	1997 (final) and 2003(preliminary)	Operator type (private, for-hire) by commodity and mode
US Commodity Flow Survey (CFS), Oregon summary tables	1997 (final) and 2003(preliminary)	% total destinations tagged for trans-shipment
US Commodity Flow Survey (CFS), Oregon summary tables	1997 (final) and 2003(preliminary)	**Total tonnage into Oregon by commodity**
Vehicle Inventory and Use Survey (VIUS), Oregon data	2002	Average trip distance by commodity and mode
Vehicle Inventory and Use Survey (VIUS), Oregon data	2002	Payload weight by commodity and mode
Oregon commodity flow estimates and forecasts by Global Insight	2003	Average trip distance by commodity and mode
Oregon commodity flow estimates and forecasts by Global Insight	2003	Commodity value and tons by commodity and mode
ODOT Truck Intercept Survey at weigh station (county-based data)	1997-1998	Average trip length by commodity and truck type
ODOT Truck Intercept Survey at weigh station (county-based data)	1997-1998	Average payload weight by commodity and truck type
ODOT Truck Intercept Survey at weigh station (county-based data)	1997-1998	Origin-destination patterns for through trips
ODOT Truck Intercept Survey at weigh station (county-based data)	1997-1998	Distribution of vehicle type by commodity
ODOT Truck Intercept Survey at weigh station (county-based data)	1997-1998	Total tonnage into/out of Portland region by commodity
Canadian National Roadside Study (NRS)	1999	Distribution of carrier type by commodity (by county?)
Portland Metro/Port of Portland Commodity Flow Survey	1994 and 1997	24-hour average weekday truck volumes by location
No data source currently available		Average Distance by Commodity by mode
Oregon Special Truck Weightings, Policy and Financial Analysis Section, ODOT, FSS (for biennial OR Highway Cost Allocation Study)	1988-2001 2x/year	Truck configuration and operating and declared weights
Oregon Special Truck Weightings, Policy and Financial Analysis Section, ODOT, FSS (for biennial OR Highway Cost Allocation Study)	1988-2001 2x/year	Truck configuration and operating and declared weights plus 2001 VMT by functional class (for 2003 Oregon Highway Cost Allocation Study, Office of Economic Analysis, DAS)

Table 8.12. External Station Target Truck Traffic Counts

AM Period (7-9am)

State	ODOT Node #	2000 AM Peak Truck Volume (7AM-9AM)					
		OB Light	OB Heavy	OB Tot	IB Light	IB Heavy	IB Tot
WA	5001	37	16	53	28	18	46
	5002	183	415	598	206	349	556
	5003	93	141	234	76	138	214
	5004	38	118	156	43	104	147
	5005	34	25	59	25	21	46
ID	5006	3	6	9	3	6	9
	5007	11	111	126	14	107	124
NV	5008	2	8	10	2	9	11
	5009	12	48	61	13	51	65
CA	5010	79	284	363	107	384	491
	5011	8	13	22	6	10	16
	Total	499	1,186	1,690	523	1,197	1,725

mid-day Off-Peak Period (9-4pm)

State	ODOT Node #	2000 Off-Peak Truck Volume (9AM-4PM)					
		OB Light	OB Heavy	OB Tot	IB Light	IB Heavy	IB Tot
WA	5001	81	31	112	71	50	121
	5002	706	1,543	2,249	731	1,651	2,381
	5003	301	617	918	303	606	910
	5004	159	456	614	164	471	635
	5005	81	85	166	76	72	148
ID	5006	3	7	10	3	7	10
	5007	11	123	137	14	113	129
NV	5008	2	9	11	2	9	11
	5009	12	54	66	13	54	67
CA	5010	363	1,309	1,672	404	1,458	1,862
	5011	61	96	157	55	87	142
	Total	1,780	4,328	6,112	1,837	4,577	6,417

ADT

State	ODOT Node #	2000 Truck ADT					
		OB Light	OB Heavy	OB Tot	IB Light	IB Heavy	IB Tot
WA	5001	162	62	224	167	64	232
	5002	1,367	3,554	4,922	1,369	3,558	4,927
	5003	544	1,088	1,632	546	1,092	1,638
	5004	314	995	1,309	323	1,022	1,345
	5005	171	150	321	175	153	328
ID	5006	45	123	168	46	115	161
	5007	177	2,186	2,363	224	1,958	2,182
NV	5008	32	158	190	33	156	189
	5009	195	951	1,145	198	939	1,139
CA	5010	891	3,216	4,107	909	3,281	4,190
	5011	113	178	291	115	181	296
	Total	4,012	12,660	16,671	4,105	12,520	16,627

8.8. Validation

Initial validation trials used commodity inputs from the first generation SWIM1 statewide model (TRANUS, 153 zones). Table 8.13 summarizes CT validation outcomes by target from these efforts. SWIM1, described in detail in [27] is implemented in TRANUS. It has 142 internal zones and 11 External Stations recording significant truck flows (>100 vehicles/day). The format of the TRANUS intersector flow matrices is similar to that from the SWIM2 PI module.

Table 8.13. CT Validation Targets and outcomes

Target source	Measure	Target	Outcome
PI component	Conserves intersector flows (output from PI)	Shipments by zone and commodity match PI output	Routinely achieved
Commodity Flow Survey	Matches observed modal shares by commodity	Coincidence ratio ≥ 0.9	Usually achieved
	Matches average trip distance by commodity	±10 percent	Large variances observed, never achieves target even in multiple runs
National Roadside Study	Percent of total destinations tagged for trans-shipment	±10 percent for each commodity	Routinely achieved
Commodity Flow Survey, ODOT truck intercept survey	Distribution of carrier type by commodity	±10 percent of observed percentage of private trucks	Routinely achieved
	Distribution of vehicle type by commodity	Coincidence ratio ≥ 0.9	Usually achieved
	Matches payload weight distribution by commodity	Coincidence ratio ≥ 0.9	Usually achieved
Portland Metro/Port of Portland Commodity Flow Survey	Matches total tonnage shipped into and out of the Portland region by commodity	±10 percent for each commodity	Cannot evaluate at present time (revisions in progress, will be available in April 2002)
ODOT traffic count database	Matches observed daily truck volumes at each site	Percent RMSE ≤ 40 percent for higher volume links (>1500 trucks/day)	Cannot reliably evaluate due to lack of counts in the Portland region and coarseness of the TRANUS assignment

The CT module was then tested within the Oregon Statewide Integrated Model (SWIM2) framework, using PI module inputs with the output trip table assigned to the weight-restricted roadway network, in the TS module.

Currently, the CT validation results indicate:

- CT was tested with PI results, and trip lengths and trips by vehicle type summaries were assessed for reasonableness.
- CT faithfully replicates the production of total commodity flow by value and tonnage, mode split, allocation to operator (for-hire versus private), average payload weight, and vehicle type.
- It is apparent from the results to date that a more robust modal allocation process is required.

Comments:

- Limited independent data exist for CT validation targets. In particular this includes, transshipment share by commodity and percent carrier type by commodity.
- Transshipment was tested, but found to be of little value within CT as currently configured, since the maximum trip length of internal-internal freight movement is less than 700 miles, with average trip lengths are typically less than 200 miles. This may include expanding the current assumption that stops at trans-shipment points will only be made for interurban movements, as well as a better means of assigning trans-shipments to specific facilities based upon their size and industries served.

- Development of average trip length targets used by the CT and PI modules is especially problematic. Although the CFS is supposed to include local as well as long distance trips the reported average trip distances are hundreds of miles, suggesting widespread under-reporting of local trips. The VIUS estimates are probably more robust, but the distance ranges used are so broad as to provide little useful information. Most other available sources are derived from the CFS, and thus suffer from the same deficiencies. In other models, commercial vehicle trip lengths are obtained from establishment surveys.

Future:

- Replace current disaggregation of truck trip ends (beta to alpha), with endogenous PI consumption/production distributions by commodity. Currently, an overall land use intensity value (employment and households per land area) is used that is not commodity-specific. Although PI operates at the beta zone level, a post-processor disaggregates key PI outputs from Beta to Alpha zones using ALD Alpha zone floorspace inventory. This data ([ActivityLocations2.csv] and [FloorspaceZoneTotalMakeUse.csv]) could be used in place of the land use intensity attribute, which measures both residential and non-residential activity. Total industry activity could be used, or a more specific industry-commodity mapping could be created.
- Identifying the location of private distribution centers may need to be revisited during model validation. Currently, a fixed list of transshipment locations developed largely by the Port of Portland, is used (see Section 3.6.2) which may be insufficient statewide and need to evolve over time. Alternatively, for-hire distribution facilities could be identified endogenously by using model-generated employment or industry activity (in 1990$) for the Transport and Wholesale Trade industries as allocated within the PI module; or the corresponding depot and warehouse floorspace data by alpha zone produced by the ALD module.
- The assumption that an alpha zone contains one or more shippers of a given commodity whose choice of carrier and vehicle type are identical may not be reasonable in the Portland region and selected other zones within the Willamette Valley. Alternate assumptions may need to be developed for those regions, such as assuming that the choice of shipper and vehicle type for each commodity shipment within each alpha zone are independent. This is consistent with our aggregate representation of firms, where we are not claiming to know about the characteristics of individual establishments, but rather just the amount of production and employment within a given zone. But since the assignment of carrier and vehicle type is a stochastic process, an unrealistic mixture of vehicles and carriers may be obtained if that employment represents a single large firm instead of several smaller ones with heterogeneous choices. There are good reasons to choose either approach. The first method is adopted for the initial validation of the SWIM2 model, as it will reduce the amount of variance associated with this part of the model, hopefully making the rest of the model easier to validate.
- Some additional CT validation target data include: 1997 ODOT Commodity Flow, Truck Intercept Survey data (vehicle type/payload weight distribution by commodity, tonnage into/out of Portland region by commodity), 1993/1997/2002 US Commodity Flow Survey (CFS), Oregon (mode split, trip distance distribution by commodity), 1994/1997 Portland Metro/Port of Portland Commodity Flow Survey (24-hour average weekday truck volumes SWIM2 TM Calibration Status 8/8/05 draft by location), 1988-

2001Oregon Special Truck Weightings (truck configuration and operating/declared weight distribution, VMT by functional class)

- CT is a micro-simulation, so theoretically it could require averaging a number of simulations for any single year to produce stable results. The Monte Carlo error and stability required are largely a function of the performance measure of interest, which can be address at a future date, if necessary.

8.9. S3 Parameters

When the full Oregon Statewide Integrated Model (SWIM2) is undergoing calibration, all CT parameters are subject to adjustment. In particular, the volume-density function is a critical parameter in the transformation from PI economic flows to tons.

9.0 ET Module

The External Traffic (ET) module generates truck trips through the model area on the study day. These 'through' truck trips are developed from baseyear trip matrices, updated each model period with a simple growth rate scaling method based on exogenously defined growth rates at the External Stations. No personal auto trips are currently assumed to travel through the model area on any one day. Additional freight trips are generated in the CT module, while person trips are covered by the PT module. The ET module creates an external-external truck trip matrix for two vehicle classes. The two vehicle classes are: regular trucks and heavy trucks over 80,000 lbs. The ET module runs concurrent with the PT and CT modules and provides vehicle trip tables for assignment in the TS module.

9.1. Theoretical Basis

External through trips are included in transport models to account for (1) border effects and (2) non-local traffic using major transportation corridors. In Oregon, the zone system and its extensive halo area minimize the need to account for border effects. However, Oregon's transportation system includes Interstate 5, the largest north-south truck corridor on the west coast extending from Mexico to Canada and I-84, the lowest east-west corridor through the Cascade Mountains along the Columbia River. Much of this traffic is not endogenous to the model system and is particularly important to properly study freight issues. To adequately represent traffic on these and other major transportation corridors, the model system needs to include external through truck trips. In Oregon, external trips are expected to account for a fraction of all network trips.

The External-External truck trips modeled within ET are developed using an simple growth method applied to a baseyear external-external trip matrix. The baseyear origin-destination trip matrix applies exogenous External Station growth rates.

9.2. Quantity Definitions and Categories

ET operates at the External Station level, shown previously in Figure 2.2. Note that External Station 5012 is the Port of Portland gateway that does not allow 'through' trucks, so is therefore not used in the ET module.

ET only models and develops trip tables for truck trips of two types. The truck types are referred to as Light and Heavy Trucks, represented by Truck Types 1-3 and 4-5, previously defined in Table 8.1. A heavy truck represents vehicles over 80,000 lbs, that require a permit to use Oregon roadways. For assignment purposes in the TS module, Light trucks are considered Type 3 (TRK3) and Heavy Trucks Type 4 (TRK4). ET truck definitions are included in the [globalTemplate.properties] file, however external station growth rates assumed the truck definition noted above.

9.3. Component Models

The ET module expands base year external-external trip matrices given exogenous growth rates among 11 external stations. ET produces two matrices for assignment in the TS module, covering light and heavy trucks.

ET relies heavily on a detailed base year traffic counts at the 11 external stations at the model edge and an baseyear External-External trip matrices. The data collection/synthesis of these inputs are discussed in section 9.6.

9.3.1. Through Trips (E-E)

SWIM2 must account for a significant number of 'through' or External-to-External (E-E) truck trips on s tate roadways (both origin and destination outside of the model area). Although these trips have limited direct economic impact to the state, they contribute to the traffic that must be accommodated on roadways.

ET starts with an initial year 1998 trip table for truck trips traveling between External Stations by vehicle type and time period. T his set of baseyear E-E truck trip tables are expanded each year to produce current year trip tables by calculating and applying a simple growth rate to each OD pair of the baseyear table. Because both ends of the trip are external, the model does not generate information to endogenously calculate a growth rate. Instead, exogenous growth rates that vary by large/small road classifications were used. The equations employed in this process to produce future year truck volume targets inbound and outbound at each external station by truck type and time period follow:

$$T_{i,j,t,v}^{y} = S_{i,j,t,v}^{0} \cdot \left(\frac{G_i + G_j}{2}\right)^{y-1998} \qquad (9.01)$$

where:

$T_{i,j,t,v}^{y}$	=	year *y* truck trips between External Station *i* and *j* in time period *t* of type *v*
$S_{i,j,t,v}^{0}$	=	baseyear truck trips between External Station *i* and *j* in time period *t* of type *v* (baseyear = 1998)
G_j , G_j	=	annual growth rate for External Station i or j, which varies by large/small road size (growth rate and road type defined in [globalTemplate.properties])
y	=	current year
t	=	time period (700=7-9AM, 900=9-4PM, 1600=4-6pm, 1800=6pm-7am)
v	=	truck vehicle type (TRK3= Light, TRK4=Heavy)
i, j	=	index for External Station zone

Note that ET's External-External trips are not symmetrical, that is, a trip from External Station *i* to External Station *j* would have different seed values and growth rates as those in the opposite direction.

9.4. Software Implementation

The ET module was implemented in java code. It provides a current year truck trip table of the full E-E truck trips, to be assigned to the roadway network in the TS module. The Through (EE) Truck Trip Table Expansion involves calculating a growth rate to apply to each cell of the baseyear trip table.

9.5. S1 and S2 Module Parameters

There are no parameters in the ET model. Input values are described in Sections 9.6.

9.6. Inputs and Outputs

ET input and output files are defined in Table 9.1 and 9.2. ET requires previous year external trip matrices, exogenously defined external growth rates, and PI import/export quantities. Additionally a commodity vehicle type assignment file is required to map PI commodities to either the Auto/Regular Truck or Heavy Truck networks.

Table 9.1. ET Inputs

Data Element	Source
External-External 2000 Baseyear trip matrices by time period (AM, Mid-day) and vehicle type (Light/Heavy trucks) [ET_TripsTruck1998EE.csvs]	exog
External Station Growth Rates, truck vehicle types, tons per truck, minimum tonnage, iterative proportional fit parameters [globalTemplate.properties]	exog

Table 9.2. ET Outputs

Data Element	Users
External-External Light and Heavy truck trip tables[Trips_ETTruck.csv]	TS

The output ET trip table includes the following attributes:

- Origin zone (alpha zone or External Station),
- Destination zone (zlpha zone or External Station),
- Time period (StartTime of 601 = AM, 901 = mid-day, etc.), and
- Truck Class (3 = light truck, 4 = heavy truck, see Table 8.1 for additional attributes).
- Truck Volume

Other ET inputs are described in the remainder of this section.

9.6.1. Baseyear External-External Trip Table

The 2000 Baseyear External-External Trip Table is an important starting point for modeling External-External truck trips. It provides the seed matrix for the iterative proportionate fit method discussed in section 9.3.1. Eight matrices were exogenously developed, representing two truck types during four time periods primarily from the 1997 ODOT Truck Intercept Survey taken at Oregon Ports of Entry. Each of these matrices has 11 rows and columns, representing the 11 External Stations.

A doubly constrained gravity model was used in the development of the baseyear E-E Trip matrix. Initially an AM (7-9am), Mid-day (9-4pm), and daily (ADT) period were culled from the data and later used to back-out the remaining two periods (PM and night).The inputs to this initial procedure (done in TransCAD) are shown below.

- **Seed Matrix**: The 1997 ODOT Truck Intercept Survey data was used, as processed for EE truck trip table in SWIM1. Since SWIM2 halo covers a larger region, the SWIM1 trip table was expanded to match the dimensions of the SWIM2 11 roadway External Zones. This involved aggregation and disaggregation, but overall matched the total volumes used in SWIM1. AM, off-peak, and ADT trip tables are assumed to use the same seed matrix.

- **Marginals** (or productions and attractions vectors): The observed traffic count data was used, after applying an assumed share of External-External (EE) truck trips. The resulting marginals were total inbound and outbound truck trips at each external station by truck type and time period. The trip shares, shown in Table 9.3 were based on SWIM1 analysis of through trips using the 1997 ODOT Truck Intercept Survey.

Table 9.3. Assumed External-External Share of External Station Truck Trips

External Station		Outbound Light Truck	Outbound Heavy Truck	Inbound Light Truck	Inbound Heavy Truck
I5 (WA)	5001	71.7%	29.6%	61.1%	25.3%
I5 (WA)	5002	71.7%	29.6%	61.1%	25.3%
I82+US97 (WA)	5003	25.1%	13.9%	38.8%	18.4%
I82+US97 (WA)	5004	25.1%	13.9%	38.8%	18.4%
I82+US97 (WA)	5005	25.1%	13.9%	38.8%	18.4%
I82+US97 (WA)	5006	25.1%	13.9%	38.8%	18.4%
I84 (ID)	5007	46.4%	45.5%	39.3%	40.5%
I5CA+US97 (CA)	5008	59.3%	55.6%	48.3%	46.9%
I5CA+US97 (CA)	5009	59.3%	55.6%	48.3%	46.9%
I5CA+US97 (CA)	5010	59.3%	55.6%	48.3%	46.9%
I5CA+US97 (CA)	5011	59.3%	55.6%	48.3%	46.9%

The resulting baseyear E-E Trip tables from this process are shown in Tables 9.4 through 9.6 for AM, off-peak, and ADT time periods.

Table 9.4. External-External 1998 Trip Table, 7-9AM Light and Heavy Trucks

AM LT EE	5001	5002	5003	5004	5005	5006	5007	5008	5009	5010	5011	Total
5001	0.00	0.00	3.65	1.51	1.33	0.11	0.77	0.18	1.10	7.31	0.78	16.74
5002	0.00	0.00	27.40	11.29	9.99	0.80	5.74	1.37	8.23	54.80	5.82	125.44
5003	4.97	24.44	0.00	0.00	0.00	0.00	0.03	0.00	0.01	0.04	0.00	29.49
5004	2.83	13.89	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.02	0.00	16.76
5005	1.62	7.98	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	9.62
5006	0.19	0.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.12
5007	0.94	4.61	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.56
5008	0.17	0.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.01
5009	1.02	5.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.05
5010	8.65	42.51	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	51.20
5011	0.50	2.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.95
Total	20.89	102.68	31.08	12.81	11.33	0.91	6.57	1.55	9.34	62.18	6.60	265.94

AM HT EE	5001	5002	5003	5004	5005	5006	5007	5008	5009	5010	5011	Total
5001	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.11	0.64	3.76	0.17	4.74
5002	0.00	0.00	0.07	0.06	0.01	0.00	1.09	2.02	12.15	71.30	3.30	90.00
5003	0.00	0.11	0.00	0.00	0.00	0.00	5.85	0.45	2.73	16.00	0.74	25.88
5004	0.00	0.08	0.00	0.00	0.00	0.00	4.39	0.34	2.05	12.01	0.55	19.42
5005	0.00	0.02	0.00	0.00	0.00	0.00	0.91	0.07	0.42	2.48	0.12	4.02
5006	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.02	0.13	0.73	0.03	1.18
5007	0.05	1.38	0.32	0.26	0.06	0.01	0.00	0.95	5.72	33.76	1.58	44.09
5008	0.09	2.45	0.39	0.32	0.07	0.02	0.72	0.00	0.00	0.00	0.00	4.06
5009	0.56	14.70	2.32	1.94	0.42	0.10	4.47	0.00	0.00	0.00	0.00	24.51
5010	4.19	110.43	17.42	14.57	3.11	0.77	33.49	0.00	0.00	0.00	0.00	183.98
5011	0.10	2.77	0.44	0.37	0.08	0.02	0.85	0.00	0.00	0.00	0.00	4.63
Total	4.99	131.94	20.96	17.52	3.75	0.92	52.10	3.96	23.84	140.04	6.49	406.51

Table 9.5. External-External 1998 Trip Table, 9AM-4PM (midday) Light and Heavy Trucks

MD LT EE	5001	5002	5003	5004	5005	5006	5007	5008	5009	5010	5011	Total
5001	0.00	0.00	8.33	4.39	2.24	0.08	0.55	0.13	0.80	23.71	3.99	44.22
5002	0.00	0.00	85.44	45.03	23.01	0.80	5.62	1.37	8.22	243.12	40.86	453.47
5003	12.23	106.60	0.00	0.00	0.00	0.00	0.09	0.00	0.01	0.42	0.07	119.42
5004	6.61	57.64	0.00	0.00	0.00	0.00	0.05	0.00	0.01	0.23	0.04	64.58
5005	3.08	26.88	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.11	0.02	30.11
5006	0.12	1.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.15
5007	0.58	5.07	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	5.69
5008	0.11	0.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.03
5009	0.64	5.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.20
5010	20.36	177.51	0.15	0.08	0.04	0.00	0.00	0.00	0.00	0.00	0.00	198.14
5011	2.79	24.31	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	27.14
Total	46.52	405.52	93.96	49.52	25.30	0.88	6.33	1.50	9.04	267.60	44.98	951.15

MD HT EE	5001	5002	5003	5004	5005	5006	5007	5008	5009	5010	5011	Total
5001	0.00	0.00	0.01	0.01	0.00	0.00	0.04	0.08	0.47	11.41	0.84	12.86
5002	0.00	0.00	0.39	0.29	0.05	0.00	1.33	2.56	15.44	377.26	27.68	425.00
5003	0.01	0.55	0.00	0.00	0.00	0.00	7.95	0.64	3.84	93.82	6.88	113.69
5004	0.01	0.43	0.00	0.00	0.00	0.00	6.18	0.50	2.99	72.93	5.30	88.34
5005	0.00	0.07	0.00	0.00	0.00	0.00	0.94	0.08	0.45	11.05	0.83	13.42
5006	0.00	0.01	0.00	0.00	0.00	0.00	0.09	0.01	0.04	1.03	0.08	1.26
5007	0.03	1.42	0.38	0.28	0.05	0.00	0.00	0.27	1.61	39.65	2.95	46.64
5008	0.06	2.97	0.55	0.41	0.08	0.01	0.23	0.00	0.00	0.00	0.00	4.31
5009	0.36	17.84	3.33	2.46	0.46	0.04	1.44	0.00	0.00	0.00	0.00	25.93
5010	9.72	479.76	89.52	66.14	12.27	1.01	38.51	0.00	0.00	0.00	0.00	696.93
5011	0.58	28.66	5.36	3.95	0.75	0.06	2.31	0.00	0.00	0.00	0.00	41.67
Total	10.77	531.71	99.54	73.54	13.66	1.12	59.02	4.14	24.84	607.15	44.56	1,470.05

Table 9.6. External-External 1998 Trip Table, ADT Light and Heavy Trucks

ADT LT EE	5001	5002	5003	5004	5005	5006	5007	5008	5009	5010	5011	Total
5001	0.00	0.00	13.29	7.68	4.18	1.10	5.22	1.95	11.72	53.48	6.77	105.39
5002	0.00	0.00	108.67	62.73	34.18	8.99	42.67	15.91	95.80	437.14	55.34	861.43
5003	18.71	158.34	0.15	0.09	0.05	0.01	16.20	0.65	3.89	17.77	2.25	218.11
5004	11.06	93.56	0.09	0.05	0.03	0.01	9.57	0.38	2.30	10.50	1.33	128.88
5005	6.00	50.75	0.05	0.03	0.01	0.00	5.19	0.21	1.25	5.70	0.72	69.91
5006	1.58	13.33	0.01	0.01	0.00	0.00	1.36	0.05	0.33	1.50	0.19	18.36
5007	8.13	68.78	4.72	2.73	1.49	0.39	0.00	0.12	0.69	3.17	0.40	90.62
5008	1.68	14.22	0.25	0.14	0.08	0.02	0.01	0.00	0.00	0.00	0.00	16.40
5009	10.12	85.60	1.48	0.85	0.46	0.12	0.08	0.00	0.00	0.00	0.00	98.71
5010	46.36	392.19	6.77	3.91	2.13	0.56	0.34	0.00	0.00	0.00	0.00	452.26
5011	5.86	49.58	0.86	0.49	0.27	0.07	0.04	0.00	0.00	0.00	0.00	57.17
Total	109.50	926.35	136.34	78.71	42.88	11.27	80.68	19.27	115.98	529.26	67.00	2,117.24

ADT HT EE	5001	5002	5003	5004	5005	5006	5007	5008	5009	5010	5011	Total
5001	0.00	0.00	0.01	0.00	0.00	0.00	0.24	0.60	3.62	12.27	0.67	17.41
5002	0.00	0.00	0.29	0.27	0.04	0.03	13.12	33.30	200.80	677.49	37.27	962.61
5003	0.01	0.37	0.00	0.00	0.00	0.00	53.46	5.68	34.12	115.15	6.33	215.12
5004	0.01	0.34	0.00	0.00	0.00	0.00	50.00	5.33	31.95	107.74	5.87	201.24
5005	0.00	0.05	0.00	0.00	0.00	0.00	7.51	0.80	4.78	16.13	0.90	30.17
5006	0.00	0.04	0.00	0.00	0.00	0.00	5.62	0.57	3.63	12.12	0.68	22.66
5007	0.20	11.50	2.37	2.17	0.33	0.27	0.00	29.14	175.15	594.85	33.15	849.13
5008	0.65	36.94	5.26	4.79	0.73	0.60	29.39	0.00	0.00	0.00	0.00	78.36
5009	3.83	219.90	31.33	28.64	4.33	3.56	180.19	0.00	0.00	0.00	0.00	471.78
5010	13.45	768.75	109.59	100.19	15.04	12.39	628.39	0.00	0.00	0.00	0.00	1,647.80
5011	0.74	42.32	6.05	5.52	0.85	0.66	34.81	0.00	0.00	0.00	0.00	90.95
Total	18.89	1,080.21	154.90	141.58	21.32	17.51	1,002.73	75.42	454.05	1,535.75	84.87	4,587.23

The resulting external-external AM (7-9am), Mid-day (9-4pm), and daily (ADT) period by truck type (Tables 9.45-9.6) were used to generate PM (4-6pm) and night (6pm-7am) period external-external trip tables by light and heavy truck type. A fundamental assumption was made that the PM trips would closely match AM trips and the night period would consist of any remaining trips when these 3 periods (AM, PM, Midday) were removed from the daily (ADT) trip tables. In selected cases, adjustments were required to reduce the PM trips (no longer match AM) so that night period trips were not negative. The PM period thus has 53 less light trucks and 45 less heavy trucks than the AM period. The resulting PM and Night period External-External Trip Tables are shown in Tables 9.7 and 9.8.

Table 9.7. External-External 1998 Trip Table, PM Light and Heavy Trucks

PM LT EE	5001	5002	5003	5004	5005	5006	5007	5008	5009	5010	5011	Total
5001	0.00	0.00	1.31	1.51	0.61	0.11	0.77	0.18	1.10	7.31	0.78	13.68
5002	0.00	0.00	0.00	6.41	1.18	0.80	5.74	1.37	8.23	54.80	5.82	84.35
5003	1.51	24.44	0.00	0.00	0.00	0.00	0.03	0.00	0.01	0.04	0.00	26.03
5004	1.62	13.89	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.02	0.00	15.55
5005	1.30	7.98	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	9.30
5006	0.19	0.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.12
5007	0.94	4.61	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.56
5008	0.17	0.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.01
5009	1.02	5.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.05
5010	8.65	42.51	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	51.20
5011	0.50	2.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.95
Total	15.90	102.68	1.34	7.93	1.80	0.91	6.57	1.55	9.34	62.18	6.60	216.80
PM HT EE	5001	5002	5003	5004	5005	5006	5007	5008	5009	5010	5011	Total
5001	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.11	0.64	0.00	0.00	0.81
5002	0.00	0.00	0.00	0.00	0.00	0.00	1.09	2.02	12.15	71.30	3.30	89.86
5003	0.00	0.00	0.00	0.00	0.00	0.00	5.85	0.45	2.73	5.33	0.00	14.36
5004	0.00	0.00	0.00	0.00	0.00	0.00	4.39	0.34	2.05	12.01	0.02	18.81
5005	0.00	0.00	0.00	0.00	0.00	0.00	0.91	0.07	0.42	2.48	0.00	3.88
5006	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.02	0.13	0.73	0.03	1.18
5007	0.05	1.38	0.32	0.26	0.06	0.01	0.00	0.95	5.72	33.76	1.58	44.09
5008	0.09	2.45	0.39	0.32	0.07	0.02	0.72	0.00	0.00	0.00	0.00	4.06
5009	0.56	14.70	2.32	1.94	0.42	0.10	4.47	0.00	0.00	0.00	0.00	24.51
5010	0.00	110.43	2.65	14.57	0.00	0.77	33.49	0.00	0.00	0.00	0.00	161.91
5011	0.06	2.77	0.25	0.37	0.02	0.02	0.85	0.00	0.00	0.00	0.00	4.34
Total	0.76	131.73	5.93	17.46	0.57	0.92	52.10	3.96	23.84	125.61	4.93	367.81

Table 9.8. External-External 1998 Trip Table, Night Light and Heavy Trucks

NT LT EE	5001	5002	5003	5004	5005	5006	5007	5008	5009	5010	5011	Total
5001	0.00	0.00	0.00	0.27	0.00	0.80	3.13	1.46	8.72	15.15	1.22	30.75
5002	0.00	0.00	0.00	0.00	0.00	6.59	25.57	11.80	71.12	84.42	2.84	202.34
5003	0.00	2.86	0.15	0.09	0.05	0.01	16.05	0.65	3.86	17.27	2.18	43.17
5004	0.00	8.14	0.09	0.05	0.03	0.01	9.48	0.38	2.29	10.23	1.29	31.99
5005	0.00	7.91	0.05	0.03	0.01	0.00	5.15	0.21	1.25	5.57	0.70	20.88
5006	1.08	10.44	0.01	0.01	0.00	0.00	1.36	0.05	0.33	1.50	0.19	14.97
5007	5.67	54.49	4.68	2.72	1.49	0.39	0.00	0.12	0.69	3.16	0.40	73.81
5008	1.23	11.62	0.25	0.14	0.08	0.02	0.01	0.00	0.00	0.00	0.00	13.35
5009	7.44	69.98	1.48	0.85	0.46	0.12	0.08	0.00	0.00	0.00	0.00	80.41
5010	8.70	129.66	6.58	3.81	2.07	0.56	0.34	0.00	0.00	0.00	0.00	151.72
5011	2.07	20.37	0.84	0.48	0.26	0.07	0.04	0.00	0.00	0.00	0.00	24.13
Total	26.19	315.47	14.13	8.45	4.45	8.57	61.21	14.67	88.26	137.30	8.82	687.52
NT HT EE	5001	5002	5003	5004	5005	5006	5007	5008	5009	5010	5011	Total
5001	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.30	1.87	0.00	0.00	2.25
5002	0.00	0.00	0.00	0.00	0.00	0.03	9.61	26.70	161.06	157.63	2.99	358.02
5003	0.00	0.00	0.00	0.00	0.00	0.00	33.81	4.14	24.82	0.00	0.00	62.77
5004	0.00	0.00	0.00	0.00	0.00	0.00	35.04	4.15	24.86	10.79	0.00	74.84
5005	0.00	0.00	0.00	0.00	0.00	0.00	4.75	0.58	3.49	0.12	0.00	8.94
5006	0.00	0.03	0.00	0.00	0.00	0.00	4.99	0.52	3.33	9.63	0.54	19.04
5007	0.07	7.32	1.35	1.37	0.16	0.25	0.00	26.97	162.10	487.68	27.04	714.31
5008	0.41	29.07	3.93	3.74	0.51	0.55	27.72	0.00	0.00	0.00	0.00	65.93
5009	2.35	172.66	23.36	22.30	3.03	3.32	169.81	0.00	0.00	0.00	0.00	396.83
5010	0.00	68.13	0.00	4.91	0.00	9.84	522.90	0.00	0.00	0.00	0.00	605.78
5011	0.00	8.12	0.00	0.83	0.00	0.56	30.80	0.00	0.00	0.00	0.00	40.31
Total	2.83	285.33	28.64	33.15	3.70	14.55	839.51	63.36	381.53	665.85	30.57	2,349.02

9.6.2. External Station Growth Rates

Growth rates for the external zones (G_j , G_j) were developed from 2000 and 2003 detailed traffic count data obtained at the Automatic Traffic Recorder (ATR) counts on state border roads. SWIM2 assumed through (E-E) trip growth rates for interstates and other smaller roads are shown in Table 9.9. These growth rates cover both Light and Heavy Truck types. These growth rates and road classification are defined in the ET section of the [globalTemplate.properties] file.

Table 9.9. Road Classification

Classification	External Stations	Annual Growth Rate
Interstates	5002,5003,5004,5007,5010	2.4%
Smaller roads	5001,5005,5006,5008,5009,5011	1.0%

Source: 2000 and 2003 Traffic counts from WA, ID, NV, CA at external road locations
Note: Data in file [globalTemplate.properties]

9.7. Validation Targets

ET was validated that the method was implemented correctly. Because ET's external-external trips do not impact the rest of the model, no additional validation is required.

9.8. Initial Validation

Testing was done to ensure that ET faithfully executes the code as specified, including applying the correct factors and growth rates.

9.9. S3 Parameters

None.

10.0 TS Module

The SWIM2 Transport Supply (TS) Module is a set of network assignment procedures called each model period to load inter-zonal vehicle flows onto multimodal transport networks and to produce measures of various utility components by skimming multimodal networks.

The TS Module includes aggregate multi-class user-equilibrium roadway assignment, aggregate optimal strategy transit assignment, shortest roadway path network skimming and optimal strategy transit path network skimming. These are fairly standard procedures implemented in most commercial transportation planning software packages. O ur implementation follows that of EMME/2's closely in order for data files created for use with EMME/2 by ODOT and MPOs to be used with minimal manipulation.[30]

The output data formats of the TS components are simple tabular data, saved as comma delimited text files for network elements, and matrix skim data, which are stored in compressed zip format. Skim matrices are developed for peak and off-peak periods, by user class for highway matrices, by trip mode and access mode for transit matrices and are written out in compressed zip format. T he highway related matrix skim data are likewise aggregated to beta zone for use by modules that require such aggregation.

10.1. Theoretical Basis

Travel time and distance skims are produced for roadway related modes (auto, various truck types) by computing the shortest generalized cost path through the network from origins to destinations. Aggregate time, distance and cost values are summed over links in the shortest paths and are stored in matrices where the rows represent origin zones and the columns destination zones. Travel choice models such as destination choice or mode choice found in the PT , CT and PI modules refer to these roadway skim matrices. Shortest path skimming procedures are very standard in aggregate transportation network based models.

For transit related origin/destination travel components, i.e. in-vehicle time, walk time, wait time, etc., a different methodology is applied. Transit skim data is computed by constructing an optimal strategy from all origin zones to a destination zone. An optimal strategy is a sub-network of the regional transit network where the sub-network contains only the links which are traversed by a hypothetical person traveling from each origin to the destination. Based on the set of links determined to be in this optimal strategy sub-network and the frequency of transit service serving each link in the sub-network, a set of route choices exist to take the traveler from each origin to each destination. The idea is that the traveler will follow the shortest path from origin to destination, but when given a choice of boarding more than one transit line that will reach his destination, the traveler will choose the line on which the first transit vehicle appears. A separate probability therefore exists that the traveler will choose each of the multiple routes possible to reach the destination, where the probabilities depend on the frequency of service for each transit line serving the traveler. These probabilities, in addition to the network traversal times, determine expected travel times for the trip from origin to destination. B y apportioning travelers onto their optimal strategy routes, the aggregate assignment of all travelers is such that all travelers are guaranteed to be assigned on their minimum expected cost path. A set of expected costs can also be computed for each transit travel component over these sub networks and according to the boarding frequencies and stored in a set of transit skim matrices. Like the roadway skims, these transit skims are used by other travel choice models.

In addition to skimming procedures, TS provides components for assigning trips to multi-modal networks. The implemented roadway assignment methodology is a multi-class user equilibrium procedure. This is a very standard aggregate network assignment procedure. Origin-destination trips are assigned to routes through the network in such a way as to ensure that at user equilibrium, no traveler can find a different route from origin to destination with a lower travel time. The aggregate roadway link volumes (for each user class – auto, truck) determined by the multi-class user equilibrium traffic assignment procedure reflect this behavioral assertion that travelers will choose the route that best suits them. Equilibrium travel time on the network is measured by user-specified volume delay functions (VDF) for each network link.

Transit trips must also be assigned to transit routes, and the optimal strategy transit assignment procedure is used to assign aggregate transit trips to the transit network. The same properties described in transit network skimming above are reflected in transit network loading. Transit trips are assigned to transit network links in the optimal strategy sub-network, trips are assigned to transit routes which represent the minimum expected travel time from origins to destinations. Time is represented by user specified functions which typically are functions of the equilibrium highway times. The optimal strategy transit assignment is standard in the EMME/2 package and its functionality is replicated here. More in-depth information about optimal strategy transit assignment can be found in [29].

10.2. Quantity Definitions and Categories

The SWIM2 TS module operates exclusively at the alpha zone level. In other words, demand is specified at the alpha zone level and network connections are made between alpha zone centroids and the highway network nodes. All skim matrices are created at the alpha zone level. Additionally, the auto and truck skims are aggregated to create beta zone level skim matrices for use by the PI module.

The TS module can assign both auto and transit trips in up to four time periods as noted in Table 10.1, covering a 24-hour day. Skim matrices from the AM peak and mid-day off-peak periods are required as inputs used in downstream modules PI, PT, and CT. Skim matrices from the other periods, PM peak and night time off-peak, run in the first and last year of a multi-year model run in order to sum daily link flows for diagnostic purposes.

Table 10.1. TS Assignment Periods

Period Name	Trip Start Time Range
AM Peak	07:00 to 08:59
Mid-day Off-peak	09:00 to 15:59
PM Peak	16:00 to 17:59
Night Off-peak	18:00 to 23:59 and 0:00 to 06:59

TS performs a multi-class highway assignment for up to 6 user classes, shown in Table 10.2, with PT auto and transit modes and CT/ET truck types defined previously in Table 7.3 and Table 8.1, respectively. Transit travel skim matrices cover two access modes (walk or drive), and four service types shown in Table 10.3, where these PT trip modes were defined previously in Table 7.3.

Table 10.2. TS Highway Assignment Classes

Code	Mode Codes	Class Description
a	DA, SR2, SR3P	All auto trips (PT SDT and LDT)
d	TRK1	Light trucks (CT)
e	TRK2, TRK3	Medium trucks (CT and ET)
f	TRK4, TRK5	Heavy trucks (CT and ET)

Note: Class codes g and h could be used to expand from 3 aggregated to the full 5 truck types.

Table 10.3. TS Transit Assignment Classes

Code	Mode Codes	Class Description
air	AIR	Air
ic	TRANSIT_WALK TRANSIT_DRIVE	Intercity Bus
t	TRANSIT_WALK TRANSIT_DRIVE	Intracity/Urban Transit
icr	HSR_WALK HSR_DRIVE	Intercity Rail

Note: Class codes c and d could be used to expand from 3 aggregated to the full 5 truck types.

The various highway and transit travel components output by TS are summarized in Table 10.4 and detailed further in Section 10.6. Note that all transit level-of-service attributes vary by type of service and access mode. The PT modules require only selected transit service attributes to cover all tour and trip mode choice alternatives.

Table 10.4. Summary of TS Travel Skim Matrices

Period/Mode		Travel Component
Auto		
pk – AM Peak auto		dist - drive distance (miles)
op – Mid-day Off-peak auto		time - congested drive time (minutes)
pk – AM Peak	trk# –truck class # (1)	fftime - free flow drive time (minutes)
op – Mid-day Off-peak	trk# –truck class # (1)	toll – toll (1990$)
Transit		
pk – AM Peak	dt - drive transit	brd - boardings (people)
op - Mid-Day Off Peak	wt - walk transit	far - fare ($)
	dic – drive intercity bus	drv -drive time (minutes)
	wic – walk intercity transit	awk - access walk time (minutes)
	dair – drive air	ewk - egress walk time (minutes)
	dicr – drive intercity rail	xwk – transfer walk time (minutes)
	wicr – walk intercity rail	fwt - first wait time (minutes)
		twt - total weight time (minutes)
		ivt - in-vehicle travel time (minutes)

(1) Truck assignment class codes used are Table 10.2 aggregations of all truck vehicle types defined in Table 8.1.
Note: TS output filenames are combinations of period+mode+travel component.zmx. Available combinations vary.

10.3. Component Models

The objective of the TS module is to assign trip tables from the CT, ET, and PT module to a multimodal network. The TS components are detailed in the remainder of this section.

- Roadway Assignment
- Transit Assignment
- Creation of Output Travel Skim Files

10.3.1. Roadway Assignment

TS loads trips to the roadway network from the PT, CT and ET modules. The TS roadway assignment and skimming procedures read an EMME/2 d211 format network file. The network covers the entire model area and is suitable for loading and skimming. These networks assume no turn prohibitions or turn penalties.

In addition to the network file, a set of volume delay function (VDF) files have also been composed. The volume delay functions defined for sets of links relate travel time on links to total flows over all user classes on the links. Thus the volume delay functions represent the way congestion affects the model. The higher the volumes, the greater the travel times, which are passed through to other travel choice components by way of the travel time skim matrices. Congested network times in TS therefore influence models throughout the entire integrated model, including non-travel choices related to spatial activity location and ultimately economic and land development in subsequent years.

TS uses the following generalized cost function in path building:

$$\text{TS Generalized cost function} = a1_v*time_l + a2_v*dist_l + a3_v*cost_l \qquad (10.2)$$

where:

v	=	index indicating vehicle type/mode
l	=	index indicating network link number
$time_l$	=	congested travel time (minutes) on network link l
$dist_l$	=	distance (miles) on network link l
$cost_l$	=	user-defined link cost, field in "extra link attributes" network file
$a1_v$, $a2_v$, $a3_v$	=	cost function weights for vehicle type v assigned consistently with PT tour mode choice coefficient values (see Section 7.5.10).

Commercial Vehicle classes in the TS multi-class highway assignment are subject to a potentially restricted network for each truck class (as noted on the network links) with limits for trucks by approximate gross weight (TRK1-5). The "extra link cost attribute" file associated with the d211 network file (see Section 10.6.1) includes user-defined link cost ($cost_l$), as defined to reflect tolls on links.

The user-equilibrium highway assignment algorithm uses the defined VDF functions to compute travel time in each iteration, with these times influencing generalized cost and therefore assigned trip routes. User-equilibrium is achieved when no traveler can improve generalized cost by switching to a different route. The algorithm is an iterative one where origin to destination demand is assigned to shortest paths based on the current generalized costs, and at each successive iteration the newly assigned shortest path flows are averaged with previously assigned flows.

The user-equilibrium solution that the network model determines is equivalent to the solution of a mathematical programming problem that involves the summation of integrals of the VDF functions. The calculation of the summation of integral functions with the assigned flows at any iteration is the value of the *objective function* of the mathematical programming problem. The objective function value at any iteration is an estimate of the optimal objective function value at true equilibrium. If the VDF functions honor certain properties, then the objective function of the optimization problem is guaranteed to decrease with each successive iteration. TS also compute a *lower bound* value with each iteration. The lower bound is the lowest possible value the objective function could be. At each successive iteration the objective function value gets smaller, and the lower bound value gets larger. Thus the difference or 'gap' between these two values declines. The ratio of the gap to the "greatest" lower bound value determined over all iterations is the *percentage gap value* that most commercial software packages use as a stopping criterion. When this percentage gap value falls below a threshold, the iterative procedure ends, and the solution is determined from the last set of averaged link flows. In SWIM2, the 'percentage gap value' is user-defined in the [globalTemplate.properties] file.

It should be noted that most transportation assignment software packages do not require that the integral functions be specified explicitly as done in TS, instead approximating the VDF functions by fitting simple polynomials to the VDFs. For TS, explicit integral functions were preferred and specified in the same form as the VDFs. This approach was more expedient, and the computed objective function is exact.

10.3.2 Transit Assignment

TS loads person trips to the transit network from PT trip tables (short and long distance), using the modes noted in Table 10.3.[31] The TS transit assignment and skimming procedures use the same base network file as the roadway procedures use augmented by the transit route definitions for the specific service modeled. Transit network times are defined as functions of the corresponding highway link equilibrium times where the functions are specified in the VDF definitions. Furthermore, the transit procedures build realistic paths by using a generalized cost function of weighted in-vehicle time, weighted out-of-vehicle, and weighted out-of-pocket cost. The weights for this cost function are consistent with those used by PT, for the various mode choice utility components (see Section 7.5.10).

The assignment of transit trips is simpler than that of roadway trips since congestion on transit service is assumed to not exist and a single loading of transit trips without iteration suffices. The transit assignment procedure is based on the optimal strategy transit assignment approach described by Spiess and Florian and made popular by its use in the EMME/2 software package [30]. The procedure is described in detail in the EMME/2 documentation, and summarized as follows:

- initialize network attributes using current roadway assignment flow pattern.
- for each destination TAZ in the trip list:
  - build optimal strategy sub-network for destination centroid node.
  - load trips from origins onto transit network links in optimal strategy.
    - for each boarding node on route through optimal strategy:
      load proportion boarding each transit line serving boarding node.
    - for non-boarding nodes:
      carry transit flows forward along optimal strategy
- update network travel time attributes.

Transit assignment is computed by period (2 periods: AM peak, Mid-day off-peak, with option for 2 more: PM peak, Night off-peak) for up to two access modes (walk and drive), and up to four service types (Air, Intercity Rail, Intercity Bus, Intracity). A separate transit network is built for each combination of period, access mode, and service type and trips for those networks is assigned. There is assumed to be no walk access for Air, therefore seven distinct transit networks, sets of transit network loadings, and sets of level-of-service skim matrices are computed, per Table 10.3.

[31] The loaded transit networks/boardings output are not fed back to downstream modules. Instead the PT module calculates mode choice based on transit frequency, a TS input described in Section 10.6.3.

It should be noted that the PT Long Distance Travel (LDT) module produces a trip table, and only assigns trips if both trip ends fall within the model area. If one end of the trip falls outside the model area, the trip remain in the output trip table (with a fixed mode share assumption), but is not assigned in TS and do not appear in resulting skims or TS trip summaries. Truck Trips with one end outside of the model area are assigned to the network. The trip end outside the model area is mapped to the appropriate external station (12 external stations numbered 5001-5012, including 11 key roadways and 1 Port of Portland station).

Finally, TS transit assignment can be turned off to improve runtimes. If specified at runtime through the MrsGUI user interface, the transit route file entries and transit mode identifiers (used in setting the skim file names) in the [globalTemplate.properties] file are commented out and the correct files path for the baseyear transit skims provided for those SWIM2 modules looking for transit skims (same across all model years). This required modifications to the TS java code to allow the transit skim locations to be split into "transit" and "non-transit" so that the transit skim locations can be identified separately from non-transit ones.

10.3.3. Creation of Output Travel Skim Files

TS writes skim matrices out in a compressed zip file format (*.zmx). The travel skims produced by TS cover the following:

- Two weekday time periods (option of up to 4), per Table 10.1;
- One auto class, and three truck classes (option of up to 5 truck classes), per Table 10.2; [32]
- Multiple level of service tables for auto, truck and transit classes, summarized in Table 10.4;

All skims are created at the alpha zone level. Once TS produces skims at the alpha zone level, it also performs a 'squeeze' function to produce selected skims at the more disaggregate beta zone level for use in PI and CT. This function currently weights all alpha zones equally, but a method to do a weighted 'squeeze' based on the trip tables is underway.

Note that TS assigns auto and truck trips to internal alpha zones and External Station zones (5000s, per Table 2.1). The TS output alpha zone travel skims are produced for all pairs of internal alpha and external station zones. When beta zone skims are aggregated from these alpha zone skims for use by PI and CT modules, the external station values are replaced by corresponding World Market zone (6000s per Table 2.2) values.

One of the level of service skim matrices computed by TS is the set of transit fare values between zone pairs (in 1990$). Fares are specified in the following way. Intra-city transit fares are specified by origin and destination fare districts. A correspondence exists between fare districts and alpha zones. The fare computed by TS for intra-city transit service is therefore determined by a lookup table based on the fare district of the origin and destination alpha zones. The fare districts and values associated with them are defined in order to best represent the cost to travel by intra-city transit between zones within metropolitan areas,

Inter-city fares are computed by summing the distance traveled between zones where inter-city transit exists and applying a distance based formula to compute fare. The following

[32] To reduce runtime in the TS module when full truck weight restrictions are not needed, the CT truck trip categories are typically grouped during assignment. The default is to use 3 truck types defined in Table 10.2.

formula is (repeated from Section 10.3.3) gives the distance-based inter-city bus or rail distance fare:

$$Fare_{i.j,m} = Dist_{i,j} * [\alpha_m*(Dist_{i,j} \hat{}\beta_m) \quad] \qquad (10.1)$$

where:
$Fare_{i.j,m}$ = Station-to-Station fare (in 1990$) for intercity mode m
$Dist_{i,j}$ = roadway distance (mile) between origin zone i and destination zone j (miles)
m = Intercity mode, where: b=intercity bus, r= intercity Amtrak and bus connectors
α_m = Multiplicative distance term in 1990$,
β_m = Exponential term on distance;

Intercity air fares are determined by skimming the fares from the route descriptions. Boarding fares are coded on the route descriptions and if intercity air/rail transfers are made to travel between zone pairs, the fares are appropriately accumulated.

Additionally, the following summary files are also created by the TS assignment procedures:

- Highway network link flow by time period (in csv format)
- Transit line boardings by time period (in csv and txt format)

10.4. Software Implementation

The key TS software components perform the following functions:

- read network description files translate those descriptions into network objects,
- apply the network path building, loading and skimming algorithms, and
- manage these components and the input/output of data files.

EMME/2 format network description files are read in by TS and interpreted. **Both roadway and transit network objects** are created from these input files. Both types of network objects contain elements to define the topology of the networks and attributes of network elements. For the transit network, a set of route definitions are read from an EMME/2 format file and translated into a set of Route objects. For both roadway and transit networks a set of link travel time functions are read in from EMME/2 format files and related to the links in the network objects.

A **LinkCalculator** object was developed that operates on a Network object and applies the link travel time functions (e.g., VDF formulas) defined in terms of other link attributes including speed, volume, capacity, distance, link type, etc. T his object was critical in integrating the volume delay travel time definitions from the various MPOs into one set applicable for this model.

A **ShortestPathTree** object was developed for use both by the roadway skimming procedure and the roadway assignment procedure. The ShortestPathTree object operates on a Network object, and is used to determine the shortest paths through a network from an origin to all destinations, from all origins to a destination, or from an origin to a destination. The shortest path is determined based on a shortest generalized cost path, where generalized cost is a link attribute representing a weighted combination of link time, distance and cost, as mentioned previously. Level of service attributes can be computed over the shortest paths to compute intra-zonal free-flow travel times, congested travel times, distances, costs, or weighted combinations of any of these.

Similarly, for transit, an **OptimalStrategy** object was developed for use by both the transit skimming and assignment procedures. As with highway level of service attributes, transit skims are computed from paths through the optimal strategies from origins to destinations where paths are determined from weighted combination of link travel components (in-vehicle time, wait time, walk time, etc.) over links in the optimal strategy subnetwork. The OptimalStategy object is therefore applied to generate the transit travel skim matrices.

Network loading for roadway assignment involves assigning all the flow of a particular user class from origins to destinations along paths for that origin-destination. An iterative equilibrium assignment algorithm that averages these flows with previously assigned flows is used. This algorithm is an implementation of the common Frank-Wolfe algorithm for assigning flows to achieve an aggregate user-equilibrium.

Network loading for the transit network consists of loading all the transit flows between an origin and a destination to links in the optimal strategy where flows are apportioned according to transit line frequency of service where multiple transit routes serve links in the optimal strategy. Transit flows are assigned and accumulated on links. Once each origin-destination pair has been assigned, the procedure is finished. There is no averaging step in the simple optimal strategy transit assignment procedure (implies no congestion exists on transit network).

In addition to the network skimming and loading procedures, TS contains modules for aggregating and writing skim matrices and for summarizing and reporting link attributes.

The network modeling procedures in TS were implemented in such a way as to allow the assignment and skimming procedures to be completed with simple inputs – network description files, travel time function files, and demand files. In a multi-year model run, each time assignment or skimming are required, the Network and Demand objects are built, allowing for changes in network related inputs to be specified to reflect specific policy or scenarios to be studied. Transit access connectors are computed after reading the network description files by connecting centroid nodes to transit route nodes according to rules specified to limit the number of connections and ensure correct behavior for access limitations.

The order of these procedures is set by the AO module job stream set-up. Currently the order of operations is as follows:

- Highway assignment for each period (2 or 4 periods)
- Highway assignment for two periods (amPeak and mdOffpeak used by other modules)
- Transit Loading and Skimming

Because the network topology is large and the number of alpha zones is large, the network modeling procedures are computationally resource intensive. The procedures were implemented with the intention that multiple computers would be used to solve the assignment problems and that each computer would have multiple computing cores. The equilibrium highway assignment algorithm was written to be distributed, with modules for computing shortest path trees and loading those trees able to run on multiple machines in parallel, and these modules themselves are multithreaded to allow for concurrent computing within each machine. For this TS uses the Distributed Application Framework (DAF, version 3), an extension to that used in the PI and PT modules (DAF version 2). The transit assignment procedures have been implemented as concurrent within a single machine, and future plans call for them to be distributed to multiple machines with each distributed module doing concurrent processing within a machine. The performance enhancement allowed by this design is very substantial.

10.5. S1 and S2 Module Parameters

The TS module requires the estimated coefficients listed in Table 10.5. The TS transit procedures build realistic paths by using a generalized cost function of weighted in-vehicle time, weighted out-of-vehicle, and weighted out-of-pocket cost (Eq. 10.1). The weights for this cost function are the same as those estimated for PT, for the various mode choice utility components (see Table 10.2). These are S1 parameters for TS as they are fixed (although they are S2 parameters for PT).

Table 10.5. TS Parameters

Component	Value	S1/S2
Transit Cost Function weights (IVT, OVT, auto operating cost)		
$a1_v$ Auto Operating cost coefficient (1990$/mile)	0	S1
$a2_v$ Mode Choice in-vehicle time coefficient (utils/minute)	1.0	S1
$a3_v$ Mode Choice out-of-vehicle time coefficient (utils/minute)	2.0	S1

Note: Fares do not influence path building; Consistent with LDT internalModeChoiceParameters.csv where mode choice model transit skims OVT=2*IVT, tourModeParameters.csv FWT=2*IVT

10.6. Inputs and Outputs

TS inputs are summarized in Table 10.6. TS requires trip lists of travel demand from CT, ET and PT, multi-class highway travel network representations, multi-service type transit route descriptions for air, rail, intercity bus, and intra-city transit for the current year, and generic volume delay function (VDFs) files for all model years, and fare assumptions.

Table 10.6. TS Inputs

Data Element	Filename	Source
Short distance person trip lists by time of day, origin zone, destination zone, and SDT trip mode (1 record per person)	Trips_SDTPerson.csv	PT
Long distance vehicle trip lists by time of day, origin zone, destination zone, and LDT trip mode (1 record per person)	Trips_LDTVehicle.csv	PT
Truck trip lists by time of day, origin zone, destination zone, and truck vehicle type	Trips_CTTruck.csv	CT
External truck trip by time of day, origin zone, destination zone, and truck vehicle type	Trips_ETTruck.csv	ET
Node and link text file network representation (EMME/2 d211 format) and supplementary network attributes file	*.d211 highway_2000_attribs.csv	exog
Roadway volume delay function (VDFs) and volume delay function integral function definitions files	statewideVdf.txt statewideVdfIntegrals.txt	exog
Multi-service type transit route description files (EMME/2 d221 format)	Air_2000_Peak.221 Hsr_2000_Peak.221 Intercity_2007_Peak_new.221 Intracity_2007Hybrid_Offpeak.221 Intracity_2007Hybrid_Peak.221	exog
Transit district fare tables by origin and destination district ($1990)	IntraCityTransitFares.csv	exog
Information on count data [	CountsIDs.txt Summary_for_ts_trucks.txt	exog
List of modes	modes.txt	exog

TS is capable of producing many network model outputs that can be used for inputs by other model components or for various network level analyses (Table 10.7). TS produces multi-class user-equilibrium highway network flows and corresponding travel times on links. TS also produces transit route boardings for the service types noted above: air, intercity rail, intercity bus, and intra-city transit. Finally, TS produces network based level of service attributes used in intra-zonal utility calculations for various discrete choice based models in other components.

The temporary in-memory demand matrices processed from the PT (SDT and LDT), CT and ET trip list can be output for SL assignment (see Chapter 12) when present in the TS section of the properties file. These demand matrices are written to disk in the form of ZMX matrix files for each assignment class, time-of-day, and year.

Table 10.7. TS Outputs

Data Element	users
Auto & Truck time & distance for interchanges between alpha zones (in compressed matrix format) (see Table 10.14)	PT, CT
Auto & Truck times & distances for interchanges between beta zones (see Table 6.17)	PI, CT
Transit skims for interchanges between alpha zones (see Table 10.18)	PT
Trip demand matrices by assignment class, time-of-day, and year (optional per properties flag)[{MODE}_{PERIOD}_[TYPE}.zmx]	SL (optional)
Assigned highway link flows by mode and period [*$period$*AssignmentResults.csv]	diagnostics
Assigned transit line flows by transit line and period (in csv and txt formats) [*$period$*RouteBoardings.csv][*$period$*RouteBoardingsReport.txt]	diagnostics
Additional auto and transit level of service skim matrices (see complete listings in Tables 10.19)	diagnostics
Trip Length distribution summaries by assignment class and period [tld_$class$_$period$.csv]	diagnostics

As noted earlier, TS assignments or skimming procedures may be run for 2 or 4 time periods. This capability exists so that assignment results for daily highway network flows and transit service boardings can be determined from all 4 period assignments in model years where observed data exists and validation criterion are evaluated (for example base year or target years) or in the final model year where data are needed for scenario comparison or policy analyses. In other model years where analyses of the assigned flows is not going to be required, it is sufficient to run the assignments for only the first two periods so that level of service skims can be produced for other model components. The time periods were defined previously in Table 10.1

Table 10.4 summarizes the range of TS output level of service skim matrices. These are identified in more detail below along with other TS inputs and outputs and their contents.

demand_matrix_{MODE}_{PERIOD}.zmx.

10.6.1. Trip Tables

Short distance and long distance person trip lists from the PT module and truck type vehicle trip lists from the CT and ET modules are assigned to the multi-modal network by the TS module. These trip list files have fields as listed in Table 10.8. Those used by TS to develop trip tables for assignment are shown in bold-faced type. Origin and destination are defined at the alpha zone level in all cases.

Table 10.8. Format of TS Trip Table Input Files

Source:	**PT (SDT)**	**PT (LDT)**	**CT**	**ET**
Filename:	Trips_SDTPerson.csv	Trips_LDTVehicle.csv	Trips_CTTruck.csv	Trips_ETTruck.csv
Fields:	hID memberID weekdayTour(yes/no) tour# subTour(yes/no) tourPurpose tourSegment **tourMode** **origin** **destination** time distance **tripStartTime** tripEndTime tripPurpose tripMode income	hhID memberID tourID income tourPurpose **tourMode** **origin** **destination** distance time **tripStartTime** tripPurpose tripMode vehicleTrip	**origin** **tripStartTime** **destination** tourMode tripMode tripFactor truckID **truckType** carrierType commodity weight distance travel time travel distance dwell time	**Origin** **Destination** **TripStartTime** **TruckClass** **Truck Volume**

Note: Only **bolded fields** are used in the TS module
* includes external alpha zones

Demand matrices for highway assignment are determined from these trip list files as follows.

Highway: Highway assignment uses demand specified as vehicle trips. Auto vehicle trip demand matrices are computed in TS by reading the person trip lists from the two PT generated trip list files (SDT and LDT) and accumulating vehicle trips in a table where rows are origin alpha zones and columns are destination alpha zones. If the PT module is run with a sample population, TS reads this from the properties file and expands the PT trip tables accordingly. Truck class vehicle trip demand matrices are likewise computed in TS by reading the CT and ET trip list files and accumulating vehicle trips in trip tables. Table 10.9 shows the relationship between mode and vehicle class in the trip list files. Flows reported by TS are always in units of number of vehicles.

Table 10.9. Vehicle Trip Rates for Person Trips

Trip Mode Identifier	Description	Vehicle Trip Rate
DA	Auto Drive alone	1.0
SR2	Auto Shared Ride 2 (driver and one passenger)	0.5
SR3P	Auto Shared Ride 3plus (driver and 2 or more passengers)	0.33

Truck trips are assigned and accumulated as vehicle trips. However, trucks in the traffic stream have more of an effect on congestion than that of a single automobile vehicle, so assigned truck vehicles are considered in terms of the number of passenger car equivalents they correspond to in order to more appropriately influence link travel times. The Passenger Car Equivalent (PCE) values are defined by truck type in the properties files. Note these definitions affect the internal assignment of truck vehicles, but truck flows reported are in units of whole vehicles. The [globalTemplate.properties] file defines the truck passenger car equivalent (PCE) as 1.0 for auto and 1.7 for truck.

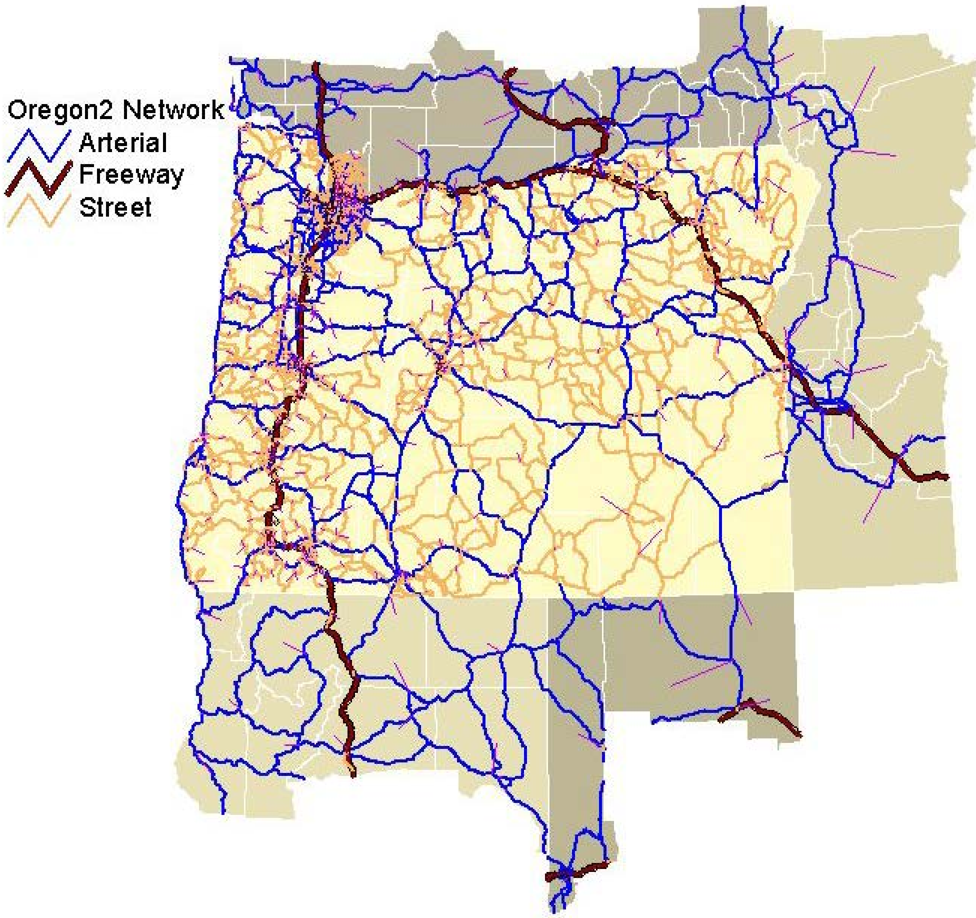
Transit: For transit assignment, person trips are read from the PT tables and accumulated in demand matrices as person trips. The PT short distance trip list includes intra-city transit trips that are distinguished by walk and drive access to intra-city transit. These trips are accumulated separately and then loaded separately on transit networks distinguished by their access type (walk or drive). The PT long distance trip list includes intercity bus and intercity rail trips that are distinguished by walk or drive access, as well as air trips with drive access only. TS computes several demand tables for assignment covering the various combinations of access mode and service type for transit trips.

10.6.2. Transport Networks

The roadway network used in the Oregon Statewide Integrated Model (SWIM2) is shown in Figure 10.1 and its development is discussed in Reference [37]. A SWIM2 Network Management Process used to edit the network files is discussed in the SWIM2 Users' Guide [1]. The SWIM2 network distinguishes auto, truck, transit (air, rail, bus, intracity) and walk accessible links. These networks assume no turn prohibitions or turn penalties. Transit route definitions are used to represent transit service in the network. Networks are developed for 1990 to 2030, in 5-year increments (e.g., 2007 network contains 2007-2012 roadway improvements). For each period, a single roadway network is created with different transit services (route files) representing an AM peak (7-9 AM) and mid-day off-peak (9 AM-4 PM), where service warrants. The contents of these files can be different for each multi-year period. The TS model implementation supports defining different highway and/or transit service attributes each model year. Each time TS runs, it computes network objects for highway and transit network models from the input files associated with the model year. The network attributes can be changed by changing the input files in different model years.

Base: 2001-2006 (1995-2000 network has also been developed)
Reference (future): 2007-2012, 20013-2018, 2019-2024, 2025-2030

Figure 10.1. SWIM2 Roadway Network



The SWIM2 networks were originally developed using EMME/2 software, which the MPOs used for their networks at the time. The MPO networks were stitched together by ODOT to create the statewide network. Because of their origin, the file formats are similar to and named like EMME/2 files. However, the files are not directly compatible with EMME/2, and model management is now done using VISUM software.

Table 10.10 identifies the current link attributes of the master SWIM2 network. Full documentation of networks can be found in Reference [37].

Table 10.10. Attributes of TS Network Input Files

Filename:	D211 Network File
Attributes in d211 input: (network link attributes)	Uniqid
	Fnode
	Tnode
	Lanes
	TSysSet
	NET_xx_xx
	SPEED_xx_xx
	MPO_xx_xx
	TYPE_xx_xx
	LANES_xx_xx
	VDF_xx_xx
	NAME_xx_xx
	BEG_MP_xx_xx
	END_MP_xx_xx
	STHWY_xx_xx
	ATR_NUM_xx_xx
	FEDURBAN_xx_xx
	WT_RES_xx_xx
	Length
Attributes in .csv input: (extra network link attributes)	LRS_xx_xx
	CAPACITY_xx_xx
	ALPHA_TAZ
	AREATYPE
	COST_A_xx_xx
	COST_D_xx_xx
	COST_E_xx_xx
	COST_F_xx_xx
	COST_G_xx_xx
	COST_H_xx_xx
Attributes in d221 input: (transit route files)	Line name
	Mode
	Vehicle Type*
	Headway
	Speed
	Description
	UL1*
	UL2*
	UL3*
	Sequence of Nodes

* Not used in SWIM2

Roadway Networks

Roadway attributes were often standardized across the state starting from the original MPO data. Key roadway network attributes from Table 10.10 (d211 Network file and Extra Link Attribute file) are noted below:

- **Functional class**. This is a key link attribute that is used in a lookup table fashion to indicate speed, capacity, and VDF attributes of the links.
- **Allowed Modes**. Indicates which transit and truck types can be assigned to the network link.
- **Area Type**. Calculated using 1998 households plus employment target data (1998 [ActivityConstraintsI98.csv] and [Employment.csv]) divided by two to get an average

density of households and employment. The values were then split into five groups that most accurately captured different densities in the state.

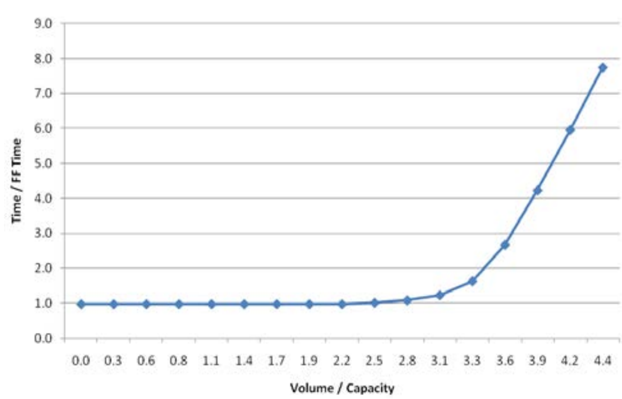
$\text{Area Type}_z = [(\text{Households}_z + \text{Employment}_z)/2]/\text{landSQFT}_z$

- **Volume Capacity Factors**. CT assumes the following Volume Capacity Factors by period, based on ODOT ATR traffic count data. The sum of the inverse of these values is also used in the SL module (10.84). Both parameters are found in the [globalTemplate.properties] file.

  am.peak.volume.factor = 0.70
  md.offpeak.volume.factor = 0.25
  pm.peak.volume.factor = 0.70
  nt.offpeak.volume.factor = 0.25

- **Volume Delay Functions (Definitions and Integral)**. The VDF formulas are used to compute link travel time as a function of assigned highway volume. The formulas can be described generally as an initial time multiplied by a function of volume relative to capacity. The initial time, or in this case free-flow time is therefore weighted by a function that increases as volume increases relative to capacity. Figure 10.2 below shows a function for index 102 for a typical link where time relative to free flow time is plotted vs. volume relative to capacity. As the volume/capacity ratio increases, beyond 2.5 in this particular function, travel time becomes greater than free flow time, that is, congestion begins to occur. If volume increases further for this link, congestion becomes worse – travel time becomes much greater than free flow time. The VDF files are built from MPO VDF files, standardized across the state. The TS module uses a combined VDF file that contains each MPO VDF and a unique field identifying which VDF to associate with each network link.

Figure 10.2. Typical VDF: Congestion given Volume/Capacity Ratio



Transit Networks

The SWIM2 transit route files include files for both urban intracity and intercity transit systems in the study area. They are specified in a d221 format, including attributes listed in

Table 10.10. Where warranted separate files exist for peak and off-peak periods. The following transit systems are included. For more information see Reference [37]:

- Urban Intracity Transit
  - Tri-met and C-Tran
  - Lane Transit District (LTD)
  - Rogue Valley Transit District (RVTD)
  - Salem-Keiser Transit
  - Corvallis Transit System
- Intercity Bus
- Intercity Rail/Amtrak (termed hsr in the model)
- Intercity Air Service

10.6.3. Network Costs

SWIM2 travel costs are incorporated into the model in multiple ways, as summarized in Table 10.11. As shown in the table, most travel costs (in 1990$) are incurred through the network links (in the form of link tolls) and transit route files (station-to-station fares). These costs are skimmed each time TS is run, and summarized by zone-pairs in TS output alpha and beta zone fare skim matrices. Transit level of service and network loadings (boardings) are distinguished by mode of access – walk or drive. Air transit has drive access and egress only. Intercity bus and rail transit have walk and drive access and egress, as well as the option to transfer to intra-city transit services. Intra-city transit has walk and drive access but only walk egress.

Urban intracity transit uses a district-based fare, where districts are defined (*alpha2beta.csv* “fare” field) and fares between districts provided in a separate TS input file (*IntraCityTransitFares.csv*). This data was developed based on local 2007 transit agency fare data and converted to 1990$.

Air fares between airports within the SWIM2 model area (Portland, Eugene, Jackson, Redmond, Pendleton, North Bend, Klamath Falls, Boise, Pasco, Eureka, Redding) were collected based on one-way fares in 1999 and converted to 1990$. They are included in the TS Air transit network route files by OD [*air_$year$_$period$.csv*].

Intercity bus and Amtrak intercity rail fares are calculated based on trip distance from 2007 Greyhound and Amtrak (including through-way buses) fare data, arriving at the following formulation, with coefficients converted to 1990$:

$$Fare_{i.j,m} = Dist_{i,j} * [\alpha_m * (Dist_{i,j} \wedge \beta_m) \quad] \qquad (10.1)$$

where:

$Fare_{i.j,m}$ = Station-to-Station fare (in 1990$) for intercity mode m
$Dist_{i,j}$ = roadway distance (mile) between origin zone i and destination zone j (miles)
m = Intercity mode, where: b=intercity bus, r= intercity Amtrak and bus connectors
α_m = Multiplicative distance term in 1990$, where: α_r = 0.4879 (0.6823 in 2007$), α_b = 1.4083 (1.9694 in 2007$);
β_m = Exponential term on distance, where: β_r = -0.2989, β_b = -0.4994;

Additional costs incurred in the PT module, including auto operating and parking costs (see PT Section 7). Auto operating costs of $0.0867 in 1990$ ($0.12/mile in 2000$) are asserted, based on work by MTC (Chuck Purvis). They assumed typically 60% to 65% of total out-pocket cost is due to gasoline, the other 35-40% is due to other factors such as oil, wear and tear, etc. To compute the cost in 1990$, the cost of a gallon of gas in 1990 (national average was $1.24/gallon) was divided by the 1990 fuel efficiency (22 mpg) and then factored up to include non-gasoline costs (multiply by 1/0.65). The auto operating cost is found in the [globalTemplate.properties] user input file.

Parking costs were obtained from local sources in roughly the year 2000 for 56 SWIM2 alpha zones in the commercial districts of Portland, Salem, Eugene, and Medford. A daily rate is assumed to be the hourly rate time 8 hours. These zonal parking costs are found in the *alpha2beta.csv* user input file.

Truck operating costs are specified as SCTG commodity-specific inputs to PI (*CommoditiesI.csv*). See PI Section 6.5.3 Time and Cost Weights for Transporting Commodities.

TS uses peak and off-peak value of time (input in the [globalTemplate.properties] file) from PT SDT tour mode choice model estimation (Section 7.5.10 converted to 1990$) as follows:

```
userClass.pk.vot = 0.0945 (High Income (>$60K) work purpose)
userClass.op.vot = 0.0632 (High Income (>$60K) non-work purposes)
```

Table 10.11. SWIM2 Travel Costs

	Fare/Toll method (in 1990cents)	
Mode	Network-based	Other
Auto	Tolls applied to Network Links (highway_$year$_attribs.txt)	Auto operating cost (globalTemplate.properties) Daily and Hourly Parking Costs by alpha zone (alpha2beta.csv)
Truck		Defined in PI commodity-specific operating costs (CommoditiesI.csv)
Urban Intracity Transit	District-based Fares (IntraCityTransitFares.csv, alpha2beta.csv “fare” field)	NA
Intercity Rail	NA	Distance-based fare (see Eq. 10.1)
Intercity Bus	NA	Distance-based fare (see Eq. 10.1)
Air	Station-to-Station fares (air_$year$_$period$.csv)	NA

10.6.4. Equilibrium Percentage Gap Value

In the Oregon Statewide Integrated Model (SWIM2), the ‘percentage gap value’ that determines when equilibrium is achieved (see Section 10.3.1) is user-defined in the [globalTemplate.properties] file, as shown below:

NUM_FW_ITERATIONS=200
FW_RELATIVE_GAP=0.00025 (0.025%)

10.6.6. TS Highway Outputs

TS output files produced by the highway assignment procedure are summarized in Table 10.12. The fields included in these output files are shown in Table 10.13.

Table 10.12. Highway Assignment Network Flow Results Files

File Names	Descriptions
amPeakAssignmentResults.csv	AM peak Multi-class equilibrium link flows
mdOffPeakAssignmentResults.csv	Mid-day off-peak Multi-class equilibrium link flows
pmPeakAssignmentResults.csv	PM peak Multi-class equilibrium link flows
ntOffPeakAssignmentResults.csv	Night off-peak Multi-class equilibrium link flows

Note: amPeak and MdOffPeak files are always produced; last two files produced in 4 period assignments only

Table 10.13. Highway Assignment Network Flow Results Files Fields

Field Names	Descriptions
id	Link id
Anode	Start node id for link
bnode	End node id for link
Capacity	Total capacity used for link in volume delay functions
assignmentTime	Equilibrium travel time from multi-class user-equilibrium solution
assignmentFlow_1	Equilibrium link flow for vehicle class 1 (auto)
assignmentFlow_2	Equilibrium link flow for vehicle class 2 (TRK1:light)
assignmentFlow_3	Equilibrium link flow for vehicle class 3 (TRK2,3:medium)
assignmentFlow_4	Equilibrium link flow for vehicle class 4 (TRK4,5:heavy)

Note: assignmentFlow1 is always auto, if auto is designated as an assignment class. Vehicles class 2 is the first truck grouping which could be one of the truck classes, or any combination of them. The table shows the fields output if three classes were defined for the 5 truck types.

TS level of service skim output files produced by the highway assignment procedure are summarized in Table 10.14. These skim matrix files are produced at the alpha zone level and then also summarized at the beta zone level. Beta zone skim matrix files are aggregations of the corresponding alpha zone level matrices and are used by model components that use more spatially aggregate impedance measures – CT and PI.

Table 10.14. Highway Level of Service Skim Files

Peak File Names	Off-Peak File Names	Descriptions
pkautodist.zmx	opautodist.zmx	Auto class alpha OD distance in miles
pkautofftime.zmx	opautofftime.zmx	Auto class alpha OD free flow travel time in minutes
pkautotime.zmx	opautotime.zmx	Auto class alpha OD equilibrium travel time in minutes
pkautotoll.zmx	opautotoll.zmx	Auto class alpha OD toll related cost in 1990 dollars
pktrk1dist.zmx	optrk1dist.zmx	Truck class 1 alpha OD distance in miles
pktrk1fftime.zmx	optrk1fftime.zmx	Truck class 1 alpha OD free flow travel time in minutes
pktrk1time.zmx	optrk1time.zmx	Truck class 1 alpha OD equilibrium travel time in minutes
pktrk1toll.zmx	optrk1toll.zmx	Truck class 1 alpha OD toll related cost in 1990 dollars
pktrk2dist.zmx	optrk2dist.zmx	Truck class 2 alpha OD distance in miles
pktrk2fftime.zmx	optrk2fftime.zmx	Truck class 2 alpha OD free flow travel time in minutes
pktrk2time.zmx	optrk2time.zmx	Truck class 2 alpha OD equilibrium travel time in minutes
pktrk2toll.zmx	optrk2toll.zmx	Truck class 2 alpha OD toll related cost in 1990 dollars
pktrk3dist.zmx	optrk3dist.zmx	Truck class 3 alpha OD distance in miles
pktrk3fftime.zmx	optrk3fftime.zmx	Truck class 3 alpha OD free flow travel time in minutes
pktrk3time.zmx	optrk3time.zmx	Truck class 3 alpha OD equilibrium travel time in minutes
pktrk3toll.zmx	optrk3toll.zmx	Truck class 3 alpha OD toll related cost in 1990 dollars

Note: Class 4 and class 5 truck files could also be included if those classes are so defined; likewise as few as 0 truck classes could be defined, as long as auto class is specified. Beta Zone versions of these files are also created, with similar filenames preceded by "beta".

TS also produces trip length distributions in aggregations of 1 minute and 1 mile (up to 1017) by assignment class and time period. These files are listed in Table 10.15. The three fields in each of these files are simply: interval, minuteTrips, mileTrips.

Table 10.15. Trip Length Distribution Files

File Names	Descriptions
tld_a_ampeak.csv tld_d_ampeak.csv tld_e_ampeak.csv tld_f_ampeak.csv	AM peak trips by trip time and distance bands (1 minute, 1 mile) Per auto (a) and truck (d,e,f) classes defined in Table 10.2
tld_a_mdoffpeak.csv tld_d_mdoffpeak.csv tld_e_mdoffpeak.csv tld_f_mdoffpeak.csv	Mid-day off-peak trips by trip time and distance bands (1 minute, 1 mile) Per auto (a) and truck (d,e,f) classes defined in Table 10.2
tld_a_pmpeak.csv tld_d_pmpeak.csv tld_e_pmpeak.csv tld_f_pmpeak.csv	PM peak trips by trip time and distance bands (1 minute, 1 mile) Per auto (a) and truck (d,e,f) classes defined in Table 10.2
tld_a_ntoffpeak.csv tld_d_ntoffpeak.csv tld_e_ntoffpeak.csv tld_f_ntoffpeak.csv	Night off-peak trips by trip time and distance bands (1 minute, 1 mile) Per auto (a) and truck (d,e,f) classes defined in Table 10.2

Note: ampeak and mdoffpeak files always produced; last two files sets produced in 4 period assignments only

10.6.7. TS Transit Outputs

Like highway assignment procedures, TS transit assignment procedures write output files that describe the level of service and network loading (boarding) for transit trips. Rather than link flows, the transit assignment results are reported as transit route boardings. These results are reported in a tabular format by transit line so that summary metrics can easily be produced. The files written by the TS transit assignment procedure are shown in Table 10.16. Also like the highway assignment results files, the files may be produced from either a four period TS model run or a two period run. The fields included in these output files are shown in Table 10.17.

Table 10.16. Transit Assignment Results Files

File Names	Descriptions
amPeakRouteBoardings.csv mdOffPeakRouteBoardings.csv pmPeakRouteBoardings.csv ntOffPeakRouteBoardings.csv	AM peak transit boardings by route over all service types Mid-day off-peak transit boardings by route over all service types PM peak transit boardings by route over all service types Night off-peak transit boardings by route over all service types

Note: amPeak and MdOffPeak files are always produced; last two files produced in 4 period assignments only

Table 10.17. Transit Assignment Route Boardings Results File Fields

Field Names	Descriptions
Count	Sequence number for routes in this file
Route	Transit route name from d221 file
Description	Transit route description from d221 file
RouteType	Service type for route – air, intercity rail, intercity bus, or intra-city transit
Mode	Highway network mode flag
wAir	N/A – walk access to Air is not modeled
dAir	Drive access Air boardings for route
wHsr	Walk access intercity rail boardings for route
dHsr	Drive access intercity rail boardings for route
wIc	Walk access intercity bus boardings for route
dIc	Drive access intercity bus boardings for route
wt	Walk access intra-city transit boardings for route
dt	Drive access intra-city transit boardings for route
wTot	Walk access boardings over all service types for route
dTot	Drive access boardings over all service types for route
Total	Total boardings over all service types and access modes for route

TS level of service skim output files produced by the transit assignment procedure are listed in Table 10.18. These skim matrix files are produced at the alpha zone level. There are no matrix files written out for transit skims at the beta zone level. Note that not every level of service attribute is needed for every service type, i.e. air skims have fewer tables than intra-city transit. Only the attributes required to compute choice model utilities by the PT module is written to output files.

Table 10.18. Transit Skim Matrix Output Files

Peak File Names	Off-Peak File Names	Descriptions
pkdairdrv.zmx	opdairdrv.zmx	Drive access Air drive time in minutes
pkdairfar.zmx	opdairfar.zmx	Drive access Air fare in 1990$
pkdairfwt.zmx	opdairfwt.zmx	Drive access Air first wait time in minutes
pkdairivt.zmx	opdairivt.zmx	Drive access Air in-vehicle time in minutes
pkdicrdrv.zmx	opdicrdrv.zmx	Drive access intercity rail drive time in minutes
pkdicrfar.zmx	opdicrfar.zmx	Drive access intercity rail fare in 1990$
pkdicrfwt.zmx	opdicrfwt.zmx	Drive access intercity rail first wait time in minutes
pkdicrtwt.zmx	opdicrtwt.zmx	Drive access intercity rail total wait time in minutes
pkdicrivt.zmx	opdicrivt.zmx	Drive access intercity rail in-vehicle time in minutes
pkdicrxwk.zmx	opdicrxwk.zmx	Drive access intercity rail transfer walk time in minutes
pkdicdrv.zmx	opdicdrv.zmx	Drive access Intercity bus drive time in minutes
pkdicfar.zmx	opdicfar.zmx	Drive access Intercity bus fare in 1990$
pkdicfwt.zmx	opdicfwt.zmx	Drive access Intercity bus first wait time in minutes
pkdictwt.zmx	opdictwt.zmx	Drive access Intercity bus total wait time in minutes
pkdicivt.zmx	opdicivt.zmx	Drive access Intercity bus in-vehicle time in minutes
pkdicxwk.zmx	opdicxwk.zmx	Drive access Intercity bus transfer walk time in minutes
pkdtdrv.zmx	opdtdrv.zmx	Drive access Intra-city Transit drive time in minutes
pkdtfar.zmx	opdtfar.zmx	Drive access Intra-city Transit fare in 1990$
pkdtfwt.zmx	opdtfwt.zmx	Drive access Intra-city Transit first wait in minutes
pkdttwt.zmx	opdttwt.zmx	Drive access Intra-city Transit total wait time in minutes
pkdtewk.zmx	opdtewk.zmx	Drive access Intra-city Transit egress walk time in minutes
pkdtxwk.zmx	opdtxwk.zmx	Drive access Intra-city Transit transfer walk time in minutes
pkdtbrd.zmx	opdtbrd.zmx	Drive access Intra-city Transit number of transit rte. boardings
pkdtivt.zmx	opdtivt.zmx	Drive access Intra-city Transit in-vehicle time in minutes
pkwicrfar.zmx	opwicrfar.zmx	Walk access intercity rail fare in 1990$
pkwicrfwt.zmx	opwicrfwt.zmx	Walk access intercity rail first wait time in minutes
pkwicrtwt.zmx	opwicrtwt.zmx	Walk access intercity rail total wait time in minutes
pkwicrivt.zmx	opwicrivt.zmx	Walk access intercity rail in-vehicle time in minutes
pkwicrawk.zmx	opwicrawk.zmx	Walk access intercity rail access walk time in minutes
pkwicrewk.zmx	opwicrewk.zmx	Walk access intercity rail egress walk time in minutes
pkwicrxwk.zmx	opwicrxwk.zmx	Walk access intercity rail transfer walk time in minutes

Peak File Names	Off-Peak File Names	Descriptions
pkwicfar.zmx	opwicfar.zmx	Walk access Intercity bus fare in 1990$
pkwicfwt.zmx	opwicfwt.zmx	Walk access Intercity bus first wait time in minutes
pkwictwt.zmx	opwictwt.zmx	Walk access Intercity bus total wait time in minutes
pkwicivt.zmx	opwicivt.zmx	Walk access Intercity bus in-vehicle time in minutes
pkwicawk.zmx	opwicawk.zmx	Walk access Intercity bus access walk time in minutes
pkwicewk.zmx	opwicewk.zmx	Walk access Intercity bus egress walk time in minutes
pkwicxwk.zmx	opwicxwk.zmx	Walk access Intercity bus transfer walk time in minutes
pkwicbrd.zmx	opwicbrd.zmx	Walk access Intercity bus transit rte. boardings
pkwtfar.zmx	opwtfar.zmx	Walk access Intra-city transit fare in 1990$
pkwtfwt.zmx	opwtfwt.zmx	Walk access Intra-city transit first wait time in minutes
pkwttwt.zmx	opwttwt.zmx	Walk access Intra-city transit total wait time in minutes
pkwtivt.zmx	opwtivt.zmx	Walk access Intra-city transit in-vehicle time in minutes
pkwtawk.zmx	opwtawk.zmx	Walk access Intra-city transit access walk time in minutes
pkwtewk.zmx	opwtewk.zmx	Walk access Intra-city transit egress walk time in minutes
pkwtxwk.zmx	opwtxwk.zmx	Walk access Intra-city transit transfer walk time in minutes
pkwtbrd.zmx	opwtbrd.zmx	Walk access Intra-city transit rte. boardings

Note: walk access to air is not allowed, so no level of service tables exist for that combination of access mode and service type.

TS can also produce route file summaries (optional) named routes_#, where # is the transit route line number defined in the input transit route file. These files summarize the sequence of nodes in the coded transit routes. The fields in these text format files are: rteIndex, rteName, segmentIndex, an, bn, linked.

10.7. Validation Targets

The TS validation targets are shown in Table 10.19. Key targets are network traffic counts by time period and vehicle classification from ODOT automatic traffic recorder (ATR) data supplemented with MPO vehicle classification counts. Roadway VMT (volume, times, distance) are compared with HPMS datasets. TS transit boardings are also compared with similar data from the major transit agencies across the state. Additional target data that could be evaluated are also included in Table 10.19.

TS validation reports consist of link based summary statistics of roadway flows by aggregate measures including range of volume categories, function classification, and aggregations of comparable link flows within each MPO region, against ODOT ATR counts (linkCategorySumaries_pmpeak_$year$.txt). The comparison includes calculation of percent error and percent root mean square error (RMSE). TS link volumes are also plotted against observed traffic counts in same or similar years, including ODOT ATR as well as MPO count data for each time period and the full day (TSPlots_tn.pdf). Separate sets of plots cover all vehicles and trucks only. Using the same data, daily RMSE is calculated and plotted for individual locations and aggregated screenline locations, shown in Figure 10.3. In 2010, upgrades to the model calibration compared the estimated link volumes to more recent HPMS count data by MPO, County, Area Type and Functional Classifications, as well as selected link locations.

Transit validation reports include summary statistics on network links and nodes to indicate measures of flows and boardings in various areas defined by geographic boundaries or at pre-determined individual locations of interest. For calibration purposes, system-wide measures were calibrated. Estimated daily transit boardings system-wide are compared against targets (assuming annual ridership data divided by 365 days). Portland ridership is also compared by transit line, where available (TSPlots_tn.pdf).

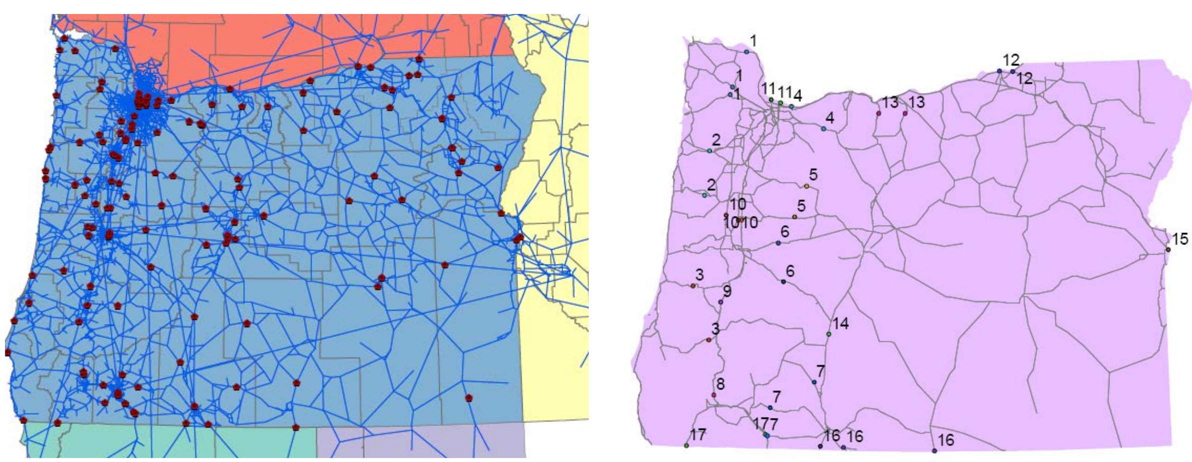
Trip length distributions by vehicle class (auto, 3 truck types) and period were also reported and reviewed (without calibration targets) to look for anomalies (TSPlots_tn.pdf). GIS plots of volume to capacity ratios were also reviewed for anomalies.

Table 10.19. TS Validation Targets

Source	Year	Target
Official Targets		
ODOT Traffic Count database (ATR data at 251 locations across Oregon)	1996-2002	Daily and peak/off-peak link flows by ATR location and aggregated to screenline counts
MPO Traffic Count databases (Metro, LaneCOG, MWVCOG,RVCOG)	Various	Peak and Off-Peak hourly link flows by vehicle type
Metro Truck Counts	2006	
Local Transit Boarding data (Tri-Met, Lane Transit District, Rogue Valley Transit District, Corvallis Transit District)	1987-1996 TriMet 1990 LTD 1993-1999 RVTD 1996 CTS	System-wide daily passenger boardings (annual/365) Transit line daily passenger boardings (Tri-Met only)
Highway Performance Monitoring System (HPMS)	1990-2002	Percent functional class within HPMS areas (Rural, Small Urban, Portland-Eugene, Salem-Medford Urbanized areas)
ODOT Transportation Monitoring Unit State VMT by vehicle type	1976-2006	Oregon State-road DVMT by county
ODOT Finance Section	1980-2002	Total State DVMT by vehicle weight (auto, light, med, heavy)
Additional Targets		
ODOT database http://www.odot.state.or.us/tdb/traffic_monitoring/vmt.htm	1997-2002	Total Annual VMT
Congestion Management Data	1982-2002	Total Annual VMT by county by urban/rural and roadway functional class

Figure 10.3. ODOT Automatic Traffic Recorders (ATR) count data location

251 ATR locations 17 Screenline aggregations



10.8. Initial Validation

The results of the roadway and transit network loadings reflect the validation of the entire model. There are no parameters to adjust that affect the quality of the TS network loadings, but rather the loadings that result from TS modules reflect the quality of modal allocation, choices of destination, allocations by time period, generation of tours, all the elements that are determined throughout the integrated model. TS modules are therefore not calibrated, but results are evaluated to diagnose network problems and issues with results from other modules.

The June 2008 and October 2010 TS validation results indicated:

- **Roadway Assignment Method Validation**. The highway network skimming procedures were validated by comparing distance skim matrices computed using EMME/2 with those computed with TS methods. During validation, the TS distance based skims matched EMME/2 output in 100 percent of origin-destination pairs, showing that the shortest paths computed by TS methods matched those computed using EMME/2.
- **Transit Assignment Method Validation.** Comparisons of optimal strategy based skims of the transit network show that TS produces reasonable transit assignments with respect to those produced by EMME/2. Although these assignments don't exactly match EMME/2 assignments, they are deemed reasonable. The differences have been isolated to differences in processing dwell time at the beginning and end of optimal strategies and are difficult to resolve without more information about the exact way EMME/2 processes these elements. By trial and error, it can be shown that results are slightly different, but the reason for the difference can't be determined. The in-vehicle and other out-of vehicle travel components have been verified to match those of EMME/2's. This implementation of the transit assignment procedures will therefore be considered validated.
- **Roadway Link Counts**. TS output traffic loading assigned to selected roadway links was compared to ODOT HPMS traffic counts on links. Autos and trucks were compared separately. For trucks, count data at the individual link level does not compare very well. However, when summarized to the Area Type, MPO, county, or facility type, the comparisons are much more reasonable. Auto link volumes are both over and underestimated. These values are underestimated in total, which may be due to PI allocation of households and workers. Next steps include looking at resolving the PI allocation. In the MPO areas, the volumes are generally very underassigned on links, while links on the highway system tend to be overassigned.
- **Transit System Boardings**. Transit boardings for Eugene and Corvallis were reasonable for a statewide model, while TriMet system-wide targets were unusually high, despite matching individual boardings by lines fairly well. Target data inaccuracies are suspected.
- **Trip Length Distributions**. Auto trip length distributions followed the typical normal curve with a long right tail, with most trips within a range of 0-30 miles and largest frequency within 0-10 miles. Truck trips were longer, as expected.
- **Statewide VMT**. Under investigation…

Comments:

- Path skimming in TS is based on shortest paths determined by minimizing a generalized cost determined as a weighted sum of link time, distance and cost. Highway time, distance and cost skim matrices may be summed over these shortest generalized cost paths.

- TS was updated to allow assignment for up to 5 truck types, auto classes as specified in an updated 2000 Roadway network. By way of entries in a properties file, a multi-class assignment can be made using the specified user classes which may include auto and/or any combination of the 5 truck types. To keep run times reasonable, TS software is currently being distributed. Code has been written and is undergoing testing.
- The roadway network, based on MPO model networks, was found to be too detailed for the SWIM2 zones. The network was pruned of smaller roadways.
- Added passenger car equivalent (PCE) for various truck types in delay calculations, using PCE factor set in the properties file.
- Added generalized cost terms in path building, as documented above.
- Added recalculation of mclogsums (aggregate PT calculations described in Section 7.3.1) after TS is run in order to provide consistent time/distance and mclogsum skims to the PI module the following year.

10.9. S3 Parameters

There are no S3 parameters anticipated for TS.

11.0 ED-PI Feedback Module (EPF)

To optional ED-PI Feedback (EPF) module allows some adjustment to the fixed modelwide economy output by the ED module. It is a simplified dynamic adjustment to the ED economic forecast output, taking into consideration the statewide composite location utilities by industry from the PI module. The PI module influence depends on relative change from prior year in the same scenario as well as those same year changes in a Reference Scenario. The EPF module is implemented as a post-processor on the current ED economic model, turned on through a properties file flag.

11.1. Theoretical Basis

The EPF module was built as an optional post-processor, to adjust ED outputs used by PI (modelwide industry 1990$), SPG (modelwide employment), and ALD (modelwide construction 1990$). When EPF is operating, these estimates are adjusted based on prior-year compounded aggregate utility measures by industry from PI as compared to a the same years in a Reference Scenario. It utilizes PI composite utilities from the prior year of the current run, as well as from the same year of a reference model run.

It should be noted that a more complete implementation is under consideration that would involve feedback of the same PI composite utilities in the ED module functional equations, rather than as a post-processor, which will require re-estimation of the ED equations.

11.2. Quantity Definitions and Categories

The EPF) module works at the modelwide level. Some inputs from other modules are aggregated from zonal data. EPF primarily uses PI industry categories (6.2), but must interface with both ED and SPG which utilize more aggregate categories (no white collar split, per Sections 3.2 and 4.2). To interface with ALD, EPF uses PI household categories to relate to residential construction impacts, and PI industry output categories for non-residential construction.

11.3 Component Models

The ED-PI Feedback (EPF) module was built as a post-processor, adjusting ED output (industry$, employment, and construction$) estimates based on prior-year compounded aggregate utility measures by industry from PI, per the following equations. :

$$EDadj_{ED\ Ind}^{yr\ i} = EDorig_{ED\ Ind}^{yr\ i}\ x\ \prod_{prior\ yrs} PI\ Influence\ Factor_{ED\ Ind}^{yr\ i} \tag{11.1}$$

Where:

$$PI\ Influence\ Factor_{ED\ Ind}^{yr\ i} = Ave_{\forall\ PI\ Activites\ in\ ED\ Ind}\left[1 + \Delta\left[\frac{1-e^{\eta L}}{1+e^{\eta L}}\right] + \mu[L]\right] \tag{11.2}$$

$$L = [(c^{yr\ i} - c^{yr\ i-1}) - ({c_{ref}}^{yr\ i} - {c_{ref}}^{yr\ i-1})] \tag{11.3}$$

$$c = PICompositeUtility_{PI\ Ind}^{yr\ i} \tag{11.4}$$

where:

$EDadj_{ED\ Ind}^{yr\ i}$ = Adjusted ED modelwide output of industry *ED Ind* in year *i*

$EDorig_{ED\ Ind}^{yr\ i}$ = Original ED modelwide output of industry *ED Ind* in year *i*

$PI\ Influence\ Factor_{ED\ Ind}^{yr\ i}$ = PI Influence Factor for industry *ED Ind* in year *i*Delta

Δ = coefficient on the exponential term of the PI Influence factor

μ = coefficient on the linear term of the PI Influence factor

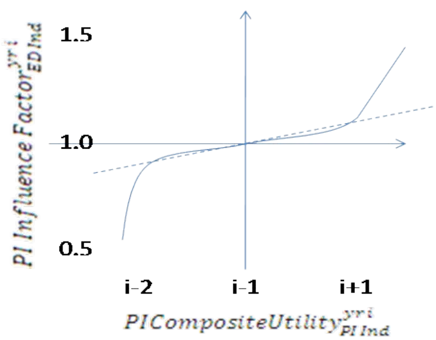
η = coefficient on the exponent of the non-linear term of the PI Influence factor

L = Linear term of the PI Influence factor

$c^{yr\ i}, c_{ref}{}^{yr\ i}, PICompositeUtility^{yr\ i}_{PI\ Ind}$ = the PI composite Utility for industry *PI Ind* in year *i* from either the current run or reference run.[ActivitySummary.csv]

Note that in Eq. 11.2, there is both an exponential and linear term which allows the adjustments per the curve shown in Figure 11.1, However, only the exponential term was required during initial calibration.

Figure 11.1. Shape of the PI Influence Factor Curve



Two intermediate files are created as exemplified below.

PI_EDfeedbackParametersI.csv

ED Industry	PI Industry	Δ Exp Term Coeff	μ Linear Term Coeff	η Utility scaling
1-	-to- many	Calibrate; Initially= 0 (i.e., linear only)	Calibrate (expect >0)	1.0

PI_EDInfluenceFactors.csv ($PI\ Influence\ Factor^{yr\ i}_{ED\ Ind}$ values should be close to 1.0)

Year	ED Industry 1	ED Industry 2	ED Industry 3	Etc.
Baseyear				
Baseyear +1				
Baseyear +2				
Etc.				

Factors based on previous compounded factors over time (multiply all previous year factors for that sector). For example, year 1998 with base year 1990, file will have factors =1 for all pre-1998 years, until PI output is available to update the factors.

11.4 Software Implementation

EPF was implemented in java code as a separate SWIM2 module. It is optional and implemented after the ED module only when a flag is indicated in the [globalTemplate.properties] file. A single class called EdPiFeedback is used to adjust ED outputs based on feedback for the PI module. The program first calculates the influence factors for ED industries associated with the PI, SPG, and ALD modules using PI composite utilities from the prior year of the current run, as well as from the same year of a reference model run. The software then updates the output files that ED produced with the adjusted values. The original values are retained in the file for comparison.

11.5 S1 and S2 Module Parameters

The EPF module includes parameters used in set-up and calibrated parameters part of Equations (3.19)-(3.22).

11.5.1. Set-up

EPF set-up includes the following entries in the scenario's User_inputs/t0 [globalTemplate properties] file.

/user_inputs/SCEN_*/t0 [globalTemplate.properties]

```
####ED_PIFeedback Propertie
epf.hh.units.conversion.factor = 38441
epf.activity.summary.reference =
@ROOT.DIR@/SCEN_OEATrend_2006_2046/t@CURRENT.INTERVAL@/ActivitySummaryReference.csv

epf.feedback.parameters = @ROOT.DIR@/PARAMETERS/ED_PIFeedbackParametersI.csv

epf.influence.factors =
@ROOT.DIR@/@SCENARIO.OUTPUTS@/t@EPF.LAST.RUN@/ED_PIInfluenceFactors.csv

## PI data from last PI run
epf.ActivitySummary =
@ROOT.DIR@/@SCENARIO.OUTPUTS@/t@PI.LAST.RUN@/ActivitySummary.csv

## Input Data in current Year
epf.PreviousActivitySummary =
@ROOT.DIR@/@SCENARIO.OUTPUTS@/t@PI.PRIOR.RUN@/ActivitySummary.csv

epf.activityDollarDataForPi =
@ROOT.DIR@/@SCENARIO.OUTPUTS@/t@CURRENT.INTERVAL@/ActivityDollarDataForPI.csv
epf.jobDataForSpg =
@ROOT.DIR@/@SCENARIO.OUTPUTS@/t@CURRENT.INTERVAL@/JobDataForSPG1.csv
epf.constructionDollarDataForAld =
@ROOT.DIR@/@SCENARIO.OUTPUTS@/t@CURRENT.INTERVAL@/ConstructionDollarDataForALD.csv

##Output Data in Current Year
epf.current.influence.factors =
@ROOT.DIR@/@SCENARIO.OUTPUTS@/t@CURRENT.INTERVAL@/ED_PIInfluenceFactors.csv

pi.working.file =
@ROOT.DIR@/@SCENARIO.OUTPUTS@/t@CURRENT.INTERVAL@/ActivityDollarDataForPI.csv
spg.working.file =
@ROOT.DIR@/@SCENARIO.OUTPUTS@/t@CURRENT.INTERVAL@/JobDataForSPG1.csv
ald.working.file =
@ROOT.DIR@/@SCENARIO.OUTPUTS@/t@CURRENT.INTERVAL@/ConstructionDollarDataForALD.csv
```

The properties file (example noted above) includes the following:

- EPF is turned on using MrsGUI (Model Runner System Graphical User Interface used to start model runs). When selected as part of the model run attributes (attribute in the Pants target), EPF code is instructed to run after the completion of the ED module. EPF is a separate module like ED.

  Note: It is recommended that EPF be turned off unless scenarios involve exogenous actions that are unlikely to be addressed by the mechanisms within the model, such as the exogenous freeway capacity enhancement used in calibration.

- A household units factors, essentially a ratio of labor dollars per household in 1990$, is used to convert household PI logsum data into dollar units consistent with the industry categories.
- The EPF calculations (see Eqs. 11.1-11.4) involve PI data (composite utilities) from prior years in both the current scenario and a Reference Scenario. Thus, these files need to be prepared for EPF to run.
  - To account for initial conditions, files containing surrogate PI logsum values (Activity Summaary.csv) in two years prior to the first SWIM2 predicted year need to be added to these SWIM2 year folders (in this case t14 and t15 for predicting t16). These files are the same, leading to no EPF impact in the first predicted year.

/SCEN_*/t14/ActivitySummary.csv
/SCEN_*/t15/ActivitySummary.csv

Field	Type	Units	Example Values	Description
Activity	Char	NA	ACCOMODATIONS	List of PI Industries
CompositeUtility	Double	NA	1.25769	Utility of Activity
Size	Double	Count or 1990$	1.71E+09	Industry specific size, either a count (for HH), or dollars (for Activity)

  - The ActivitySummaryReference.csv indicates the PI logsum values of the reference run that need to be tabulated before EPF can run. Currently these are created in each tn year folder of the reference scenario (the reference scenario name is noted in the globalTemplate.properties file, as indicated above).

/SCEN_*Reference*/tn/ActivitySummaryReference.csv

Field	Type	Units	Example Values	Description
Activity	Char	NA	ACCOMODATIONS	List of PI Industries
t(n-2)_CompositeUtility	Double	NA	1.25769	Utility of Activity
t(n-1)_CompositeUtility	Double	NA	1.25769	Utility of Activity

11.5.2. Calibrated Parameters

EPF calculations (see Eqs. 11.1-11.4) contain three parameters, which vary by activity type (industry or activity). Only values for the linear term μ were used. Values for Δ and $\boldsymbol{\eta}$ were set to 0 and 1, respectively, to have no effect. The initially calibrated μ values are shown in the table below. [33]

The resulting industry-specific EPF μ parameter values are shown graphically in Exhibit 1. Household μ parameters are used only in processing ED residential construction dollar forecasts, used by ALD. All other (industry-specific) μ parameters were used in processing the remaining ED outputs.

[33] It is recommended that these values be revisited when issues with Boise growth rates are corrected, as they may have impacted calibration.

Table 11.1. Industry-specific μ parameter values & η values

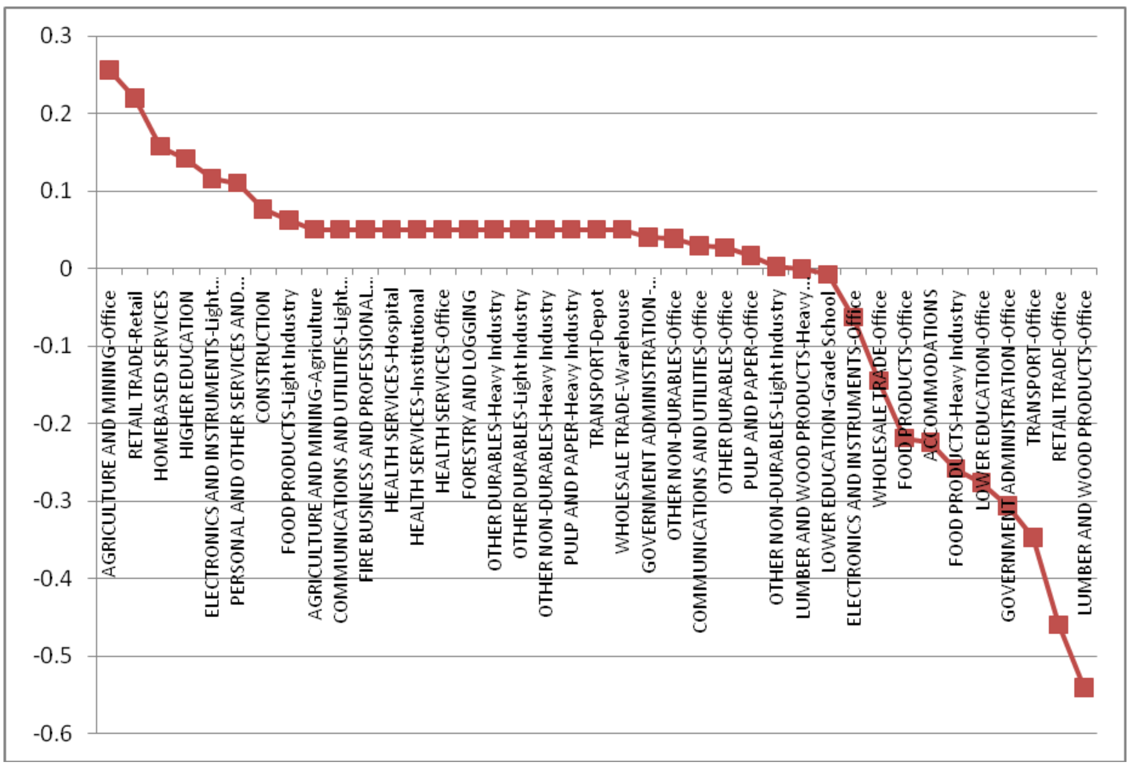
PI_Activity	Delta Exp	Mu Linear Term Coeff	Eta Utility
ACCOMMODATIONS	0	-0.224548387	1
AGRICULTURE AND MINING-Agriculture	0	0.05	1
AGRICULTURE AND MINING-Office	0	0.255947785	1
COMMUNICATIONS AND UTILITIES-Light Industry	0	0.05	1
COMMUNICATIONS AND UTILITIES-Office	0	0.028936022	1
CONSTRUCTION	0	0.076469181	1
ELECTRONICS AND INSTRUMENTS-Light Industry	0	0.115891583	1
ELECTRONICS AND INSTRUMENTS-Office	0	-0.063155199	1
FIRE BUSINESS AND PROFESSIONAL SERVICES	0	0.05	1
FOOD PRODUCTS-Heavy Industry	0	-0.25846034	1
FOOD PRODUCTS-Light Industry	0	0.062384711	1
FOOD PRODUCTS-Office	0	-0.219089265	1
GOVERNMENT ADMINISTRATION-Government Support	0	0.039780809	1
GOVERNMENT ADMINISTRATION-Office	0	-0.305797656	1
HEALTH SERVICES-Hospital	0	0.05	1
HEALTH SERVICES-Institutional	0	0.05	1
HEALTH SERVICES-Office	0	0.05	1
HIGHER EDUCATION	0	0.14149038	1
HOMEBASED SERVICES	0	0.157159356	1
LOWER EDUCATION-Grade School	0	-0.007788441	1
LOWER EDUCATION-Office	0	-0.276413632	1
FORESTRY AND LOGGING	0	0.05	1
LUMBER AND WOOD PRODUCTS-Heavy Industry	0	-0.000535879	1
LUMBER AND WOOD PRODUCTS-Office	0	-0.541052368	1
OTHER DURABLES-Heavy Industry	0	0.05	1
OTHER DURABLES-Light Industry	0	0.05	1
OTHER DURABLES-Office	0	0.026794393	1
OTHER NON-DURABLES-Heavy Industry	0	0.05	1
OTHER NON-DURABLES-Light Industry	0	0.001908227	1
OTHER NON-DURABLES-Office	0	0.038392134	1
PERSONAL AND OTHER SERVICES AND AMUSEMENTS	0	0.109862719	1
PULP AND PAPER-Heavy Industry	0	0.05	1
PULP AND PAPER-Office	0	0.01624851	1
RETAIL TRADE-Office	0	-0.459387882	1
RETAIL TRADE-Retail	0	0.219145016	1
TRANSPORT-Depot	0	0.05	1
TRANSPORT-Office	0	-0.346893102	1
WHOLESALE TRADE-Office	0	-0.145150842	1
WHOLESALE TRADE-Warehouse	0	0.05	1

A positive μ parameter indicates a need to increase the ED model-wide industry output for that industry in response to the increased transportation capacity improvements, to allow growth in the impacted area without stealing from un-impacted areas.[34] In contrast, several office sectors and accommodations, with the highest negative μ values were showing the reverse relationship. There are two identified possibilities for the reverse relationship. First, these industries could be moving into the unaffected areas to occupy space that has been

[34] For example in the calibration scenario, capacity enhancements in the Willamette Valley would not draw from un-impacted areas in the model halo and Boise, in particular. The calibrated parameter from this capacity scenario indicate that Boise activity was impacted in sectors such as retail, education, electronics, food products, and other industries, and an overall increase in ED growth was required to remove any impact to Boise. This is indicated by the positive μ values for these industries.

vacated by other industries moving out of these same unaffected areas. Second, these industries might experience net negative benefits from the capacity improvements. Not all industries can expect to benefit from capacity improvements; there are usually winners and losers with infrastructure projects. In the EPF equations, if L is negative μ will also need to be negative. The impacted industries with the large negative Mu parameter value represent supporting industries (e.g., office-support sectors, accommodations, or secondary processing of agriculture goods into Food products) which could suffer when their associated primary industries are drawn into the capacity improvement region, or who move into the Halo areas when other industries outbid them in the capacity improvement region. These industries could be investigated further in follow-on work. For industries where the secondary impacts of capacity improvement are larger than they primary impacts, it may be more appropriate to use a slightly different treatment which responds directly to the secondary impact directly than to use the existing EPF equations designed to respond to primary impacts.

Figure 11.2. μ values by Industry



It is recommended that the EPF parameters be revisited when the Reference Scenario Boise Growth issues are resolved, which may have impacted calibration of these parameter values. During calibration, Boise was capture significant model growth in industry and households starting quite dramatically in 2014 (t24). This work avoided this issue in large part by calibrating to year 2013 (t23) and earlier. However, further EPF parameter tightening and validation should be revisited now that these issues are resolved.

11.6 Inputs and Outputs

EPF requires only a single parameters file for the three calculation parameters, μ, $\boldsymbol{\eta}$, and Δ and data from other modules. The format of the parameters file is noted below.

Table 11.2. EPF Inputs

Data Element	Source
EPF Parameter Values [PI_EDfeedbackParametersI.csv]	exog
Current Run PI statewide composite utilities by industry [ActivitySummary.csv]	PI
Reference Run PI statewide composite utilities by industry [ActivitySummaryReference.csv]	PI (from Reference Scenario)
Compounding ED-PI Influence factor values by year and industry [ED_PIInfluenceFactorsI.csv]	EPF
Properties file/EPF setup [globalTemplate.propertes]	Exog

/parameters/PI_EDfeedbackParametersI.csv

Field	Type	Units	Example Values	Description
PI_Activity	Char	NA	RETAIL TRADE-Office	List of PI Industries and Households
SPG_Industry	Char	NA	RETAIL TRADE	SPG Industries mapped to each PI industry
SPG_officeShare	Double	%	Between 0-1	Share of industry in white collar office
ALD_category	Char	NA	RES or NRES	Industries used in NRES, households in RES
EDSector-FYI	Char	NA	ORET	ED Industries mapped to each PI industry
Delta Exp Term Coeff	Double		0	EPF Delta Exponential Value by activity
Mu Linear Term Coeff	Double		-0.0078 to +0.2559	EPF Mu Linear Value by activity
Eta Utility Scaling	Double		1 (not use if Delta=0)	EPF Eta Utility Scaling Value by activity

EPF modifies three ED output files used by the PI, SPG, and ED modules.

Table 11.3. EPF Outputs

Data Element	Used by
Compounding ED-PI Influence factor values by year and industry [ED_PIInfluenceFactors.csv]	EPF
EPF-adjusted count of modelwide employment by SPG industry [JobDataForSPG1.csv]	SPG1
EPF-adjusted modelwide residential and nonresidential final demand of new construction$ [ConstructionDollarDataForALD.csv]	ALD
EPF-adjusted modelwide quantities of production activity ($ flow) by PI industry/institution [ActivityDollarDataForPI.csv]	PI

Essentially the original ED output files provided one value for each category (row). That original value field is retained as Old*, and a new value, calculated by EPF is added. This way no changes are required in the other SWIM2 modules.

11.7 Validation Targets

In calibration of the EPF parameters, iterative adjustments were made to the EPF parameters in order to achieve the target industry activities. Below is the multi-stage scheme for model runs completed in 2009 to initially calibrate the PI-ED feedback parameters.

The validation target was essentially to have a significant freeway capacity improvement in the Willamette Valley (Capacity Scenario noted in Stage 1b) have no impact on activity growth in Boise and the halo areas (match Reference Scenario, Stage 1a), while retaining the full benefit in the Willamette Valley (match the Capacity Scenario without EPF).

0) **PREPARATION** (two 4-day runs)
   a. Run **Reference Scenario** 2006-2024;
   b. Run **Capacity Scenario** 2006-2024 (PI-ED feedback flag OFF)

1) **STAGE1: Set μ Parameter initially** – 3 yr spatial only run (4 hr run)
   a. Run Capacity Scenario 2006-2009 Spatial-only run with EPF flag ON (ED-ALD-SPG-PI, use t16 travel skims from 1b above instead of running travel model)
   b. Calibrate **μ** for each industry and household type so Boise impact is removed.

2) **STAGE2: Refine μ Parameter** – 6 yr spatial only run (6 hr run)
   a. Run Capacity Scenario 2006-2012 Spatial-only run with EPF flag ON (ED-ALD-SPG-PI, use t16+t19 skims from 1b above instead of running travel model)
   b. Finer Calibration of **μ** for each industry and household

3) **STAGE3: Refine μ Parameter with Full Model feedbacks** – 6 yr full model run (1-2 day run)
   a. Run Capacity scenario 2006-2012 **full** run with PI-ED feedback flag ON (no transit assignment, PT 10% sample)
   b. Test/re-calibrate **μ** under full model

4) **STAGE4: Evaluate and set Δ and *η* Parameters** – 6 yr spatial model run (1-2 days)
   a. 4 Runs of Capacity Scenario 2006-2012 Spatial-only run with PI-ED feedback flag ON (ED-ALD-SPG-PI, use t16+t19 skims from 1b above instead of running travel model)
      Run1: Δ +10 & ***η*** +10
      Run2: Δ +10 & ***η*** -10
      Run3: Δ -10 & ***η*** +10
      Run4: Δ -10 & ***η*** -10
   b. Set initial Δ and ***η*** values, as needed, to remove over-time impact to Boise.

11.8 Initial Validation

Following the staged calibration process noted above, the validation target is essentially to have the freeway Capacity improvement in the Willamette Valley (Capacity Scenario noted in Stage 1b) have no impact on activity growth in Boise and the halo areas (match Reference scenario, Stage 1a), while retaining the full benefit in the Willamette Valley (match the Capacity scenario without EPF).

The initial μ values attempted (Stage 2b) caused an overflow of the PI module due to interactions that cannot be fully anticipated in calculating μ from static data. The values were then scaled down to 25% of the calculated value. PI did not overflow with the smaller values, and Boise growth was dampened as desired. The model results over time also changed significantly when the full model was run with full transport feedback (Stage 4a, versus spatial only of earlier steps). The location of activities with EPF apparently was significant enough to alter the travel results (relative to the ‘borrowed’ travel results used from Stage 1b in Stages 2 and 3). Thus it was important to run the full SWIM2 model for the remainder of the calibration work.

After initial calibration of the μ parameter (Stage 2b), no further adjustment was deemed necessary to the other non-linear parameters, essentially nullifying the non-linear term in the PI Influence Factor equation (11.2). The over time results tended to oscillate a bit over time, particularly in the years before and after the full model run, where travel results used by the spatial model were updated.

There was some attempt to try to evaluate these ED-PI feedback parameter values relative to theory and the economic feedback assumed in SWIM1.[35] This is complicated by the fact that few published elasticity values exist, and that the variables available for implementing economic feedback in the SWIM1 model differ significantly from those in SWIM2. SWIM1 has an overall emphasis on costs for industry (and doesn't consider some benefits appropriately) which is generally a disadvantage of SWIM1 but it does allow a direct relationship between model-wide growth and cost changes. In SWIM2, as in the real world, growth can increase even if costs increase (for instance transportation infrastructure improvements can lead to more travel and more business opportunities, increasing both costs and benefits). Simple elasticity values on production costs assume a world much simpler than either the real world or SWIM2. Follow on work might be better to directly look at the prices in export and import markets, and the elasticity of change of imports and exports, which could use some of the data collected on empirical elasticities.

11.9 S3 Parameters

All three EPF parameters are S3 parameters and can and should be revised in further calibration, before confidently using this module.

[35] At five-year intervals, SWIM1 was assumed to adjust statewide exports of affected goods proportionally, assuming that market demand for these goods reacts to the change in price. The model assumes that if a scenario resulted in a one percent increase in consumption costs for those outside of Oregon to buy Oregon goods, they will buy one percent less with a resulting decrease in Oregon production.

12.0 Select Link Module (SL)

The optional Select Link (SL) module generates highway assignment paths for later use in generating traditional path analysis outputs such as select link results and subarea matrices, as well as route choice results for the micro simulated trips produced in PT (SDT, LDT) and CT. SL is a post-processor that is optionally added to the end of a SWIM2 model run. It currently uses EMME/3 software installed on the TLUMIP SDC computer cluster.

12.1. Theoretical Basis

The TS module assigns trips and generates skim matrices that are used as network indicators in the other SWIM2 modules. The TS module uses the traditional Frank-Wolfe link-based assignment algorithm in a threaded fashion to improve run times. Frank-Wolfe assignment consists of multiple shortest path searches each time with updated link costs. A new path set is created for each iteration of the algorithm. Without developing complex data structures and interfaces to work with these data structures, the resulting path files can be quite large (GBs of data), especially when multiplied by the number of assignment classes and assignment time periods.

The next generation assignment methods (such as INRO's Projected Gradient method) are much more efficient in terms of data storage and convergence. Thus, the SL module was developed to re-assign the SWIM2 roadway demand (from PT SDT, PT LDT, CT, and ET) to the network using standard travel assignment software packages that employed Projected Gradient in order to develop a Select Link data set for later use. The inconsistency of using TS for assignment within SWIM and Projected Gradient for Select Link is less than ideal. However, the results of the two assignments were compared and found to be quite close to one another. TS tends to employee more focused path set than EMME/3. Long term, it is possible that TS may be replaced by one of these next generation assignment methods, not available when SWIM2 was developed.

The SL assignment is done for an entire day, using daily capacities derived from the four existing time period capacities. A daily assignment was chosen for a few reasons. 1) It is difficult to assign trips within peak periods at a statewide level. For example, there are trips that travel for multiple hours across assignment time periods. A daily assignment avoids this time period/travel distance complication, especially when the results will be reported at the subarea level. 2) As mentioned before, data storage and runtime is an issue, and moving from four time periods to one time period means approximately four times less data and runtime. 3) Getting the SL module up and running and used for actual application was desired over a perfect theoretical solution. Long term, it is desirable to improve the SL module assignment to have better time of day awareness.

12.2. Quantity Definitions and Categories

The SL module runs a daily multi-class assignment using auto and truck demand input by time of day processed by TS module from the SWIM2 modules PT, CT, and ET trip tables (for attributes see Section 7.6, 8.6, and 9.6, respectively). SL outputs daily path files for auto and truck and generates select link or subarea matrices (multiple select links) by mode, purpose, and time of day for each SL assignment class (consistent with TS settings in the [globalTemplate.propertes] file). However, data can be summarized in other ways based on the micro simulated trip data.

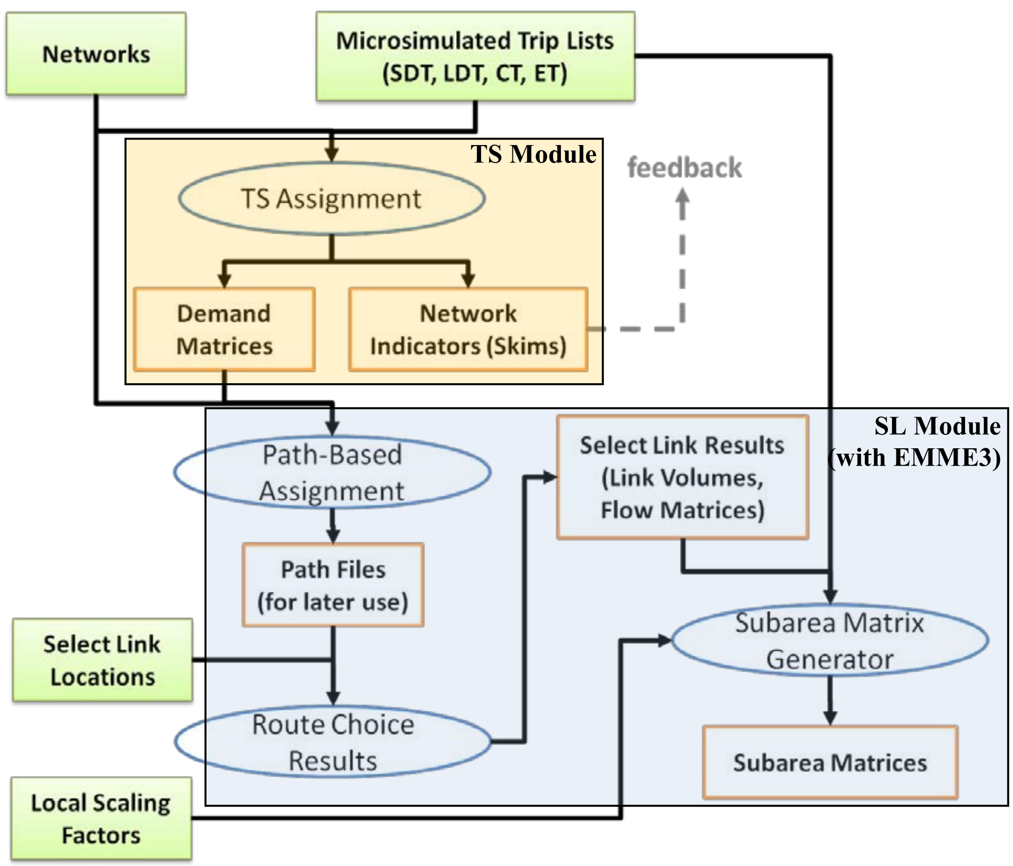
The resulting subarea matrices are written to a CSV file with a column for each matrix by mode, purpose, and time of day. The PT (SDT and LDT) trips are written as mode "auto" and the CT and ET trips as mode "truck." For testing purposes, the PT (SDT and LDT) trips were aggregated to HBW, HBO, and NHB trip purposes. The assignment of trip purposes was based on the following rule:

Home-Based Work (HBW): Any trip with one end at home and the other end at work.
Home-Based Other (HBO): Any trip with one end at home and the other end not at work.
Non-Home-Based (NHB): Any trip with neither end at home.

12.3 Component Models

The SL module consists of a series of components. The following flow chart illustrates the components of the SL module.

Figure 12.1. Select Link (SL) Module Flow Diagram



12.3.1 TS Trip Tables

The SWIM2 TS module reads the PT (SDT and LDT), CT and ET trip lists and, when present in the TS section of the properties file creates demand matrices for SL assignment (see Chapter 10). These demand matrices are written to disk, in the form of ZMX matrix files. TS writes the assignment matrices for each assignment class for each time-of-day for each year, using the following file naming convention:

[demand_matrix_{MODE}_{PERIOD}.zmx.]

12.3.2 Network and Demand Conversion to EMME/3

The next step is to create an EMME/3 databank with the network and demand matrices used by TS. The TS network format is similar to EMME/3's network format, but not quite the same. As a result, the TS network and extra attributes CSV file are read into R, updated, and written out in EMME/3 batch in format. The R script does the following to convert the TS network to EMME/3 format:

1. Converts the 1hour capacity field to a daily capacity using TS assignment period capacity factors (see Section 10.6.3) in the [globalTemplate.properties] file.
2. Moves the capacity from the extra link attributes CSV file (e.g., [highway_2000_attribs.csv]) to the UL3 field in the network file
3. The EMME/3 license available only supports 99 functions. Therefore, the SWIM2 link volume delay (VDF) functions from 101-105 were changed to numbers 91-95.
4. The EMME/3 license available only supports node numbers up to 99,999. Therefore, the 700k series, 800k series, and 900k series nodes were changed to 7000s, 8000s, and 9000s respectively.

The EMME/3 format TS modes file [modes.txt] and VDF file [statewideVdf.txt] are also used in SL.[36] In addition to writing out an EMME/3 format network file, the R script converts the ZMX matrices to EMME/3 text batch-in format files.

The R script also calls three EMME/3 macros – newbank.mac, importNetwork.mac, loadMatrix.mac. These macros create a new databank with 1 network scenario and 4 matrices, load the modes file, load the VDF file, and import the SWIM2 network and daily demand matrices output by TS. Example command line call:

```
R --no-save < genSWIMPaths.R
SCENARIOPATH=z:\models\oregon2tm\SCEN_test\t16
```

12.3.3 Run Path-Based Assignment

The genSWIMPaths.R script also runs EMME/3 Path-Based Traffic Assignment (module 5.25) to assign the daily demand to the daily network utilizing EMME/3's new Projected Gradient algorithm. The Projected Gradient algorithm stores paths for each assignment class to a binary file outside of the databank. These path files can be used later for select link analysis without re-running the model. The daily assignment uses the same generalized cost impedance as TS (see section 10.3.1).

Note that SL components discussed in 12.3.2 and 12.3.3 are run by the SWIM MrsGUI user interface with the following Java command with the "g" generate parameter:

[36] Since these files rarely change, they were manually converted to EMME3 format for use by both the TS and SL modules. This included adding all required fields for the 201 and 411 files, respecting EMME3's 80 characters per line max, and converting all TS vdf attribute names to EMME3 attribute names.

java -cp tlumip.jar;. -Dlog4j.configuration=log4j.xml com.pb.tlumip.sl.SelectLink g

12.3.4 Generate Select Link Flow Matrix Data

After running the assignment and generating paths, the path sets can be later queried and select link volumes and flow matrices generated. T he selectLinkPG.mac and saveMatrix.mac are run for each link in selectLinks.csv. An example [selectLinks.csv] input file is shown in Table 12.1.

Table 12.1. Example User Link input [selectLinks.csv]

FROMNODE	TONODE	DIRECTION	STATIONNUMBER
17388	17389	IN	10012
17389	17388	OUT	10012
20361	20353	IN	10013
20353	20361	OUT	10013

Where:
DIRECTION is IN or OUT and is only used if the user wants to generate subarea matrices
STATIONNUMBER is the station (zone) label for the subarea matrices

The resulting select link volume for auto demand is saved in the extra attribute @avol and the truck demand in @tvol. The select link flow matrices are saved to mf3 (auto) and mf4 (truck). T hese matrices are written out to EMME/3 batch-out format with the saveMatrix.mac macro. The R script then reads in the assigned demand matrices and all the matrices generated for all the selected links and saves out a CSV file with these attributes:

- route share by assignment class,
- link fromnode, link tonode,
- link direction,
- origin,
- destination, and
- station number.

The percent of demand using each select link is calculated by dividing the select link flow matrix value by the assigned demand for each zone pair, shown in Figure 12.1.

Figure 12.2. Select Link OD Demand Calculation

Aflow	1	2		Auto	1	2		Share	1	2
1	30	100	/	1	50	100	=	1	0.6	1
2	20	100		2	20	200		2	1	0.5

An example command line call is below, and a sample output selectLinkResults.csv output file is contained in Table 12.2:

R--no-save < genSelectLinkData.R
SCENARIOPATH=z:\models\oregon2tm\SCEN_test\t16

Table 12.2. Example Link Output [selectLinkResults.csv]

ASSIGNCLASS	FROMNODETONODE	DIRECTION	FROMZONE	TOZONE	PERCENT	STATIONNUMBER
a	17813 17811	OUT	1501	1	1	10012
a	17813 17811	OUT	1501	3	1	10012
a	17813 17811	OUT	1501	9	1	10012
a	17813 17811	OUT	1501	52	1	10012
a	17813 17811	OUT	1501	53	1	10012
a	17813 17811	OUT	1501	54	1	10012
a	17813 17811	OUT	1501	64	1	10012
a	17813 17811	OUT	1501	73	1	10012

Note that the SL component discussed in Section 12.3.4 is run from MrsGUI user interface with the following Java command with the “d” data parameter:

java -cp tlumip.jar;. -Dlog4j.configuration=log4j.xml com.pb.tlumip.sl.SelectLink d

At this point in the SL module, there are a few types of for the SL location results:

1) select link volumes,
2) select link flow matrices, and
3) subarea matrices.

Cases one and two are straight forward and therefore not described. The creation of subarea matrices, not only at the zone pair level, but also at the micro simulation level, is done by the SL module components described in section 12.3.5 and 12.3.6..

12.3.5 Generate Subarea Matrices

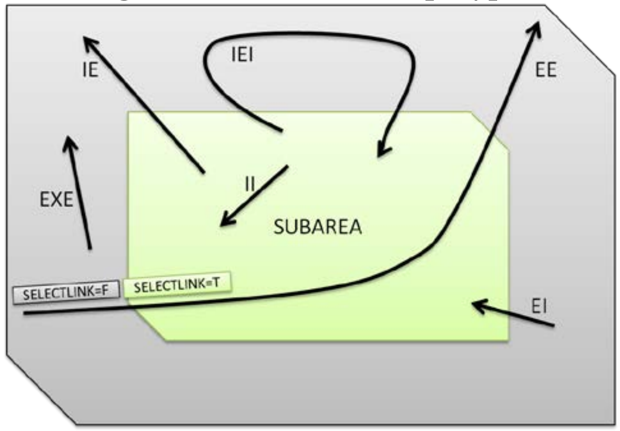
After SL calculates the zone pair share (percent) using each user-specified select link location, the results are then appended to the SWIM trip lists for PT (SDT, LDT), CT, and ET. The auto (a) assignment class results are appended to the SDT and LDT tables, where as the truck (d) assignment class results are appended to the CT and ET tables. Once the select link percent data has been appended to the trip lists, then various types of travel summaries can be prepared using the micro simulated trip list attributes. These summaries can include, for example, the commodities using a link(s) (or a screenline(s)), the household income distribution of all travelers using a link, subarea matrices by trip purpose, subarea matrices by truck class, etc. Currently, subarea matrices by mode, trip purpose, and time of day are created. An example of the appended route choice results to an abbreviated PT-SDT trip list (in terms of records and attributes) is in Table 12.3.

Table 12.3. Example Route Choice Results with new SL fields for each chosen link

hhID	Tour Purpose	origin	dest	Trip StartTime	Trip EndTime	Trip Purpose	Trip Mode	Inc	**Link 17813-17811**	**Link 17813-17812**
15538	SHOP	2327	2363	1400	1400	HOME	SR2	3400	**80%**	**20%**
1903376	SHOP	2328	2372	900	900	SHOP	DA	9500	**100%**	**0%**

When SL generates the subarea matrix, each select link location becomes a new origin or destination using the input station number. Each micro-simulated trip is converted to one of the following trips types in relation to the subarea (II, IE, EI, EE, IEI, and EXE), as shown in Figure 12.3.

Figure 12.3. Subarea Trip Types



If the select link direction=In then the link becomes a row in the matrix. If the select link direction=Out then the link becomes a column in the matrix. For example, a trip list record with appended select link percents for links with Direction=In results in EI relations in the matrix. If a trip list record has 0 percent then the OD pair is either II or EXE and is aggregated in the traditional manner. A more thorough explanation of the creation of the subarea matrix is described in Section 12.3.6 Weaving Paths.

Before creating the subarea matrix, the trips need to be scaled to match the subarea forecast. It is recommended that the subarea be created for a base and future year SWIM2 run that best matches the subarea (local model) in terms of the population and employment forecasts, not necessarily the same model run year. This is accomplished as follows:

1) The [sl_scaling.csv] file is input with the fields in Table 12.4. SWIM2 values can be obtained from PT outputs of [SynPop_TazSummary.csv] and [Employment.csv]. Local values must be obtained from an outside source.

Table 12.4. Example Select Link trip scaling input [sl_scaling.csv]

SWIMZONE	SWIMHHS	LOCALHHS	SWIMEMP	LOCALEMP
100	500	1000	200	220
101	100	110	50	100

2) A “hh” and “emp” factor is calculated as simply the ratio of the SWIM2 households and the SWIM2 employment to the local (subarea) households (hh) and employment.

3) If the trip maker’s home zone (not necessarily trip origin, but rather tour production zone) is in the subarea then the trip will be scaled according to the “hh” factor for that zone. Otherwise the employment factor is used to scale the trip. The theory behind the scaling factors is that trips produced by local households and businesses are primarily influenced by the population (household) forecasts. Trips produced outside

the local area are attracted to the subarea and therefore influenced by the employment forecasts.

4) If the trip is an EE trip, then the trips are adjusted according to an input scaling factor (sl.ee.scaling.factor in [globalTemplate.properties] file). The recommended scaling factor (currently set at 0.95) is based on the following:

   Local forecast population for Oregon ÷SWIM population for Oregon zones

The output matrix is saved to a CSV file in the following form, where matrices are produced for each purpose, class and time period:

- FROMZONE
- TOZONE
- MATRIX1
- MATRIX2
- MATRIX3
- etc.

The zone numbers are the SWIM2 alpha zones except for the newly created sub-area station zones (as input as the station number field in the selectLinks.csv file). The analyst needs to allocate the SWIM2 subarea internal zones to the local zone system, as in Table 12.5.

Table 12.5. Example Subarea output [sl_subarea_demand_matrix.csv]

FROMZONE	TOZONE	A_WORK_AM	D_WORK_AM	etc..
2327	200	5	4	
10001	200	6	8	

Note that the SL component discussed in Section 12.3.5 is run by the SWIM MrsGUI user interface with the following Java command with the "s" data parameter:

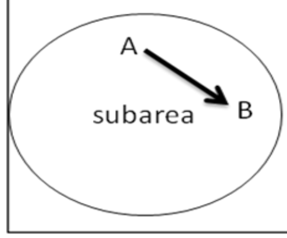
```
java -cp tlumip.jar;. -Dlog4j.configuration=log4j.xml com.pb.tlumip.sl.SelectLink s
```

12.3.6 Weaving Paths

It is fairly straightforward to convert the SL augmented trip lists (including the select link results data, e.g., Table 12.3) to subarea matrices. It gets a bit complicated when the path enters and exits the subarea more than once. These paths, called weaving paths, require special logic when converting them to matrix form. Before describing the weaving paths solution, the simpler cases are illustrated. Below are examples of the II, IE, EI, and EE paths shown graphically in Figure 12.3. The II path does not cross the subarea boundary so it produces no select link results and therefore no SL matrix entries. The IE path produces a select link result for origin=A to destination=B via link=c where link=c is a direction=OUT link. The IE path produces two trips. Similarly the EI path produces two trips. The EE path produces three trips. The weaving example (W) requires knowledge of the select link ordering to assign the trips to the matrix. This is due to the fact that, according to the example, there are two direction=OUT links and it is not known which is the first out link "connected" to the origin zone.

Figure 12.4. Subarea Matrix Creation

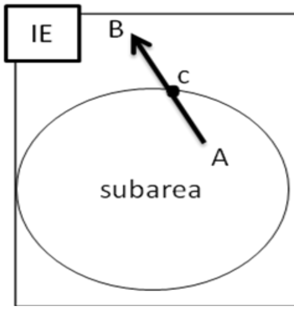
II



No Select Link Results

	A	B	c	d
A				
B				
c				
d				

IE

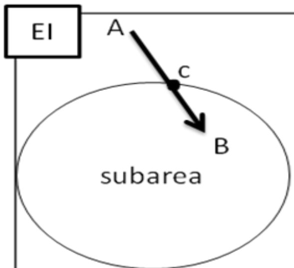


Select Link Results
for links c:

A-c-B (Dir=OUT)

	A	B	c	d
A			1	
B				
c		1		
d				

EI

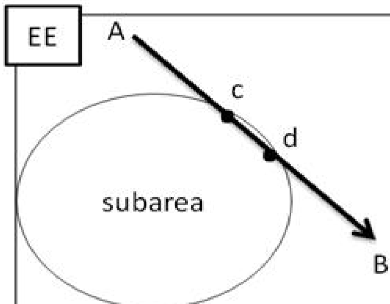


Select Link Results
for links c:

A-c-B (Dir=IN)

	A	B	c	d
A			1	
B				
c		1		
d				

EE



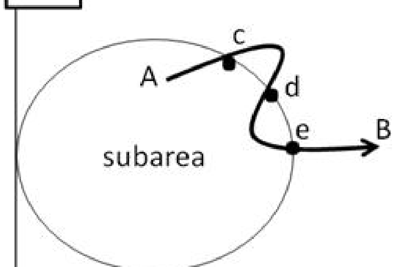
Select Link Results
for links c and d:

A-c-B (Dir=IN)
A-d-B (Dir=OUT)

	A	B	c	d
A			1	
B				
c				1
d		1		

Weaving Path Example

W



Select Link Results
for links c,d,e:
+ Ordering (c,d,e)

A-c-B (Dir=OUT) -> **Ac**
A-d-B (Dir=IN) -> **cd,de**
A-e-B (Dir=OUT) -> **eB**

	A	B	c	d	e
A			1		
B					
c				1	
d					1
e		1			

The getNodeSeq.R script is used to get the node sequence for a path from the EMME/3 path files in order to properly assign the weaving paths. This script reads the weaving paths file output, loops through each zone pair identified in the file, and gets the link ordering from the EMME/3 path files using the savePathNodes.mac file. The script writes out the updated weaving paths file with the ORDERING field. The subarea matrix generation component then reads the results and completes the creation of the subarea matrices. Currently only the shortest path between an zone pair given the calculated path set is used to determine the link ordering. This is almost always correct, but is not guaranteed to be correct. This can be further improved if warranted in a later version of the SL module. An example of the weaving paths file is below.

Table 12.6. Example Subarea Weaving Paths output [sl_weaving.csv]

OD	LINKS	PERCENTAGE	ORDERING
2466 551	17555 17556;17558 15839;15839 17555	1	**3 1 2**
946 2466	17555 15839;15839 17558;36737 36738	1	**1 2 3**
2466 425	17555 17556;17558 15839;15839 17555	1	**3 1 2**

12.4 Software Implementation

The SL module is implemented with three tools: EMME/3, R, and Java. EMME/3 is used for path-based (Projected Gradient) assignment and path file creation. EMME/3 was selected for assignments since ODOT is familiar with it and because EMME/3 has a next generation assignment method that saves paths efficiently. R is used for various data processing tasks and for gluing together sub-model components. R was selected for this task due to its wealth of data processing functionality, flexibility, and familiarity by ODOT staff. Java is used for appending the Select Link results to the large micro simulated trip data sets (from SWIM2 modules PT, CT and ET) and for generating the subarea matrices from those data sets. Java was selected for this task because it efficiently handles large data sets. The SL module can be run through either the SWIM2 user-friendly MrsGUI interface or from the command line. The creation of the basic path files, the source of the Select Link or subarea queries, can be created automatically after a SWIM2 model run if the "SL Paths” option is flagged when starting the run using MrsGUI user interface.

Programs:

1. assignPG.mac – runs the path-based assignment and generates the path files
2. importNetwork.mac – import the SWIM network into EMME
3. loadMatrix.mac – load an EMME matrix from a text file
4. newbank.mac – create an EMME databank
5. saveMatrix.mac – save an EMME matrix to a text file
6. savePathNodes.mac – gets the node sequence for an OD from the path files
7. selectLinkPG.mac – runs select links against the path files
8. genSelectLinkData.R – R wrapper script for selectLinkPG.mac
9. genSWIMPaths.R – R wrapper script for importNetwork.mac and assignPG.mac
10. getNodeSeq.R – R wrapper script for savePathNodes.mac
11. tlumip.jar – TLUMIP Java code

To run the SL module in the SWIM user interface, run the "SL Paths" target to run the path-based assignment, followed by the "SL Generate Select Link Data" target to generate the route choice results, followed by the "SL Synth Trips" target to generate subarea matrices.

12.5 S1 and S2 Module Parameters

The SL module uses the same parameters as used in TS (Sections 10.6.2 and 10.5). These include:

- TS volume delay functions (VDF)
- SWIM2 Networks and link attributes such as speed and capacity
- TS generalized cost impedance functions.
- TS assignment period daily capacity factor. The current daily factor, 10.84 is set in the sl.capacity.factor in [globalTemplate.properties]. This parameter must be kept consistent with the corresponding TS parameters, specified in the same file.

The only difference between the TS and SL assignments is that the TS assignment is done four times per class – once for each time of day, whereas the SL assignment is done once at a daily level.

12.6 Inputs and Outputs

The SL module requires the following inputs and outputs. Note that SL will always produce select link results [selectLinkResults.csv], and if run further a subarea matrix can be produced [sl_subarea_demand_matrices.csv][sl_weaving.csv]. Several intermediate files are generated by SL and deleted at the end of the run.

Table 12.7. SL Inputs

Data Element	Source
SWIM2 Auto and Truck Demand Matrices demand_matrix_{MODE}_{PERIOD}.zmx]	PT, CT, ET
List of links of interest or desired subarea external stations [selectLinks.csv] (see Table 12.1)	exog
SWIM2-to-local area household and employment data to set trip scaling factors [sl_scaling.csv] (see Table 12.4) (1)	exog
SWIM2-to-local area External-External trips scaling factor (sl.capacity.factor) [globalTemplate.properties]	exog
SWIM2-to-local area External-External trips scaling factor (sl.ee.scaling.factor) [globalTemplate.properties]	exog
Network modes in EMME/3 format [modes.201] (2)	exog
Network Volume Delay Functions in EMME/3 format [statewideVdf.411] (2)	exog
TS EMME/3 format roadway network [network.211] (also used by TS)	exog

(1) SWIM2 values can be obtained from PT outputs of [SynPop_TazSummary.csv] and [Employment.csv]. Local values must be obtained from an outside source.

(2) These files are in EMME/3 format which is slightly different than those used by the TS module.

Table 12.8. SL Outputs

Data Element	Source
EMME/3 databank with daily assignment [emmebank]	Diagnostics
EMME/3 path files for each assignment class c# [PATHS_s1_c1, PATHS_s1_c2]	Diagnostics
EMME/3 scaled select link(s) results [selectLinkResults.csv] (see Table 12.2)	Diagnostics
EMME/3 scaled subarea trip matrices results by mode, trip purpose, and time of day [sl_subarea_demand_matrices.csv] (see Table 12.5)	Diagnostics
EMME/3 weaving paths file in subarea analysis [sl_weaving.csv] (see Table 12.6)	

12.7 Validation Targets

The SL module results was validated against traffic counts and the existing TS assignments. In addition, the SL functionality was tested for reasonableness in the following projects in 2010:

- select link for Cornelius Pass Road, at Highway 30 just south of Oregon-Washington in northwest suburbs of Portland [46]
- subarea matrix flows for the ODOT Corvallis Albany Lebanon Model (CALM).[47]

12.8 Initial Validation

In the SL link test for the Cornelius Pass Road analysis, the following information was reported as reasonable. The SL functionality worked as expected, but encountered a memory error in producing the final results, that is being investigatetd.

- The percent of ODs auto and truck flows using the link in either direction by county of origin and destination (tables).
- Figures showing detailed locations for the trip origins and destinations of auto and truck traffic.

In the SL link test for the Corvallis Albany Lebanon Model (CALM) analysis, the following information was reported as reasonable.

- comparison to SWIM2 TS module Annual Average Daily Travel (AADT) results including overall assignment and external station link volumes.
- the pattern of the SL sub-matrix output, including the spatial distribution of in/out trips within the subarea, and a breakdown of trips by time of day and trip purpose.
- In actual application, further validation will include comparison of the SL module results to traffic counts.

The results show that the SL results compare very well with SWIM2 results, with an R-squared of 0.99 for the totals, as well as for auto and truck by themselves. Since the SL process uses EMME/3 assignment, it is not expected to match the SWIM2 TS assignment results exactly. Additionally, TS is run by time-of-day (AM, MD, PM, NT), whereas SL is one daily assignment, which will lead to different results. Figure 12.4 shows the full SL results compared to SWIM2. The comparison was very reasonable by auto and truck volumes alone, as as the total volume.

Figure 12.4. SL Validation SL (EMME/3) to SWIM2 Total, Auto, Truck Vehicles

The results show that the SL results compare very well with SWIM2 results, with an R-squared of .99 for the totals, as well as for auto and truck by themselves. Since the SL process uses EMME3 assignment, it is not expected to match the SWIM2 TS assignment results exactly. Additionally, TS is run by time-of-day (AM, MD, PM, NT), whereas SL is one daily assignment, which will lead to different results. Figure 2 shows the full SL results compared to SWIM2. The auto and truck volumes alone were compared as well, as shown in Figure 12.5. Both compare as well to SWIM2 as the total volume.

Figure 12.5. SL Comparison to Total Vehicles

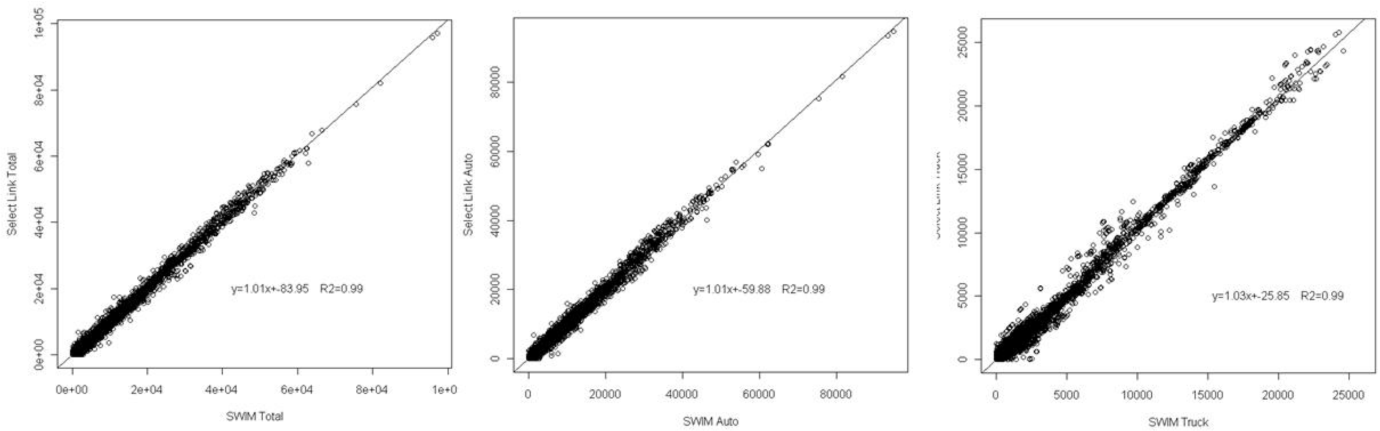
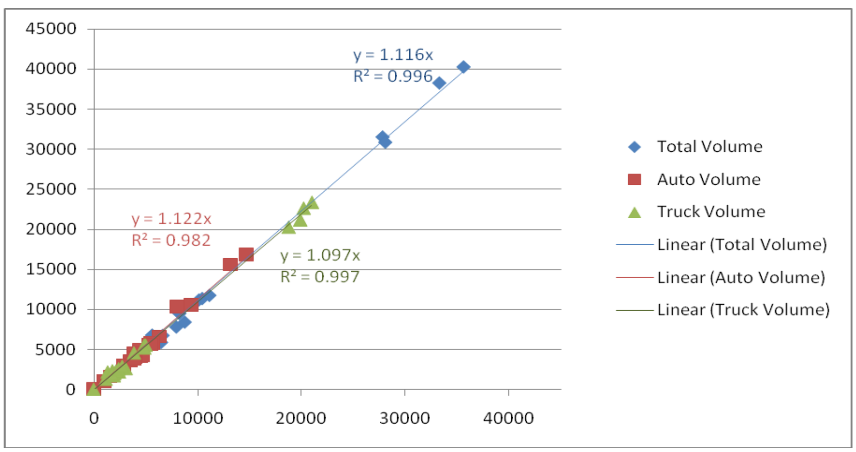


Figure 12.6 shows a scatterplot of the CALM external station volume data from each source. The lines of fit and R-squared value show that the SL and SWIM2 data are very comparable, with an R2 of almost 1.00.

Figure 12.6. Volume Comparison, Select Link to SWIM2 for CALM External Stations



There was some discussion about the need for a process to develop the scaling factors to match SWIM2 link volumes with counts at the subarea border, in the test a default scaling factor of 1 was used.

The SL process will be very useful for isolating SWIM2 results for sharing with MPO and urban model applications. The SL CALM application shows that the SL process is able to reproduce SWIM2 patterns of travel at a subarea-matrix level, and use of the EMME/3 model assignment compares reasonably with TS assignment, despite some differences in the assignment methods. The validation of the SL results went beyond the subarea external stations and successfully compared results for links within the full CALM sub area. There are some fluctuations in the volumes, but the overall fit of SL link volumes to SWIM2 volumes is good. The spatial organization of trip flows into and out of the subarea is also reasonable.

12.9 S3 Parameters

There are no S3 parameters for the SL module.

References

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