

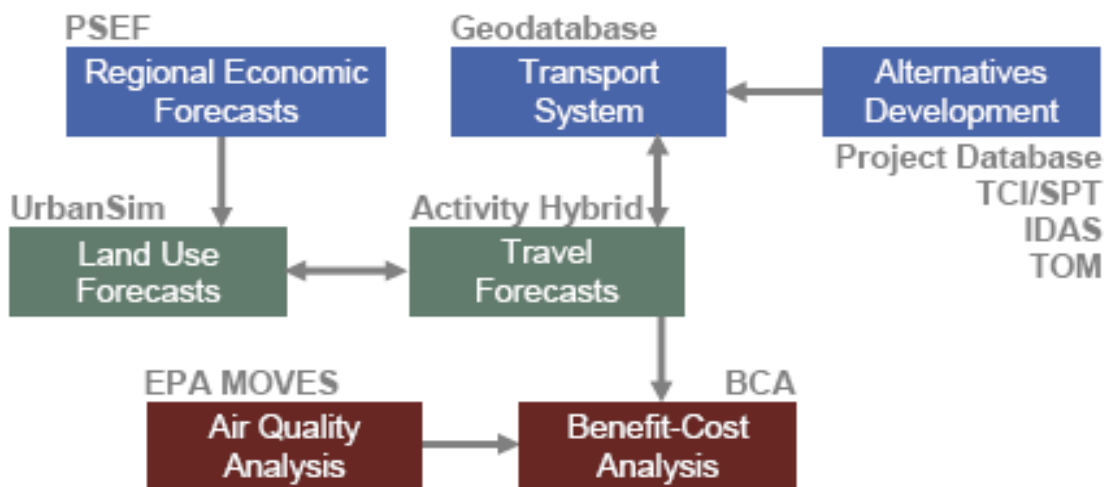


Travel Demand Forecasting / OCTOBER 2009 /

The Puget Sound Regional Council (PSRC) has developed a customized set of computer programs and mathematical procedures to forecast future travel patterns and conditions within the four counties (King, Kitsap, Pierce, and Snohomish) of the Puget Sound region. These programs and procedures are collectively referred to as the “regional travel demand forecasting model” or simply as the “travel model.” The travel model produces data that are used to analyze the likely impacts of travel forecasts on the region’s transportation infrastructure and environment and thus provides the foundation from which the PSRC develops many of its plans, most notably the regional transportation plan, *Transportation 2040*.

This paper describes the overall travel demand modeling and forecasting process used by the PSRC. In doing so, it provides an overview of the basic modeling framework and concepts, it explains the how the model is used and applied, and it lists the key input and output data used and produced by the model. The audience for the following paper is intended to be the lay individual with little or no prior knowledge of travel demand modeling.

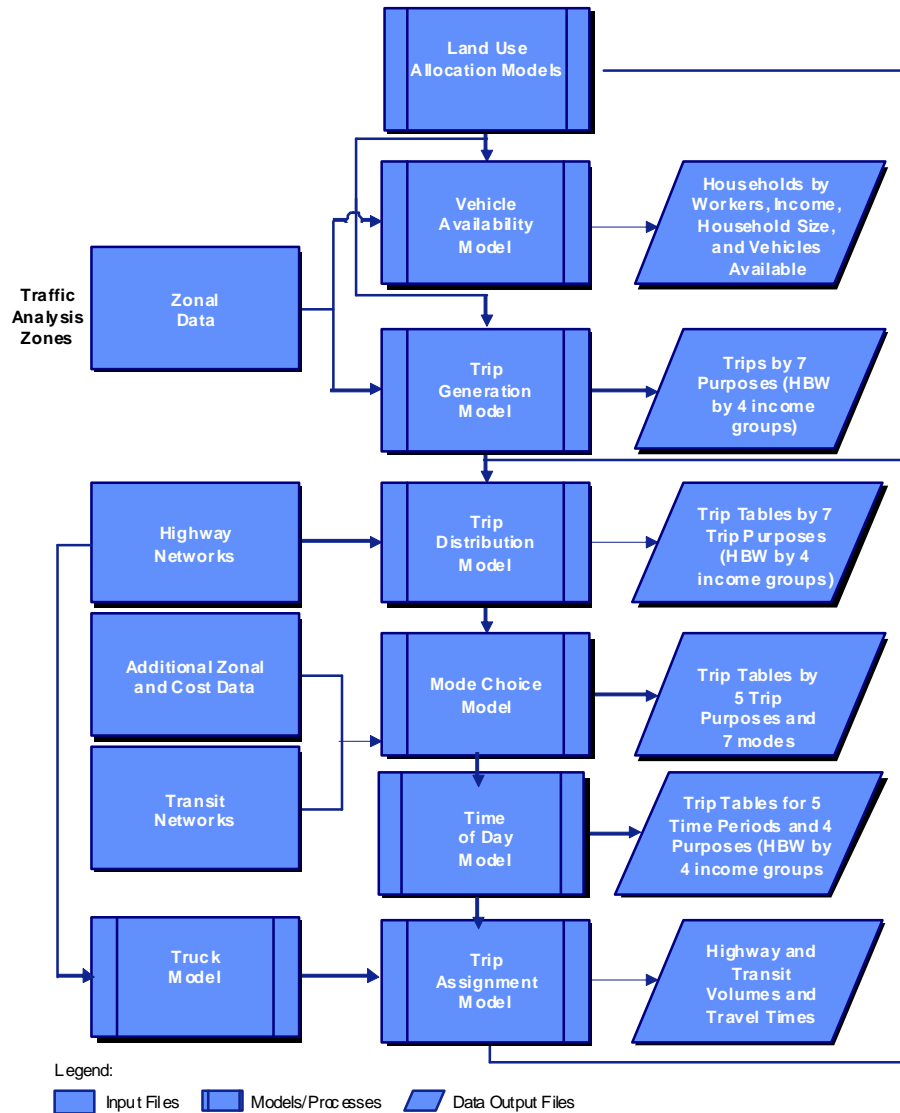
Data produced from the travel model (this includes estimates of current travel as well as future travel forecasts) comprise the centerpiece of the PSRC integrated modeling system. This integrated modeling system is referred to as the Version 2.0 series of the travel model. (The Version 1.0 series were “stand-alone” travel models not fully integrated with a land use model.) Within this overall framework, the travel model interacts directly with the land use model (UrbanSim), and it is the primary source of input data for the air quality (EPA Moves) and benefit-cost analysis (BCA) tools.



Overview

Each trip made by each person residing in the Puget Sound region is estimated by the model. In 2006, for example, approximately 13.7 million “person-trips” were made in the region each day. This equated to approximately 80 million vehicle miles of travel on the roads, 385,000 transit boardings, and 1.4 million bicycle and walk trips per day in 2006. As the region grows, and as more people live and work here, these numbers are expected to increase. By 2040, for example, the number of person-trips occurring each day is expected to exceed 19 million (a 40 percent increase).

The PSRC travel demand forecasting process includes seven basic components: 1) household vehicle availability; 2) person trip generation; 3) trip distribution; 4) mode choice; 5) time of day; 6) trucks; and 7) vehicle trip assignment. Land use allocation is performed using a separate modeling process based on the Urbansim framework.



The majority of the travel behavior represented in the travel model is estimated from a household travel survey. For the Puget Sound region, the last such survey was conducted in 2006. The survey sampled approximately 4,750 households over a two-day period concerning many aspects of each household member’s daily life, including each person’s travel behavior and habits.

What is the travel model used for?

The travel model is used to support the technical analyses of transportation projects and investments under consideration in the region. These analyses occur primarily through the process that adopts a regional transportation plan. Data from the travel model also supports environmental and benefit-cost analyses for transportation projects. These projects may include roadway, transit, non-motorized, or freight investments as well as demand and system management strategies, such as pricing. While the regional travel model supports mostly system-level regional planning activities, it is also used as the basis for corridor or subarea studies conducted by the PSRC or its member jurisdictions. In addition to transportation analysis, the travel model also supports the growth management and economic development activities at the agency.

Within the context of the recent *Transportation 2040* planning process, the travel model, either directly, or indirectly through air quality and benefit-cost analyses, provided much of the data used to develop the findings for the *Policy Analysis and Criteria Evaluation Report*. This report detailed the evaluation of each of six transportation system alternatives considered during the alternatives analysis phase of the planning/environmental review process and its findings will inform the development of a preferred alternative and updated regional transportation plan.

What are the advantages and limitations of the travel model?

Travel forecasting models have been in use at the PSRC for five decades. During this time, the state of the modeling practice has experienced significant advancements as its methods have become increasingly robust. This evolution has led to respect and appreciation for the use of model output data and analyses to inform decision-making.

The primary advantage of the travel model is the ability to objectively compare the performance of transportation alternatives. Performance can be defined in many ways, including the measures used recently for the Transportation 2040 transportation plan update:

- mobility (travel time savings, travel reliability, vehicle operating/ownership costs)
- economic prosperity (accessibility to jobs (low/high wage, clusters, freight)
- environmental stewardship (vehicle emissions, energy use from vehicles)
- quality of life (accident cost savings, non-motorized travel)
- equity (geographic distribution of transportation benefits, income distribution of transportation benefits, distribution of transportation benefits to commercial and personal users, distribution of transportation benefits to historical disadvantaged populations)

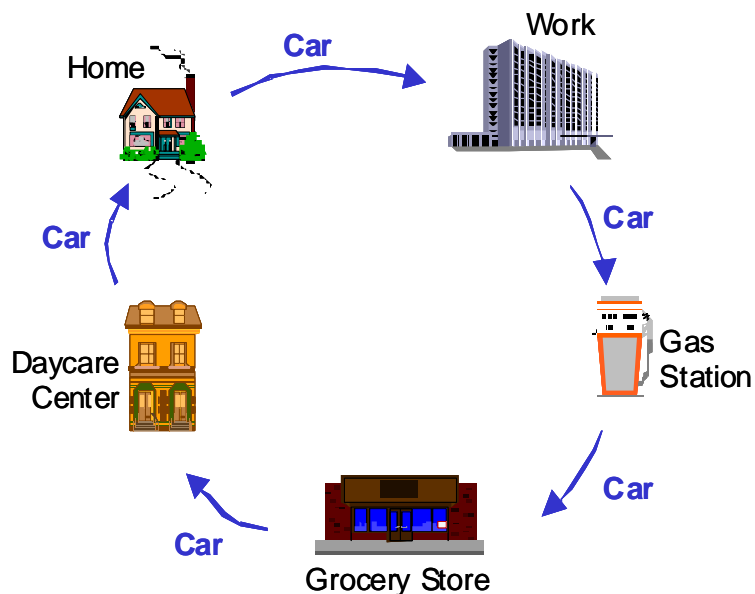
The current limitations of the travel model lie with the coarse spatial resolution of the data sources and the lack of linkages among travel decisions (such as deciding to drive to work in the morning because you want to shop on the way home). Overcoming these limitations and improving behavioral sensitivity form the basis behind the continued development of an activity-based model and, once deployed, will replace the current trip-based model. The first phase of this work, to implement an activity-based trip generator, is complete. The activity-based model will estimate the daily travel patterns of each individual in the region (rather than the aggregate patterns of households in broader geographies) and it will better connect decisions about mode, destination and time of day with decisions about making trips or tours.

How do we use the travel model?

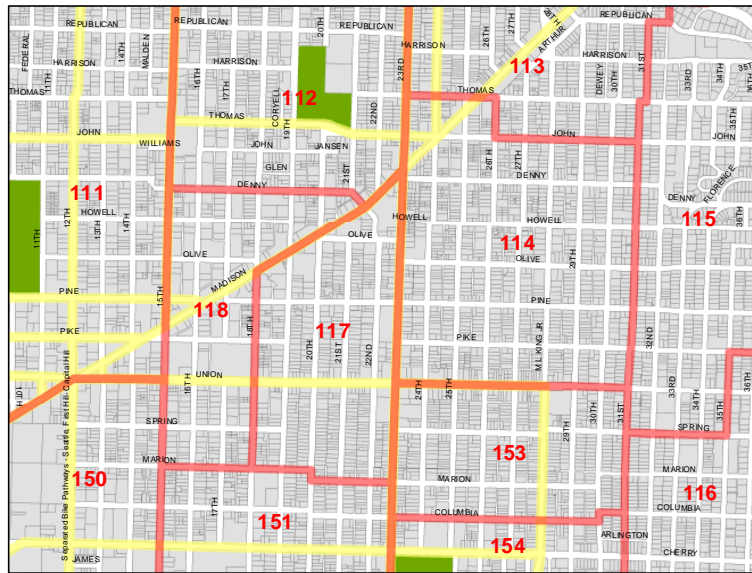
The PSRC model is undergoing a change from traditional trip-based models to an activity-based approach. This approach is currently implemented only for the trip generation model. Activity-based modeling focuses on the fundamental reasons behind personal travel, (i.e., the need to accomplish activities) rather than simply computing the end product (i.e., the number of person-trips). By focusing on the activities that ultimately lead to travel, this approach is more behaviorally consistent than the traditional approach and it allows for the need to travel to be influenced by transportation system conditions, costs, and policies.

The first step in the PSRC process is to create a daily activity pattern for every resident of the region based on characteristics of the population and of the transportation system. One attribute that strongly affects trip-making is the number of vehicles that are available to a household, so this data is initially estimated for households in the region with a separate model. The modeling process is most concerned about those activities that occur outside of the home and require travel, such as going to work or going shopping, even though a person may participate in many activities during the course of a day, such as preparing dinner, doing laundry, or watching TV. Thus, in this context, a daily activity pattern consists of all of the travel a person must undertake in order to accomplish the day's activities. Each person's daily travel itinerary is represented by a series of "tours" and each tour is categorized into one of seven general purposes: work, school, serve/escort passenger, personal business, shopping, meal, and social/recreational. This categorization is relevant for subsequent steps in the modeling process as certain tour and trip characteristics, such as trip length and duration, mode, and time of day, differ by purpose.

A tour is defined as a series of linked trips that begin and end at the same location, which in most cases is a person's home. The tour shown in the diagram below begins at a person's home; its primary destination is work; and there are three stops (gas station, grocery store, and daycare center) on tour before it ends at the person's home. Since the primary destination of the tour is work, and it begins and ends at a home, this is termed a "home-based work" tour. After the daily activity pattern and number of tours and stops are established for each resident of the region, it is then a straightforward process to deconstruct each tour and create the individual trips that each person makes.



Although trips are generated for each individual living in the region, these data are aggregated into larger areas known as “Transportation Analysis Zones” (TAZs) to be consistent with the remaining model components. The TAZ (areas bounded by rose color) becomes the geographical basis for the remainder of the modeling process. This sample of TAZs are located along the Madison Street corridor in the Capitol Hill neighborhood in central Seattle.



In total, there are currently 938 TAZs used in the PSRC model structure. They come in all shapes and sizes and relate specifically to the transportation infrastructure found within their immediate vicinity. In terms of land area, smaller TAZs are typically found in dense urban environments, while larger TAZs are found mostly in rural and fringe areas. In terms of travel activity, smaller TAZs generally correlate with high levels of activity while larger TAZs typically generate relatively low levels of travel activity.

After the number and purpose of every trip made by each person in the region is accounted for, the next step in the modeling process is to determine the location of the destination for each trip. This is typically the second step in the overall modeling process and it is known as trip distribution. The distribution process is based on the travel “impedance” between the origins and destinations. Travel impedance is a relative measure of how difficult it is to travel from one TAZ to another TAZ and it is expressed as a function of time, distance, and cost. The trip distribution functions are expressed a combination of travel time, tolls, and vehicle operating cost between TAZs. Unique impedance functions have been calculated for each trip purpose based on observed trip duration characteristics (from the household activity survey), and developed in a way that as the impedance between origins and destinations increases, the less likely it is for an origin to be matched with a destination.

After determining “where” travel is occurring (i.e., between which TAZs), the next step in the overall modeling process is to determine “how” travel occurs. This step is known as mode choice and it estimates which mode of transportation will be used to make each trip. There are 6 basic modes of travel represented in the PSRC model. They are:

- 1) single-occupant vehicle (SOV);
- 2) 2-occupant vehicle (HOV 2);
- 3) 3-or-more-occupant vehicle (HOV 3+);
- 4) transit;
- 5) bicycle;
- 6) walk.

Within the general transit category, five transit sub-modes are also explicitly represented in the model. The five sub-modes are:

- 1) ferry;
- 2) commuter rail;
- 3) light rail;
- 4) premium bus (limited stop/express service);
- 5) local bus.

For the work trip purpose, the SOV mode is subdivided into four additional categories that represent workers with different household incomes, and the transit modes are separated by riders who walk to a transit stop versus those who drive to a park and ride lot and then board a transit vehicle.

Although unique mode choice models are used for each trip purpose in the PSRC model framework, they share many fundamental aspects. For trips between each pair of TAZs, the mode choice models use household demographic information (i.e., household income, household size, vehicle availability), information about the degree of urban character (i.e., number of street intersections, retail square feet, presence of biking/walking trails), and information about the “level of service” each mode provides.

Level of service is typically characterized in terms of travel time and cost. For the private vehicle modes such as the SOV, travel costs include vehicle operating cost as well as any tolls and parking costs that the traveler pays while making the trip. For the public transit modes, travel time is typically broken down into the time spent outside the transit vehicle (i.e., walking to/from the transit stop, waiting, transferring) versus the time spent while riding inside the transit vehicle, and travel cost is represented by the fare the traveler pays while making the trip. After all of this information is tabulated, the mode choice models use it as input to calculate the probability or likelihood that each mode will be used for travel between each pair of TAZs.

After determining the mode of travel, the next step in the process is to determine “when” or during which time of the day travel is occurring. In the PSRC model framework, five separate time periods are used. They are:

- 1) AM Peak Period (6:00 am to 9:00 am);
- 2) Mid-Day (9:00 am to 3:00 pm);
- 3) PM Peak Period (3:00 pm to 6:00 pm);
- 4) Evening (6:00 pm to 10:00 pm);
- 5) Night (10:00 pm to 6:00 am).

For the home-based work, shopping, and other trip purposes using the three private vehicle modes (SOV, HOV 2, HOV 3+), a time of day model is used to estimate the probability of travelling during each of the five time periods between each pair of TAZs. The probability of traveling in a time period is determined mostly by its level of congestion, and as the level of congestion increases during a given time period (e.g., the am peak period) relative to the other time periods (e.g., night or mid-day), the more likely it will be for travel to shift to the other time periods. For the remaining trips, percentages calculated directly from the household activity survey results are used to determine the time period during which travel occurs.

The final step carried out in the overall modeling is known as trip assignment. In trip assignment, trips occurring between each pair of TAZs are assigned to specific routes for each of the private

vehicle and public transit modes. For the private vehicle modes, vehicles are assigned to roadway routes (arterials, expressways, freeways) so that both time and tolls are minimized for each trip. The private vehicle mode is represented by 11 different vehicle classes: They are:

- 1) SOV (general, non-work purpose);
- 2) SOV1 (work purpose, low wage workers);
- 3) SOV2 (work purpose, low/medium wage workers);
- 4) SOV3 (work purpose, medium/high wage workers);
- 5) SOV4 (work purpose, high wage workers);
- 6) HOV-2 Person (all purposes);
- 7) HOV-3+ Persons (all purposes);
- 8) Vanpools (AM and PM peak periods only);
- 9) Light Trucks;
- 10) Medium Trucks;
- 11) Heavy Trucks.

The vehicle assignment process is carried out for each vehicle class simultaneously, but each of the five time periods is assigned separately. The procedures recognize that some of the most desirable (fastest) routes become overloaded and other routes are used to avoid the slower speeds resulting from congested conditions. The assignment process is repeated until all potential routes between all pairs of TAZs are performing equally.

For transit modes, transit riders are assigned to specific routes, or segments of routes, and it is carried out only for the AM and Mid-Day time periods. Although each transit mode is subject to a separate assignment, transit riders are allowed to optimize their overall trips and use multiple modes during the course of an assignment for an individual. For example, a ferry rider may walk to a ferry terminal and then board the ferry, or a ferry rider may walk to a bus stop, take the bus to the ferry terminal, and then board the ferry. In both cases, the trips are part of the ferry route assignment, even though the latter case included travel on a bus. Similar to vehicle route assignment, the transit assignment procedures recognize that the objective of the transit rider is to minimize overall travel time and that multiple routes may serve the same pair of TAZs equally well, but unlike the vehicle assignment, this is not performed in an iterative fashion, it is performed a single time for each mode.

Commercial vehicle and truck travel are estimated independently from passenger travel. The overall structure of the truck model is similar to the passenger model framework. Truck trips are generated, distributed, and then assigned to specific routes. There is no truck mode choice model as all travel is assumed to occur via the truck mode.

Using the TAZ-level employment data provided by UrbanSim, the truck model estimates travel for three different categories of trucks: light, medium, and heavy. Light trucks are defined as having four or more tires, two axles and weighing less than 16,000 pounds. The light truck category also includes all commercial vehicles such as taxis, rental cars, school buses, ambulances, etc. Medium trucks are defined as having six or more tires, two to four axles, and weighing between 16,000 and 52,000 pounds. Heavy trucks are defined as being double- or triple-unit, having 5 or more axles, and weighing more than 52,000 pounds.

The truck model converts trucks to passenger car equivalents (PCE) prior to route assignment. This conversion accounts for the fact that large trucks occupy more space on roadways than do passenger cars and, therefore, is important for representing the contribution of truck travel to congestion and overall travel speeds. The following PCE assumptions are used: light trucks represent 1.0 PCE; medium trucks represent 1.5 PCEs and; heavy trucks represent 2.0 PCEs.

UrbanSim and the travel model function in an integrated fashion, that is, UrbanSim produces data needed by the travel model and the travel model, in turn, produces input data for UrbanSim. The travel model data used by UrbanSim is produced for each pair of TAZs. It includes the following:

- am peak period travel times (all modes);
- am peak period SOV travel times plus tolls and distances (non-work);
- am peak period trips (SOV non-work, transit, bike, walk);
- data from the mode choice models (work log sums, nhb utilities for each mode).

The sequential process for a fully integrated UrbanSim/travel model run includes 40 separate UrbanSim runs (for each year from 2001 through 2040) and 5 separate travel model runs (for 2006, 2015, 2025, 2035, and 2040). In this process, the data that UrbanSim receives from the travel model is updated four times during the course of an integrated run and it is used for each UrbanSim run during the 2007-2015, 2016-2025, 2026-3035, and 2036-2040 time periods, respectively.

Reporting Year	2006	2015	2025	2035	2040
Travel Model Inputs	2006	2020	2020	2040	2040
Land Use Model Run for Handoff	Start 2006	2007-2015*	2016-2025*	2025-2035*	2036-2040*
Travel Model Run Used by upstream Land Use Runs	2006	2015	2025	2035	End 2040

The data that the travel model receives from UrbanSim (population and taz files) is updated five times and is used for the 2006, 2015, 2025, 2035, and 2040 travel model runs. In this integrated framework, the regional growth and development pattern is allowed to respond to changes in the transportation system performance and changes in transportation system performance are allowed to influence the regional growth and development pattern.

What data are used in the travel model?

Most of the data the travel model needs to function is built into its internal databases. The travel model does, however, rely on some input data from external sources. The primary source of external data is UrbanSim, the group of models that simulates the regional growth and development pattern. UrbanSim provides two key input files to the travel model: 1) a population file; and 2) a TAZ data file.

Model Step	Input Data	Source
Activity Generation	Population	UrbanSim
	TAZ Data	UrbanSim
Trip Distribution	Travel Times	Travel Model
	Travel Costs	Travel Model
Mode Choice	Travel Times	Travel Model
	Travel Costs	Travel Model
	Parking Costs	Parking Cost Model
	Transit Schedules	Geodatabase
Time of Day	Transit Fares	Geodatabase
	Urban Character	Geodatabase
	Travel Times	Travel Model
Truck Model	TAZ Data	UrbanSim
Route Assignment	Roadway Types	Geodatabase
	Roadway Lanes	Geodatabase
	Roadway Tolls	Geodatabase
	Roadway Speed Limits	Geodatabase
	Roadway Lane Capacities	Geodatabase
	Roadway Lane Restrictions	Geodatabase
	Transit Schedules	Geodatabase
	Transit Stops	Geodatabase

The population file includes detailed demographic information about every person living in the region. Because this data exists at the level of the individual person, the file contains several million records, depending on the year. The information includes:

- household id number;
- number of persons in household;
- household annual income;
- relationship to head of household;
- gender;
- age;
- student status;
- grade/level in school;
- worker status;
- hours worked per week;
- residence TAZ;
- workplace TAZ;
- workplace type.

The taz data file provides summary information about the type and number of jobs located within each TAZ. This file contains 938 records, one record for each TAZ. Each job is grouped into one of six general employment categories:

- retail;
- financial, real estate, service (fires);
- government;
- education;
- wholesale, communication, transportation, utility;
- manufacturing.

Other input data is collected and prepared directly for the travel model. This data exists at the TAZ level (e.g., parking rates) or at the transportation network level (e.g. speed limits, travel lane capacities, frequency of transit service, location of transit stops).

Some of the network data is updated for future years to represent planned transportation improvements and investments. For example, if a bridge (such as SR 520) is planned for reconstruction and widening in 2015, then the “modeled” 2015 roadway network needs to reflect the changes that will result from this project (i.e., 8 travel lanes across the bridge instead of 4) in order to produce a realistic traffic volume forecast and help determine the likely impacts of the project.

Input data for future years is also frequently manipulated to test “what if” scenarios. For example, one scenario might test the effect of implementing tolling on the regional freeway system that would vary by time-of-day, with higher tolls being charged during the AM and PM periods of peak usage. These types of tests are typically performed during a planning process to help inform the development of many of the policies included in the region transportation plans.

Output data exist at the individual level (e.g., daily activity pattern), the matrix level (e.g., TAZ-to-TAZ trip tables), or at the network level (e.g., vehicle volumes). It should be noted that much of analytical and performance data produced by the model is calculated or derived from this basic data set. For example, vehicle-miles-traveled (VMT) is calculated by multiplying the vehicle traffic volumes on each roadway segment by the segment distance.

Model Step	Output Data	Temporal Detail	Spatial Detail
Activity Generation	Activity Patterns and Tours	Daily	All Persons
	Trip Origins and Destinations	Daily	TAZs
Trip Distribution	Person Trips	Daily	TAZ matrix
Mode Choice	Person Trips by Mode	Daily	TAZ matrix
Time of Day	Person Trips by Mode	32 time periods	TAZ matrix
		(auto) 5 time periods (other modes)	
Truck Model	Truck Trips by Type and Time of Day	5 time periods	TAZ matrix
Route Assignment	Roadway Traffic Volumes and Speeds	5 time periods	Link/Road
	Transit Ridership by Mode	5 time periods	Segment/Route

Additional Information

More detailed information can be found at: <http://www.psrc.org/publications/#models>. There are three reports that the reader of this report may find particularly useful.

- 1) *Activity-Based Model Phase I Final Report: Activity Generator Model Estimation, Calibration & User Guide*(Jan 2009)
- 2) *PSRC Travel Model Documentation: Updated for Congestion Relief Analysis (for Version 1.0)*(Sep 2007)
- 3) *Land Use and Travel Demand Forecasting Models: PSRC Model User's Guide (for Version 1.0)* (Jan 2007)