

**RIDERSHIP FORECASTING ANALYSIS FOR IMPLEMENTING AN INTEGRATED TRANSIT  
SYSTEM IN THE PUGET SOUND REGION USING EMME/2**

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# Ridership Forecasting Analysis For Implementing An Integrated Transit System In The Puget Sound Region Using EMME/2

## Introduction

The Central Puget Sound region of Washington state is experiencing significant growth with population expected to increase 50% and employment 53% between 1990 and 2020. In response to growing transportation problems, the Washington state legislature authorized the creation of Sound Transit, a new regional transit agency serving the urbanized areas of King, Pierce and Snohomish counties, which includes the cities of Seattle, Tacoma, Everett, and Bellevue.

On November 5, 1996, voters within the three-county Sound Transit District approved an increase in local taxes to fund Sound Move, the agency's ten-year regional transit system plan. The tax increase creates a funding source for the 80% local share of the \$3.9 billion project.

Some of the key features of the *Sound Move* are <sup>3</sup> :

- 25 miles of electric light rail transit connecting a central Corridor between Seattle-Tacoma International Airport, downtown Seattle and the University of Washington, along with a starter light rail line in downtown Tacoma. (Figure 1)
- 81 miles of commuter rail service using Burlington Northern tracks between Everett, Seattle, Tacoma and Lakewood (Figure 1)
- 100 or more miles of "HOV expressway" combining state-funded completion of continuous HOV lanes and Sound Transit funded direct access ramps to park-and-rides, transit centers and other Community Connections (Figure 1).
- 20 new regional express bus routes using the HOV expressways to provide speedy and reliable suburb-to-suburb transit connections (Figure 1).
- region wide coordination of schedules and fares among all local and regional transit agencies.

## Usage of the Sound Transit Model

Sound Transit developed an EMME/2 based incremental transit model to assist in the development of the Sound Move plan. The model is now being used to support environmental and conceptual design work underway by Sound Transit.

Examples of the analyses being performed are:

- Ridership forecasting for Central Light Rail alignment alternatives to provide transportation related information for the draft EIS;

- Rail station area traffic impacts analyses;
- Zone-to-zone travel times and travel distance analysis for light rail alternatives;
- Analysis to support system wide fare and service integration, including forecasts of future operating costs and ridership by transit agency;
- Ridership forecasts for regional express bus route alternatives;
- Estimation of demand for park-and-rides
- Systems level analysis of TDM/TSM alternatives to HOV direct access facilities;
- Select route, segment or node analysis to determine origin / destinations of transit segment users

This paper focuses on presentation of unique EMME/2 features used to assist with the Sound Transit analysis.

### **The Sound Transit Forecasting Model**

The Sound Transit (ST) forecasting model uses a three stage, incremental modeling methodology to produce detailed forecasts of transit passengers as a result of changes in demographics, auto travel times and costs, transit fares, and transit service levels between two locations within a corridor.<sup>1</sup> The ST model is based on a 737 zone system and covers the transit service areas with the three counties : King, Pierce and Snohomish.

Because the ST model is incremental, it is directly based upon observed rather than estimated baseline travel patterns of transit users. In 1992 the existing transit operators carried out extensive on-board origin-designation surveys. These surveys included between 20 and 60 percent of actual weekday transit travel. The King County survey, the largest of the survey, included origin and destination data for about 40 percent of the King County Metro transit riders.<sup>1</sup>

The origin-designation surveys were expanded to 100 percent of the weekday transit ridership to produce trip tables reflecting origins and destinations of the transit riders in 1992 by time of day (peak and off-peak) and trip purpose (commute and non-commute). The ST model was then validated to replicate route level boardings. The expanded survey transit trips were assigned to the model network to validate daily boardings. The results indicated an excellent match between the modeled and actual boardings on most routes within the ST boundaries.

The three-stage incremental model begins with changes in demographics. Base Year (1992) expanded trips are grown based on Puget Sound Regional Council (PSRC) forecasts of growth in regional travel. The PSRC model outputs are based on using the adopted transportation plan and forecasts of population and employment in each jurisdiction.

In the second stage of ridership forecasting analysis, other external changes, in highway travel time (congestion) and costs (including parking costs), transit fares and household income are taken into consideration. A mode choice model was used to capture the sensitivity of demand with respect to changes in these external factors and to provide estimates of zone-to-zone modal shares for transit users relative to shares for auto users. The first two stages of the Sound Transit model result in a forecast of zone-to-zone transit trips within and to/from the ST boundaries for 2010 classified by time of day, trip purpose and mode of access (i.e., walk or drive access to transit).

In the third and final stage of the ridership forecasting analysis, the incremental changes in the transit level-of-service are taken into consideration. The resulting transit trips from this stage of the ridership forecasting analysis are assigned to the future year (2010) transit network reflecting characteristics of transit service between any two areas/locations.

For producing forecasts for the Sound Transit system, all alternatives are evaluated using a single consistent Stage 1 and Stage 2 forecast. This allows planners to concentrate on comparing and contrasting alternative transit scenarios through the use of Stage 3 forecasts. As indicated before, the goal of this modeling exercise is not a feasibility study, but an effort to plan the implementation of a coherent regional transit system, to identify problem areas and possible solutions to them.

Transit assignment and reporting features available in EMME/2 have helped in producing detailed model results and supporting information of potential interest to a variety of audiences.

### **Ridership Forecasting Analysis of Light Rail Alignment Alternatives**

The Sound Transit board has selected a set of alternatives to be studied in the light rail project's draft environmental impact statement and conceptual design. The ST model has been used to provide detailed ridership forecasts for each of these alternatives including: segment ridership, link volumes, and station boardings and alightings by mode of access and egress.

In all over 20 light rail alignment alternatives were modeled for all the six segments. The light rail alignment alternatives differed from one another in one or more the following respects : (i) routing, i.e., the travel markets served and the stations to serve those markets; (ii) station locations (geographical); (iii) the routing of the feeder buses to the rail stations; (iv) travel times associated with alternative alignments and vertical profiles (v) and availability of park-and-rides at rail stations

The ST model uses links in the base network to establish a separate right-of-way for the light rail line. These links are connected to the rest of the transit network (streets) by means of access links (walk links facilitating walk access/egress to a bus transfer or access a park-and-ride lot). To represent changes in light rail alignments, the links representing the light rail were re-routed. In addition, the various types of access links were also accordingly modified to represent any changes in the geographical locations of a light rail station.

Obviously the EMME/2 based ST model does not distinguish between the differences in the physical layout of the light rail line (in terms of grades or whether it has an elevated or a tunnel or an at-grade section). In the model it was enough to represent such differences in terms of the travel time and travel distance required by the light rail to traverse the section. Upon completion of the network coding, the Stage 3 portion of the ST model was run for each of the alternatives.

The results documented and provided from the model runs for the light rail alignment alternatives to the EIS team included : (i) the overall the number transit trips ;(ii) summaries of total daily boardings for the light rail, commuter rail lines and regional express bus routes ;(iii) transit volumes on the light rail links and commuter rail links ;(iv) peak period boardings and alightings at rail stations by mode of access and egress ;(v) and unconstrained demand in persons at park-and-rides connected to the light rail stations.

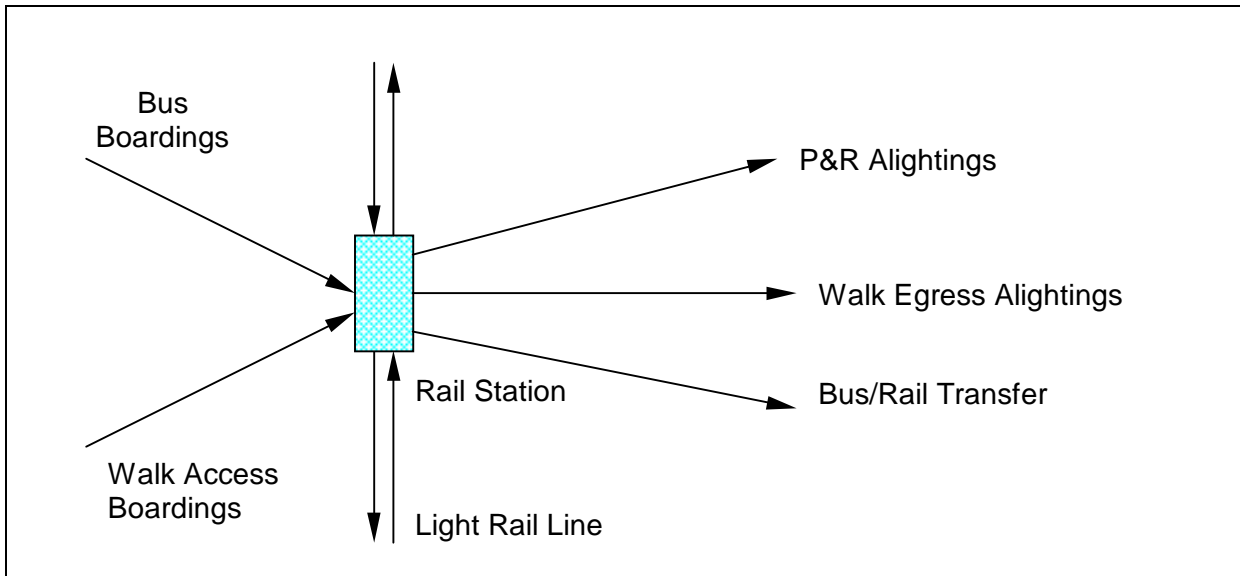
Of the model output results indicated above, the procedures used to derive the peak period station boardings and alightings by mode of access and egress and the procedure to calculate the drive access demand at park-and-rides deserve special mention. In the other cases the transit assignment features under module 6 of EMME/2 were used.<sup>4</sup> Transit boardings are reported route by route under module 6.21 and transit link volumes can be plotted out in module 6.22.

### **Peak Period Rail Station Boardings and Alightings by Mode of Access and Egress**

In the ST model there are three kinds of access and egress modes for those who board the rail line. They may be walk access/egress, bus or rail transfer and drive access/egress. The modes of access and egress at a rail station are represented in Figure 2. The following steps were followed in these calculations.

Step 1. The first step was to prepare a select line transit assignment. The light rail lines were the selected lines and this was a transit assignment for the peak period.

Step 2. In the ST model walk links connect the rail stations to nodes representing park-and-ride lots. The park-and-ride lot node is in turn connected to the appropriate zone centroids. The light rail related park-and-ride passengers were determined by plotting out the auxiliary transit volumes (module 6.22) on the links representing the walk to the P&R lot node. These volumes would then represent station alightings by drive egress mode.



**Figure 2. Representation of PM Peak period Boardings and Alightings at a Light Rail Station by Mode of Access and Egress.**

Step 3. The following kinds of boardings and alightings at nodes produced under module 6.22 of EMME/2 were used : (a) Total boardings (b) Initial boardings (c) Total alightings (d) Final alightings.

Step 4. The following calculations give us the desired results :

At a rail station node :

Total boardings = Total of walk access + bus / rail transfer boardings

Initial boardings = walk access only boardings

Total boardings - Initial boardings = bus / rail transfer boardings

Auxiliary transit volumes = p&r related rail alightings (from Step 2)

Final alightings = walk egress only + P&R related alightings

Final alightings - P&R related alighting = walk egress only alightings

Total alightings - Final alightings = bus/rail transfer alightings

All these calculations can be performed in the network calculator or by hand. It should be mentioned that the model produced fairly reliable estimates for station boardings and alightings by mode of access and egress especially in the downtown Seattle or University district areas. However, the ST model has certain limitations in producing accurate results for the number of walk access boardings/alightings for stations in outlying areas with limited pedestrian facilities. The penalties for transferring to a bus in addition to the wait times may have exaggerated the attractiveness of the walk only option over a bus transfer option to/from the rail stations.

## **Select Line Analysis Feature of EMME/2 Transit Assignments**

One of the special features in EMME/2 transit assignments that proved useful on several occasions was the select line features of the EMME/2 transit assignments. This analysis requires the use of an additional options transit assignment and yields the volumes of only those trips that actually use a given line, as well as the corresponding trip matrix. Transfers from the selected line to other transit lines can be inferred from the boardings / alightings of the other lines at common stops. The method can also be used for specifying certain segments only of a transit line resulting in trips on that specific segment only. The select line analysis features of EMME/2 were used in several other analyses requiring the demand estimation of park-and-ride users, transit travel time and distance analysis, calculations of bus operating costs etc. These procedures are described in detail below. The procedure for implementing the select line analysis is described in detail with an example in page no. 4-375 of the EMME/2 Users Manual, Release 8.0.

## **Rail Station Area Traffic Impacts Analysis**

The ST model can be used to produce the number of trips by drive egress from a park-n-ride lot to surrounding destination zones. These estimates are made by use of a select line transit assignment. The link extra attribute was used to select the walk link connecting the rail station node to the P&R lot node. The trips obtained from the select line assignment (auxiliary transit attribute) was saved in a matrix.

The drive egress trips from a park-n-ride facility can be added to expected future background traffic in order to analyze future traffic area impacts. Background traffic can be estimated using existing traffic counts in the vicinity of the station and applying growth factors obtained from a the Puget Sound Regional Council model or from a sub-area traffic model. This procedure is consistent with incremental nature of the ST model.

## **Zone to Zone Travel Times and Light Rail Travel Distance Analysis**

One of the standard features of the EMME/2 transit assignment is that zone to zone transit travel times can be saved in matrices. Unweighted components of total travel time such as in-vehicle, waiting, boarding times (impedance) were used to analyze the travel time benefits from a light rail alternative. One of special types of analysis required by the EIS team was an estimate of the average in-vehicle (bus or rail) distance traveled by a light rail rider and the average distance traveled by the light rail rider while on-board the light rail only. Once again the additional options feature of EMME/2 was used in this analysis.<sup>4</sup> A demand matrix of the light rail trips was prepared using the select line (rail line) procedures. An average transit distance matrix was created from the additional options transit assignment by saving additional strategy attribute. Link length was specified as the additional in-vehicle attribute with the path operator being set to = +. A weighted global average transit travel distance was obtained by using the light rail users demand matrix as the weight. To calculate the travel distance for the light rail portion only of the trip a similar analysis was performed with link length=0 for all links except the light rail links.

## **Analysis for System Wide Fare Integration**

One of Sound Transit's objectives is a uniform, single-ticket fare system and integrated fare policy for the region's entire public transit service network. Integrated fare structures set common ways to price trips, especially those that involve a transfer between systems. One of the applications of the ST model was to approximately estimate the share of light rail riders who transfer into a bus and cross fare zones. A select line procedure was used to save the transit trips that used light rail. An estimate of the share of rail boardings and alightings who transfer to a bus was made (using procedures similar to the mode of access and egress procedures described earlier). To calculate the share of light rail riders who cross a zone or pay a two zone fare, a matrix containing the value 1 for an O-D pair which crosses a zone and zero for the rest was prepared. This matrix was multiplied with the light rail demand matrix to obtain the share of light rail riders crossing a fare zone. This share was multiplied with the share of bus transferees to obtain the desired result.

## **Calculation of Operating and Maintenance Costs Parameters**

Another application of the ST model was to calculate weekday (bus) platform hours and platform miles. An easy way of arriving at these estimates from the model is by modifying the transit vehicle table in module 2.02. A variable used to convert the number of bus vehicles required per hour into weekday platform hours was calibrated using the model run for base year (1992). It should be noted that the number of transit vehicles required is produced as a standard transit assignment result in module 6.21. This number was used as the "operating costs (/hr)" variable in the transit vehicle table. When the transit assignment is performed with this transit vehicle table the value under the column "operating costs" in the transit line summary report gives the platform hours. To calculate platform miles the variable "energy consumption (/mi)" was used. This variable should contain a number representing a factor for converting one hour platform miles into weekday platform miles. The column under "energy consumption" in the transit line summary report contains the estimates of the weekday platform miles. It must be recognized that these estimates are approximate and the accuracy of these estimates is limited by the accuracy of the bus network detail with regards to speeds, turning movements, delays at intersections and link lengths.

## **TDM/TSM alternatives to HOV Direct Access Facilities**

One of the applications of the ST model was to assess the impacts due to Transportation Demand Management (TDM) alternatives to HOV direct access facilities. The TDM alternative modeled assumed that the Sound Transit budget for HOV direct access facilities was instead used to increase transit service and to provide transit fare discounts in the districts with direct access projects. This was translated into fairly simple modifications of the inputs into the ST model in terms of changes to route headways, transit fares and increase in segment travel times (for buses) due to non availability of the direct access facilities. The increase or decrease in transit trips to/from the identified districts was one of the outputs required to assess the impacts of the TDM alternative to HOV direct access facilities.

The Transportation Systems Management (TSM) alternative includes improvements to improve transit speed and reliability, including arterial HOV lanes, transit signal priority, and queue jumps. The TSM alternative assumed that the Sound Transit budget for HOV direct access facilities was instead used to improve transit operations and increase transit service in the districts with direct access projects. Improvements in transit operations were translated into improvements in segment travel time for buses. The non availability of direct access facilities was translated into increase in segment travel times for buses. The increase or decrease in transit trips to/from the identified districts was one of the outputs required to assess the impacts of the TSM alternative to HOV direct access facilities.

### **Future Applications of the ST Model**

Sound Transit plans to work with the other transit operators in the region to conduct an on-board survey of the transit trips after the implementation of Sounder commuter rail and Regional Express bus service. The new survey information will be used to update the base-year data in the model and combined with the latest demographic and land use forecasts from the Puget Sound Regional Council to produce new Stage 1 and Stage 2 forecasts. In the future ST model may also be used for long range transit planning applications, to forecast transit ridership for rail extensions that go beyond the ten year Sound Move plan.

### **Summary Conclusions**

The procedures and techniques described above represent only some of the many that are being used in various planning applications for implementing the Sound Move plan. The ST model with its reliance on the PSRC model for growth in trips and on the incremental approach has proved to be reliable for the purpose of transit modeling in the region.

The ST model has proved to be an extremely efficient tool for testing a new network alternative, since a model run takes less than an hour to complete. Some special features available in EMME/2 have enabled the users of the model to produce results in a quick and efficient manner. It is hoped that the our experience in the use of the ST model proves useful to other agencies attempting to model transit in their region.

### **Acknowledgement**

The opinions and views presented in this paper are solely ours and do not necessarily represent official policy of the Sound Transit and its staff.

## References

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