MnPASS System Study

Technical Memorandum #3

Travel Demand Forecasting Approach

technical

memorandum

prepared for

Minnesota Department of Transportation

prepared by

Cambridge Systematics, Inc.

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February 3, 2005 (Revised)

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1.0 Background

This memorandum describes the approach used for customizing the Metropolitan Council ("Council") travel demand forecasting model to allow us to analyze alternative toll facility scenarios. The memo has been updated from earlier versions based on previous comments, review of the Council model documentation, test model runs, and the implementation of different elements of the proposed methodology.

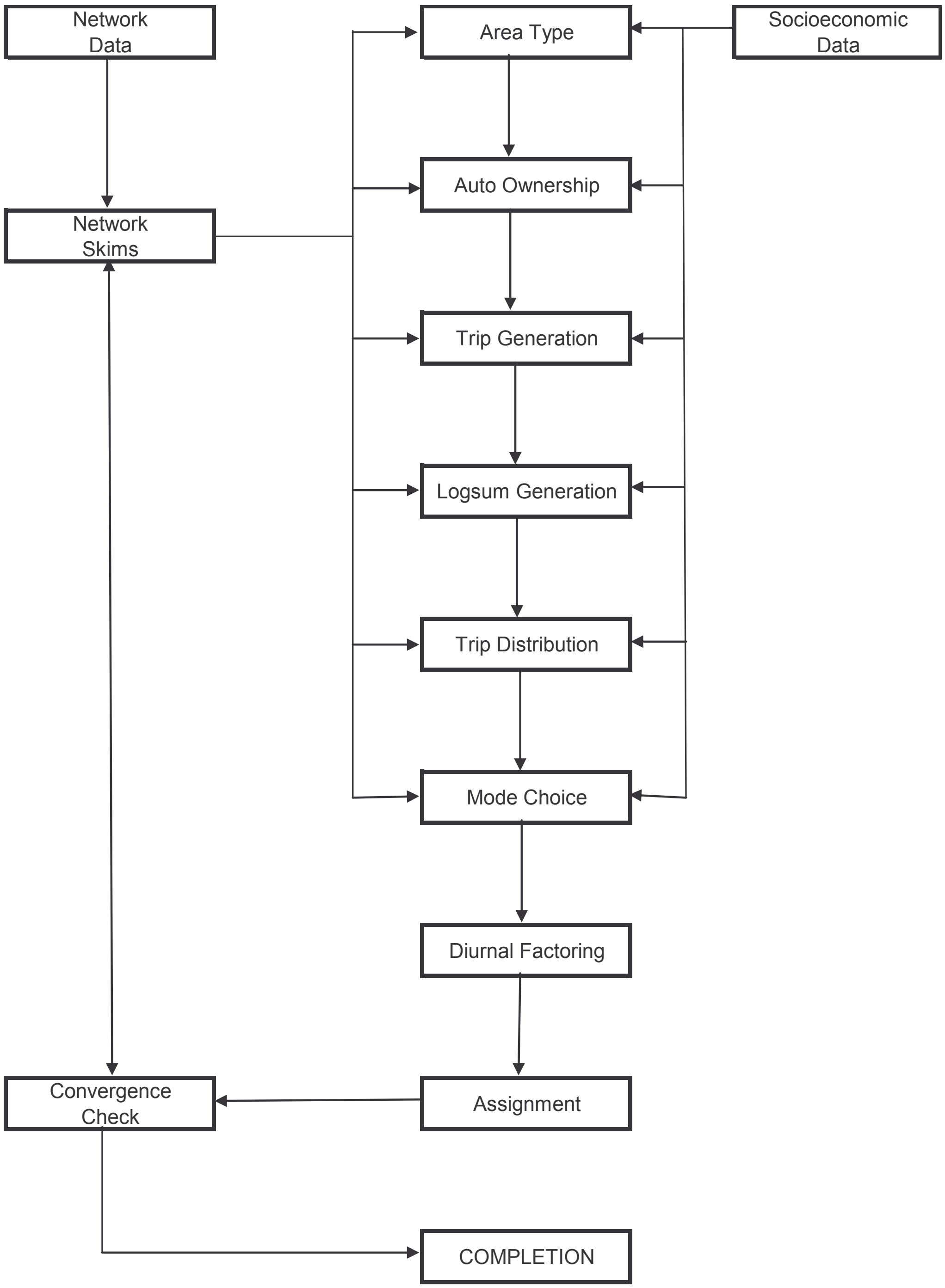
Because the Council model development anticipated the need for tollroad analyses, it was an effective tool for our forecasting work. However, within the Council model process, we needed to make several model refinement decisions as described below.

The overall flow of the Council model is shown in Figure 1. The basic inputs to the system are the forecast year-specific socioeconomic estimates and network representation. The networks are skimmed to provide zone-to-zone time and cost estimates, and then the different model components are applied sequentially. If the assigned travel volumes imply travel times that are substantially different than the input times, the skims are adjusted and the model system is applied again. Once the output travel times from the trip assignment are similar to the input travel times, the model application is complete.

The application of the model system to the toll scenarios under consideration required us to modify the basic model system at several points of its implementation. The most important modifications were the inclusion in the mode choice model of new parameters to allow for the estimation of trips by tolled single-occupancy vehicles and trips by tolled high-occupancy vehicles. The output of this revised model step fed into the highway assignment process from which summary measures of toll lane usage were derived.

The remainder of this memorandum describes the different modeling steps which were revised to allow for analysis of the toll lane scenarios.

Figure 1. Council Twin Cities Regional Model Process Flow



Source: Twin Cities Regional Model User's Guide, March 2004.

2.0 Modifications

Trip Distribution / Destination Choice Model

Trip distribution / destination choice models forecast trip patterns given zone level estimates of trip origins and trip destinations and interzonal impedance measures. The Council's trip distribution/destination choice model uses the mode choice model component to determine the composite impedance between zones. This procedure is useful, because it captures the effects of the impedance for all available modes in determining origin-destination patterns, not just the highway mode, as is often the case.

One of the effects of using composite impedances (or other multimodal feedback mechanisms) in trip distribution/destination choice is that when transportation improvements are made for any mode, the distribution of trips within the region is altered. This is probably more behaviorally accurate than the fixed trip table assumption, but it makes the measurement of the user and systemwide benefits of the improvements more difficult to understand.

To compare user and systemwide benefits for alternatives most directly, it is desirable to have a common basis of origin-destination trips. Therefore, for the Round 1 analyses, we developed a single set of origin-destination trip tables for each of the system alternatives based on the 20 cent per mile toll level for that system. Then, we simply changed the toll level in the last iteration of the model run to represent the choice to use or not use the toll lanes at different toll levels. This process was considered a reasonable compromise, in that it picks up the trip distribution impacts of new capacity, but allows for meaningful comparison among toll rates. While we might expect travelers to make home/work location decisions based on additional capacity, the precise toll rates in use on a particular facility should not influence that behavior to a major extent, especially since the toll rates would be set dynamically.

The Round 1 findings using this approach resulted in some counter-intuitive findings. We found that overall network travel times were forecast to decrease as a result of the toll lane system. Though increasing capacity should be expected to result in longer trips resulting in higher VMT, the overall system equilibrium should not be worse than the base condition. We believe the fact that the combined iteration of the mode choice and trip distribution/destination choice models did not fully reach equilibrium after eight iterations is the reason for these unstable results. Though the segment-specific forecasts looked reasonable, the system performance measures did not.

To address this issue, we modified the model's feedback mechanism to include iterating only the mode/route choice component of the model when moving from the base case to the MnPASS cases. The same trip distribution was used for the base and build scenarios. Since the base and build scenarios had the same number of zone-to-zone trips, these model outputs could be compared directly with each other to allow for benefits assessment. We believe that this method will tend to slightly underestimate travel demand in the proposed MnPASS corridors, and may slightly overstate the mobility benefits, since it does not allow for an increase in the trips that could take advantage of the added capacity.

External Trip Modeling

Based on analyses of the Council base year and forecast year model output, the percentage of trips in the highway corridors under study that have external origins and/or destinations is very small. Therefore, for modeling purposes, neither external-to-external nor internal-external trips were made eligible for the toll lanes. No changes were made to the external modeling components of the model system in either Round 1 or Round 2.

Because the toll facilities are expected to operate on a subscription basis, they will only be available to travelers who would use the facilities on a regular or semi-regular basis. Therefore, most non-residents of the study area are not likely to subscribe in large numbers. However, for adjacent counties, a significant percentage of commuters make work trips to and from the travel demand model region. Mn/DOT staff analysis of the 2000 CTPP data indicate that 49 percent of Wright County resident workers, 42 percent of Sherburne County resident workers, and 53 percent of Saint Croix County resident workers have jobs in the seven county Metro Region. We would expect that some of these adjacent-county residents would subscribe to the toll system depending on the specific highways that have toll lanes, but on a corridor-specific level, the number of such travelers will be within the overall error range of the internal model output.

Mode Choice Modeling to include Toll Choice

The Council mode choice model allows for the introduction of new toll facilities both for SOVs and HOVs. However, it does not include any toll parameters as no such facilities currently exist. The basic tradeoffs between time and cost are included in the purpose-specific mode choice equations (as summarized in Table 1), but we needed to determine the alternative-specific constants to use for the toll highway modes based on other models.

Table 1. Implied Values-of-Travel Time for the Council Regional Travel Model

Trip Purpose	Implied Value-of-Time ($/hr)
Home-Based Work	$12.28
Home-Based Non-Work (Home-Based Work-related, shopping, and other trips)	$5.71
Home-Based School	NA – No Cost Coefficient
Non-Home Based Work	$2.54
Non-Home Based Other	$5.71

Source: PB Consult, Inc., *Twin Cities Regional Model: Development of the Twin Cities Year 2000 Mode Choice Model* (March 2004).

Several mode choice models that include toll lanes have been developed by others. Two modeling efforts were analyzed in detail for the purpose of transferring alternative specific constants. The first effort was the Congestion/Road Pricing Study, conducted for Mn/DOT and the Council by Wilbur Smith Associates and others.[1] The demand modeling for this study consisted of the development of stated preference models based on surveys of Twin Cities residents conducted by Resource Systems Group (RSG) in the fall of 1995. From these surveys, RSG developed multinomial and nested logit mode choice models that forecast how travelers would change their travel under the following scenarios:

- Add HOV lanes;
- Add supplemental capacity with tolls;
- Add supplemental capacity and toll all lanes; and
- Enhance transit

These models are relevant because they were developed from Twin Cities data. However, the analyses are nine years old, and they are based on stated preferences, rather than revealed choice data.

The second toll-lane related mode choice modeling effort that was analyzed to help with the development of Council model toll parameters was the SR-91 Impact Study by Edward Sullivan.[2] The modeling for this study was conducted by Jia Yan and Kenneth Small, and includes the modeling of route, time-of-day, highway mode, and transponder purchase choice. Several multinomial and nested logit models were developed to analyze the travel choices related to SR-91 and the Eastern Tollroad corridor. These models are appealing because they are based on actual travel choices, rather than stated choices, and because they relate to express lane operations that are similar to those that would be anticipated for the Twin Cities region.

The models that were developed for both the Congestion Road Pricing Study and the SR91 study include parameters related to the highway travel time and toll costs, as well as trip and traveler characteristics. The models include mode specific constants for the toll mode, but the trip and traveler model parameters change the effective constants for different travel market segments.

To develop toll mode constants for the Council model from these models, we calculated the ratio of the toll alternative specific constants and the highway travel time coefficients for different market segments based on travelers' ages, genders, income levels, education levels, and trip purposes. So, for instance, we calculated the ratio of the toll constant to the highway travel time coefficient for high income, 35-to-49 year old, males with college degrees, as well as for the other combinations of these variables. We then estimated the rough distribution of these cross-classified market segments within the Council model's study area based on decennial Census tabulations. Specifically, we determined the percentage of each cross-classified market segment within each of the Council model's trip purpose and auto availability market segments. Table 2 shows the weighted average equivalent travel time (in minutes) of the toll mode specific constants for the Council model market segments.

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[1] The model development effort is summarized in *Congestion/Road Pricing Study Technical Memorandum 6: Results of Metrowide Personal Interviews* (January 1996) developed for State of Minnesota and Metropolitan Area of Minneapolis – St. Paul by Wilbur Smith Associates et. al.

[2] See *Continuation Study to Evaluate the Impacts of the SR91 Value-Priced Express Lanes: Final Report* (December 2000) prepared for Caltrans Traffic Operations Program by Edward Sullivan, Cal Poly State University.

Table 2. Equivalent Travel Time of the Transferred Toll Mode Constants

Market Segment	Equivalent Travel Time of the Transferred Toll Mode Constant (Minutes)
Home-based Work trips by 1-vehicle households	-0.46
Home-based Work trips by 2-vehicle households	-2.89
Home-based Work trips by 3+ vehicle households	-1.58
Home-based Work trips to CBD locations	-0.45
Other trips by 1-vehicle households	0.88
Other trips by 2-vehicle households	0.00
Other trips by 3+ vehicle households	-0.17
Other trips to CBD locations	-3.43

Based on the parameters of the SR91 and Congestion Road Pricing models and assumptions about the Twin Cities' distribution of trip and traveler characteristics by purpose (including household income, gender, educational attainment, and age), the differences between the free highway mode and toll mode constants range from a 0.88 minute penalty (non-commute trips by 1-vehicle households) to a 2.89 minute advantage (home-based work trips by 2 vehicle households). There is an additional advantage for the toll mode for trips to the CBD—0.45 minutes for work trips and 3.43 minutes for non-work trips. These travel time equivalencies appear to be within a reasonable overall range.

The average equivalent times vary by auto availability level. This is because the equivalent time penalties for the toll mode choice constants are based on the relating the market segments defined by the SR-91 analyses to the Council model's market segments. The Council model's vehicle availability market segmentation was intended for other model components (e.g., trip generation and distribution), and not specifically for toll choice. This finding shows some potentially interesting relationships between auto availability and willingness to pay a toll that may not be immediately obvious, but could be resolved by further research and surveys specific to this purpose.

The equivalent travel times were converted into mode constants based on the purpose-specific travel time parameters, and added to the model system's mode choice model input specifications. The modified mode choice parameters were then used for each model run.

Time-of-Day Factoring / Highway Assignment

The Council model factors peak and off-peak traffic volumes to 24 unequal time periods. We continued to use these day-part definitions for our analyses. Therefore, we did not change the basic structure of the assignment procedures.

In addition, we changed the assignment routine to include the treatment of new assignment groups (toll lanes, HOT lanes, and new ramp types), and added the appropriate constraints on using the various facilities.

Convergence Check

The Council model is run iteratively until the network travel time skims that result from the final loaded highway network are sufficiently close to the network travel times that were input into the model stream. In successive iterations of the model runs, the input and output times generally converge. In our initial application of the revised model that included a toll mode, we found that the model did not adequately converge in a reasonable number of iterations. Therefore, to maintain feasible model run times and to improve convergence, we applied a Method of Successive Averages (MSA) algorithm to the model system. With this technique, the following steps are followed:

1. The model system was run with free-flow travel times;
2. The loaded travel times that are obtained from Step 1 are used as inputs to a second model run;
3. The loaded travel times that are obtained from Step 2 are averaged with the loaded travel times from Step 1 (weighted equally), and these average times are used as inputs to a third model run;
4. The loaded travel times that are obtained from Step 3 are averaged with the loaded travel times from Step 2 (weighted 2/3 for Step 2 and 1/3 for Step 3), and these average times are used as inputs to a fourth model run;
5. The loaded travel times that are obtained from Step 4 are averaged with the loaded travel times from Step 3 (weighted 3/4 for Step 3 and 1/4 for Step 4), and these average times are used as inputs to a fifth model run;
6. The loaded travel times that are obtained from Step 5 are averaged with the loaded travel times from Step 4 (weighted 4/5 for Step 4 and 1/5 for Step 5), and these average times are used as inputs to a sixth model run;
7. The loaded travel times that are obtained from Step 6 are averaged with the loaded travel times from Step 5 (weighted 5/6 for Step 5 and 1/6 for Step 6), and these average times are used as inputs to a seventh model run;
8. The loaded travel times that are obtained from Step 7 are averaged with the loaded travel times from Step 6 (weighted 6/7 for Step 6 and 1/7 for Step 7), and these average times are used as inputs to an eighth model run;

For Round 1, this eight-iteration approach was applied to the base condition and to each of the system scenarios for the 20 cent toll level. For the other toll levels, the last step of the model run process was run with the alternative toll level. This process ensured that most of the differences between alternative toll levels were a result of mode and route choice differences, as opposed to trip distribution differences, but that the comparisons between base (no-build) conditions and the improvement scenarios reflected the availability of the new lanes.

For Round 2, we applied the eight iteration approach for the future year base conditions and established future year trip tables. These trip tables were then used for subsequent analyses and comparisons between the build and base scenarios. For each forecast year, the base trip table was assigned to the toll scenario networks. The assignment results were fed back to the mode choice model and run through the assignment again, and so on, until four iterations of the mode choice/assignment process were completed. The process for Round 2 allowed for the direct comparison of the base condition and the toll scenarios because a fixed trip table was used.

Network Modifications

The tollroad scenarios were represented by modifying different Council highway and transit networks, and applying forecast year trip tables to those network scenarios. The network/trip table forecast regimes are:

- Base Year Scenarios – Year 2000 trip table assigned on year 2000 highway and transit networks;
- Year 2013 Scenarios – Council 2010 trip table assigned on networks consisting of projects in the TIP and the Ten-Year Work Program; and
- Year 2030 Scenarios - Council 2030 trip table assigned on the 2013 networks described above;

Prior to modifying the Council networks, we reviewed the networks in the areas that are directly affected by the toll scenarios, and identified potential issues with the base cases. As issues were found, we consulted with Council staff.

For the highway networks, the toll facilities were included in the networks as new links with one of two new assignment groups – SOV toll facilities and/or HOV toll facilities. Standard SOV and HOV highway facilities are already included in the Council model. The capacities, free flow speeds, and per lane volume-capacity relationships for the toll facilities are similar to the parallel freeways or arterials, and reflect network model coding for similar facilities elsewhere, unless project team members identified geometric and operational constraints that would dictate otherwise. For Round 1, the managed lane speeds and capacities were based on analyses of comparable facilities.[3] For Round 2, we assumed that the managed lanes would be comparable to ramp-metered highway lanes. Table 3 summarizes the default free flow speeds and capacities for freeway facilities and the proposed toll lanes.

The tolls for the new lanes were coded for the network links based on the anticipated locations of transponder readers, and reflected specific per mile toll levels.

Enhanced Transit Service Evaluation. We were asked to evaluate how BRT service could be enhanced by MnPASS lanes. To aid this evaluation, we tested the impact of allowing express

[3] See Technical Memorandum from Elizabeth Peart to Project File, dated September 23, 2004.

buses in the TH 36 corridor use the MnPASS lanes rather than the congested non-tolled lanes as an adjunct to the Round 2 analysis. For this test, we re-routed the small number of buses currently using adjacent freeway segments to the toll lanes.

Table 3. Default Free Flow Speeds and Capacities for The Revised Council Twin Cities Regional Model

Facility Type	Capacity Per Lane (pcphpl)	Free Flow Speed (mph)
Metered Freeway Segment[1]	1,950	74
Unmetered Freeway Segment[1]	1,750	74
Freeway On-ramp[1]	1,300	37
Freeway Off-ramp[1]	650	37
Managed Lane Segment (single lane)[2]	1,700/1,950	60/74
Managed Lane On-ramp	1,700	30
Managed Lane Off-ramp	1,700	30
Ramp between Managed Lanes	1,700	30

1 Capacity and free flow speeds shown for existing freeway types are the systemwide average values. Some specific facilities have different values to reflect geometric and operational constraints.

2 The Round 1 analyses used managed lane speeds and capacities based on a review of other facilities. The Round 2 analyses assumed that the lanes could be built to be consistent with general freeway lanes.

Network Skims

To include tolls in the mode choice model, we skimmed the modified highway networks to obtain highway time and distance and toll costs. For these skims, tolled vehicles were allowed to use the entire existing network, plus the new toll facilities. The non-toll vehicle skims did not allow vehicles to use the toll facilities.

For the initial model runs toll skims were retained only for those origin-destination pairs where the toll time is faster than the non-toll time, thereby limiting the skim table to those origin-destination pairs where toll lanes are of direct benefit to users.

For the Round 2 analyses, transit skims were developed in the same way as for the current Council model. For the adjunct scenario with improved transit service on TH 36 we reflected the new times and costs associated with the transit improvements that could be made through the use of the new lanes. We did not make changes to the transit network that would affect zonal transit accessibility, so we changed line-haul times, frequencies, and costs only.

3.0 Model Outputs

In addition to the standard outputs of the Council travel demand model, we produced several types of results summaries for each scenario, including:

- Systemwide measures – We calculated person-miles traveled, person-hours traveled, vehicle-miles traveled, vehicle-hours traveled, and linked and unlinked transit trips; and we developed formatted summaries that were used by the benefits analysis.
- Toll revenue – We calculated daily revenue by toll facility based on the toll levels and travel volumes by time-of-day.

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