Independent Peer Review of Tolling Scenarios and Traffic Model

This report was written by Yoram Shiftan in collaboration with the Peer Review Panel for the Washington State Department of Transportation.

The Peer Review Panel includes, in addition to Yoram Shiftan, the following members (in alphabetical order):

- Chuck Purvis – Metropolitan Transportation Commission (San Francisco)
- Erik Sabina – Denver Regional Council of Governments
- Teresa Slack – Georgia State Road & Tollway Authority
- Richard Walker – Portland Metro MPO

September 23, 2008

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1. Objectives

The objectives of the peer review were as follows:

- Evaluate the techniques used to generate information on traffic, their credibility, and their reliability for informed decision-making regarding the use of tolls.
- Assess the assumptions of the model with respect to tolling and traffic analysis.
- Recommend any additional refinements or changes to the modeling procedures and processes.

2. Overall Review

The Peer Review Panel concluded that, overall, PSRC uses good modeling practice, comparable to the best in the nation, and is consistent with leading trip-based models in the U.S. In recent years, PSRC has incorporated new elements that have significantly enhanced the model's ability to support variable pricing analysis. These various enhancements are detailed in Section 4 below. The Peer Review Panel, however, raised several concerns and observations regarding some of the procedures and results:

- The results show high destination diversion.
- Improve consistency in the modeling process and assumptions.
- Improve model focus on the target corridor.

These issues are discussed in detail in Section 6.

Accordingly, the Peer Review Panel's main recommendations are to slightly modify the model, improve its consistency, and try to gain a better understanding of the results by looking at them in more detail and conducting additional model runs under different assumptions. The detailed recommendations appear in Section 7.

3. Review Resources

The review is based on documentation provided by WSDOT/PSRC and on discussions with the WSDOT/PSRC modeling staff.

These documents were available for this review:

Cambridge Systematics (2007), *PSRC Travel Model Documentation (for Version 1.0) updated for Congestion Relief Analysis*, Final report for the Washington State Department of Transportation and Puget Sound Regional Council.

Blain, L. (2008), *Time, Cost, and Reliability in Traffic Assignment*, Puget Sound Regional Council, Innovations in Travel Modeling 2008, Portland, OR, June 22-24, 2008

Outwater, M. and Kitchen, M. (2008), *Value of Time for Travel Forecasting and Benefit Analysis*, Memo to the Regional Pricing Coordination Team.

PSRC (2007), *Traffic Choice Study*.

Various handouts provided by WSDOT with their various model run scenarios.

In addition to the foregoing documents, input was received from the various phone conversations and meetings with members of the PSRC and WSDOT modeling teams, in particular Maren Outwater and Chris Johnson from PSRC and Craig Helmann from WSDOT.

4. New PSRC Modeling Features for Toll Analysis

In recent years, PSRC has devoted significant efforts to improving its travel-demand model in order to better analyze travelers' responses to varying tolls. The most significant effort was the Traffic Choice Study, to be elaborated in Section 4.1. Additional elements are discussed in Sections 4.2-4.4. The model used to estimate the effect of the different tolling scenarios is the PSRC Travel Model, Version 1a. The documentation provided was for Version 1. Version 1a differs from Version 1 in three issues:

1. New values of times inferred from the Traffic Choice Study were adopted; these are higher for work trips and similar for non-work trips.

2. Only 20% of the toll cost is used in the calculation of the friction values for the non-work trip-distribution models.

3. Reliability was added to trip assignment, and some other changes were made to the impedance calculations to improve the validation of speed on freeways.

These three points are further detailed in the three sections to follow. The time-of-day model, which is another unique feature of the PSRC models, is described in Section 4.4.

4.1 Traffic Choice Study

This study was conducted to see how travelers change their travel behavior in response to variable tolls for road use and to estimate new values of times for this purpose. The unique study makes a significant contribution to the model by developing a local value of time for variable tolls. To conduct the study, Global Positioning System (GPS) meters were placed in about 275 vehicles, and driving patterns were observed before and after the experimental tolls were charged for the use of all major freeways and arterials in the Seattle metropolitan area. Participants were given a travel budget from which tolls were deducted. The travel budget was set so that participants would not lose any money; and, in fact, the incentives was offered of keeping the remaining budget if drivers changed their travel behavior and avoid paying the toll. The intention was to observe revealed preference behavior regarding the paying of tolls, and the results were used to update the value of times (VOT) in the PSRC model.

It should be emphasized that the value of time was estimated as a function of path choice, with all time and money costs associated with all paths being observed directly. This approach reflects the VOT only for path choice, and not necessarily for other choice components, such as mode choice or destination choice.

There is a significant amount of research (mostly the work of Kahneman and Tversky) that people value loss and gain differently. There may be a question about the way this experiment was conducted as to whether people viewed a toll situation as a gain, whereas it is really a loss; however, we do not think this is a problem for this study.

As a result of this study, new values of time were inferred and applied specifically for the toll study as the main update to Version 1. These values are higher for work trips than those previously assumed in the PSRC regional travel model – Version 1, but are similar for non-work trips.

There are two new sets of value of time: the higher ones are titled "trip assignment" and used only for assignment; the lower ones, titled "mode choice," are used for all other purposes. The HOV values of time in Table 1b of the Value of Time Memo are used only for assignment; they were created from a weighted average of the SOV values of time by vehicle occupancy, income, trip purpose, and time of day, based on the 2006 household survey of HOV trips. This helped PSRC to recognize differences without stratifying trips into these segments. These values are applied for different time periods, whereas other VOT are not differentiated by time of day because they are already segmented by trip purpose and income.

The "trip assignment" VOT is inferred from the Traffic Choice Study. The "mode choice" values are simply lower values used for skimming the network as input to mode-choice and destination/distribution modeling, while the "trip assignment" values were used only for final trip assignment. This was done empirically based on

the judgment that lower VOT should be used for mode choice and destination than for assignment/route choice.

Overall, PSRC uses a wide range of values of time segmented by income group based on the traffic choice study and segmented by choice (route vs. mode) based on the literature review and empirical analysis. Segmentation by income group is a good practice, supported by theory, and is common in other models, as well such as, that used in Denver and Portland. Segmentation by choice, is somewhat less common. In DRCOG, for example, the values of time are consistent for all model components according to the "CAB" (consistent across the board) concept. On the other hand in some cases values of times can really vary across different choices.

4.2 Distribution Model

In PSRC, traditional doubly constrained gravity models were used for all purposes. For home-based work trips, individual gravity models were developed for each income group. For HBW trips, log sums from the mode- choice models were used for the friction factors by income group, so they included all LOS variables that appear in the mode-choice model. The highway operating cost model includes operating cost by mileage, toll, and parking, so all these variables are entered into the logsum for trip distribution. This is an advanced practice and contributes to better distribution analysis; a similar approach is used in Portland, but not in Denver and the Bay Area.

For non-work trips, log sums were not used, and the impedance factors included only time and toll cost. No other costs, including auto operating cost, were figured in. As mentioned above, for the non-work trips only 20% of the toll cost is used (when skimming the networks) in calculating the friction factors, based on the practice that destination choice is not that sensitive to tolls. This practice is not very common however a similar practice was employed in Portland, where only 25% of the toll was used to determine trip distribution, based on professional judgment and the reasoning of the Columbia River Crossing (CRC) Tolling Team. The Bay Area did not use the toll cost at all for trip distribution; in other words, it did not view distribution as sensitive to the toll cost. Denver uses 100% of the toll. As can be seen, then, the practice varies greatly.

4.3 Counting for Reliability in Traffic Assignment

One of the new features of the PSRC model is that unreliability penalty is incorporated into assignment as an augmentation to the Volume Delay Function for freeways, so that reliability influences final assignment. Changes in the unreliability penalty (against a baseline model run) are captured as a benefit (positive or negative) in the benefit-cost analysis. As pricing results in changes in average speed conditions (V/C), it also affects the unreliability penalty. Reliability is an important factor in

travel choice, and it is important to captures the consequence of tolling not only through its impact on travel time but also through its effect on reliability.

Another unique feature of the PSRC assignment model is that value of time for assignment is segmented by income level, so that the effect of the toll can vary for different income groups. In Portland, no differentiation was made to isolate income classes or trip purposes for the Columbia River Crossing Project although previous work has done so, and the Bay Area does not include cost in trip assignment. In Denver, there are different values of time in the model; however, one value of time is used for skimming for assignment, the middle income value ($8/hr) for peak network, and the lower VOT ($6/hr) for off-peak.

4.4 Detailed Time-of-Day Choice Model

The PSRC model includes a detailed time-of-day model for auto trips. It is very important to have such a choice model for auto trips, as it enables the time- of-day choice of these trips to be sensitive to level-of-service variables, among them the variable toll. For transit and non-motorized trips, fixed factors are used. This unique feature of the PSRC is not very common and has not been applied in any of the areas of the Peer Review Panel.

The model presents five time periods. However, it should be noted that the night period, from 10 PM to 6 AM, is in practice mostly an early morning period, as a large proportion of the traffic during this period occurs between 5 and 6 AM. The five time periods use five different networks, so that the time-of-day choice models are sensitive to both congestion and tolls. These five time periods are further divided into 32 time periods to reflect variations within the main time periods. The 32 time periods are used only for auto trips, and they are not sensitive to travel time; however, 30-minute time periods are assigned in the peaks to represent tolls according to 30-minute time periods in assignment.

5. Other Elements of the Model

This section describes some of the other elements of the PSRC model not discussed above and their implications for variable tolling analysis. The issues discussed in this section are not unique to PSRC; they are in general common practice in most urban travel-demand models.

5.1 Feedback to Land Use, Economic Variables, and Auto Ownership

A toll can have long-term impact on land use and other economic variables, and this can further affect travel patterns. In the PSRC model, land use and other economic variables are assumed constant and, therefore, are not affected by the toll. The only economic variable that is not assumed fixed is auto availability. Auto-availability

models include auto, transit, and non-motorized accessibilities, so that auto availability can vary with changes in accessibility.

The lack of sensitivity of land use and other economic variables to toll is a common practice in other areas, and it is accepted for this type of analysis. For the Portland CRC study, land use was held constant (due to New Starts considerations). However, Portland is considering the option to make additional runs in the future that will address the land-use allocation impact of a toll project. In Portland, the regional totals for households and employment remain the same. However, depending upon the analysis objectives, Metroscope (its land use allocation model) is occasionally used to assess the impact of accessibility and travel costs on the household and employment allocation throughout the region. Like PSRC, the auto-availability model includes transit accessibility as an influential variable.

5.2 Trip Generation

Trip generation has no LOS variables or any feedback from lower-level models, and therefore it is not sensitive to tolls. This means that there will be no elimination of trips as a result of a toll. With the application of tolls, some trips may be expected to be eliminated; however, in most models including those used by the Peer Review members, it is a common practice not to take such trip elimination into consideration.

It is interesting to note that some trip elimination was observed in the Traffic Choice Study; see Figure 7 on page 13 there. Trips segments per week were reduced by about 6%. On page 22, it is written: "There were 4.8% fewer trips under network tolls (mainly trips not made, and a modest mode choice response)." PSRC could use this information to consider some impact that a toll might have on trip generation, but as said above this is not common.

5.3 Mode Choice

New mode-choice models were developed by Cambridge Systematics to support transit planning but are not used for the regional models and the tolling analysis. The current mode-choice models are multinomial logit; although, the available alternatives really suggest potential nested structures. Mode choice model was not estimated: rather, its parameters were developed, based on the literature and on practice; and only the constants were estimated, based on the proportions from the 1999 household survey. Seven modes are included: drive alone, share ride2, share ride4, transit walk access, transit auto access, walk, and bicycle. Different modes are used for different trip purposes; only the home-based work purpose includes all seven modes. Overall, the mode-choice model is consistent with common practice elsewhere but it is recommended to move toward use of locally estimated models. .

5.4 Truck Model and External Trips

The PSRC Truck Model uses gravity and fixed time periods factors so it is not sensitive to congestion pricing, except for route choice, where it is considered. The

same applies to external trips, and this is common in other areas; i.e., external trips and truck trips are not sensitive to tolls.

6. Main Concerns and Recommendations

This section summarizes the main observations raised by the Peer Review Panel and its recommendations to overcome concerns.

One of the main concerns generated by the results obtained so far is the high destination diversion obtained as a result of the implementation of variable tolling. The results show that 24% of the drivers change their trip destination and do not cross the lake under conditions of moderate and higher toll rates. There is concern that this high diversion is obtained despite the fact that only 20% of the toll cost is taken into account in trip distribution. This result is not consistent with current experience, which shows that people tend to shift time or mode before they shift destination. However, the unique features of the Seattle area, where there are competing destinations on the east side of the bridge, may justify these results. Therefore, the Peer Review Panel concluded that although the study results may look strange, they do make sense. Further investigation is required to analyze them.

In order to better analyze these results and to understand whether this high destination diversion indeed makes sense, it is suggested that there is need to be able to "tell the story" behind the results. Specifically, they should be examined at a more disaggregate level that includes:

- trip purpose;
- driver's income level;
- district-to-district level (i.e., the areas to which these trips are shifting)

It is also recommended that checks be made to catch any possible mistakes in the model run/calculation leading to these results. Is it a problem with the model? Or is it an accurate result? This is part of understanding and "telling the story."

Still another recommendation is to run the model under several different assumptions, among them:

- Hold trip tables fixed and look only at the mode and route- choice changes. This would reflect short-run effects.
- Test changes in destination constraint assumptions to understand their impact on diversion.
- Conduct a series of sensitivity analyses for different variables.
- Estimate elasticities.

An overall recommendation is to improve the consistency of the model. In this regard, it is suggested that auto operating cost also be included in non-work trips in the trip-distribution model. Currently, no operating cost is included in the skims for non-work trips into trip distribution. In this case, the toll reflects a 100% increase in cost. If operating cost is included in the cost, the toll will then reflect a lower percentage cost increase. For example, when the bridge toll in the Bay Area increases from $3 to $4, this was a 33% increase in the toll, but it was only an 8% increase in total cost (parking cost is not included in either Portland or the Bay Area). The significant percentage increase in cost can represent over-sensitivity to the toll.

In this regard, another suggestion is to adjust the values of times, making them consistent among the model's components. The decision to use a lower value of time for trip distribution than that inferred from the traffic-choice study for trip assignment results in the toll being converted to a higher time equivalent, thus making for higher destination diversion. Overall, it is recommended that a consistent value of time be used among all components as long as there is no stronger empirical evidence for the use of different values of time for different model components. If future studies find value of time vary by choice, these different value of times should be adopted.

These two adjustments, making value of time consistent and including operating cost in the trip-distribution model, should result in less destination- choice change.

The recommendation regarding improved consistency should apply to all other elements of the model. For example, although, the use of proportions of the cost in trip distribution works in the right direction of reducing destination diversion, It would be better to use the full cost and to adjust the models' parameters to reflect travelers' behavior in regard to the real values of LOS variables. This may implies different value of time, but this is a case when travel behavior indicates different value of times for different choices. As a general guide, it is more consistent to use the actual values of LOS variables variable and adjust the model parameters when needed.

The Peer Review Panel is also concerned at how well the model performs for the 520 bridge given that it is a regional model. A specific concern focuses on the model's performance for the bridge in terms of speed/volume convergence and validation. Although the model is converged and validated at the regional level, there is a question whether speeds and volume-to-capacity ratios on the bridge are realistic. In general, there is need for more focused study and analysis of the bridge corridor.

7. Conclusions and Summary of Recommendations

Tolling scenarios are difficult to model and pose new challenges to travel- demand models. The Peer Review concludes that the PSRC travel-demand model and forecasts are in accordance with the best state of the practice of analyzing varying tolls today; and their tools are sufficient for this level of analysis, having proved useful with the limited experience so far. Pendyala (2005) concluded, based on an extensive review of the literature and of practice, that toll and road-pricing analysis is

generally conducted using a combination of traditional travel-demand forecasting models and specialized stated-preference market research that helps identify potential market response and the adoption of alternatives in the event of pricing implementation. The Peer Review Panel views PSRC practice as being in common with this general description. PSRC did not use a stated-preference study, but the traffic-choice study provided a different and perhaps better insight than stated-preference surveys. These surveys can still be useful as will be discussed below. Vovsha et al. (2005), while advocating advanced tools, including activity-based models and micro-simulation, concluded that the best contemporary starting point for toll facility evaluation is a well-calibrated, advanced, regional modeling system. This system can be enhanced with additional local surveys, including stated-preference data, to modify forecasts. The Peer Review Panel is in agreement that PSRC has such a model. Vovsha et al. further stated that the four-step model with static assignment is the most frequently used for variable toll analysis. This view is also supported by Spear (2005), who deduced that investment level traffic and revenue studies for toll facilities used existing, locally developed travel- demand models, when available, and then supplemented them with additional, independently collected data focusing on the corridor where the proposed toll facility was to be built. The Panel is in agreement with these sources and, accordingly, finds the PSRC model credible for this phase of tolling analysis.

The process of improving travel-demand models is a continuous and seemingly endless process, and variable tolling analysis and implementation cannot wait for the ideal tool. Therefore, although the Peer Review Panel has various recommendations for improving the model, it is suggested that these improvements should not delay variable tolling planning. This holds in particular for the conclusions emanating from most of the real world applications to date, that value-pricing schemes have an impact and generally yield benefits consistent with the objective of the scheme (Pendyala, 2005). The detailed recommendations are of two types: short- term recommendations that should be implemented as soon as possible, and mid-term, more strategic recommendations that should be applied as the project proceeds. Activity-based models and advanced network simulation tools (dynamic traffic assignment and micro-simulation) are in different stages of development or use in some metropolitan areas, and they should significantly improve our ability to analyze and understand travelers' responses to variable tolling scenarios and other policies; however, they are considered longer-term recommended approaches. As such, they are not discussed in this memo, since it is not feasible to develop them in a time frame needed for the 520 variable tolling projects. Although it is important to continue to develop such advanced tools, the analysis and implementation of variable tolling projects should not wait for such tools to become available.

7.1 Short-Term Recommendations

1. Given the highly sensitive results regarding the high destination diversion, the Review Panel suggests looking at the results in more detail in order to gain a

better understanding of them and to be able, as it were, to "tell the story" behind them. The panel, therefore, recommends that the results be examined at a more disaggregate level, including:

- by trip purpose,
- by income level,
- by district-to-district level (i.e., to see what areas these trips are shifting to)

2. In order to better understand what is happening, it is also suggested that the model be run under several different assumptions. These include:

- a single constrained gravity model, to see the effect, if any, of doubly constrained;
- fixed trip tables and looking only at the mode and route-choice changes, which is a kind of short-run effect before drivers adjust their activities to change destination;
- a consistent VOT.

3. It is suggested that the overall consistency of the model be improved. This will entail using a consistent value of time following the trial runs with such values as indicated in the previous point. It also involves other consistency improvements, such as including the operating cost of non-work trips in the trip-distribution model, and considering the use of the full cost of the toll in all model components versus adjusting model parameters when needed.

4. There is need to check whether any mistake in the model run/calculation leads to these results. Is it a problem with the model? Or is it perhaps a true result? This is part of trying to “tell the story.” For example, it may be that given high-paid jobs and the concentration of activities on the east side of the lake, trip distribution is really more sensitive to the tolls here than in other areas.

5. There is a suggestion to look at the specific performance of the bridge traffic in addition to the regional level convergence of the model. Specifically, do traffic and speed fluctuate from iteration to iteration on the bridge, or are they stable?

6. The Panel suggests running the model with different toll rates under a similar toll scheme and estimating the derived elasticity from this process. The results can then be compared to the literature (some elasticity figures can be found in Pendyala, 2005, and in Chapter 14).

7.2 Strategic Mid-Term Recommendations

Although the Peer Review Panel concluded that the PSRC tools are sufficient for this stage of the analysis, they also suggest taking further steps as the project proceeds in order to obtain a better understanding of travelers' responses and the consequences of variable tolling. These more strategic, mid-term recommendations can be divided into three main issues:

1. While the use of the regional model is important and sufficient for this level of analysis, since it can include a wide array of potential responses to pricing, including mode shift, destination shift, and time of day shift, a more detailed corridor-specific analysis should be conducted as the project advances. This advanced analysis should include new data collection with a focus on the bridge traffic (origin-destination surveys, traffic and vehicle classification counts, and travel- time runs) and a detailed traffic analysis of the bridge. The performance of the model and how it converges for the bridge traffic should be examined in detail and compared to these data.

2. Stated-preference surveys and modeling should be conducted to try to better understand the various types of responses to variable tolling in this corridor. Such surveys should focus on the 520 corridor and provide travelers who participate in the survey with the choice of a whole array of potential responses, including changing mode, changing time of travel, changing destination, canceling the trip, and chaining it with another trip (i.e., reorganizing the daily activity pattern). Such a stated-preference survey and model can help to understand the high destination diversion obtained from the model. Stated-preference surveying and modeling are time-consuming tasks; at a minimum, therefore, PSRC should analyze its previous stated- preference survey to see what can be learned from it regarding value of time for different travel choices.

3. Finally the Peer Review Panel strongly supports providing the results in the form of ranges rather than a single value to reflect various uncertainties in the process, as well as the distribution of some of the important variables. This approach should reflect, among others, the fact that there is a distribution of value of time (VOT) in the population, and not just one level or even a few levels differentiated by income groups. Income is a continuous variable and represents a wide variability rather than merely four income levels. For this purpose, it is also suggested that a series of sensitivity analyses be run, based on variability in some of the important variables, such as VOT, land use, and an external variable such as fuel cost.

References

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