City of Bellevue, City of Kirkland, City of Redmond (BKR)

Peer Review

April 2016

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U.S. Department of Transportation
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FHWA-HEP-16-058


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Original: **April 2016**

Final: **April 2016**

Prepared for:

U.S. Department of Transportation

Federal Highway Administration

TMIP

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Technical Report Documentation Page

1. Report No. FHWA-HEP-16-058	**2. Government Accession No.**	**3. Recipient's Catalog No.**
4. Title and Subtitle City of Bellevue, City of Kirkland, City of Redmond (BKR) Peer Review		**5. Report Date** April 2016 **6. Performing Organization Code**
7. Author(s) Rachel Copperman, Ph.D.		**8. Performing Organization Report No.**
9. Performing Organization Name And Address Cambridge Systematics, Inc. 100 CambridgePark Drive, Suite 400 Cambridge, MA 02140		**10. Work Unit No. (TRAIS)** **11. Contract or Grant No.** DTFH61-10-D-00005
12. Sponsoring Agency Name and Address United States Department of Transportation Federal Highway Administration Office of Planning, Environment, and Realty 1200 New Jersey Avenue, SE Washington, DC 20590		**13. Type of Report and Period Covered** Final Report March 2016 to April 2016 **14. Sponsoring Agency Code** HEPP-30
15. Supplementary Notes The project was managed by Sarah Sun, COR for Federal Highway Administration.		
16. Abstract This report details the proceedings of a peer review of the City of Bellevue, City of Kirkland, and City of Redmond (BKR) plan for an improved travel demand model. The primary objective of the BKR peer review was for the Peer Review to review and comment on the BKR model design plan and help BKR decide what type of model to develop.		
17. Key Words Peer review, MPO, BKR, travel modeling, enhanced four-step model, activity-based model	**18. Distribution Statement** No restrictions.	

19. Security Classif. (of this report) Unclassified	**20. Security Classif. (of this page)** Unclassified	**21. No. of Pages** 36	**22. Price** N/A

Form DOT F 1700.7 (8-72) **Reproduction of completed page authorized**

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1.0 Introduction

1.1 Disclaimer

The views expressed in this document do not represent the opinions of FHWA and do not constitute an endorsement, recommendation or specification by FHWA. The document is based solely on the discussions that took place during the peer review sessions and supporting technical documentation provided by the City of Bellevue, City of Kirkland, and City of Redmond (BKR).

1.2 Acknowledgments

The FHWA would like to acknowledge the peer review members for volunteering their time to participate in this peer review. Panel members include:

- Billy Charlton – Puget Sound Regional Council;
- Bud Reiff – Portland Metro;
- Joe Castiglione — San Francisco County Transportation Authority;
- Ken Lindmark — City of Calgary;
- Kyung-Hwa Kim – Atlanta Regional Council.

Additional biographical information of each peer review panel member is located in Appendix C.

1.3 Report Purpose

This peer review was supported by the Travel Model Improvement Program (TMIP), sponsored by FHWA. TMIP sponsors peer reviews so planning agencies can receive guidance from and ask questions of officials from other planning agencies across the nation. The peer review process is specifically aimed at providing feedback to agencies on travel modeling endeavors.

The primary objective of the BKR peer review was for the Peer Review to review and comment on the BKR model design plan and help BKR decide what type of model to develop.

The peer review panel convened for two half-days (February 24th, 2016 and February 25th, 2016). During that time, BKR presented a model development plan and asked for comment on the plan. The panel discussed these items and offered a series of formal recommendations to BKR.

1.4 Report Organization

The remainder of this report is organized into the following sections:

- **Overview of the BKR Model -** This section highlights the uses of the model and discusses key characteristics of the BKR region.
- **Expectations of a New BKR Model -** This section discusses BKR's existing model, desires for a new model, and the agency's goals for the current peer review.
- **Peer Review Discussion -** This section details the key discussions of the peer review panel with BKR over the course of the peer review meeting.
- **Peer Review Recommendations -** This section highlights the official recommendations made by the peer review panel. Some of the key discussion points are revisited here, but some new details also are added.

Four appendices also are included:

- Appendix A—List of Peer Review Panel Participants;
- Appendix B—Peer Review Panel Meeting Agenda;
- Appendix C—Peer Review Panel Member Biographies; and
- Appendix D—Documentation Provided to Panel Members by the City of Bellevue and Documents Referenced in this Report.

2.0 Overview of the City of Bellevue, City of Kirkland, and City of Redmond (BKR) Model

2.1 BKR Model Background

Through an interlocal agreement in the early 1990's, the cities of Bellevue, Kirkland and Redmond (BKR) in Washington joined forces and developed the BKR Model to help carry out various planning activities. Since then, the model has undergone many rounds of minor to moderate updates, but the model construct and vehicle oriented nature remain unchanged. The BKR model supports the following multimodal planning and scenario analysis:

- Citywide long- and short-range multimodal planning,
- Corridor and sub-area analyses,
- Land use scenario analyses,
- Multimodal project identification and prioritization,
- Development impact review and transportation concurrency analyses,
- Citywide development impact fee assessment,
- Travel demand management program development and analyses,
- Construction impact analyses and detour route planning,
- Air quality and energy consumption analyses,
- Tolling and HOV studies, and
- Facility design and operations support.

2.2 Regional Characteristics

The cities of Bellevue, Kirkland, and Redmond are located in the east side of the Puget Sound region, as shown in Figure 1. This sub-area of the Puget Sound region is located just across Lake Washington from Seattle. Two east-west bridges connect Seattle to the City of Bellevue, the I-90 Express and Route 520. The three cities, combined, span 70 square miles, and have a population of 278,000, and 260,000 jobs. The ratio of population to employment means there are more jobs than residential workers, thus resulting in an influx of workers from outside the sub-area region into the region every workday. Thirty percent of the employment in the sub-area region is in the high-tech sector. This high level of high-tech employment is partially driven by the location of Microsoft Corporation headquarters in the City of Redmond, which attracts 50,000 employees per day.

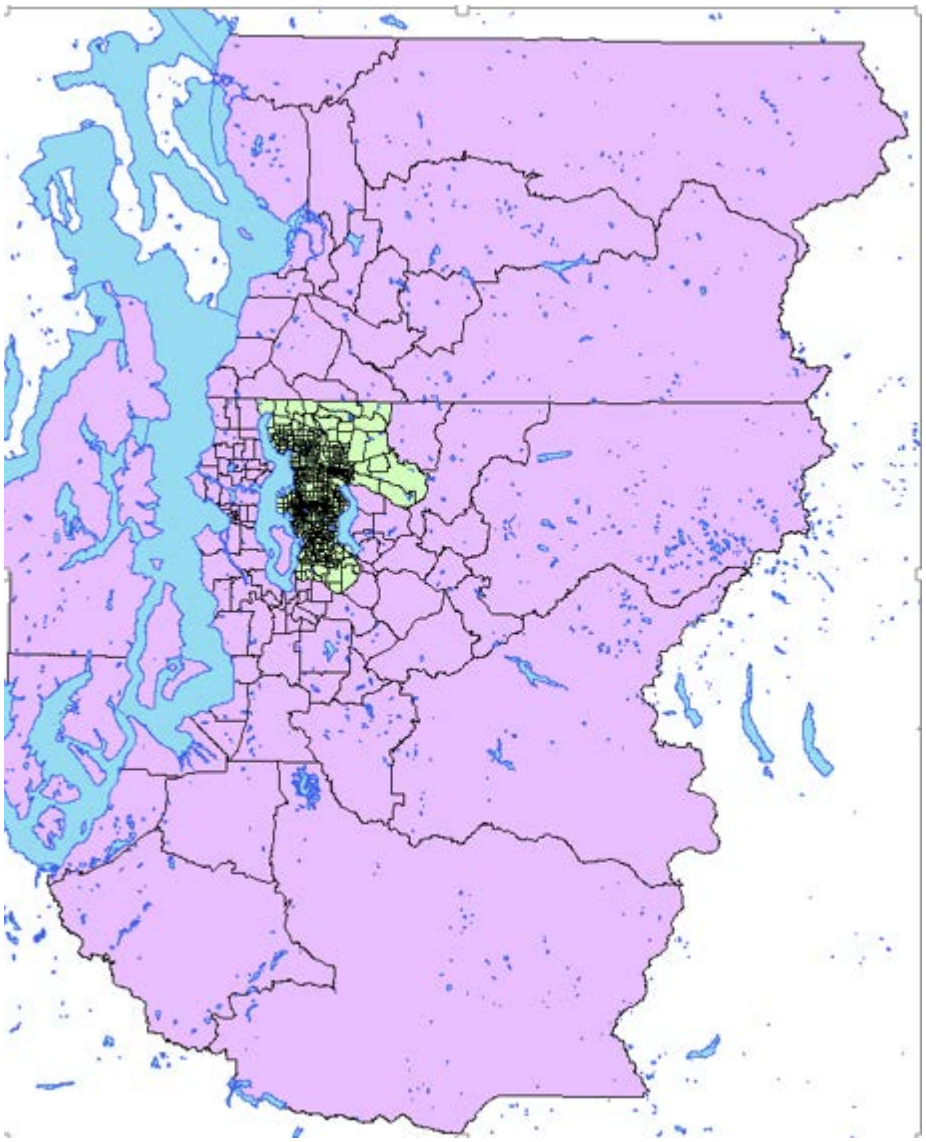

Figure 1 City of Bellevue, City of Kirkland, and City of Redmond Regional Boundary

(Source: City of Bellevue, February, 2016.)

3.0 Expectations of a New BKR Model

3.1 Existing Model

The current BKR model is a four-step, trip-based model modeled in EMME. It includes a fixed rate cross classification trip generation model, a gravity model for trip distribution, and a mode choice model that focuses on vehicle travel, with the following mode options: Single occupant vehicle (SOV), high occupancy vehicle with two occupants (HOV 2), high occupancy vehicle with three or more occupants (HOV 3+), and park and ride. Non-motorized modes are not explicitly represented. Highway assignment includes a multi-class equilibrium assignment using EMME. The EMME model results, after post processing using software developed in house, are frequently used to support traffic operation analysis in conjunction with Dynameq, a dynamic traffic assignment model, and Synchro, a traffic signal optimization and intersection analysis tool.

The BKR model is closely tied to the Puget Sound Regional Council (PSRC) regional model. It covers the same area as the PSRC regional model with much more refined traffic analysis zones (TAZ) and transportation networks within the three city area. TAZs outside the three city area are aggregated and treated as external zones. Trip ends for the external zones are taken directly from the PSRC model, which is combined with trip ends from the zones within the BKR area for trip distribution, mode split and traffic assignment.

3.2 Future Model Update

Several new developments have prompted BKR to initiate a major update to their model. First, the City of Kirkland and City of Redmond have either completed or are in the process of migrating from vehicle oriented performance measurement to multimodal performance measurement. The City of Bellevue is poised to develop multimodal measures as well. The existing vehicle focused model cannot effectively support multimodal analysis and planning functions. BKR is interested in having a model that can more explicitly model non-motorized travel.

Second, the BKR model is often used to assess the transportation impacts of mixed use developments and land use scenarios with different densities. The existing BKR model is not sensitive to changes in certain aspects of these scenarios. For example, the current model assumes that similar households located in downtown Bellevue generate the same number of trips as households located in the fringe areas of Kirkland or Redmond. This “static” and “fixed” trip generation approach may not accurately reflect the complex and dynamic nature of the human travel decision making process in the real world.

Third, newly collected survey data and recent advances in the PSRC regional model make it a logical time to develop the next BKR model. The City of Bellevue joined with PSRC to conduct a new household activity survey. The survey provided new information on regional travel behavior. PSRC has completed major updates to its 4-step model and has recently released their activity based model for use in application. BKR would like to leverage these successes in the development of the new model.

BKR identified four primary expectations for the new BKR model:

1. The model must have a multimodal focus and have the ability to generate multimodal (i.e. highway, transit, bike) performance metrics.

2. The model must be sensitive to changes in land use, accessibility, transportation policies, and provide output that better supports traffic operational analysis. For example:
    a. The model should have the ability to examine mixed use and high density developments within the urban area,
    b. The model should be sensitive to change in access or cost by different modes,
    c. The model should have the ability to test different tolling and parking surcharges, and
    d. The BKR model should provide improved input to the BKR region-wide dynamic traffic assignment (DTA) model in Dynameq to better support a variety of traffic operational analyses.
3. The results of the model should be intuitive and repeatable. The results should make sense and the results should be easy to explain and interpret. The model will be routinely used in development impact review and concurrency analyses. Thus, it is important that the new model is capable of performing consistently and that the results can be repeated.
4. The model should be practical. It should have reasonable run times (i.e. take no longer than overnight to complete), should not be too complex to develop and calibrate, and should be easy to maintain and update.

3.3 Goals for the Current Peer Review

The primary goal of the Peer Review was to review the draft model design that was developed by BKR with the help of RSG by:

- Reviewing model components, their subcomponents and data requirements,
- Identifying opportunities for improvement,
- Discussing uncertainties of inputs and assumptions and advise on how they can be managed, and
- Estimating resources required for implementation.

In reviewing the draft model design, BKR desired for the panelists to focus their attention on answering the following question: "What are proven, best practice modeling techniques that can be cost effectively incorporated into the next BKR model?"

4.0 Peer Review Discussion

The first day of the peer review was spent by BKR discussing plans for a new BKR model. During this discussion, many topics came up which initiated discussion among peer review panel members and between panel members, BKR, and RSG. This section documents the key points that arose during these discussions.

4.1 Review of Model Design Plan

BKR consulted with RSG to explore two options for improving the BKR Model. The first option was to develop a hybrid/enhanced trip-based model and the second option was to adapt PSRC's activity-based model (ABM), SoundCast, to the BKR modeling region. BKR directed the panel's attention toward reviewing the hybrid/enhanced trip-based model design, for the following reasons:

- Data needs are high for ABM and calibration of an ABM is complex given the many component models and candidate parameters that could be adjusted;
- Practical concerns about run time and simulation variation, especially given the frequent need to use the model for Impact analysis and other small scale analyses; and
- SoundCast could be used for certain special policy analyses, and BKR could use the hybrid/enhanced trip-based model for day-to-day analyses.

There are several key features of the hybrid/enhanced trip-based model, compared to their existing trip-based model, that will be discussed in detail in the subsequent sections:

- Has a more refined zone system,
- Includes non-motorized travel,
- Includes more segmented trip purposes – work trips by occupation and/or income,
- Reflects accessibility impact on trip generation by moving away from using static trip generation rates,
- Uses accessibility measures consistently and iteratively throughout the modeling process,
- Model sequencing is more reflective of the personal travel decision making process in the real world by modeling mode choice before trip distribution and modeling non-home-based trips after work and school trip distributions to improve non-home based trip estimates,
- Takes advantage of the regional model for external trip/tour generation and freight travel, and
- Is more responsive to time of day and overall congestion throughout the day.

4.1.1 TAZ System and BKR Model Regional Boundary

The BKR model will be enhanced by doubling the number of TAZs from the current model to a total of 1500 TAZs. The zones would be very disaggregate within the three city region and include TAZs outside of the three cities but within the PSRC region at a more aggregate level. Figure 2, below, shows the proposed BKR model boundary delineations and TAZ system. Light

orange are TAZs within the cities of Bellevue, Kirkland, and Redmond and their surrounding/buffer areas. Dark orange TAZs are outside of the three city boundaries but within the BKR model. Areas in gray are within the PSRC region, but will not be modeled directly within the BKR model.

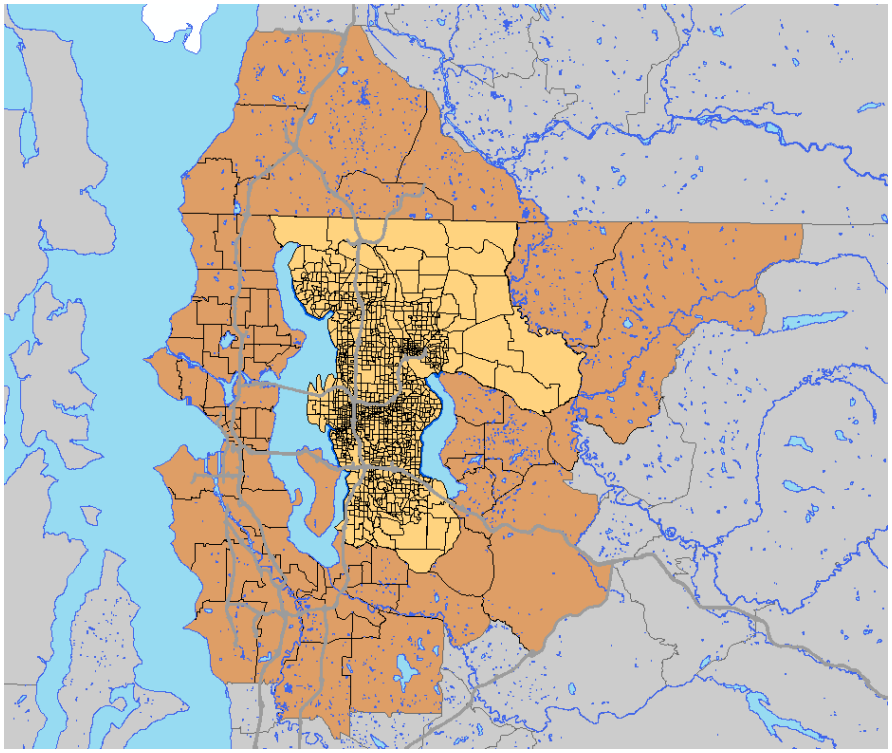

Figure 2 Proposed BKR Model TAZ system

The panel agreed that making BKR regional boundary smaller than PSRC region is a good idea. However, the panel suggested expanding the north and south boundaries to ensure that most residential locations of people who work within the BKR region are included as internal zones within the BKR model.

4.1.2 Land-Use and Sociodemographic Data

The enhanced BKR model will take in as input ten supply-side employment categories:

- Agriculture and forestry (NAICS 11, 21)
- Construction (NAICS 23)
- Manufacturing (NAICS 31-33)
- Transport, warehousing, utilities (NAICS 22, 48, 49)
- Wholesale trade (NAICS 42)
- Retail trade (NAICS 44, 45, 72)
- Information/high-tech (NAICS 51, 54)
- Financial, insurance, real estate (NAICS 52, 53, 55)
- Consumer, health, business services (NAICS 56, 61, 62, 71, 81)
- Government, K-12 education

The categories were designed to be consistent with the PSRC model categories.

The panel stated that the employment categories should line up with the trip purpose categories as much as possible. For example, government should be separated from K-12 education, since school trip destinations will be correlated with K-12 education and not government. The panel also suggested that BKR model should consider separate categories for university employment, hospitality employment, and healthcare related employment.

Socioeconomic data will be obtained from PSRC's population synthesis by aggregating from parcel and block groups to BKR TAZs. BKR mentioned concerns with issues involving random sampling of the population synthesis, especially when analyzing a very small geographic area. The panel stated that the same random seed should be used when running the population synthesizer and that when BKR is concerned with exploring socio-demographic changes for only a single zone or small sub-area, the analysts should run the population synthesizer on only the zone or sub-area of interest and combine the new data with the original socio-economic data for all other TAZs.

4.1.3 Bicycle Network and Assignment

BKR plans to develop an extensive bicycle network and has identified the following components for inclusion on the network links:

- Facility Type: Separated right-of-way, Marked, Shoulder, or Shared right-of-way,
- Slope of road,
- Width of bicycle lane, and
- Adjusted vehicle volumes.

The panel stated that the list may be more detailed than necessary. Vehicle facility type can be used as a proxy for vehicle volumes. Elevation gain is a better measure than slope. The panel stressed that the bicycle network must be an all-streets network. The panel confirmed that bicycle assignment should be handled in separately than other network supply models because of increased network detail and different relevant link attributes. The panel indicated that accessibilities from bicycle improvements may primarily result in route choice changes rather than shifts in mode choice. The bicycle assignment model takes in as input bicycle trip outputs from the demand model. The state-of-the-practice bicycle assignment models tend to be logit models and are fundamentally different from vehicle assignment models, especially since bicycle lanes do not have capacity constraints. The results of bicycle assignment model do not need to be fed back into the demand model because the bicycle impedances do not change due to the lack of capacity constraints.

4.1.4 Transit Modeling

The enhanced/hybrid trip-based model includes two sub-modes within the transit: bus and LRT. Transit travel times are linked to the auto network. BKR was concerned that adding too much complexity into the mode choice model via additional sub-modes would add to time needed to run the model. The panel assured them that mode choice runs very quickly. Additional time will be needed to set-up the skims, but once they are in place running the skims should not take too long.

The panel commented that from a political standpoint it may be important to model LRT separately from bus within mode choice, but from a modeling standpoint this is less important. The panel also suggested that BKR consider adding additional nests for access type, such as park and ride or kiss and ride.

4.1.5 Highway Network and Assignment

BKR is considering adding network capabilities so that the assignment is sensitive to intersection delay as well as designing the generalized cost function such that delay, or congested time, is weighted more heavily than free flow time. This methodology is based on current research under the SHRP2 L04 project that is investigating a means of incorporating reliability in static assignment.

The panel cautioned BKR to not incorporate intersection delay functionality into the network. They stated that it was a burden to maintain and that there was no evidence that is helped with calibration and validation. They stated that there are fundamental problems with static assignment that cannot be solved with intersection delay.

With regard to using perceived time within the generalized cost function, the panel cautioned against weighting congested time differently from free flow time; however they did not have detailed knowledge of the SHRP2 L04 project and thus could not comment directly on the methodology. The panel did suggest to incorporate a separate mode for tolled facilities within the network since they exist in the area.

4.1.6 Multimodal Accessibility Measures

BKR wants a coherent treatment of accessibility throughout the model, and have put together a set of seven accessibility measures that they are considering including in their model:

- Households within ½ mile of each zone,
- Total employment within ½ mile of each zone,
- Retail employment within ½ mile of each zone,
- Number of employees within ¼ mile of transit stops,
- Number of local intersections within ½ mile of each zone,
- Retail employment density within a half mile of each zone, and
- Total employment density within a half mile of each zone.

They were interested in hearing the panel's recommendations on how to incorporate accessibility measures into the model.

The panel commented that different accessibility measures are used for different purposes. Logsums are desirable for informing models, but are difficult for modelers to explain to themselves and to clients and the public. The panelists suggested to not abandon logsums altogether.

With regard to the other accessibility measures, the panel suggested using network-based measures (i.e. time and distance) rather than using crow fly distance. They also suggested adding a decay function to calculate the accessibility measure. This will make locations farther away less accessible than those closer in, while eliminating "cliff effects" where a location just outside of the radius is not included while a location just inside the measure is included.

The panel also said that it is important for TAZs to be properly designed so that accessibility measures perform optimally. Other accessibility measures they suggested considering were number of intersections by type and employment within 30 minutes of transit.

4.1.7 Auto Ownership Model

The enhanced BKR model will include an auto ownership model that will take in as input the following population synthesis variables:

- Household size
- Household income
- Age of head of household
- Number of working and non-working adults, and
- Number of children above and below driving age.

In addition they are considering using variables that measure accessibility to work, school, retail, and service locations.

The panel cautioned that using accessibility measures in auto ownership model could result in a model system that is too sensitive to accessibility. The panel said that when running the modeling system, turn on and off certain components to control the sensitivity. Hold the auto ownership model constant for most model runs.

The panel suggested including accessibility to usual work place location within the auto ownership model. They also suggested modeling auto availability instead of auto ownership, if the household travel survey differentiates between the two. They also suggested calculating accessibility based on the auto ownership level (e.g. zero vehicles vs. one or more vehicles).

4.1.8 Home-Based Trip Purposes

BKR is considering the following home-based trip purposes:

- Home-based work stratified by income and by sector (i.e. high-tech, government/office, other),
- Home-based college,
- Home-based high school,
- Home-based elementary school,
- Home-based shopping,
- Home-based recreation, and
- Home-based other.

The panel suggested adding personal business, social, and recreational trips as trip purposes. They highly recommended incorporating a usual work location model before trip generation. The usual work location model is a better way to handle the modeling of high-income high-tech jobs rather than trying to generate high-tech work trips directly within trip generation and then modeling them as a separate trip purpose within the destination choice model.

4.1.9 Mode Choice

BKR identified a set of modes they are interested in assessing. These include:

- SOV, HOV 2, HOV 3+
- Bus
- Light rail
- Park and ride
- Non-motorized (bike, pedestrian)
- Freight: heavy, medium, light trucks
- Telecommute/work at home, and
- Activities performed online (i.e., shopping, meeting).

The model would be a nested logit model with non-motorized, auto, and transit at the upper-level nest. Bike and walk would be nested under non-motorized. The transit nest would be

divided into walk-to-transit and drive-to-transit. The auto mode would include SOV and HOV as the next level nest, with HOV 2 and HOV 3+ further nested under HOV. Finally, toll and non-toll would be nested under each occupancy-level auto mode.

The panel agreed with BKR that freight will be borrowed from the PSRC model and not directly modeled within the BKR model. The panel stated that telecommute/work at home is a work location choice decision and not a mode. Activities performed online or at-home are not modeled in the state-of-the-practice activity-based models.

The panel suggested including taxi/ride-sharing as its own mode. The latest household travel survey did include questions asking about taxi/ride-sharing, although very few individuals reported making trips by this mode. However, including taxi/ride-sharing directly as its own mode will give the analysts flexibility later on to do scenario testing. Specifically, it will help with autonomous vehicle modeling. BKR can assert the constant now since the household travel survey probably does not contain enough data to properly estimate the constant.

Similarly, the panel recommended nesting each individual transit mode within the transit nest. They suggested including all modes into the structure that may occur in the future. This would include bus, LRT, and BRT. FTA has accepted BRT as a mode, whose alternative-specific constant may be asserted, for example as ½ of the rail constant. It is easier to have a placeholder for each mode now rather than trying to add it in later.

The panel also recommended including more detailed modeling of park and ride and kiss and ride modes. One suggestion made by a panelist was to add informal park and ride which would allow most TAZs that don't have parking charges or restrictions to accept the ability to park and ride in non-formal park and ride locations.

The panel agreed with modeling toll modes directly within the mode choice model, since the mode choice model can capture implied value of time. Doing it this way is more difficult to estimate, but it does not add much additional computation time during model application. The panel did caution, that if toll is included in mode choice then it will also need to be included as a separate mode in the assignment model.

4.1.10 Trip Distribution

The trip distribution model would distribute trips separately by trip purpose. Depending on the trip purpose being modeled, various multimodal accessibility variables and land use size variables (e.g. employees by category, park acres, number of households, number of hotel rooms) would be included in the model.

The panel agreed with the procedure laid out in the modeling plan. The panel was supportive of the use of shadow pricing techniques for, e.g., constraining workplace choices to actual jobs available. They stated that the model will not work well without shadow pricing and that any locations that have capacity constraints, such as park and ride locations must have shadow pricing.

The panel suggested to make sure the accessibility measures and choice set reflects auto availability. They also suggested including dummy variables where needed during model calibration. They cautioned that big datasets generated from passive data sources may be inadequate for detailed model calibration, but supported using the data at the district-to-district level as an additional source for model calibration and validation.

4.1.11 Number of Time Periods

BKR is contemplating modeling and assigning trips at the daily level and then allocating to AM and PM peak periods. This methodology would decrease run times and ensure consistency between more disaggregate time periods and daily totals.

Time-of-day issues are paramount to many policy decisions that the agencies will need to analyze. The area has an influx of workers from outside of the modeling region during working hours; thus there is a lot of directional congestion within the region that would not be captured appropriately if trips were modeled at the daily level. Given the region's emphasis on tolling by time-of-day, the model and skims need to capture varying price and travel times by different times of day. In addition, if the agencies are interested in examining peak spreading then they will need to include disaggregate time periods. On the other hand, the panel was okay with maintaining only peak and off-peak transit skims.

The panel stated that BKR can always sum up more disaggregate time periods to obtain the daily total, and thus inconsistency between finer time periods and daily totals should not be a concern. The panel stressed that modeling at least four to five time periods is very important, and BKR may want to consider skimming and assigning up to nine time periods (e.g. three 1-hour periods in the AM peak, three 1-hour periods in the PM peak, mid-day, evening, and night). All panel members cautioned against skimming at a finer disaggregation than one-hour increments, but most panel members supported modeling as low as half-hour increments if development of an ABM was pursued.

The panel did agree that it is a run-time trade-off, in that the more time periods that the model includes the greater the run-time of the model. However, the panel cautioned that time-of-day modeling should not be compromised and that BKR should find other ways to manage and decrease run-time issues.

4.1.12 Hybrid Modeling Approach

The hybrid modeling approach would begin by modeling home-based trip generation at the disaggregate person-level. The disaggregate trip generation would replace cross-classification tables that are used in traditional four-step models. These trips at the disaggregate level would then feed into mode choice, which would also be handled at the person-level. Trips would then be aggregated immediately after mode choice and fed into trip distribution. Based on the mode, purpose, and trip destination, non-home based trips would be generated. These non-home based trips would be categorized into work-based trips if they are associated with a work trip or non-work-based trips if they are associated with a non-work-based trip. The main benefit of this approach is that the model can capture the modal and spatial consistency between the non-home-based trip and the home-based trip it is linked to.

This modeling approach has been adopted by the Salt Lake City and Anchorage MPOs and has been included within the Tennessee and Iowa statewide models. These agencies chose to adopt this approach since they were relatively satisfied with their four-step model and wanted to adopt incremental improvements without starting over with a new model.

The panel's main concern with this approach is the model's lack of sensitivity to the policies that the agencies would be interested in analyzing, especially those related to time-of-day. Even though the model is at a disaggregate level for trip generation and mode choice, non-home based trips represent approximately 40% of all trips. Given that non-home based trips are represented at the aggregate-level, the model would still be missing valuable information for a large percentage of trips. Time-of-day consistency between home-based and non-home based

trips is also lost with this approach. The model would not be able to guarantee a continuous path through both space and time. If BKR is interested in analyzing demand management strategies, then having a means to analyze finer time-of-day disaggregation is necessary for modeling the appropriate sensitivities to these strategies. The panel stressed the importance of BKR to really consider the policies they are interested in analyzing and consider whether the enhanced/hybrid model will be able to address these analyses to the extent desired.

4.1.13 Interfacing with PSRC's ABM

BKR is interested in designing the enhanced model so that it can interface with PSRC's ABM. For trips generated from the area outside of BKR, one option would be to take the results from the regional model and aggregate them to BKR zones.

The panel was not convinced that the enhanced BKR model would ensure that trips coming into BKR from outside the area would be appropriately sensitive to travel demand management polices that the agencies may be interested in testing out (e.g. providing employees bus passes). They did agree that large-scale regional projects, such as adding in rail line into the BKR region, might be better handled by PSRC's ABM directly rather than using the enhanced/hybrid trip-based model.

The panel stated that there are a lot of details that still need to be worked out and a lot of issues that will need to be addressed with regard to integration of the enhanced/hybrid BKR model with the PSRC ABM. The panel agreed that trying to integrate the enhanced/hybrid BKR model may not be as desirable and will be much more complicated than either adopting PSRC's ABM or not integrating the BKR model with the PSRC model at all.

4.2 Concerns and Benefits of Adopting PSRC's Activity-Based Model

BKR identified a number of concerns with adopting PSRC's activity-based model to the BKR area including:

- Simulation variation for spatially disaggregate analysis (i.e. analyzing local projects),
- Run-time issues, and
- Complexity concerns of model development, calibration, application, and maintenance.

The panel's response to these concerns are discussed in the next section along with their assessment of the benefits of adopting PSRC's activity-based model.

4.2.1 Simulation Variation

BKR is concerned that ABM results will differ significantly by model run when analyzing local projects and thus will require conducting multiple time intensive model runs to get presentable results. They prefer that the model results be relatively easily reproducible.

The panel agreed that when analyzing one particular zone, simulation variation can be an issue. The larger the area that is analyzed, the less simulation variation is an issue. However, the panel argued that simulation variation can be managed and controlled. In addition, the panel pointed out that simulation variation is attenuated by static assignment procedures, and if the results are fed into DTA then the issue with ABM simulation variation is a minor issue compared to the simulation variation that exists within DTA models.

They also noted that when analyzing individual local projects or polices both the hybrid/ enhanced trip-based model and an ABM are going to have issues in analyzing the results, though they may are different types of issues. With the hybrid/enhanced trip-based model the

issues may be more related to the lack of sensitivity to a particular analysis, while with the ABM the issues may be due to simulation variation problems.

4.2.2 Run Times

PSRC's ABM takes 30 hours to run, while the existing BKR model takes only 45 minutes including assignment. Thus, there is legitimate concern that moving toward an ABM would significantly increase the time needed to run the model. However, PSRC is working on improvements to the model to decrease run-times.

The panel noted that depending on the zone system and time-of-day periods chosen for the enhanced/hybrid trip-based model, run times may not be significantly different from those that would exist in an ABM developed for the area. The panel also noted that run-times can be managed through improved hardware and multi-threading capabilities, decisions regarding time-of-day disaggregation, proper project management, and through simulating a smaller sub-area population or sampling the population at different rates.

4.2.3 Model Complexity

The enhanced/hybrid trip-based model is a simpler model than an ABM. Some of the panel members agree that given BKR' familiarity with trip-based model the enhanced/trip-based model may be easier to understand than an ABM. In addition, there are less data needs for a trip-based model and trip-based models are easier to calibrate.

The panel did agree with BKR that data and input requirements of ABMs can be burdensome. The panel did not believe that it would be more difficult to calibrate the ABM then the enhanced/hybrid trip-based model. They believed calibrating an ABM is more intuitive than calibrating a trip-based model. They also thought that adopting the PSRC model will be less complicated than developing the enhanced/hybrid model from scratch and then finding a way to integrate the model with PSRC's ABM. PSRC is willing to work with BKR on ABM training and data sharing.

4.2.4 Benefits of Adopting PSRC's ABM

Throughout the Peer Review meeting, the panel questioned BKR on why they devoted so much attention during the peer review to presenting the enhanced/hybrid trip-based model over discussion of adopting PSRC's ABM. Given the existence of PSRC's ABM and the desire of the BKR model to be sensitive to changes in land-use, accessibility, transportation policies, the panel thought that adopting PSRC's model was the prudent option. There were differing opinions on whether BKR should begin adoption of the PSRC model immediately or whether it should be a longer term plan. Some of the panel members thought that it was best to wait until the PSRC ABM has been used by PSRC for a longer period of time prior to adopting the model for BKR to ensure the model has been fully tested and vetted.

Since BKR would develop the enhanced/trip-based model from scratch rather than incrementally improving their existing trip-based model, most of the panel members believe that adoption of PSRC's model will be less complicated, cost less, and take a shorter time to develop. BKR has a strong interest in being able to properly examine a variety of complex policy strategies. An ABM is the most appropriate tool for examining these scenarios, especially since it can handle analysis related to time-of-day.

5.0 Peer Review Panel Recommendations

On the second day of the meeting the peer review panel spent about one hour in an executive session, closed to all other participants of the meeting. The reason for this closed session was to allow panel members to speak freely and openly among themselves while developing formal recommendations. This section details those panel recommendations.

The panel provided three options for the new BKR model:

1. Develop a stand-alone enhanced/hybrid trip-based model that does not integrate with the regional model;
2. Incrementally add components to existing trip-based model;
3. Adopt PSRC's ABM.

The panel also had other general comments and recommendations.

5.1 Stand-Alone Enhanced/Hybrid Trip-Based Model

The panel does think the enhanced/hybrid trip-based model that was discussed during the meeting is a reasonable approach to improve the traditional trip-based model. However, they had concerns that the integration with PSRC's ABM would be unnecessarily complicated, and thus suggested they create a stand-alone model that does not integrate with PSRC's ABM at all.

The panel did have several concerns with the enhanced/hybrid trip-based model that suggested that the model may not be the optimal option for BKR:

- The model will be less sensitive to critical policies than an ABM,
- The model may be more expensive and take longer to build than adopting PSRC's ABM,
- It is not an incremental approach, since BKR would build the model from scratch,
- The NHB segmentation may add complexity without significantly improving the model, and
- The model, as presented at the peer review, lacks an adequate time-of-day model, and thus will be insensitive to travel demand management strategies.

5.2 Incrementally Add Components to Existing Trip-Based Model

If BKR is not ready to move to an ABM but may be in a few years once PSRC's ABM has been in use for a longer period of time, then a viable option would be to incrementally improve their existing trip-based model by adding components of interest. For example, BKR could add a bicycle component or add accessibility variables to the existing model.

5.3 Adopt PSRC's ABM

The panel acknowledges there are concerns with adopting PSRC's ABM such as simulation variation, increased complexity with setting up and maintaining an ABM compared to a traditional trip-based model, unfamiliarity with ABM, and higher run times. However, all of the panel members believe all of those issues can be managed or overcome, especially with PSRC's support. They all agree that an ABM will be the most sensitive to the policy scenarios that BKR wants to analyze, compared to the other model options. Given the existence of PSRC's ABM that covers the same region as the BKR modeling area, most of the panel

members believe adapting PSRC's ABM will be cheaper and quicker than developing a new model from scratch.

5.4 Other Recommendations and Next Steps

The peer review panel made additional comments and recommendations to BKR, irrespective of the model chosen. They highlighted that data concerns are paramount for all model types. In addition, the panel supports making the BKR regional boundary smaller than the PSRC region. The panel suggested that to aid in the decision-making process BKR should develop a scope-of-work and budget for each of the three approaches that includes an analysis of the costs, concerns, and benefits of each modeling option.

Appendix A List of Peer Review Panel Participants

This section lists all individuals who attended the meetings, including panel members, City of Bellevue, City of Kirkland, City of Redmond staff and affiliated agencies and consultants, and peer review support staff.

A.1 Peer Review Panel Members

Panel Member	Affiliation
Billy Charlton	Puget Sound Regional Council
Bud Reiff	Portland Metro
Joe Castiglione	San Francisco County Transportation Authority
Ken Lindmark	City of Calgary
Kyung-Hwa Kim	Atlanta Regional Council

A.2 BKR and Affiliated Agency Staff

Name	Affiliation
Hu Dong	City of Bellevue
Dave Berg	City of Bellevue
Paula Stevens	City of Bellevue
Sean Wellander	City of Bellevue
Shuming Yan	City of Bellevue
Gwen Rousseau	City of Bellevue
Gary Hendricks	Pierce County
Iris Cabrera	City of Kirkland
Vince Bernardin	Resource Systems Group
Patrick McGrath	City of Redmond

A.3 TMIP Peer Review Support Staff

Name	Affiliation
Sarah Sun	Federal Highway Administration (FHWA)
Rachel Copperman	Cambridge Systematics, Inc.

Appendix B Peer Review Panel Meeting Agenda

Table B-1: February 24, 2016 Agenda

Time	Description
1:00-1:10	Welcome and Introductions (City of Bellevue – Paula Stevens)
1:10-1:20	Opening Remarks (City of Bellevue – Dave Berg)
1:20-1:35	Background Information • City of Bellevue (Shuming Yan) • City of Kirkland (Iris Cabrera) • City of Redmond (Patrick McGrath)
1:35-2:00	Informal Panel Presentations (Panel Members)
2:00-5:00	Critique Draft Model Design (City of Bellevue – Shuming Yan)
5:00-6:00	Executive Panel session if needed (Panel Members)
6:00-7:00	Reception (All)

Table B-2: February 25, 2016 Agenda

Time	Description
8:00-8:10	Recap of Day 1 Panel Discussion (Cambridge Systematics – Rachel Copperman)
8:10-10:40	Review/Critique Draft Model Design Continued (City of Bellevue – Shuming Yan)
10:40-11:10	Discuss State of the Practice of Activity-Based Models (Panel Members)
11:10-11:55	Summarize Panel Discussions and Resolve Outstanding Questions (Panel Chair – Ken Lindmark)
11:55-Noon	Closing Remarks (City of Bellevue – Paula Stevens)
Noon	Adjourn

Appendix C Peer Review Panel Member Biographies

C.1 Billy Charlton, Puget Sound Regional Council

Billy Charlton is the Director of Data at Puget Sound Regional Council in Seattle, Washington. He has more than two decades of experience building and using advanced travel forecasting models, and emphasizes use of technology, software, and industry best practices to improve the quality of the tools available to decision makers. He is currently a member of the Transportation Research Board's ADB45 Committee on Travel Forecasting Resources.

C.2 Bud Reiff, Portland Metro

Bud Reiff is a Principal Researcher and Modeler at Portland Metro, where he has managed household survey data collection and analysis, freight model development, trip-based model update, and various model application projects. Prior to joining Metro in 2008, he held a similar position for 15 years at the Lane Council of Governments in Eugene, Oregon, and had been a travel forecaster for the cities of Seattle and Portland. He has conducted research in *Urban Design Variables and their use in Travel Demand Models*, and in *Transportation Planning Performance Measures*.

C.3 Joe Castiglione, San Francisco County Transportation Authority

Joe Castiglione is a Deputy Director for Technology, Data and Analysis at the San Francisco County Transportation Authority (SFCTA) with 18 years experience in the development, application and refinement of advanced travel demand forecasting models. Prior to joining the SFCTA, he served in a variety of technical roles on travel forecasting and transportation planning projects in both the public and private sectors, focusing on activity-based travel demand forecasting models and their integration of with advanced dynamic roadway and transit network models. He has extensively applied these model systems to transportation and land use planning and investment analyses.

C.4 Ken Lindmark, City of Calgary

Ken Lindmark has been with the City of Calgary's Transportation Planning group since 2004. His current assignment is Manager of the Forecasting Division.

Ken's prior professional experience includes 20 years as a modeling specialist with the City of Portland, Oregon. In Portland, he was responsible for implementing the City's transportation model and applying it to a variety of studies and strategic plans. Ken began his career with a transportation consulting firm in Newport Beach, California in 1980.

Ken received his Bachelors Degree in Geography/Urban Planning at California State University Fullerton. He also has a Masters Certificate in Municipal Leadership from the Schulich School of Business, York University and a Certificate in Transportation Systems Management from the University of California Irvine.

C.5 Kyung-Hwa Kim, Atlanta Regional Council

Kyung-Hwa Kim is a Sr. Principal Planner at Atlanta Regional Commission (ARC). She worked at Metro in Portland, Oregon for 20 years as a modeler before she joined ARC as a Performance Analysis and Monitoring section manager.

Her 20 years of experience at Metro spanned simple data analysis to complicated activity based model development. Now she manages air quality, climate changes, scenario modeling, congestion management planning, safety, performance measures, environmental equity, and project prioritization at ARC. Kyung-Hwa holds a Master's degree in Urban Planning from Portland State University and a Bachelor's degree in Psychology from Portland State University. She also studied Ethnomusicology at Seoul National University before she immigrated to the United States from Korea.

Appendix D Documentation Provided to Panel Members by the City of Bellevue and Documents Referenced in this Report

BKR Model Design Peer Review Presentation
Prepared by City of Bellevue and Resource Systems Group, dated February 16, 2016.
Provides an outline of the BKR model design plan.

SHRP2 L04 Report: Improving Our Understanding of How Highway Congestion and Pricing Affect Travel Demand
Published by Transportation Research Board, Washington D.C., 2013.

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This report is being distributed through the Travel Model Improvement Program (TMIP).

Federal Highway Administration

U.S. Department of Transportation
Federal Highway Administration
Office of Planning, Environment, and Realty
1200 New Jersey Avenue, SE
Washington, DC 20590

April 2016

FHWA-HEP-16-058

U.S. Department of Transportation
Federal Highway Administration