Using a DTA model to evaluate road tolling strategies for the Alaskan Way Viaduct Replacement Project

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1 OVERVIEW

Recent applications and research in toll modeling suggest that Dynamic Traffic Assignment (DTA) modeling is gaining acceptance in the industry as a suitable modeling platform for a variety of planning studies and projects. By blending the traffic assignment capabilities of travel demand modeling tools with the intersection/link analysis capacity of traffic simulation tools, DTA modeling effectively bridges the “gap” between the more commonly used macroscopic and microscopic paradigms. Despite increasing acceptance and use, however, DTA modeling for the purposes of tolling analysis and development of toll revenue projections has been limited, even though the benefits and effectiveness of such applications appears promising. This short paper briefly summarizes a current effort to develop such a model to support updates to the tolling and revenue analysis for the Alaskan Way Viaduct Replacement Tunnel Project in Seattle, Washington. The primary objectives and motivations for using DTA are first described and are followed by an overview of the study methodology and tolling model development process. The expected results and findings of the study are then described in addition to how this work will potentially add value to toll modeling/forecasting.

2 OBJECTIVES, MOTIVATIONS AND INNOVATION

2.1 Background

Lack of funding has led the Washington State Department of Transportation (WSDOT) to undertake toll studies on several state facilities recently to assess the feasibility and effects of implementing tolls. This has resulted in three currently tolled freeway facilities in the Puget Sound Region and consideration of tolls on several others (Figure 1).

On toll studies to date, WSDOT has utilized the regional metropolitan planning organization macroscopic model—a traditional four-step planning model that statically assigns traffic—to develop traffic forecasts. While this modeling tool has provided what many local transportation planners believe to be conservative estimates of toll facility traffic and relatively high estimates of diverted traffic; it has served an important purpose for what has been needed to date: conservative toll revenue projections and an upper range of traffic diversion impacts appropriate for EIS purposes.

This approach was used for the EIS analysis and initial toll revenue projections for the SR 99 Alaskan Way Viaduct Replacement Program (AWVRP) and its preferred alternative, a deep bored tunnel. To fund construction of the tunnel, WSDOT has determined that it needs to toll it. This, in turn, has generated concerns over the impacts from traffic diverted away from the tunnel because of tolls. SR 99 carries over 100,000 vehicles per day (vpd) through greater downtown Seattle, a major activity center with over 180,000 jobs (see SR 99 Area Detail in Figure 1). The alternative routes to using the tunnel are via signalized arterials through a downtown zone congested with pedestrians, autos, and transit (over 200 bus routes in peak periods) or by the use of the parallel Interstate 5, which carries 270,000+ vpd and is heavily
congested in both directions throughout the day (Figure 2). The macroscopic model projected a substantial amount of diversion would occur to these congested alternate routes (from 30 to 60 percent depending on toll rates and analysis year). This is believed to be overstated because the macroscopic model does not fully account for the operational effects of signalized intersections and queuing influences from bottlenecks on these alternate routes under congested conditions.
Following completion of the FEIS for the project, WSDOT assembled a committee to assess potential toll diversion impacts to Seattle city streets and make recommendations for mitigation. With the intent of building upon, but refining previous analyses, WSDOT made the decision to develop a DTA tolling model for use in support of this committee, and to inform updates to toll revenue projections. A DTA tolling model was chosen because it is expected to more accurately reflect delays encountered on alternative routes, leading to a more realistic estimate of toll diversion.

### 2.2 Objectives and Key Drivers

The objective of this effort is to develop a DTA tolling model that more accurately predicts traffic flows and travel times through the study area in comparison to the static macroscopic model and to use this model to evaluate potential diversion and their impacts; as well as potential toll traffic and associated revenues. Factors making the DTA more suitable for these purposes include:

1. In uncongested conditions, static models produce constant traffic flows that represent the average conditions. In contrast, DTA models produce time-dependent flows that closely follow the observed link or movement volumes.
2. In congested conditions, static models produce traffic flows that represent the desired link volume and not the one that can actually go through a link. Static models are structurally incapable in constraining flows to not exceed capacities. As a result, in congested conditions unrealistic flows and travel patterns are produced. In contrast,
DTA models produce volumes that more closely match the observed values and never exceed capacity.

3. Dynamic models are significantly more capable than static models in replicating or estimating congestion patterns, bottlenecks, queues, and spillback phenomena.

4. Dynamic models yield simulated speeds that are much closer to the observed values. This is due to the fact that vehicle simulation is used instead of link-specific analytical functions. DTA models, unlike static ones, capture accelerating, decelerating, merging, and queuing.

Key drivers for development of the DTA tolling model include the heightened concern over diversion impacts from the tolled tunnel; the associated formation of the committee to assess impacts and identify possible mitigation; and the need to develop more realistic estimates of toll traffic revenues. Imminent tolling of SR 520 in the region also offers the opportunity to “ground-truth” the DTA model against actual toll diversion.

2.3 Innovation

Multiple user classes and static assignment are part of the established practice for tolling and other road pricing studies. In contrast, and to our knowledge, there are very few DTA models that have been developed outside academia for the same purpose and very few, if any, consider drivers as a non-homogeneous population. This study will develop a DTA model using multiple user classes—possibly as many as the planning model contains—and then compare the static and dynamic approaches.

3 METHODOLOGY

3.1 Model Development

The key steps in preparing the DTA tolling model will include a combination of activities that tie together aspects of traffic operations analysis and travel demand modeling. These are briefly described below.

3.1.2 Data Collection

Since the initial traffic demand and vehicle loadings on the DTA network will be supplied from the demand matrix (see section below), the volume data collected for model development will be primarily for refining the demand matrix and calibrating the DTA model network. This data will include 24-hour directional link counts by 15-minute increments and peak period (2-hour) intersection turning movement volume counts. For the purposes of calibration, directional link counts typically only need to cover major access routes and paths through the arterial network. Therefore only 5-10 percent of the total links in the network will need to be represented in the link count database (see Figure 3). Intersection counts and signal timing/phasing data are available for the majority of intersections within the DTA network from previous studies.
Travel time data will be compiled in order to refine and gauge feedback of the model’s performance. At a minimum, previously collected travel time runs (see Figure 3) for a variety of downtown arterial routes will be used if additional travel time data is not readily available. However, if possible third-party vendor traffic data (speeds and travel times) will be used to supplement the information provided by the previous travel time runs.

3.1.3 Network Development
The DTA network will initially be imported from the regional planning model to establish a preliminary network skeleton and necessary details will be added, including the following:

- Link lengths and speeds
- Lane channelization, especially at intersections
- Ramp connections and geometry
- Parking restrictions by arterial and time-of-day
- Transit lanes, including time-of-day restrictions
- Centroid connector locations

3.1.4 Demand Matrix
The preliminary input demand matrices for the study area will be extracted from the regional macroscopic model which is multi-modally based and reflects trip classification by typical purposes over five time periods.

The DTA simulation period will represent five hours from 1:00 PM to 6:00 PM and will be sliced in 15-minute intervals. This duration will allow for adequate time to capture both a typical PM peak hour and a midday afternoon hour and also allow for the time required for network loading and dissipation. Demand matrices by three auto vehicle classes (i.e., single-occupant, two-occupant, and three or more occupants) and three truck groupings (small, medium and large) corresponding to the study area and DTA simulation period will be provided by the macroscopic model. Additionally, the home-based work single-occupant vehicle trip matrix is disaggregated into four income groups. Subsequently, the total origin-destination demand matrix for the DTA simulation period will be run through a static matrix adjustment process to replicate actual traffic counts throughout the study area. Depending on the quality of the obtained results from the static adjustment process, the model will be further refined by applying dynamic matrix adjustment to get the model speeds and volumes even closer to the observed values.

For future year application, the total demand matrix resulting from the base year DTA model calibration and validation effort will be grown according to implied growth projections exhibited in the macroscopic model between the base and future years. Future year total demand will be further classified into demand matrices by vehicle class, trip purpose, and/or income group (based on relevant information from the macroscopic model) to suit toll modeling analysis.
Figure 3: DTA Model Traffic Count and Travel Time Data Locations for Downtown Seattle
3.1.5 Calibration/Validation

Steps investigated to minimize discrepancies between model outputs and field data will include both quantitative and qualitative considerations. In addition to traffic counts, other empirical data such as speed (including prevailing queue lengths) will be important for being able to detect sources of discrepancies. Discrepancies are essentially caused by an imbalance in the DTA model between time-varying demand and capacity. This could be contributed by a number of factors including network capacity and signal timing parameters, assigned local traffic flow, and the global origin-destination demand matrix. The goal is to achieve a close match between model and actual counts and speeds within the study area for both PM midday hour as well as peak-hour. This includes estimated versus observed comparisons for the following measures:

- Vehicle counts by link
- Average vehicle speeds
- Average link or segment density
- Link or sub-route travel times
- Intersection turning movement counts

4 EXPECTED RESULTS & FINDINGS

The DTA model will be used to test a variety of toll scenarios to estimate the amount of toll traffic in the tunnel and traffic diverted to city streets. Scenarios will vary primarily by varying toll rates by direction and time of day. The tolling committee will identify potential actions to mitigate the impact of toll scenarios on city streets and, if applicable, effectiveness of these actions will be assessed using the DTA model. It is anticipated that the dynamic model’s superior ability in representing traffic phenomena and its increased accuracy in estimating drivers’ experienced travel times will provide better estimates of the traffic flow patterns and drivers’ responses under various tolling scenarios. At a minimum, the dynamic model will not allow for cases in which the desired flow exceeds capacity and will not generate unrealistic traffic flow patterns to base conclusions upon.

5 VALUE TO PRACTICE OF TRAVEL MODELING

This paper describes a simulation-based DTA model incorporating network equilibrium, which will be developed for evaluating different tolling options. Most DTA models for road pricing applications assume homogeneous perception of tolls for all drivers despite the fact that value-of-time varies significantly across individuals because of different socio-economic characteristics, trip purposes, attitudes and preferences. Conventional (static) traffic assignment models account for user-heterogeneity by including multiple vehicle classes but are limited in their ability to model traffic flow propagation adequately enough and, more often than not, result in infeasible traffic flow patterns. This study will demonstrate the capability of the DTA model as an effective tool for predicting toll traffic assignment and associated traffic diversion. This will provide a more detailed means to represent the interaction between travel...
choices, traffic flows, and travel time, and cost measures in a temporally coherent manner. Also, DTA models have typically been used for small subarea analyses. This project demonstrates that DTA models can effectively model a large portion of a major city, and model it for pricing application analyses. This study will benefit development of other DTA models for tolling studies WSDOT may undertake; and has implications related to integrating DTA models with regional planning models for better traffic assignment.

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