Integrated Passenger & Commercial Vehicle Model for Assessing the Benefits of Dedicated Truck-only Lanes on the Freeways

by

Sundar Damodaran, Ph.D., P.Eng. & Mauricio Alamillo, M.A.Sc.
Ministry of Transportation, Ontario

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ABSTRACT

Background

The concept of dedicated truck-only lanes has been proposed more than twenty years ago and since then, several jurisdictions have undertaken studies exploring the concept. While the nature of these studies range from research, to proof-of-concept to detailed design-and-build project studies, most of these studies have a common issue to deal with, i.e., predicting/forecasting the commercial vehicle demand, along with all the other class of passenger vehicles demand as well as system-wide impacts (both benefits and disbenefits) of various truck-only treatments for evaluation purpose. This is the primary focus area of this paper.

Issues Related to Modelling

Travel demand forecasting models, either regional or state/province-wide, are a key planning tool for such studies. The levels of detail and market segments covered in regional models vary across the regions/jurisdictions that have explored the concept of truck-only lanes. Two key areas related to demand modelling of commercial vehicle demand are a) how well it is integrated with the passenger demand models, and b) how the parameters related to truck traffic behavioural aspects have been developed and incorporated. This paper will include a cursory review of some of the previous studies with regard to demand modelling approach and methodology, in particular the two issues mentioned, as well as evaluation techniques.

GGH Case Studies

The second part of the paper presents an overview of a case study involving a strategic assessment of truck-only lanes in the freeway network in a regional context within the Greater Golden Horseshoe, in Central Ontario. The use of a regional macro-level travel demand model for the strategic analysis and a mesoscopic sub-area model will be presented, along with a discussion of technical results of these two analyses.

Background

The concept of reserving lanes for the exclusive use of trucks, similar to the way carpool and high-occupant vehicles (HOV) lanes operate, had been proposed and studied since the early 1990's. One of the major studies that examined the feasibility of dedicated truck-only lanes in an urban expressway corridor, in a planning context is the one prepared for Southern California Association of Governments (SCAG) for the SR-60 in the Los Angeles metropolitan area(1). This study considered the technical, social (or community), and financial feasibility of trucks lanes in that corridor.

Since then, there have been several research studies as well planning and/or policy studies that addressed this topic in varying levels of detail. Very few studies that explored the feasibility of dedicated truck lanes actually proceeded to implementation, which is as an indication of the state of practice when it comes to truck lanes as a system management measure, in North America. For a comprehensive literature on a wide variety of studies, see the joint National Cooperative Highway Research Program (NCHRP) and National Cooperative Freight Research Program (NCFRP) research project report on separation of vehicles in "CMV-only" lanes (2).

A common element in many of these studies deals with how to quantify the impacts of a scheme that involves preferential treatment for one or several class of vehicles in the roadways. While a good understanding of the traffic/demand profile and operational characteristics of an existing corridor can be developed from current or past data, a planning feasibility study will require the ability to forecast and carryout scenario/option evaluation, taking into account all impacts. It is imperative that such analyses and evaluations are done with the aid of a travel demand forecasting model.

Features of Analytical Tools:

A travel demand model is a planning tool that forecasts demand and impacts on the system. To be an effective planning tool, the model should have, as a minimum, the following key features:

- Accounts for supply-demand equilibrium with the ability to forecast demand that is sensitive to supply-side interventions;
- The level of detail or resolution, in both input and output data, should be to the appropriate extent that fits the nature of the scheme (i.e., conceptual/strategic or operational/tactical) being studied;
- The forecasting horizon should be sufficiently long (typically 30 years); and
- In addition to the input data, i.e., the land use, demographic, socioeconomic indicators and other causal variables, the model should include policy sensitive variables which can be varied to perform "sensitivity" analysis on the forecasts/results to aid planning and decision-making.

The description above, of a desirable model that forms part of a planning tool, is not only specific to truck-lanes, but also to other applications in general. The issues related to demand modelling for truck-lanes are more complex in that the model will have to address different class of road users in their preference and behavioural responses to any measures.

Issues Related to Modelling

In most cases, a regional or a large-area model of some sorts may already be available for the corridor where a truck lane is to be studied. In such cases, the available model needs to be reviewed to explore to the extent to which it can serve the needs of truck lane analysis. Some of the primary considerations will be whether the model is an integrated passenger and freight/goods movement model, and if so, are the commercial vehicle trips treated in the same level of detail as the passenger vehicle trips.

It is not uncommon that commercial vehicles are treated, if at all, in a simplistic manner in regional travel demand forecasting models. Where commercial vehicle demand models exist, they may be “vehicle-based” or “commodity-based”, with varying levels of sophistication. Also, commercial vehicles demand model may be stand-alone (not integrated), or partially or fully integrated with the passenger demand model. Partial integration may be achieved through bridging or data/information sharing between the two models on the common elements of the supply side (for example, the road network), whereas only a fully integrated model will be able to account for the interaction between the two primary class of vehicles, i.e., passenger cars and trucks on the road network, similar to traffic operations in real-world. This last requirement is of particular interest for evaluating truck-lanes which will be impacting the performance of both classes of vehicles.

Example of a fully integrated commercial vehicle and passenger model for a regional area is the one in use at the City of Calgary. Probably the most advanced among such models in any urban region in Canada, this model includes all forms of commercial vehicles, treating the trips made by these vehicles using a tour-based approach(3). By building on the regional passenger travel demand model, this model simulates the peak and off-peak network conditions arising from the trip assignment technique that jointly loads all vehicle classes of passenger and commercial vehicle types. Such an approach will be ideally suited for evaluating the impact of truck lanes on the overall network performance at a wider system level.

Scope of Truck Lanes:

There are several issues related to the definition of truck lanes, in terms of design, operation, regulation, enforcement, etc. While many of the physical aspects of the way in which a truck lane is expected to operate are relevant and important from the demand modelling perspective, the most important factor is defining what type of vehicles are allowed to use the reserved lanes. The definition of trucks may vary across jurisdictions, and it is important to define these in the early stages of study inception, so that the model specifications can be reviewed or refined to meet the needs of the study. A key consideration is if the light-duty commercial vehicles, such as minivans and pickups operated by small businesses, couriers, service vehicles, etc., will be permitted in the truck lanes. Representation of these classes of commercial vehicle classes in the model explicitly, would be advantageous when testing different truck lane options.

Model Parameters:

There are several model parameters in any model, depending upon the type of model, which can grouped into two major categories: a) those pertaining to the operations of trucks in traffic stream, and b) those related to the behavioural aspect of truck demand. A few key ones are discussed below:

Passenger Car Equivalents (PCE) are used to bring the medium and heavy vehicles into a common normalised unit for traffic modelling and analysis. While a standard parameter is recommended in the Highway Capacity Manual, researchers have found that PCE factor can vary with the more-detailed vehicle classification of medium (single-unit) or heavy (combination-units) trucks and other factors such as terrain and road type (4), i.e., rural vs urban freeway, arterial roads with signalised intersection, etc. Most models use the PCE factors globally based on the vehicle class, rather than varying it by road type and/or location.

Speed-Flow / Volume-delay functions are performance functions used in macro[1] models to represent the interaction between supply and demand at the link/segment level. Travel time on a link is expected to increase as demand increases, reflecting the build up of congestion and in turn

[1] Macro models are also “static” models in the sense that they represent network conditions for a time period, say a peak hour, without any temporal re-distribution of demand. Microsimulation and mesoscopic models are able to address that aspect, and they use different functions and methods to simulate traffic conditions.

affecting other trip behavioural decision making process of demand that potentially could use that link. As with PCE factors, most models use a set of functions which are applied to different road types, based on various attributes. Traffic volume is treated as equivalent passenger cars, without being able to differentiate between trucks and autos in terms of performance measures (vehicle-hours and vehicle-km) for each class of vehicles. In other words, the metrics used for measuring congestion, i.e., volume-to-capacity ratio, travel time or speed, etc., are geared towards passenger cars with very little attention to how congestion levels affect performance of trucks in the traffic stream, given their different acceleration/deceleration characteristics. This issue is further complicated if differential speed limits[2] for heavy vehicles are to be considered. Micro or mesoscopic simulation models are better suited for analysis of detailed traffic performance at the highway corridor or sub-area level.

Value-of-Time is a parameter used in network models to account for the differences in the way each class of users on the road network perceive congestion. More specifically, it is a measure of how users might prefer or willing to pay an additional premium in travel price, in order to save travel time. This parameter will influence the way in which trucks select the routes they take in the road network. Presumably, a user class that has a high value of time will prefer a faster route, even if that route involves an additional out-of-pocket cost in terms of toll. The issue however, is to know what values to adopt within a model, based on local knowledge about traffic pattern and behaviour of trucking firms in the region.

GGH Case Studies

A research study (5) explored the concept of dedicated truck lanes or truckways though the urbanised areas of the Greater Toronto and Hamilton Area (GTHA). This research conducted an analysis of potential benefits and impacts of two alternative truck-only options, using three different analytical tools; a) macro regional travel demand model, b) microscopic simulation model of the freeway system, and c) GIS tool that quantified accessibility measures. The alternative options of truck-only facilities were a) converting one of the outer lanes on the Highway 401 through the entire study area (approximately 75 km from Halton in the west to Durham in the east), and b) creating an exclusive 4-lane truck-only roadway between Burlington in the west to Scarborough in the east). The three tools were used to quantify impacts of truck-only alternatives in terms of a) traffic volume, truck-lane usage, and travel time, b) traffic performance and safety (risk of collision from lane changes and manoeuvres), and c) accessibility measures at a refined geographic level of analysis, respectively.

The two alternatives evaluated were selected mainly for the purpose of proof-of-concept as it did not have a planning objective. The research demonstrated the applicability of the analytical tools developed in the research, with some mixed findings, especially in the areas of safety and accessibility impacts. Nevertheless, this study made significant advances in creating an integrated passenger and commercial vehicle modelling tool for the region.

Other Strategic and Operational Studies

Subsequent to the above research study, the concept of truck-only lanes on the freeway system through a larger area of Central Ontario, i.e., the Greater Golden Horseshoe (GGH) area (see Figure 1) have been explored at the Ministry of Transportation, Ontario (MTO), using travel demand forecasting models that are available in-house for MTO's planning studies.

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[2] It is not common to have different speed limits for heavy vehicles in most North American jurisdictions, as compared to Europe. For example, in the U.K. there has been research on methods to have differential speed-flow curves for different classes, i.e., light and heavy vehicles. See http://www.saturnsoftware.co.uk/ugm08/Speed_Flow_Curves_Presentation.ppt for a presentation on this topic.

Figure 1 - Greater Golden Horseshoe

Two types of models were used. The first one is a traditional four-stage regional (macro) model for the GGH, in Emme platform, and the second one is a corridor/sub-area (mesoscopic) model for a highway corridor within the GTA, in Dynameq platform. The two models are described below, along with some of the key model parameters used.

<u>GGH Macro/Strategic Model:</u>

This regional multi-modal model has been developed for the Ministry, using the household travel survey completed in 2006 and other data such as the Census of 2006. The model covers the GTHA and the ten surrounding Counties/Regions with a total population of approximately 8.7 million residents in 2011. The passenger model uses a hybrid tour-and-trip-based approach, covering travel during the two peak periods in a week-day, using eight sub-modes of travel including active transportation modes of walking and bicycling.

On the freight side, the model uses a 3-step (trip generation, distribution, and assignment), vehicle-based approach using three class of trucks, viz., light, medium (single-unit), and heavy (combination-unit) trucks. The passenger and commercial vehicle models are partially integrated, using a common network. The partial integration is achieved through a bridge wherein the network conditions (travel times for the time period in consideration) from the passenger model is brought into the commercial vehicle model, for a joint auto and commercial vehicle trip assignment to achieve equilibrium. It is termed “partial integration” due to the lack of feedback from the commercial vehicle model back into the passenger side. This limitation notwithstanding, the model is deemed adequate for studying the concept of truck lane.

Selection of potential highways for truck lanes could be done through the screening process that is proposed in the literature (for example, see the research study (4) by Roorda et.al.). The screening process can make use of existing data on the traffic profiles by corridor in great details, comparing against a set of thresholds or guidelines suggested in the literature, to select corridors for detailed study.

However, availability of a regional model for the large area also meant that the screening could be done using the traffic forecasts for a future time horizon, which is more appropriate from a planning perspective. Therefore, using a similar approach, combining the number of lanes, total forecast volume, truck percentage, and potential truck lane usage, a set of potential highway corridors were identified.

Given the nature of study being conceptual and strategic in nature, modelling analysis was conducted for all the corridors combined in a single model run, instead of running each corridor separately[3]. Demand modelling and analysis were done for both the current conditions (base year) and forecasting horizon year (2031) for the “do-nothing” and “truck-lane” scenarios. The truck-lane scenario represented converting one lane in each direction on select highways to a “truck-only” lane. The truck lanes were defined as “non-mandatory” (meaning trucks may choose to stay on the general-purpose lanes [GPL]), restricted to medium and heavy trucks (vehicles above 4,500kg).

Performance measures used to compare the two scenarios included system-wide vehicle-km, vehicle-hours, and lane-usage on the designated truck-lane and the GPL’s. The truck-lane usage was also examined by segment in each corridor against the capacity of a single lane, to determine the list of corridors with potentially high demand for truck usage in the long run. In addition to system-wide performance metrics, the network-wide impacts of re-routing of both class of vehicles, i.e., trucks moving to highway corridors to take advantage of reserved lanes for their use, as well as cars that shifted from highway corridors due to reduction of available capacity for their use, was examined visually to understand the impacts.

From these analyses, it was found that overall, truck travel times improved significantly whereas the total travel time for autos in the GPL worsened only marginally. The increase in auto travel time was only marginal, due to the flexibility of passenger cars to use alternate arterial routes parallel to highways. The level of truck lane utilisation was used as a major indicator to rank potential highway corridors where truck lanes may be beneficial. Figure 2 shows a plot indicating the lane utilisation in the truck lanes.

Figure 2 - Truck Lane Usage - 2031 A.M. Peak Hour

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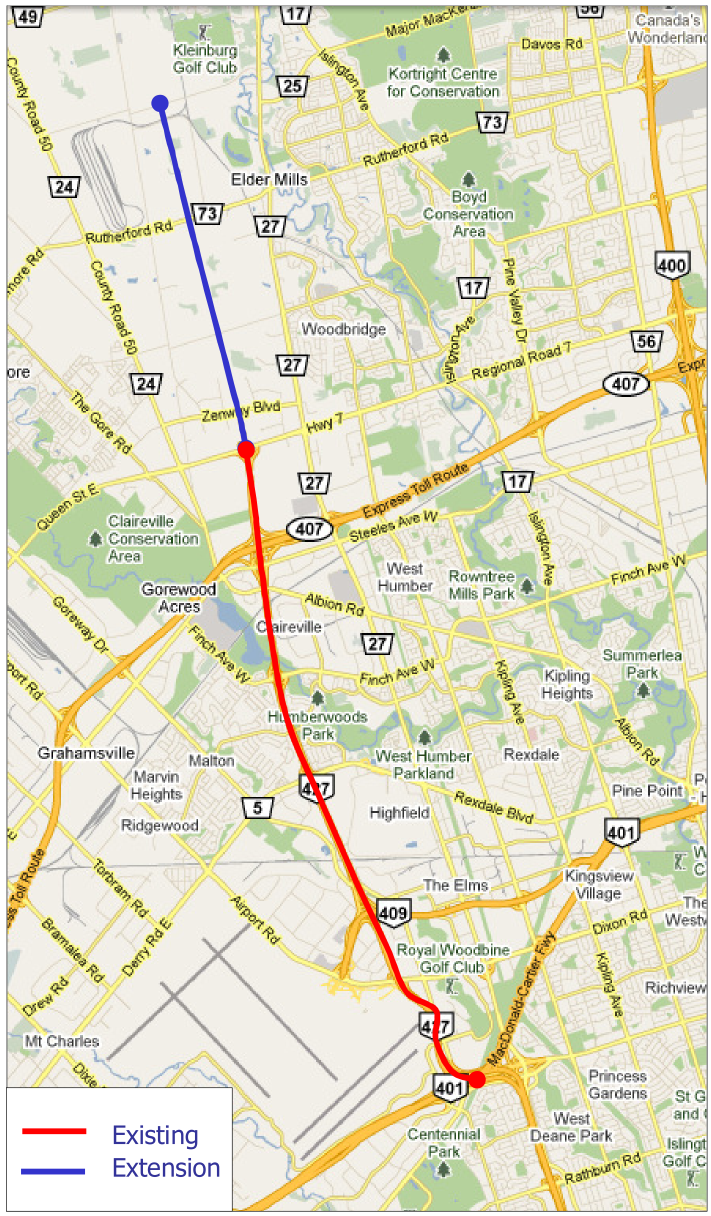
[3] This process is similar to project prioritization technique in which all projects are considered at once, and ranking them and removing projects based on certain objective criteria.

Highway 427 Corridor/Sub-area Mesoscopic Model:

Thus, the macro model results showed that at the system level, a network of truck lanes in the GGH will provide significant travel time savings to trucks. However, many operational aspects of truck lanes could not be studied or quantified from a macro model. These include weaving and merging of traffic, increase in lane changes as trucks move from inside to outside, propensity to increase safety from segregation of trucks and cars, or potentially increasing the risks of collision due to increased lane changes, etc.

In order to explore these factors with a mesoscopic model, one of the potential highway corridors identified in the previous phase, viz., Highway 427 was selected as a test bed to examine these factors. One of the features of a mesoscopic model is the dynamic traffic assignment (DTA) which offers a sense of realism in traffic simulation by accounting for saturation in links or intersections, queuing, and queue spill-backs, as well opportunity to conduct safety analysis using vehicle trajectories from the model simulations.

Figure 3 - Highway 427



The corridor selected (Highway 427) is shown in Figure 3. It includes approximately 13km of the existing highway from the interchange with Highway 401 at the bottom to Highway 7 at the northern limit, as well as the future proposed extension up to Major Mackenzie Road in York Region.

This corridor serves several key truck traffic generators in the Pearson Airport vicinity, as well major intermodal terminals in Vaughan and Brampton, in the northern limits of the corridor.

The development of the sub-area model involved cutting out a small cordon from the macro GGH Model for the area around the highway corridor, and detailing the network to code signalised intersections and other lane configurations on the highway mainline sections as well weaving sections and intersections at off/on ramps from/to the highway. In all, about 90 intersection details, including signal timings, were coded. Due to the large level of detail, the model testing was limited to the existing conditions, i.e., the base year.

As with the macro model, two scenarios of “do nothing” and a “truck lane” option were tested. Demand matrices for five vehicle classes, viz., single-occupant vehicles, high-occupancy vehicles, and three classes of trucks (light, medium, and heavy) were imported from the macro model for the DTA.

Figure 4 shows a comparison of the sub-area corridor model in the macro (Emme) and meso (Dynameq) layers. Figure 5 shows an example of the types of results that could be obtained from the mesoscopic model, which includes delay at signalised intersections, speed on the links, and queue lengths. The meso model provided closer examination of traffic performance by a small window of time period, say 5-minute intervals within the simulation period. This provides additional insights into traffic operation under both scenarios to be able to assess the impacts.

Figure 4 - Sub-area Corridor Model

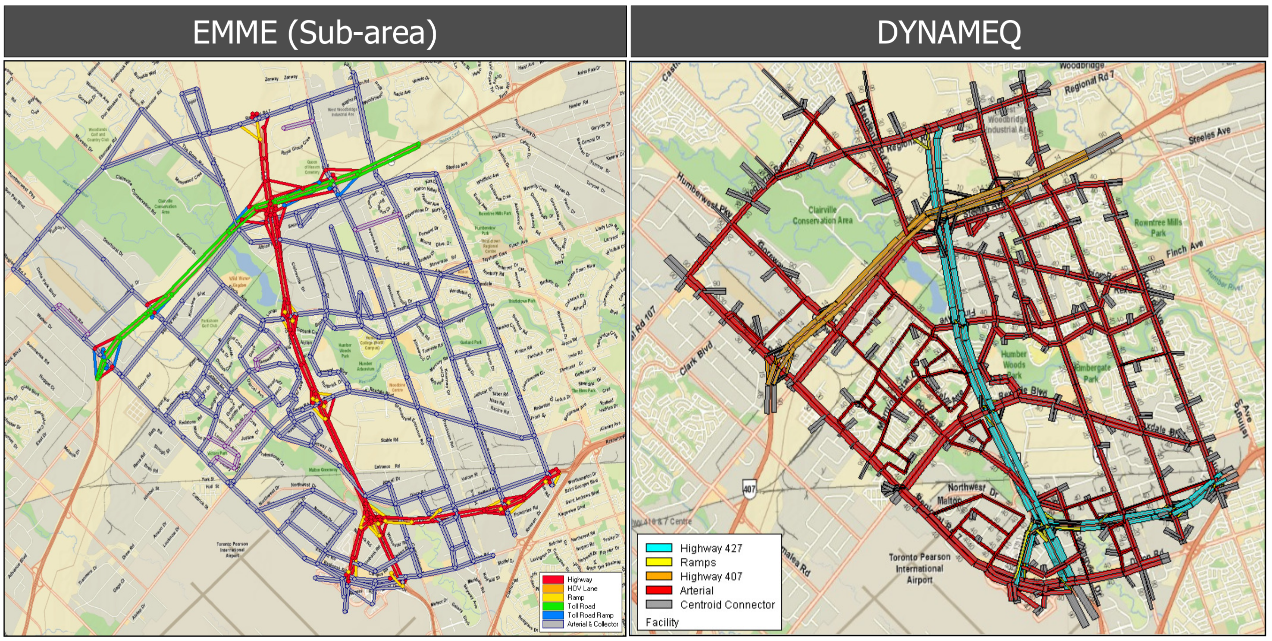
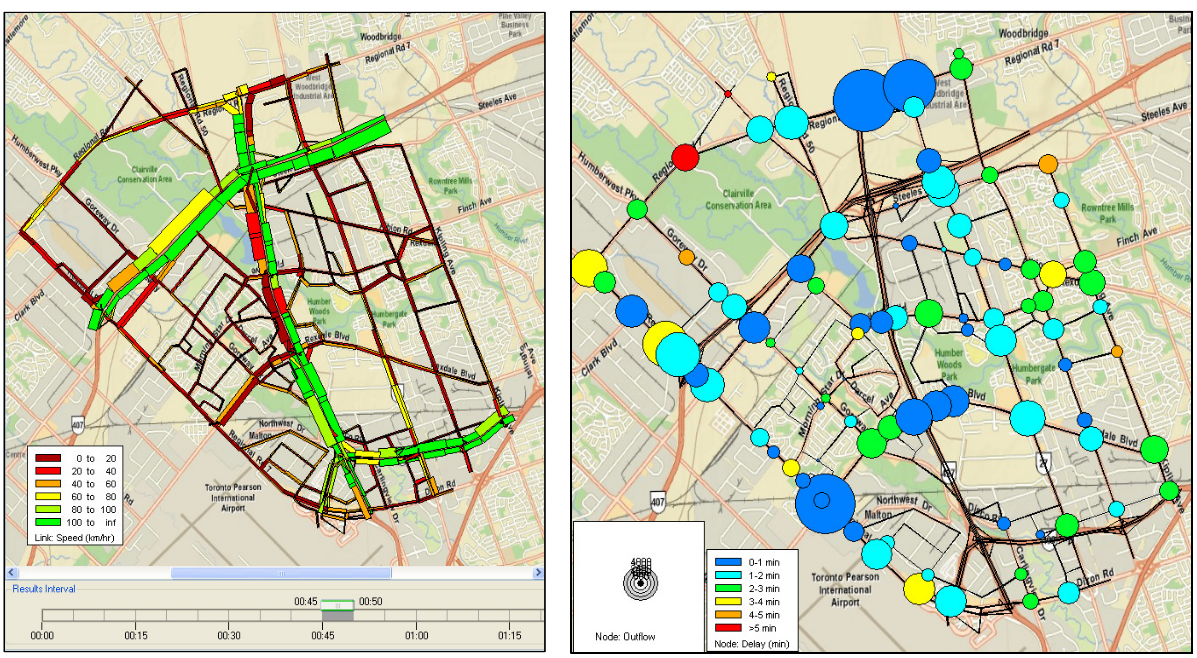


Figure 5 – Results from the Dynamic Traffic Assignment Model



Conclusion

The paper demonstrated the use of two different modelling tools to evaluate the concept of truck-only lanes in the Greater Golden Horseshoe. The strategic macro model was found to be effective and adequate to quantify the benefits and impacts of truck lanes at a system level.

The use of mesoscopic model (Dynameq) for the Highway 427 corridor provided additional insights that could not have been obtained from an Emme model. Specifically, the presence of two major highways intersecting the corridor (Highway 401 and Highway 409), within a close proximity resulted in too much of weaving by trucks thereby diluting some of the advantages of a dedicated truck lane. This exercise clearly indicated that a mesoscopic (DTA) model would be more appropriate for urban expressway corridors for studying truck lanes.

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