MODELLING TRUCK MOVEMENT ACROSS THE CANADA-US BORDER: A VISSIM DYNAMIC TRAFFIC ASSIGNMENT APPLICATION[1]

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Introduction

Transportation by trucks plays a significant role in the trade between Canada and its international partners. It is reported that approximately 57% of the trade between Canada and the U.S. is done by road (Transport Canada, 2012).In 2017, approximately 11 million two-way truck movements were recorded at the land-border crossings between Canada and U.S., representing $387 billion in imports and exports(Transport Canada, 2018). At the provincial level, Ontario houses approximately 42% of all Canadian trucking companies. In fact, Ontario is known to have the busiest road network with Highway 401 being one of the busiest corridors in North America. The corridor not only services Toronto, the largest metropolitan area in Canada, but also facilitates the movement of goods between Canada and the U.S.(Transport Canada, 2018).Along with Highway 402, the two corridors are highlycritical as they connect Montreal and Toronto to major U.S. destinations through the Ambassador Bridge in Windsor and the Blue Water Bridge in Sarnia. These border crossing bridgeshandle 28% and 13% of the daily truck traffic, respectively (Maoh, Khan, & Anderson, 2016).

The Ambassador Bridge has been in operation since November 1929 and is the only truck cross-border facility in Windsor. The importance of this border corridor has prompted the Ontario government to invest in a $1.4 billion parkway that will connectHighway 401 to the future Gordie Howe International border crossing.The latter is currently under construction in Windsor and is expected to become operational in the year 2024.The addition of this crossing is expected to optimize the flow of truck traffic and relieve congestion from the local corridor currently utilized to provide access to the Ambassador Bridge. It will also create redundancy of the existing transportation infrastructure, which enables the system to become more resilient. The total cost for the new crossing, which will provide a direct connection to Highway 401, is expected to be $5.4 billion (Windsor-Detroit Bridge Authority, 2018). The presence of the new crossing after 2024 will more likely affect the flow of trucks between western Ontario and the U.S. through Sarnia and Windsor. As such, the pressing question here is:*how will the volumes of trucks crossing to the U.S. via Sarnia and Windsor be affected once the Gordie Howe International Bridge (GHIB) becomes operational*?

An effective way for examining the changes in traffic flows is through microscopic traffic simulation models. These models have been generally used in urban settings to examine how traffic will flow on the transportation network. However, these microscopic models have rarely, if at all, been used to study regional truck movements across the Canada-U.S. border. Therefore, the objective of this research is to establish a microsimulation network model in VISSIM to simulate the flow of individual trucks between Toronto and Chicago via Sarnia and Windsor before and after the GHIB becomes operational. The work will rely on running a Dynamic Traffic Assignment (DTA) algorithm in VISSIM to accurately depict the movement of individual trucks in the traffic stream and across the Canadian border.

Background

The trade between Canada and its international partners in 2017 was worth $1,107 billion dollar where $703 billion was just between Canada and the United States, the highest value traded yet (Transport Canada, 2018).Ontario is the most trade-intensive province in Canada. The provincial GDP proportions of

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exports and imports can be compared to countries such as Germany, China and Italy and represent 50% of Ontario's GDP (Anderson, 2014). One of the biggest markets for Ontario's exports is the U.S. In 2016, 80% of goods were exported through Ontario and Québec, Canada's Continental Trade and Gateway Corridor, to the U.S. (Transport Canada, 2017). It is important that the flow of these goods between the two countries remains uninterrupted for sustainable economic growth. The movement of these goods is heavily dependent on efficient border crossing facilities, especially for goods required for just-in-time deliveries and supply-chain logistics.

As the movement of goods increases, improved border processes become necessary. Increased border inspections and delays cause queues that result in major losses to industries on both sides of the border. To find a solution to this pressing issue, researchers in the field have studied various aspects of the border to determine ways of improving processes at the border crossings. The governments of both countries have implemented a Customs Trade Partnership Against Terrorism (C-TPAT) program that companies can register with voluntarily and must comply with certain security measures to build trust between companies and governments (Goodchild, Albrecht, & Li, 2009). The trucks that belong to these companies can use FAST (Free and Secure Trade program) lanes at the border crossings with minimal delays. The objective of this program is to aid in reducing the overall delay at the borders. The effects of such programs and other proposed changes at border crossing facilities can be simulated in advance to be aware of any unexpected traffic conditions and plan a mitigation response.

Microscopic traffic simulations, more commonly known as microsimulations, model the actions of individual vehicles such as acceleration, deceleration and lane changes in response to its surrounding traffic environment (Barceló, 2010). Microsimulation models have been used in various traffic management and transportation engineering scenarios. Hidas (2002) used a multi-agent based simulation to model lane change behaviour in congested traffic conditions. Traffic emission modelling combined with speed management in an urban area was modeled in a microsimulation environment by Panis, Broekx, & Liu (2006).

The majority of the work in literature focuses on microsimulation models of intersections, freeway sections, multimodal scenarios and so on to study issues related to traffic safety, traffic operation, and autonomous vehicle movements.By comparison, studies on cross-border traffic movement is a relatively unexplored area in the context of traffic microsimulations. Khan (2010) is an exception as the study was first to calibrate a microsimulation model in VISSIM to generate detailed traffic flow data at the Ambassador Bridge crossing.The generated data from the microsimulations was then employed to develop machine learning models to determine the effectiveness of intelligent transportation systems (ITS) strategies in predicting delay and queues in real time.

The simulation of isolated corridors can be completed by manually assigning traffic demand over the network and observe changes due to proposed changes in the network. On an isolated corridor such as the one used in the study, it is common for the user to manually assign traffic demand over the network however, as the network increases in complexity and extent, the use of a route choice model becomes a necessity. When the network is extensive and complex, the manual assignment of traffic demand becomes unreasonable and the network becomes prone to error. VISSIM has an imbedded route choice model, the dynamic traffic assignment, that runs an iterative procedure to find the shortest path between an origin-destination pair.

The dynamic traffic assignment algorithm is derived from the Wardrop's first principle: "*No driver can unilaterally reduce his/her travel costs by shifting to another route.*" (Wardrop, 1952). Wardrop's first principle gives rise to the User Equilibrium used in traditional static traffic assignment. Here, each driver aims to reduce their travel cost and time on the road network. The driver is assumed to have knowledge of his/her routes by experience. While the static traffic assignment provides an hourly view of route performance, it is limited in its ability to present actual variations in performance at smaller time intervals. More specifically, the algorithm cannot depict detailed field conditions, such as speed-density relationships, that result in increased travel time and congestion on the network (Chiu, et al., 2011). Dynamic traffic assignment remedy this limitation as it has the capability of generating time-varying link or path flows on a simulation network (Varia & Dhingra, 2004).(Li, et al., 2013)used an approximate dynamic traffic assignment to simulate evacuation scenarios. Their team used traffic data from the Hurrricane Katrina evacuation in southeastern Louisina and used an analytical DTA assignment to model the network with evacuation routes and contraflow. Varia & Dhingra, (2004) used a simulation based DTA to model a multiple-origin multiple-destination network with signalized and unsignalized intersections. They tested two performace measures to validate field conditions: methods of successive averages (MSA) and genetic algorithm (GA). They concluded that MSA provided more realistic results than the GA optimization.

Methods of Analysis

This research analyzes the movement of trucks between Toronto, ON and Chicago, IL. As Figure 1 shows, two alternativesroutes are available for this corridor: Ambassador Bridge (Windsor, ON) and Blue Water Bridge (Sarnia, ON). Since freight trucks originate from many different locations in the Greater Toronto Area (GTA) and use various routes to reach Highway 401, the origin for the study was chosen to be Woodstock, Ontario, approximately 140 km west of Toronto, ON. The figure below highlights the study area.

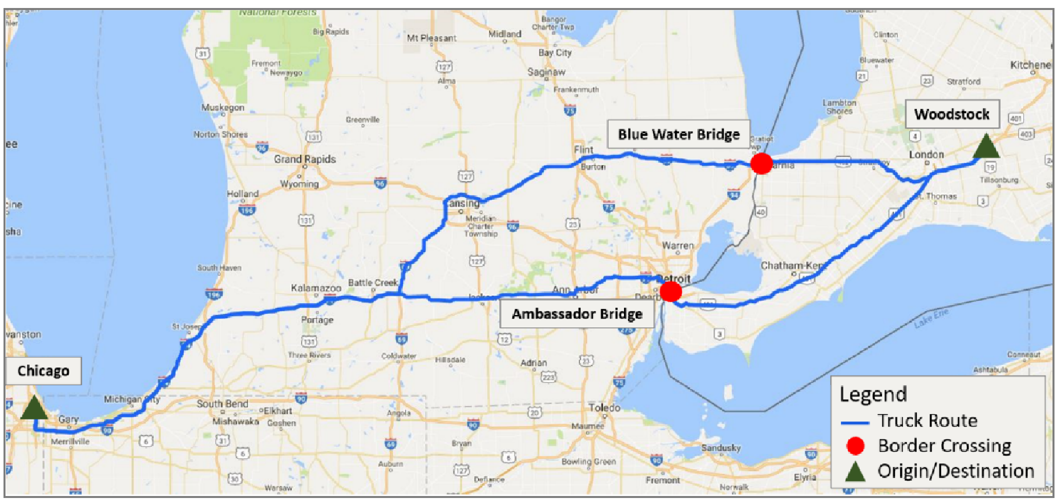

Figure 1 Study Area

<u>VISSIM</u>

VISSIM is a microscopic simulation software that models multimodal traffic operations (PTV Group, 2017). The software has the capability of replicating realistic conditions such as road capacity, speed changes, design of simple and complex intersections, and traffic volume. It also generates several validation measures such as travel time, traffic queues, delays in the network, and levels of service. VISSIM allows the user to manually assign routes or employ a route choice model on the network. Static routes define traffic proportions and volumes on each path. If the network is complex or extensive, a dynamic traffic assignment (DTA) can be employed to calculate the best path based on travel time, distance, and cost with an origin and a destination location and traffic volumes. The objective of this study necessitated the use of a DTA to determine the capability of VISSIM to validate existing traffic conditions.

<u>Dynamic Traffic Assignment (DTA)</u>

This module within VISSIM allows the user to implement a route choice model that calculates the 'best' path based on iterative simulations. DTA considers that drivers may not have all the information when making a route decision. The iterative process collects travel time and cost information on a path and uses this information in the next iteration to find a better route. The choice of these paths in VISSIM are based on the discrete choice model. The traffic assignment runs for multiple iterations until the cost does not vary significantly and the model converges. The tool automatically varies the traffic conditions between simulation runs to ensure effective statistical results and realistic model convergence.

Model Calibration

The microsimulation model was calibrated using data generated byRemote Traffic Microwave Sensor (RTMS) units owned by the Cross-Border Institute. These sensors provide traffic count of the trucks heading to the Ambassador Bridge. The mapping of GPS data between Toronto and Chicago indicated that 60% of the truck traffic favoured Ambassador Bridge when presented with both alternatives (Gingerich, Maoh, & Anderson,2016). This information was used to add the remaining 40% to determine the total microsimulation input volume. The traffic volume was simulated for a full weekday divided into 5 time periods: early morning (12 AM – 6 AM), morning peak (6 AM – 9 AM), Mid-day (9 AM – 3PM), afternoon peak (3 PM – 7 PM), night-time (7PM – 12 AM) (WilburSmith Associates, 2010). A report published by Washington State's Department of Transportation on VISSIM Simulation Protocol suggested that to establish baseline validation measures, the simulation should be executed 11 times(Washington State Department of Transportation, 2011). The acquired data should then be used, with the statistical information, to determine the number of simulation runs required for a stable network. For this study, it was assumed that 11 runs would be sufficient to stabilize the network.

Scenarios

1. Base Case

The road network was tested with no delays at the borders to ensure connectivity and establish a reference time and traffic proportion to compare the border crossing scenario with.

2. Border Crossings

Once the reference network was established, border crossing time distributions were implemented to simulate border crossings. The time distributions in *Figure 2*and*Figure 3* were implemented in the model.

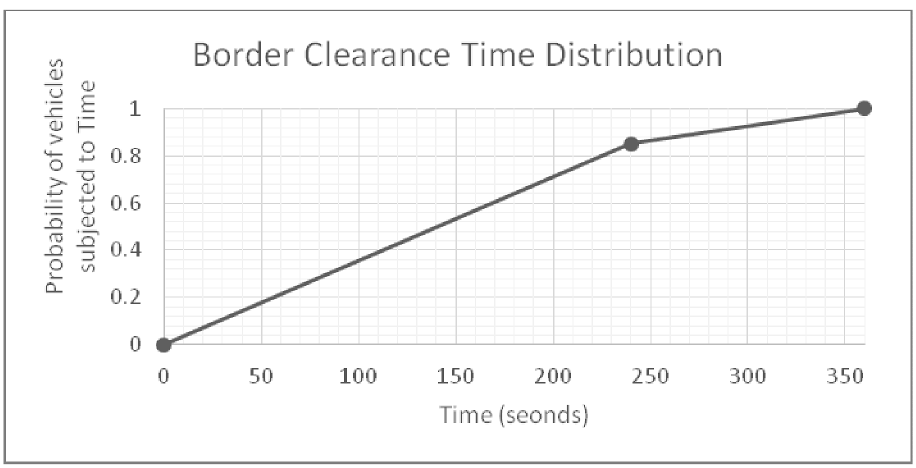

Figure 2 Border Clearance Time Distribution for Regular Freight Trucks

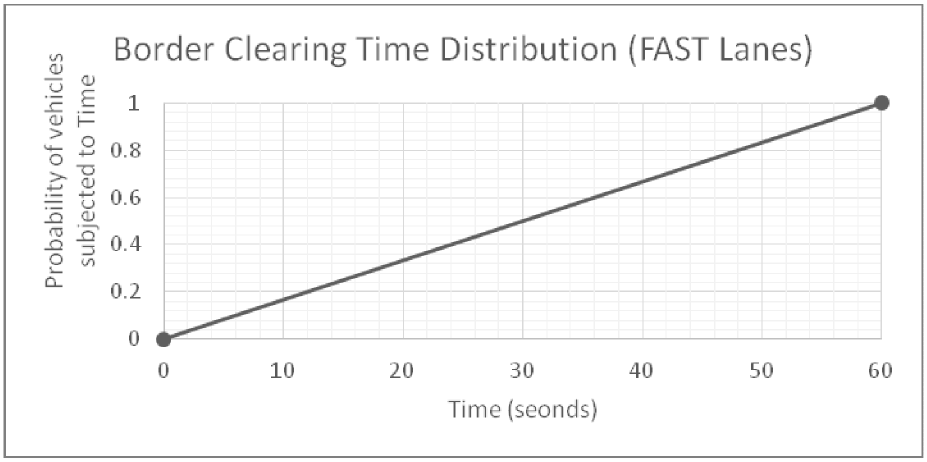

Figure 3 Border Clearance Time Distribution for FAST Program Trucks

Border crossing times were aggregated in previous research and it was found that, on average, it took trucks 5 to 15 mins to cross the border including clearance at the inspection booths (Gingerich, Maoh, & Anderson, 2016). Since a time distribution was required to simulate the clearance process, it was assumed that, on average, it would require freight trucks 2.5 to 4 minutes for clearance.

Vehicle Classes

Freight traffic proportions include both regular and FAST program trucks. A similar condition was also established in the microsimulation model for realistic delay conditions at the border. It was found that 44% of all shipments crossing the Ambassador Bridge are part of the FAST program. This proportion was noted to be 31% at the Blue Water Bridge (Goodchild, Albretch, & Lueng, 2009). For this study, 40% of the total truck volume was assumed to utilize the FAST program. These trucks would experience minimal delay, a minute or less, at the simulated border crossings in VISSIM.

Results and Discussion

This section of the research paper presents the results for the DTA algorithm. To evaluate the performance of the VISSIM transportation network, travel time reported from Google Maps and traffic proportions extracted from GPS and RTMS data were used as validation measures.

Travel Time

The time a vehicle spent traversing each path as well as the average time it spent on the VISSIM road network was recorded. The travel time was validated with the time reported by Google Maps to ensure accuracy of the results. These are presented in *Table 1*for each route.

Table 1 Travel Times reported by Google Maps for the Border Crossings

Google Maps Reported Travel Time	
Northern Route (Blue Water Bridge)	**Southern Route (Ambassador Bridge)**
6 hr. 20 mins	6 hr. 32 mins

The travel times extracted from the VISSIM simulations for the base case and the border crossing scenario are presented in *Table 2*and*Table 3*, respectively. It is assumed that Google Maps considers any delays, including cross-border inspection and clearance times, into the reported travel times. The travel time for the base case scenario was comparable to the time reported by Google Maps. The border crossing scenario resulted in approximately an hour more than the time reported by Google Maps which is not an unreasonable result considering the extent of the network. It was noted that with each simulation run, the travel time for the two alternatives decreased by a few minutes. It is expected that a sufficient number of runs will allow the results on the network to stabilize since the travel time will decrease further, making the border crossing scenario comparable to the values reported from Google Maps (i.e. real time traffic conditions).

Table 2 Travel Times extracted from the VISSIM simulation for the Base Case (No Delays)

Simulated Travel Time – Base Case	
Northern Route (Blue Water Bridge)	**Southern Route (Ambassador Bridge)**
6 hr. 29 mins	6 hr. 22 mins

Table 3 Travel Times extracted from the VISSIM simulation for the Border Crossing Scenario

Simulated Travel Time – Border Crossings Scenario	
Northern Route (Blue Water Bridge)	**Southern Route (Ambassador Bridge)**
7 hr. 41 mins	7 hr. 17 mins

Traffic Proportions

Traffic proportions on each path, as extracted from the GPS data, were used as another validation measure of the network performance. The GPS data showed that when border crossings are operating under steady-state conditions, 60% of the truck traffic favours Ambassador Bridge (Gingerich, Maoh, & Anderson, 2015). The traffic proportions extracted from the GPS data for Ambassador Bridge and Blue Water Bridge are presented in *Table 4*.

Table 4 Traffic Proportions extracted from GPS Data

Traffic Proportions – GPS Data	
Northern Route (Blue Water Bridge)	**Southern Route (Ambassador Bridge)**
39.7%	60.3%

The values in Table 4were used as a reference to validate the base case scenario and the border crossing scenario results. The traffic proportions for each route were recorded and extracted from the VISSIM simulation. The base case results, as presented in*Table 5*, report that the truck traffic was found to be almost evenly split between the two crossings. The traffic split was 53.5% for the Ambassador Bridge and 46.5% for the Blue Water Bridge. This is an intuitive result as there is no delay simulated at either crossing and the travel time for each alternative is comparable.

Table 5 Traffic Proportions extracted from the Base Case VISSIM Simulation

Traffic Proportions – Base Case	
Northern Route (Blue Water Bridge)	**Southern Route (Ambassador Bridge)**
46.5%	53.5%

The results for the border crossing scenario are presented in*Table 6*. The share of the truck traffic favouring Ambassador Bridge is 63.8% and the Blue Water Bridge is 36.2%, respectively. The results for this scenario are very close to the GPS reference data. It is expected that if more iterations are simulated and the network is given sufficient time to stabilize, the proportions will reflect the reference data even more closely, further validating the performance of the microsimulation model.

Table 6 Traffic Proportions extracted from the Border Crossings VISSIM Simulation

Traffic Proportions – Border Crossings Scenario	
Northern Route (Blue Water Bridge)	**Southern Route (Ambassador Bridge)**
36.2%	63.8%

The results obtained from the VISSIM simulation were extracted from a network that only contained freight trucks on a simulation network. The inclusion of passenger vehicles, both as background traffic and cross-border traffic, should make the network conditions even more comparable to the field. The stabilization of the VISSIM network with increased simulations runs as well as the implementation of the limitations will allow for the network to be used for further research. Once the network stabilizes and results are validated with reference data, it will provide a baseline transportation network that can be used to test alternative scenarios such as increased delay at one of the crossings, the addition of the future Gordie Howe International bridge to the network, lane closures and accidents, and the effect of the presence of connected vehicles in the cross-border traffic stream.

Conclusion

The objective of this study was to build a microsimulation model for dealing with the movement of trucks between Canada and the US. Since the efficient movement of freight trucks between border crossings is crucial to the trade between Canada and the U.S., it is necessary to study these flows and the factors that affect them. The uninterrupted flow of goods between the countries is necessary for cost-efficient processes. The development of a microsimulation model that mimics real life conditions is critical for assessing the conditions that will lead to better border crossing performance.Such model can be used for testing alternative scenarios about the border (e.g. closure of Primary Inspection Booths, introducing more FAST lanes, etc.).

In this paper, the VISSIM microscopic model developed and tested made use of RTMS traffic count from Windsor along with GPS data to determine truck volumes at the two major western crossings between Ontario, Canada and the Detroit, U.S. An average weekday was simulated in five time periods to provide the network with realistic proportions for peak and off-peak volumes during the day. The simulation was repeated 11 times with varying traffic conditions for statistical variation between runs. Average travel time, path travel time and traffic proportions from the simulation runs were compared to the GPS reference data. The travel time showed that the simulated border crossings took an average of 7.5 hours to traverse the corridors whereas Google Maps reported an average of 6.5 hours. The simulated traffic proportions indicated that approximately 64% of truck traffic favoured Ambassador Bridge whereas reference data showed a proportion of 60%. It is expected that if the simulation is iterated for more than 11 runs, the network will stabilize further, and the results will be even more comparable to the reference data.

It can be noted that even with the limited number of simulationruns, the results are still intuitive and can be improved further. Once the network reaches convergence and is validated with reference data, future research will focus on examining the impacts of having the Gordie Howe International bridge as part of the network. The simulation model will also be used to test alternative scenarios depicting varying shares of advanced technology such as connected vehicles in the traffic stream to evaluate what share of these connected vehicle will lead to better cross-border performance.

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