Assessing the Potential Impacts of Unexpected Closure of a Major Crossing between Canada and the U.S.

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Introduction

A reliable cross-border transportation system is essential to the economic productivity of a nation. The effects of different kinds of disruptions along transportation networks have been of interest to researchers, who attempt to quantify these impacts for the purpose of identifying critical portions of the network. The impacts of network disruptions have been studied in terms of multimodal freight transportation networks. For example, Burgholzer et al. (2012) implemented a traffic microsimulation model to identify critical links by examining the delay to network users due to the successive removal of each link in the network. The duration, time of occurrence, and level of capacity reduction were accounted for in the simulation. The model was found to be more effective for large networks with more available alternative routes and the authors recommended incorporating the transportation cost as a decision parameter. Travel time has also been used as an indicator of criticality (Ukkusuri and Yushimito, 2009). The effects of congestion were found to be better represented through this method than the traditional V/C ratio. Disruptions in multimodal flows have also been examined within a multi-industry economic approach, measuring the undelivered supply and unmet demand arising from successive removals of individual links (Darayi et al., 2017). The results outlined the importance of integrating the multimodal transportation network with the multi-industry economic model to gain a more complete understanding of the effects of network disruptions.

The Ambassador Bridge and the Blue Water Bridge in southern Ontario respectively carry approximately 29% and 14% of cross-border freight flows moving between Canada and the United States (Gingerich et al, 2016). The closure of one of these border crossings is expected to have significant impacts on the flow of cross-border freight that will need to reroute to the alternative crossing, especially when considering time-sensitive shipments. The criticality of highway segments in the province of Ontario has recently been studied by Ashrafi et al (2017) with an emphasis on freight transportation, where criticality was quantified in terms of the cost associated with a network disruption. The cost was determined as a function of the value of shipments, the time delay due to a disruption, and the associated value of time, and the criticality was determined based on the difference between the base scenario and scenarios where network links were removed. The present paper will quantify the criticality of the two border crossings of interest with respect to the change in congested travel times, examining scenarios where each bridge is shut down and freight flows must divert to the alternative crossing.

Data

The study area for this research is the province of Ontario and its corresponding trucking road network, including connections to external regions in adjoining provinces and in the United States. The zones of analysis were taken as the province's 49 Census Divisions (CDs), as well as a series of 25 external zones, which represent destinations in other provinces and the United States that are accessible through border crossings and major highways. Since this research focuses only on the Canadian side of the freight patterns within Ontario, the external zones were specified as abstract regions, including all destinations in a respective province or in the United States that are accessible through a certain link (e.g. Quebec via

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Highway 401, or Michigan via the Ambassador Bridge). The road network used in the analysis consists of 22,570 links and 14,444 nodes, and contains information about the design capacity, design speed, and length of each link. Since the network was built for analysis in EMME, each link is one-directional. A two-way road is represented by two one-way links, each with its specified design speed and capacity.

The dataset used by Ashrafi et al. (2017) was employed for this study, which obtained truck flow data for each of the 74 analysis zones (i.e., 49 CD and 25 external zones) from the Ministry of Transportation of Ontario's (MTO) Commercial Vehicle Survey (CVS) for the year 2012. Hourly factors were applied to distribute these flows to hourly intervals throughout the day. For the purpose of this paper, the hourly interval with the heaviest flows was selected for analysis, namely the 1:00 pm hour. The hourly passenger flows in the study region were also obtained for the same interval, to be used as background traffic and improve the representation of actual network conditions in the model.

Methods of Analysis
A traffic assignment routine was run using the EMME 4.3 software for three scenarios: a base scenario using status quo conditions, a scenario where the Blue Water Bridge was closed, and a scenario where the Ambassador Bridge was closed, using the truck and passenger origin-destination flow matrices described in the previous section as inputs. Through a User Equilibrium traffic assignment routine in EMME, which uses the Second Order Linear Approximation (SOLA) method to solve the User Equilibrium Traffic Assignment Program , and the input flows for the two vehicle classes (truck and passenger), outputs of the traffic flows on each link and the travel time between regions were obtained for each scenario. These values were then used in the quantification of criticality for the two bridge crossings.

The added cost due to the closure of each of the two border crossings is related to the increase in travel time on network links, as truck traffic is diverted from the closed crossing. The expectation is that each closure scenario would exhibit a notable increase in travel times on links leading to the crossing that remains open. Conversely, the travel time is expected to decrease on links leading to the closed bridge. The congested travel time on each link was calculated for the base case and the two closure scenarios using the conventional link performance function, as outlined below:

$$t_c^i = \left[t_f^i\left(1 + 0.15\left(\frac{v_i}{c_i}\right)^4\right)\right] * v_i$$

where:
t_c^i = congested travel time on link *i*
t_f^i = free-flow travel time on link *i*
v_i = traffic volume modeled on link *i* (sum of truck and passenger flows)
c_i = capacity of link *i*

Results
The flows on road links in the southern portion of Ontario, southwest of the Toronto region, are where the most significant impacts are noted, given the location of the two crossings of interest. Figure 1 shows the truck volumes on links for the 1 pm hourly interval that were simulated for the base case, where traffic flows are allowed to take place without any disturbances. Figures 2 and 3 show the truck volumes simulated on the network links for the two scenarios where the Blue Water Bridge is closed and where the Ambassador Bridge is closed, respectively. For the purpose of this simulation exercise, the network was considered to be empty initially and flows were assigned to the links following a shortest path algorithm. As such, a number of links in the network show no flows, since only one hourly interval was simulated. The traffic patterns observed through this analysis do still reflect the expected network conditions.

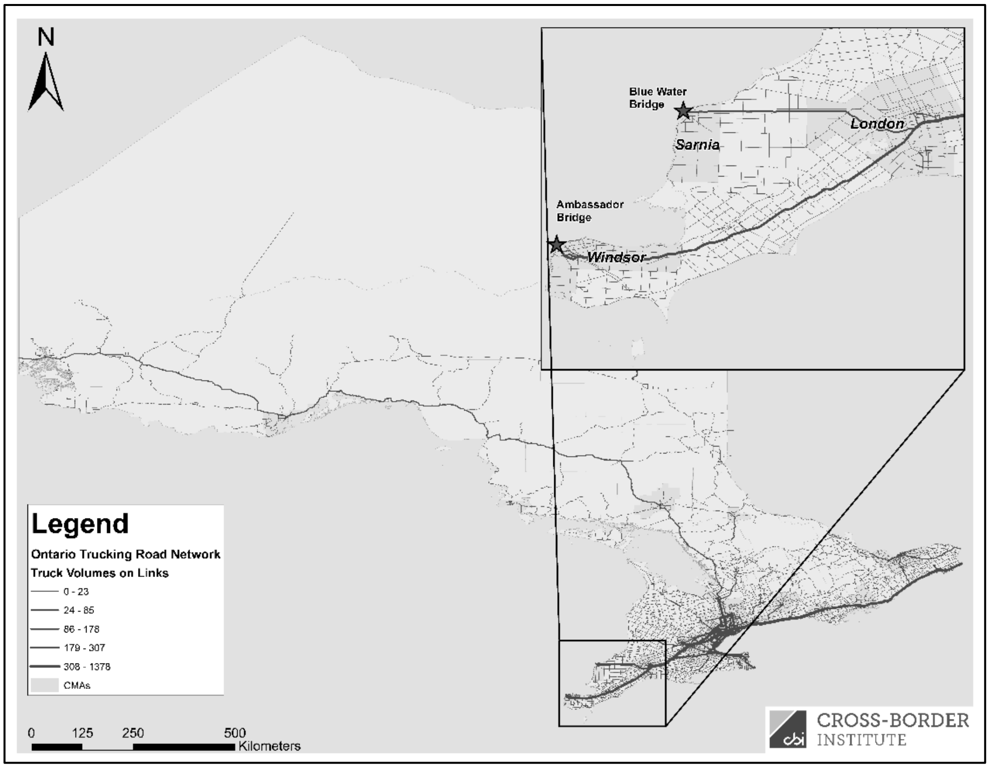

Figure 1: Truck Volumes on Links for Base Case

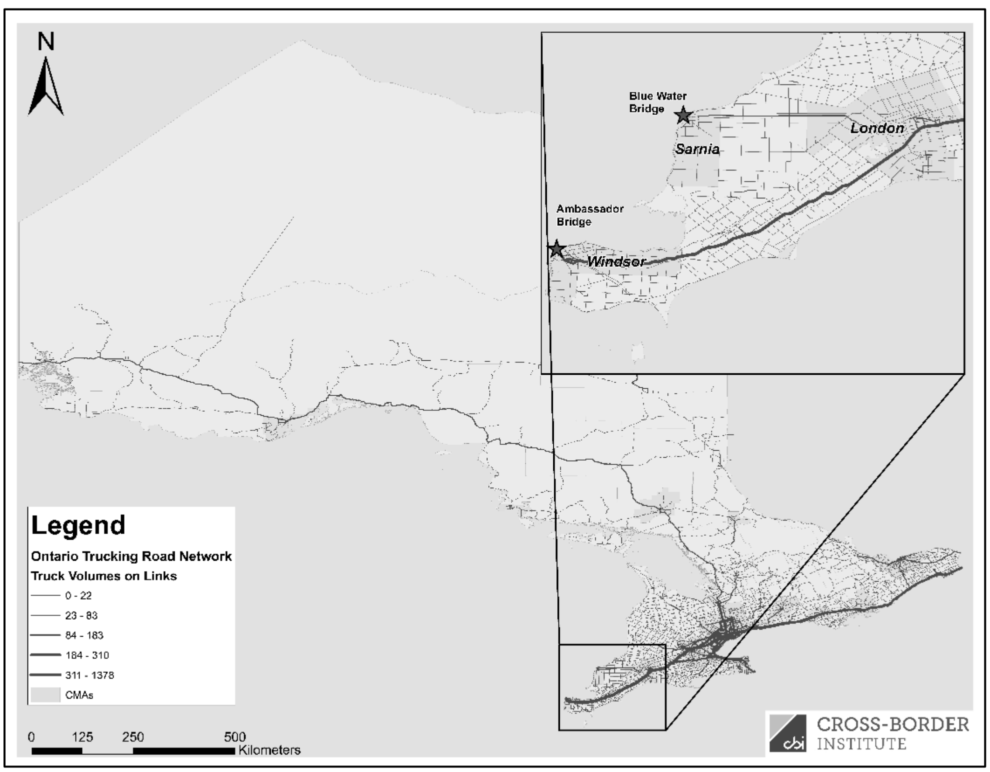

Figure 2: Truck Volumes on Links for Simulated Closure of Blue Water Bridge

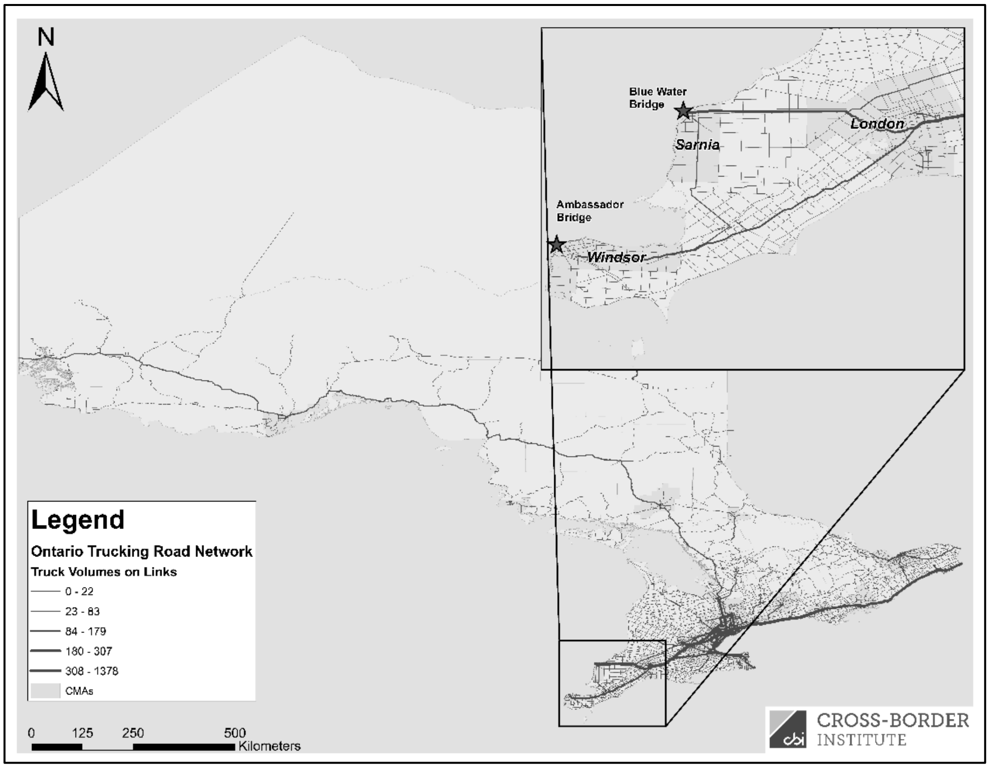

Figure 3: Truck Volumes on Links for Simulated Closure of Ambassador Bridge

A clear shift can be seen from the base scenario, when the Blue Water Bridge is closed, showing the diversion of trucks toward the Ambassador Bridge. Similarly, when the Ambassador Bridge is simulated as closed, trucks are noted to reroute to the alternative crossing. Highway 401 near the Windsor region continues to exhibit heavier flows in the Ambassador Bridge closure scenario. This can be attributed to the heavy concentration of manufacturing industry in the region, which produces goods that need to be shipped throughout the province and across the border. These effects are what would be expected in case of such closures. A comparison of the congested travel times calculated for each scenario also supports the same conclusions. When examining the network link that carries all US-bound traffic across the Ambassador Bridge, the change in travel time from the base case is of approximately 473.5 minutes (7.9 hours). This is an extremely long delay that would have a significant impact on trade. A similar analysis of the Blue Water Bridge shows an increase of only 7.3 minutes from the base case. The magnitude of this delay, which is significantly shorter than the other scenario, could be explained by the fact that the Blue Water Bridge carries lower volumes than the Ambassador Bridge and its capacity may not be utilized entirely during the base case. Additional flows of diverted traffic would experience shorter travel times until capacity is reached and delays begin to accumulate.

Conclusion

This paper examined two of the most heavily used border crossings between Canada and the United States, the Ambassador Bridge and the Blue Water Bridge in southern Ontario, outlining a measure of their criticality based on the changes in congested travel times observed on the network from the base case to each closure scenario. The analysis showed a clear shift in traffic flows onto routes leading to the alternative crossing. These heavy traffic volumes lead to increased travel times and increased congestion on the network. The resulting delays will be analyzed in detail as this work continues, in order to quantify the effect that each closure has on the alternative crossing. An extension of this work could also consider the commodity types transported, in order to compute the economic impact of the closure scenarios.

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