ASSESSING THE IMPACTS OF A MAJOR HIGHWAY INFRASTRUCTURE PROJECT: THE WINDSOR-ESSEX PARKWAY

Hanna Maoh, William Anderson and Shakil Khan
University of Windsor

Introduction

Simulation modeling is one of the more well-established methods that have been used to forecast and tease out the impacts of newly constructed major infrastructure transportation projects. These impacts are primarily assessed by simulating travel demand and traffic flows on the links of the upgraded road network. The objective is to quantify the levels of congestion, accessibility and tailpipe emissions for passenger and commercial vehicles for any given future horizon.

The Windsor-Essex Parkway is one of Ontario's largest transportation infrastructure projects. This parkway is being constructed to facilitate a new cross-border corridor between Canada the United States through Windsor, Ontario. Currently, the existing cross-border corridor via the Ambassador Bridge handles a substantial volume of trucks that cross the border on a daily basis. The new corridor is expected to not only facilitate the movement of trucks through the region but also to divert heavy traffic from urban roads to the new higher class constructed highway. Once completed, the parkway will connect Highway-401 in southwest Ontario to Interstate-75 in Detroit, Michigan, through a new international bridge on the Detroit River.

The Alignment of the Windsor-Essex Parkway is presented in Figure 1. The parkway is designed as a six-lane controlled access freeway facility comprising 11 tunnels and service roads. The designed capacity of the new crossing will be able to accommodate future travel demand, which will help improve the border crossing process. The new parkway is expected to impact the region's transportation system in terms of usage and performance.

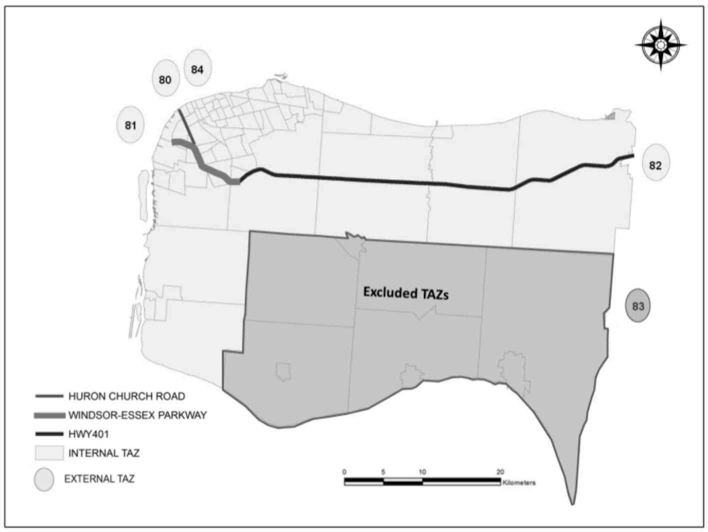

Figure 1. Windsor-Essex Parkway and Internal/External TAZs of the Windsor-Essex Region

Given the magnitude of the new parkway, this paper aims at forecasting and simulating the impacts that the parkway will have on the region and cross-border transportation between Canada and the US by quantifying changes in congestion, accessibility and emission levels for passenger and commercial travel with projected data for the year 2031. With a focus on cross-border transportation, four scenarios were defined and analyzed:

- **Scenario 0 (AMB 100, Without WEP)**: In this scenario neither the Windsor-Essex Parkway nor the new Detroit River International Crossing (DRIC) Bridge have been built. This allowed us to simulate the long-run performance of the regional highway network in the absence of any major changes.

- **Scenario 1 (AMB100)**: A case in which all cross-border traffic is assumed to still go through the Ambassador Bridge after the development of the Windsor-Essex parkway. The DRIC Bridge is not built in this scenario.
- **Scenario 2 (AMB50)**: An alternative and more balanced case in which the Ambassador Bridge and the new DRIC bridge have equal shares of the cross-border traffic.
- **Scenario 3 (AMB0)**: An alternative and unbalanced case in which all cross-border traffic is assumed to go through the new DRIC Bridge.

Scenarios 1, 2, and 3 all assume completion of the Windsor-Essex Parkway.

The remainder of this paper is organized as follows. The next section provides an insight to the simulation modeling efforts in the field of highway infrastructure. Then we discuss the data used for the simulation analysis and provide details of the methodology adopted to perform the simulations. The results pertaining to traffic congestion, accessibility and emissions are then presented and discussed. Finally, research conclusion is drawn and future recommendations are made.

Literature Review

Transportation simulation models are powerful tools widely used by transportation practitioners to model travel behavior, traffic flows and to evaluate the impacts of new public transport and highway infrastructure projects. Transportation simulation models can be categorized into three main types. The most commonly used type, also known as macroscopic model, models traffic by assigning trips on the transportation network to estimate vehicle flows on each link of the network. The second type of simulation models is more detailed and focuses on microscopic simulations. It is more computationally intensive since it is used to model the movement and interaction of individual vehicles (Nguyen et al., 2012). However, the successful application of microscopic simulations is often limited to parts of the urban network as the feasibility of constructing and calibrating a large scale network at the microscopic level is usually very low (Kitamura and Kuwahara, 2005). The third class, also known as the Mesoscopic simulation approach, employs an intermediate level of details to handle traffic flows on the network. Simulations under this modeling approach are less computationally intensive.

Simulations in transportation work have been used extensively in the past to forecast the impacts of transportation and land use policies. These policies are usually simulated through integrated urban models (IUMs) (Farber et al., 2009). The latter are computer simulation programs used to capture the inter-linkages between the land use and transportation systems. Within this system, both land use changes and traffic flows are simulated over time. However, this requires a well-established land use model capable of simulating changes in residential and commercial land uses. Unfortunately, the development of such a model is not trivial and requires data and resources. Consequently, most metropolitan planning organizations around the world make use of the four-stage model or the urban transportation planning system (UTPS). In this system, land use changes are predicated exogenously and then fed into the transportation modeling system.

Since urban form has its impact on the transportation system, researchers normally attempt to simulate a variety of development scenarios to assess how land development impacts transportation system usage and performance. In Canada, a number of studies made use of the IUM approach to simulate such development scenarios. For instance, using *IMULATE*, an integrated urban model, Behan et al. (2008) simulated *Smart Growth Strategies* for the city of Hamilton, Ontario. In a similar vein, Niemeier et al. (2011) evaluated the long-term impacts of different residential growth patterns on vehicle travel and pollutant emissions in California. The study used an integrated simulation approach coupled with long-term land development scenarios.

To investigate the effect of an aging population on transport demand and sustainability, Maoh et al. (2009) developed a simulation framework known as *IMPACT* (Integrated Model for Population Aging Consequences on Transportation) for analyzing the effects of population aging on transport demand and sustainability in Hamilton, Ontario. *IMPACT*, a geographic information system (*GIS*) based urban transport simulation model, was used to simulate various demographic policy scenarios over time. *IMPACT* is developed with a conventional four-stage transport simulation model that is coupled with a powerful demographic model. Simulations in *IMPACT* allow the analyst to project spatio-temporal changes in population at the traffic analysis zone level. Consequently, those changes are used to predict traffic flows on the transportation network.

Issues of *generated traffic* have often jeopardized proposed highway projects and sparked controversy among urban transport researchers (Kang et al., 2009). Generated (induced) traffic occurs as a result of road improvements/new construction, and according to critics, the improvements draw new traffic known as induced traffic and/or divert traffic from other routes known as diverted traffic. Collectively this traffic is termed generated traffic and it can return a facility to its original congested state in a very short time. Kang et al. (2009) explored the issues of generated traffic for two contentious highway projects in the Hamilton Census Metropolitan Area, Canada. The authors used *IMULATE* to examine the impacts of adding these two roads to the urban transportation network.

Method of Analysis

Datasets for Simulations

The simulations conducted in this paper were based on predicting growth in population and employment in the Windsor-Essex region for the period 2006–2031. Predictions were performed at the Traffic Analysis Zones (TAZ) level using the 2006 census tract delineations shown in Figure 1. Predictions were performed for every five years starting in 2006, and were used to update the 2006 origin-destination matrices for passenger vehicles, light commercial vehicles, medium commercial vehicles and heavy commercial vehicles. The O-D matrices were predicted for 4:00 pm on a typical weekday and then assigned to the Windsor road network using a *Stochastic User Equilibrium* traffic assignment routine that was developed within the *COMMUTE* simulation model.

COMMUTE is a traffic assignment simulation program that can be used to assess the **C**onsequence of **M**otorized **M**obility on **U**rban **T**ransportation and the **E**nvironment. The results from *COMMUTE* can be analyzed to generate various measures of transportation system usage and performance for the Windsor-Essex region. In this paper, data for the four scenarios defined in section 1 were created and used to run simulations depicting various cross-border transportation situations as described earlier. The results from these simulations were then compared and analyzed.

As shown in Figure 1, the zoning system for our study area consisted of 79 internal zones and 5 external zones. External zone (#80) represents the Ambassador Bridge cross-border point. Another external zone (#84) represents the Tunnel between downtown Windsor and Detroit and was incorporated as part of the zoning system. Zone (#81) represents the new Detroit River Crossing that will be developed in the future to connect Detroit to the Windsor-Essex Parkway, and was also introduced into the zoning system. To capture the trips between the region and the rest of Ontario, zone (#82) connecting to Highway 401 at the east tip of the Windsor-Essex region was introduced. Finally, external zone #83 connecting the southeastern part of the region to south Windsor was created as part of the zoning system.

It is worth noting that the analysis was confined to the internal zones forming the Windsor Census Metropolitan Area (CMA). Therefore, a number of zones in the southern part of the Windsor-Essex region were excluded from the analysis, as shown in Figure 1.

Simulation Approach

An integrated modeling framework, as in Figure 2, was used to not only simulate traffic flows but also estimate congestion, accessibility and associated emissions. The devised framework is a composite of three integrated modules: *M6, COMMUTE* and *ArcGIS 10. M6* is a Graphical User Interface (GUI) developed to provide an interactive environment for generating emission factors from MOBILE6.2C. The latter is the Canadian version of the US MOBILE6. The Canadian version has been recalibrated by Environment Canada to accommodate the characteristics of the Canadian vehicle fleet. The input variables that were relevant to the characteristics and activities of the motorized vehicles include: vehicle activity, vehicle fleet characteristics (e.g. age distribution per vehicle type; 23 age categories in total) and fuel characteristics (USEPA, 2012). To reflect local conditions, meteorological data for 2006 were obtained from the archives of the weather station at the Windsor Airport (42.2756° N, 82.9556° W). As shown in Figure 2, for a specified pollutant p, travel speed s and road type h, MOBILE6.2C initially reads in the meteorological information along with data on vehicle characteristics and activities to calculate emission factors. These factors are generated in units of grams of emissions per kilometre or per hour for different driving speeds and road class.

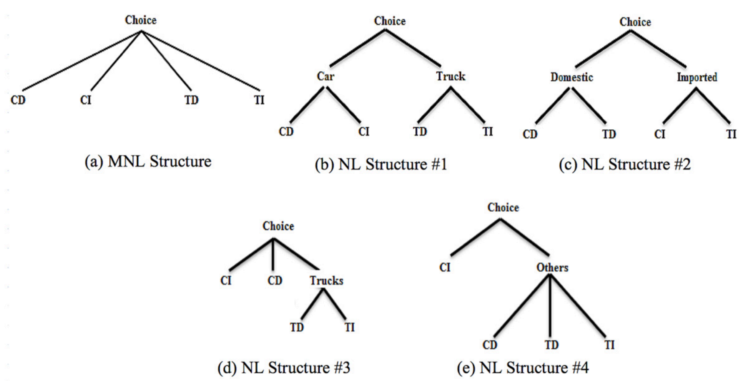

Figure 1. Discrete Choice Model Structures

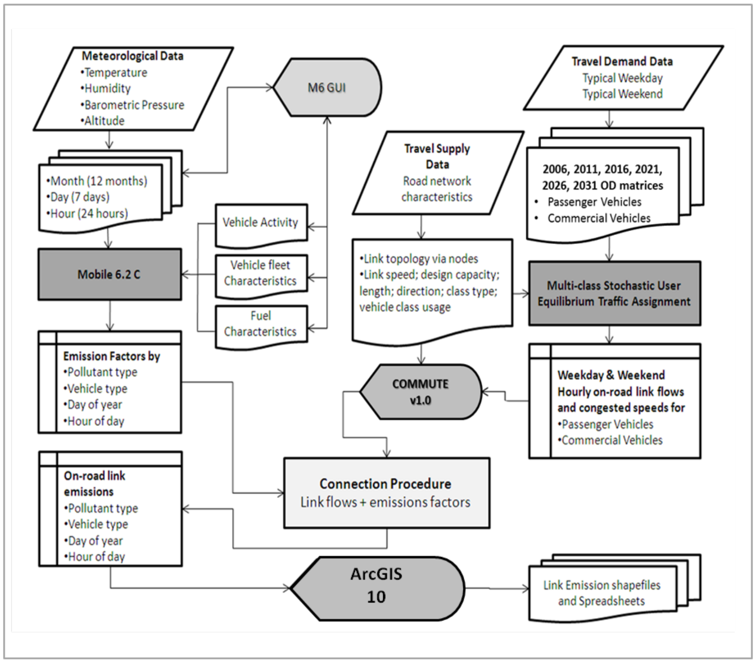

Figure 2. Modeling Framework for Estimating On-road Link Flows and Emissions

Emission factors for the following pollutants were produced by running *M6*: Hydrocarbons (HC), Carbon monoxide (CO), Oxides of nitrogen (NO_x), Carbon Dioxide (CO_2) and Particulate matter of aerodynamic diameter 2.5 microns or less (PM2.5). The latter included the following pollutants: Organic carbon (OCarbon), Elemental carbon (ECarbon), Gasoline particulate matter (GASPM), Lead (Pb), Sulphur dioxide (SO_2), Sulphate (SO4), Brake Wear Particulate (Brake) and Tire Wear Particulate (Tire).

Link traffic flows were estimated directly in *COMMUTE* by executing a multiclass traffic assignment algorithm. Before the algorithm is engaged, trips for all types of commercial vehicles are expressed in passenger car equivalency (PCE) units. The specified PCE values for heavy, medium and light commercial vehicles were

2.5, 2.0 and 1.5 respectively. The multiclass traffic assignment algorithm proceeds to estimate link flows $q^t(g, l)$ for vehicle class type *g* (*g = PV=Passenger vehicles, LCV=Light commercial vehicles, MCV=Medium commercial vehicles* and *HCV=Heavy commercial vehicles*) and road link *l*. Upon convergence, congested speeds $s^c(l)$ were calculated for each link *l* based on the achieved congested travel times $t^c(l)$ per link *l*. Next, the $s^c(l)$ values are then used to estimate the associated emissions (in grams) on each link for each vehicle class *g* following the approach in Anderson et al. (1996). Next, *ArcGIS 10* was used to map the traffic flows and associated emissions on the Windsor road network. *COMMUTE* produces traffic volumes and stores the information in GIS shapefiles. These shapefiles were then loaded in *ArcGIS 10* for mapping and visualization and analysis purposes.

Results and Discussion

Traffic Congestion

Congestion index *C.I* (also referred to as volume-to-capacity ratio) is calculated from the assigned traffic volume on each link of the network. In the simulated scenarios, directing 100% of border crossing traffic volume to pass through the new bridge will result in some increase in congestion since the estimated congestion index (*C.I*) was 0.86 (AMB0 scenario). The segment of E.C. Row Expressway from Huron Church Road to Walker Road is observed to operate well above capacity under all scenarios, whereas the segment of the North-bound Huron Church Road between E.C. Row Expressway and Wyandotte Street is observed to operate below capacity when 100% of border crossing traffic is directed towards the DRIC (AMB0). However, the same link is shown to operate above capacity (*C.I* = 1.25) in the AMB100 scenario.

Location Accessibility

Service (or Market) areas represent the distance that can be reached from a specified location within a specified amount of time, and reflect the level of accessibility that the road network offers travelers within the specified time window. A service area in the spatial context takes the form of polygon, known as service area polygon.

Such polygon provides a visual depiction of the accessible area from a given point within the prescribed time window. Service area analysis was performed with the Network Analyst Extension of ArcGIS 10.0 (ESRI, 2012). The road network used to run the simulations in *COMMUTE* was employed in the Network Analyst to perform the service area analysis. Simulated congested travel time, $t^c(l)$, was used as the impedance to generate the service areas.

To explore the impacts that the new Parkway has on accessibility, service area analysis was performed for 5, 10 and 15 minute travel windows in the afternoon peak hour (4:00 pm) under the simulated scenarios. The service areas are calculated for three locations in the vicinity of the (1) Central Business District (CBD); (2) University Plaza (Intersection of Huron Church Road and Tecumseh Road) in proximity to the Ambassador Bridge; and (3) intersection of Malden Road and Laurier Road in proximity to the new parkway.

The calculated service area polygons are shown in Figure 3. Comparing AMB 100 case demonstrates that the addition of the Parkway alone results in a very significant increase in accessibility, even in the CBD, which is not located close to the new highway. This is because the transfer of traffic away from existing roads has a broad effect on congestion in the region. Among the three Parkway scenarios, changes in the distribution of cross-border flows have small but measurable impacts on accessibility. This is expected as the major feeding-links of traffic volume are common to both crossing bridges. However, minor reductions in service areas for *CBD* and the *University Plaza* for 10 and 15 minutes travel time suggest that the AMB50 scenario has the potential to mitigate any delays on the network when compared to the other two scenarios.

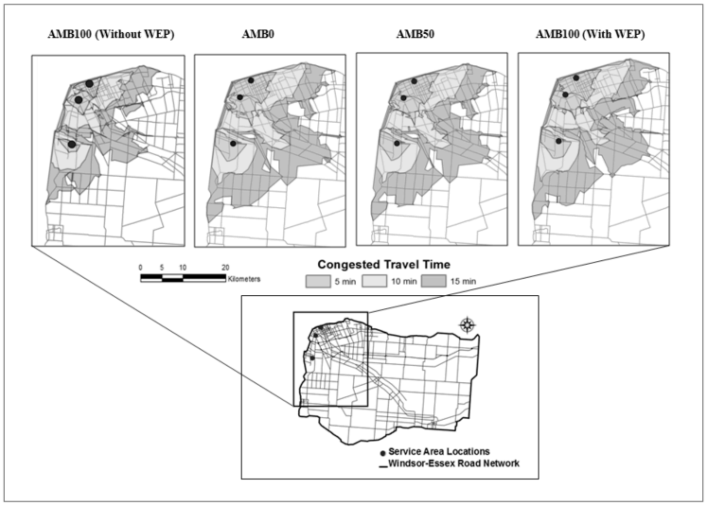

Figure 3. Service Areas under the Base Scenario and the Three Simulated Border Crossing Scenarios for 5, 10 and 15 Minute Drive Times – 4:00 pm

Emissions

The summary of the emission estimates is provided in Table 1. The estimates for HC emissions in the three scenarios featuring the new Parkway ranged from 0.56 to 0.59 tonnes. For CO emissions, the estimated levels were 12.49, 12.48 and 10.63 tonnes respectively for AMB100, AMB50 and AMB0. NOx emissions estimates were also in close range for the three scenarios, as were CO_2 estimates. AMB0 scenario emission estimates were less than or equal to those of the other scenarios for all pollutants. The slightly higher emission values in the AMB100 scenario could be attributed to the existence of multiple signalized intersections on Huron Church Road on the approach to Ambassador Bridge. These intersections cause vehicles to operate in a stop and go mode, which leads to some delays during the afternoon peak hour. Consequently, higher levels of CO, NOx and CO_2 are emitted. The most noteworthy result here is that all three Parkway scenarios produce much lower emissions estimates that the AMB100 (without WEP) scenario. The estimated levels of total hydrocarbons (HC), carbon monoxide (CO), oxides of nitrogen

(NOx) and carbon dioxide (CO_2) in the AMB 50 scenario were 0.59, 12.48, 2.84 and 409.71 tonnes, respectively. These levels were 20%, 21%, 18% and 17% lower in the AMB100 (without WEP) scenario.

Table 1. Total Emission Estimates for the Windsor-Essex Area for 4:00 pm Peak Hour, 2031

Scenario	Vehicle type	HC (tonnes)	CO (tonnes)	NOx (tonnes)	CO_2 (tonnes)
AMB100 (Without WEP)	PV	0.61	10.05	1.19	280.07
	LCV	0.02	0.65	0.07	16.38
	MCV+HCV	0.11	5.07	2.2	193.49
	TOTAL	**0.73**	**15.76**	**3.45**	**489.95**
AMB100	PV	0.5	8.1	1.01	254.61
	LCV	0.01	0.52	0.06	12.95
	MCV+HCV	0.08	3.87	1.77	143.33
	TOTAL	**0.59**	**12.49**	**2.84**	**410.89**
AMB50	PV	0.5	8.09	1.01	254.84
	LCV	0.01	0.52	0.06	12.99
	MCV+HCV	0.08	3.87	1.77	142.67
	TOTAL	**0.59**	**12.48**	**2.84**	**409.71**
AMB0	PV	0.5	8.17	1.01	254.84
	LCV	0.01	0.52	0.06	12.99
	MCV+HCV	0.04	1.94	0.89	70.68
	TOTAL	**0.56**	**10.63**	**1.96**	**338.51**

WEP: Windsor-Essex Parkway. PV = passenger vehicles, LCV = light commercial vehicles, MCV = medium commercial vehicles and HCV = heavy commercial vehicles

The estimates of total PM2.5 and PM 2.5 due to Brake and Tire for the all scenarios are presented in Table 2. For AMB50 scenario, the estimate of particulate matter (PM2.5) for all commercial vehicles was 61.80 kg. This is 18% lower than the no Parkway/no DRIC Bridge scenario. Thus, the Parkway/Bridge project has the potential to reduce total regional pollution emissions by almost one-fifth. Note that this is a region-wide estimate, which is not restricted to the cross-border corridor. The percentage reduction within that corridor would be much higher since the heavy commercial vehicles are the main contributors of Brake and Tire PM2.5 emissions.

Table 2. Total PM2.5 and Brake and Tire PM2.5 Estimates for all Commercial Vehicles, 2031

Emissions	Border Crossing Scenarios			
	AMB 100 (without WEP)	**AMB100**	**AMB50**	**AMB0**
Total PM2.5	75.03 kg	62.38 kg	61.80 kg	61.21 kg
Brake and Tire	1.02 kg	0.80 kg	0.80 kg	0.79 kg

Simulated Travel Times

The simulated travel times from the east of Hwy3/Hwy401 interchange to the Ambassador and DRIC Bridges during the afternoon peak hour (i.e. 4:00 pm) in 2031 are presented in Figure 4. The free flow travel times from Hwy3/Hwy401 interchange to the Ambassador and DRIC Bridges are estimated at approximately 10 and 6 minutes, respectively. In the case of the AMB100 scenario (where all cross-border traffic is assumed to still go via the Ambassador Bridge after the development of the Windsor-Essex Parkway) the time needed to travel from Hwy3/Hwy401 interchange to the Ambassador Bridge is estimated at 25 minutes. Interestingly, travel time on the new Windsor Essex Parkway from Hwy3/Hwy401 interchange to the new DRIC Bridge does not vary significantly across the three scenarios. This is due to the high capacity that the parkway has to offer.

By comparison, travel time on the Huron Church corridor from Hwy3/Hwy 401 to the Ambassador Bridge exhibits a significant and noticeable drop in the three scenarios. In AMB0, travel time drops to half thus allowing the Huron Church corridor to have better level of service. On the other hand, the difference in travel time on the Huron Church corridor between the AMB50 and AMB0 is negligible. The travel time patterns from the two border crossings to Hwy3/Hwy 401 follow a very similar trend as those shown in Figure 4.

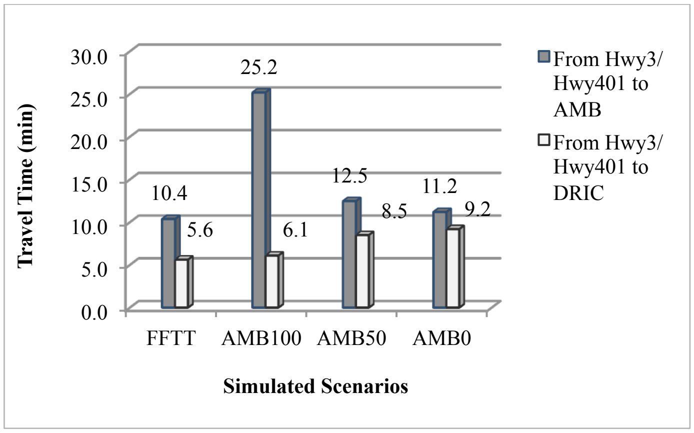

Figure 4. Travel Times from Hwy3/Hwy401 Interchange to AMB and DRIC (*Note: FFTT = free flow travel time)*

Conclusion

The Windsor-Essex Parkway is being built to facilitate cross-border transportation between Canada and the United States, but its effects on the performance of the highway transportation system will be felt throughout the Windsor-Essex region. This research was aimed at forecasting and simulating these impacts by quantifying changes in congestion, accessibility and emission levels for passenger and commercial travel for the year 2031. Simulations were performed with projected data for the region for the year 2031. The study area comprised 84 Traffic Analysis Zones (TAZ). Four scenarios depicting various cross-border transportation situations were defined, simulated and analyzed. The devised framework for simulation modeling was a composite of three integrated modules: *M6, COMMUTE* and *ArcGIS 10.* Our approach was distinguished from previous studies in that it is set within a model of the entire metropolitan highway system, and can therefore assess the impact of future scenarios on the network outside the border corridor.

As expected, the differences in all indicators are greatest between the base scenario (without the Parkway) and all three Parkway scenarios, indicating the profound impact that the new road has on all aspects of the regional transportation system. The results suggest the Windsor-Essex Parkway is expected to operate below capacity in all three simulated scenarios. However, the AMB0 scenario will result in some increase in congestion (Congestion Index, *C.I*=0.86). In general, the results suggest that the new infrastructure will improve the performance and level of service of the transportation system when a balanced cross-border scenario (i.e. AMB50) is involved. Under this scenario, the travel times from Hwy3/Hwy401 interchange to the DRIC and the Ambassador Bridge are estimated at 8.5 and 12.5 minutes, respectively. The emission results indicate that the Parkway/Bridge project has the potential to reduce total regional pollution emissions by almost one-fifth.

The study suffered some limitations that are worth mentioning. These were primarily due to the non-availability of trip generation and trip distribution models for the region. For instance, to forecast the productions and attractions for passenger and commercial vehicles trips, the model parameters used in the zonal based linear regression analysis were obtained from the Calgary region. For future studies, it is imperative to have real data pertaining to the Windsor-Essex region. For that purpose, this study recommends conducting passenger and commercial vehicle surveys in the future.

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