

Simulating the Impacts of RFID Enabled Lanes at the Canada-U.S. Border: An Application to the Ambassador Bridge

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ABSTRACT

The use of Radio Frequency Identification (RFID) technology at border crossing facilities is believed to improve the performance and throughput of these facilities. However, the benefits of implementing RFID technology are highly dependent on the proportion of passenger vehicles and commercial carries that are able to take advantage of the RFID equipped lanes and as well as the number of RFID lanes that are available. This study simulates the potential benefits of using RFID technology under various scenarios that depict certain increases in the number of RFID equipped lanes. The movement of individual passenger and commercial vehicles, the interactions among them, and their passage through primary inspection and RFID enabled lanes at the Ambassador Bridge is simulated in the VISSIM micro-simulation traffic software. The conducted analysis evaluates the efficacy of using RFID technology to achieve a reduction in border-crossing time. A crossing time improvement of 7% is observed with the introduction of 3 RFID enabled lanes.

1. INTRODUCTION

Efficient and secure movement of goods and people across the Canada-US border is vital to support the economies on both sides of the border. Nearly 30% of Canada-US road trade passes through the existing four lane Ambassador Bridge between Windsor, Ontario and Detroit, Michigan with nearly 8,000 trucks crossings every day (PBOA, 2015). The bridge is ranked as the largest land border crossing for commercial vehicle volumes (CBSA, 2016a). The enormous movement of commercial vehicles through this corridor is sometimes subjected to extended delays resulting in significant economic losses. In order to meet increased long-term travel demand and reduce the likelihood of disruption in moving surface trade between the two countries, Gordie Howe International Bridge (GHIB), a new six-lane bridge across the Detroit River is being constructed. The new bridge will provide a much needed additional border crossing option in this busy trade corridor.

While the development of a new infrastructure such as the GHIB provides system resilience, its introduction should be accompanied with emerging Intelligent Transportation System (ITS) technologies. An example of the latter is the use of Radio Frequency Identification (RFID) technology at border crossing facilities. This technology is believed to improve the performance and throughput of these facilities. RFID enabled documents have a radio chip embedded, which allows them to communicate with a ground station that is typically 10 to 15 feet away from the card. Such touch less technology is believed to reduce the time it normally takes border custom agents to process passenger vehicles crossing the border. Vehicles in this situation will have to go through RFID enabled lanes. Travelers only need to hold the RFID enabled document by the windshield of their vehicle to enable the computer system in front of the primary inspection booth to automatically display the traveler's personal information on the officer's computer screen.

The benefits of implementing RFID technology are highly dependent on the proportion of vehicles that are able to take advantage of the RFID equipped lanes. This, in turn depends on the number of drivers, both passenger and commercial who have acquired RFID enabled documents such as Nexus and or/ enhanced drivers licenses (EDLs) and the Free and Secure Trade (FAST) cards. The choice by travellers to acquire these processing documents is not independent of the number of lanes in the Canada Border Services Agency (CBSA) plazas that are equipped with RFID in that the more lanes there are, the greater the benefit of these travel documents.

This research provides a framework for simulating the potential benefits of using RFID technology at an existing border crossing (the Ambassador Bridge) under various RFID adoption scenarios. The objective is to examine the effect of incremental increases in the number of RFID equipped lanes on crossing times. The movement of individual passenger and commercial vehicles, the interactions among them, and their passage through primary service booths at the existing Ambassador Bridge is simulated in the VISSIM micro-simulation traffic software (PTV America, 2016). The conducted analysis is used to evaluate the efficacy of using RFID technology to achieve a reduction in crossing time.

2. CONTEXT

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. Micro-simulation models are more detailed and focus on microscopic movements of vehicles in a traffic stream. Since these models simulate the movement and interaction of individual vehicles, they are more computationally intensive (Nguyen et al., 2012). Furthermore, the successful application of microscopic simulations is often limited to parts of the urban network. Constructing and calibrating a large scale network at the microscopic level is usually very time consuming and non-trivial (Kitamura and Kuwahara, 2005). The application of micro-simulation models to assess the impacts of various measures of effectiveness in queuing facilities is well documented in the literature (see for example Ceballos and Curtis, 2004; Al-Deek et al. 2005; Khan, 2010; Brijmohan and Khan, 2011; and Aksoya et al. 2014).

2.1 Application of Radio Frequency Identification (RFID) Technology in Transportation

Over the last few decades the use of Radio Frequency Identification (RFID), in terms of optimizing transportation and logistics operations, has gained considerable credibility. The conducted research points to the fact the benefits of implementing and managing RFID based transportation facilities outweigh the cost deterrents given the improvement in system performance. RFID has broad range of application in various forms of transportation, including surface, air and marine transportation. For example, RFID is commonly used in processing flows at toll and inspection plazas, automated baggage handling and container tracking.

The first significant application of RFID in the trucking industry was the implementation of weigh-in-motion system to allow trucks to bypass as they approach a weight station (Engineering.com 2016). The system would read the RFID tag of the approaching vehicle and based on the information/data received from the vehicle, it would transmit a bypass or no bypass signal to the vehicle. This resulted in an overall significant processing time savings for all the stake holders involved. However, as in the case of any emerging technology, implementing of RFID in transportation also faces many challenges. These include but not limited to: cost of implementation, transaction security and privacy issues and compliance with jurisdictional regulations.

3. METHOD OF ANALYSIS

In this study, a micro-simulation traffic model is used to reproduce as accurately as possible the flow of heavy commercial vehicles through the conventional primary inspection and Radio Frequency Identification (RFID) enabled lanes of the CBSA Plaza of the Ambassador Bridge. In micro-simulation approach, the movement of individual vehicles, the interactions among them, and their passage through inspection stations are digitally represented in a near-continuous time sequence. The micro-simulation model used in this analysis simulates the exact lane configurations of the existing CBSA inspection plaza. The model is calibrated based on available

data from various sources such that the model parameters reproduce actual primary inspection lane performance. This included several tests of different vehicle arrival rates and inspection times at the primary booths to produce the same throughput observed from Remote Traffic Monitor Sensor (RTMS) System. As for the physical capacities of the Canadian Custom Plaza at the Ambassador Bridge, there are currently 13 and 10 lanes available for passenger and commercial vehicles, respectively (CBSA 2016b). Two of the passenger’s lanes are designed for NEXUS travellers and one of the commercial vehicle lane is designated for trucks using the FAST program. The framework for micro-simulation modeling is presented in Figure 1.

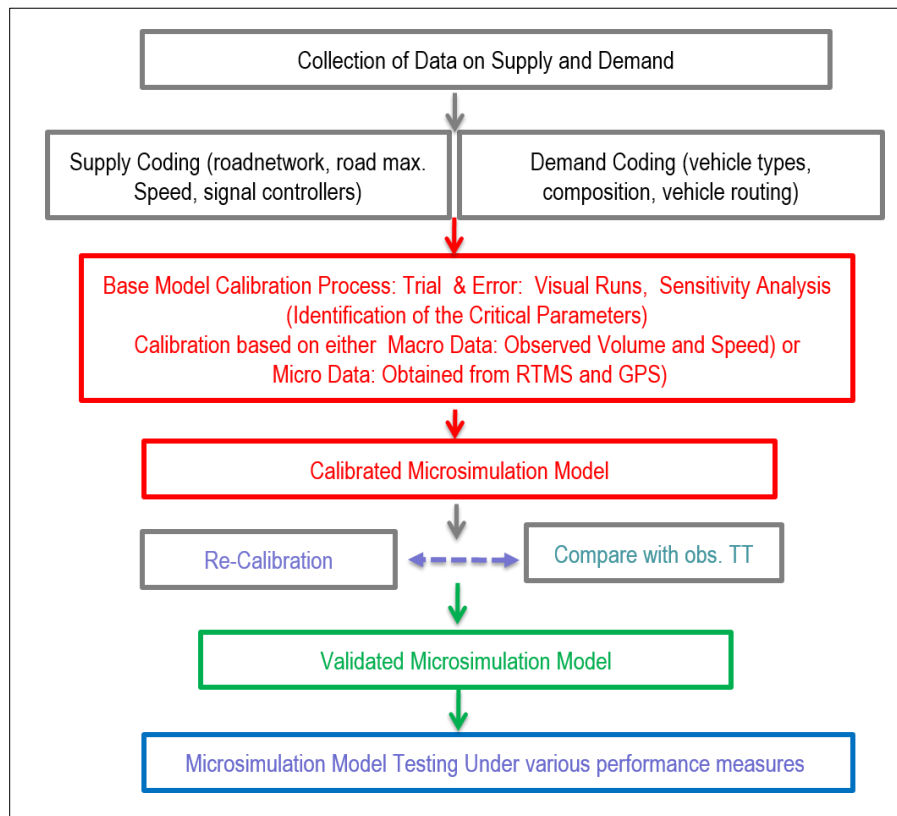


Figure 1. Framework for developing a calibrated Micro-Simulation Model

The effect of RFID technology on border crossing wait times is assessed by defining different inspection time distributions (taking account of both mean times and the variability across times) separately for RFID enabled and conventional inspection lanes for commercial vehicles, mainly heavy duty trucks.

The hypothesis is that RFID enabled lanes will have clearance times with lower mean and standard deviation compared to non-RFID clearance times. The micro-simulation model provides great flexibility to model not only the length of queues for each service booth, but also the traffic dynamics in the plaza including the distribution of vehicles from one, two or three lanes on an approach road to a larger number of queues in the plaza; and the interactions of vehicles in the plaza.

For any given increase in the number of RFID equipped lanes, the estimated reduction in wait time (defined as the time interval from when a vehicle joins a queue to when it is released from the primary inspection or RFID enabled booths) is obtained from the simulated crossing times.

After the development of a microsimulation model that is capable of reproducing the performance of the inspection plaza under the RFID and conventional inspection lane, the adoption of RFID enabled lane was simulated. Through this simulation structure and as a proof of concept, the reduction in crossing times is quantified for the commercial vehicles with respect to: 1) the status quo scenario 2) increased RFID enabled lanes.

4. DATA

This research makes use of traffic count data from various sources. First, data collected via a RTMS system that was deployed by the Cross-Border Institute, University of Windsor, in May 2015 are used to estimate the volume of the Canada bound commercial and passenger traffic entering Canada (i.e. south bound traffic). Figure 2 presents the locations of the sensors forming the RTMS System.

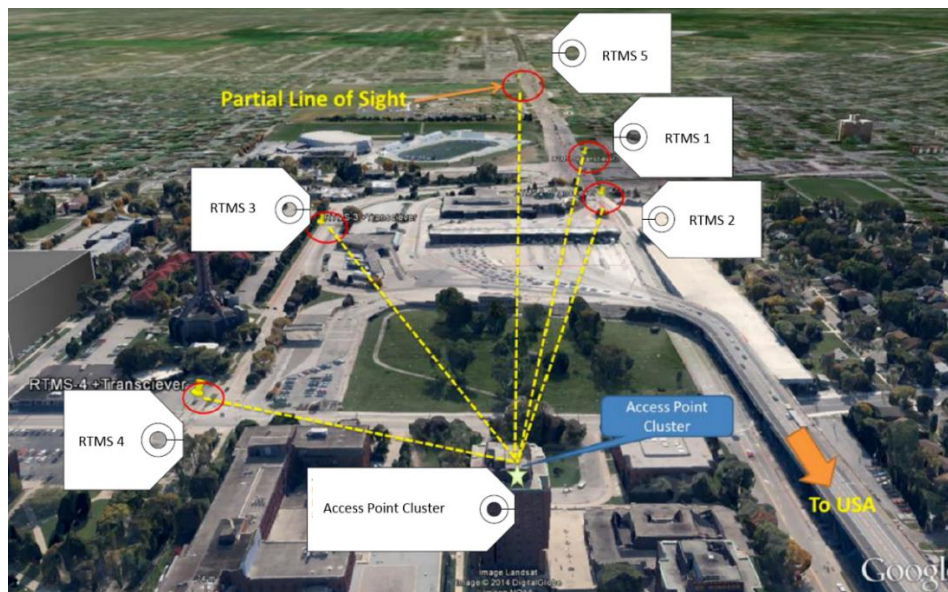


Figure 2. RTMS Data Acquisition System at the Ambassador Bridge (Base Image Source: Google Map)

The collected data consists of minute to minute vehicle count for six vehicle classes (based on length) that enter from US into Canada. This data, which was observed by RTMS unit #2 for the period June 8 – 14, 2015, form the basis for calibrating the micro-simulation model used to generate aggregate statistics as a starting point. The exact location of the RTMS sensor recording the count of vehicle exiting from the Canada custom Plaza is shown in Figure 3.



Figure 3. RTMS Monitoring Station at the Exit of the Canadian Custom Plaza at the Ambassador Bridge (Base Image Source: Google Map)

A summary of the volume of commercial vehicles used to calibrate the model are presented in Table 1. These volumes are calibrated against an average crossing time of approximately 17.50 minutes obtained from analyzing the crossing time of 10,827 commercial vehicles that crossed the Ambassador Bridge in June, 2013 (Gingerich et al. 2016). The crossing time was estimated by geocoding GPS pings generated by commercial carriers within a geo-fence (total length of 2.75 Km) located on both sides of the Canada US border at the Ambassador Bridge, as shown in Figure 4 (Gingerich et al. 2016). These data were used to generate a crossing time distribution for trucks entering Canada from the US, as shown in Figure 5. The distribution formed the basis for developing a processing/dwell time cumulative distribution function in simulations conducted for this analysis.

Table 1. Count of Trucks Crossing the Ambassador Bridge to Canada, June 8 – 14, 2015

Day	Trucks
Monday	3,571
Tuesday	4,204
Wednesday	4,270
Thursday	4,328
Friday	4,243
Saturday	2,503
Sunday	1,283

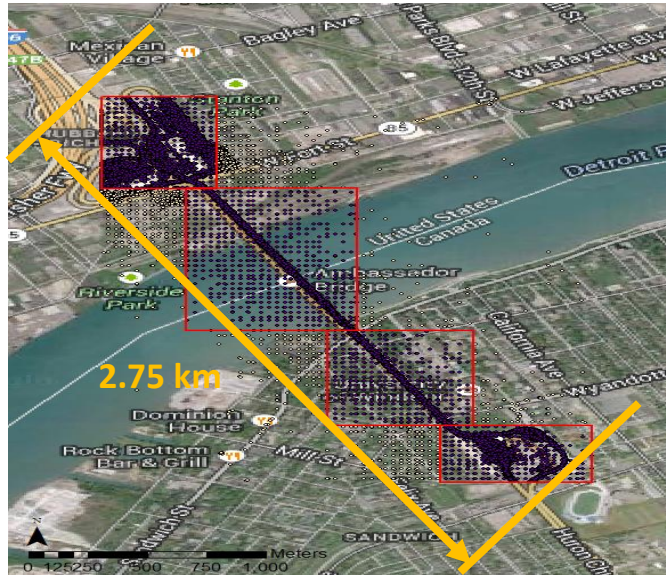


Figure 4. Geo-fence tracking GPS pings of commercial vehicles across the Ambassador Bridge (Source: Gingerich et al. 2016)

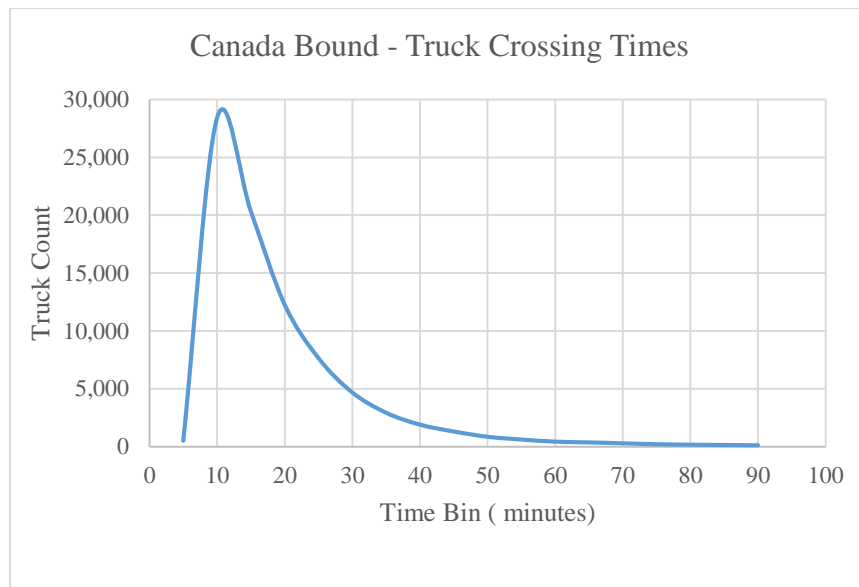


Figure 5. Crossing Time Distribution Adapted in VISSIM Simulation (Source: Gingerich et al. 2016)

This study also made use of the processing times estimates obtained from a more focused virtual geo-fence constructed around the inspection booths as shown in Figure 6. The work is accredited to Gingerich et al. (2016). The dots within this geo-fence, separated by the physical barrier (inspection booths) represent pings from an individual carriers. The elapsed time between a given set of two pings provides a fair assessment of the observed inspection time. For more reliable estimate of the inspection time, all pairs of pings (175,782 observations), observed within this geo-fence were averaged. The resulting processing time was estimated at 1 minute.

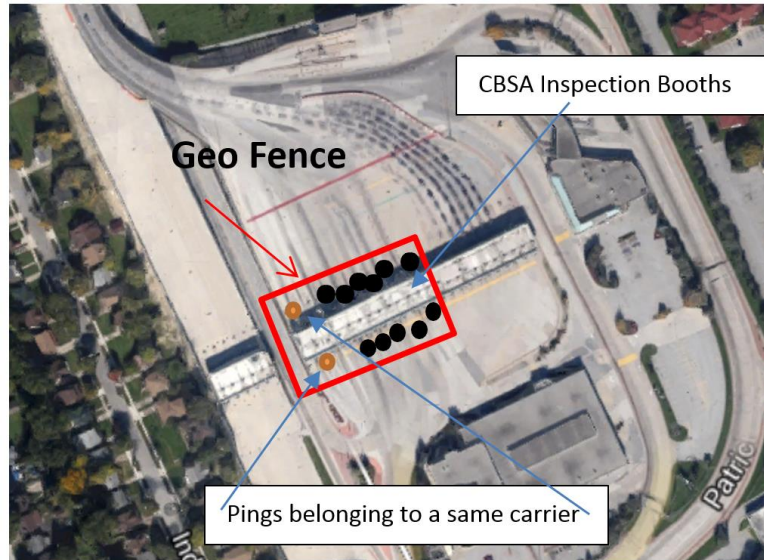


Figure 6. Geo-fence for Estimating Inspection Time at the Ambassador Bridge

5. MODELING TOOL

5.1 Vehicle Interaction and movements in VISSIM

The vehicle interaction and movements in VISSIM microscopic traffic simulation software are mainly based on two models:

- 1- Car-following Model
- 2- Lane-Change Model

The psycho-physical Car-following model was developed by Wiedemann (1974). The model uses vehicle-driver-units that incorporate several stochastic variations. This in turn guarantees that virtually no two vehicles have exact same driving behavior. The model is based on three key parameters that define the human driving behaviour. These include 1)- Look ahead distance, 2)- Look back distance and 3)-Temporary lack of attention. These parameters are calibrated for various traffic configurations that include but are not limited to Urban and Freeway road facilities. On the other hand, the Lane change Model, developed by Sparmann (1978) relies on a set of rules to mimic the real-world traffic conditions. These rules pertain to rational driving behavior. The combination of the calibrated parameters of both models mimic realistic driving behavior in Vissim.

5.2 Model Evaluation Criteria

The following processing time ranges are used as the evaluation criteria to calibrate and validate the mirco-simulation model:

- Conventional primary inspection lanes (Non-RFID): between 120 sec – 300 sec.
- FAST lane : between 60 sec -180 sec

- 10 lanes to be simulated including 1 RFID enabled lane
- Observed average crossing time – 17.5 minutes (to cover a distance of 2.75 km and includes processing time at the inspection plaza)

The simulated crossing time is compared with the observed crossing time to validate the model.

6. RESULTS

The results pertaining to the micro-simulation model calibrated for commercial vehicles are presented in Table 2. A total of 10 lanes are simulated including one FAST lane. The model resulted in an average simulated crossing time of 18.65 minutes with close to 93% predictive ability for the system.

Table 2. Preliminary Results of the Calibrated Microsimulation Model for Commercial Vehicles

Conventional Inspection Lane	FAST Lane	Avg. Observed Crossing Time (min)	Simulated Avg. Crossing Time (min)	Percent Difference
9	1	17.50	18.65	6.57%

The results pertaining to scenarios in which the FAST lane is replaced by an RFID enabled lanes are presented in Table 2. The RFID lane is represented by a processing time distribution that ranges between 30sec-60sec whereas the processing time for the conventional primary inspection lanes (Non-RFID) remains unchanged (i.e. 120 sec – 300 sec). For maintaining consistency for comparing results, a total of 10 lanes were simulated including one RFID lane. The scenario with 3 RFID enabled lanes resulted in an average simulated crossing time of 17.27 minutes which is 7.40% lower than the simulated crossing time of 18.65 minutes used as a bench mark.

Table 2. Preliminary Results of the RFID Based Microsimulation Model for Commercial Vehicles

Conventional Inspection Lane	RFID Enabled Lane	Bench Mark (min)	Simulated Avg. Crossing Time (min)	Percent Difference
9	1	18.65	18.49	-0.86%
8	2	18.65	18.01	-3.43%
7	3	18.65	17.27	-7.40%

7. CONCLUSIONS AND FUTURE WORK

A microsimulation model is calibrated to assess the reduction in processing times by implementing increased RFID based processing lanes for commercial vehicles at the Canadian Inspection Plaza of the Ambassador Bridge. The data used in model calibration is obtained from

various sources including an in-house developed RTMS data acquisition system and GPS ping records for a very large number of Canadian trucks. The calibrated micro-simulation method offers a great flexibility to simulate various configurations featuring RFID and conventional inspection lanes for commercial carriers and assess the savings that can be realized by implementing more RFID enabled lanes. The results show that the introduction of 3 RFID enabled lanes can improve the system performance by as much as 7%. This improvement might not seem significant, however, it should be noted that this saving pertains to a simulation period that was confined to 3,600 seconds (i.e. one hour). On annual basis, the introduction of a single of RFID enabled lane could potentially lead to significant savings in crossing times.

Future work includes model re-calibration for simulating passenger vehicles processed at conventional and NEXUS lanes of the inspection plaza and performing sensitivity analysis under various system capacities. This include simulating the RFID adoption under reduced system capacity scenarios; for example, 75% lanes open, and 50% lanes open. Furthermore, crossing time savings will be assessed in terms of monetary measures that can be realized by implementing more RFID enabled lanes. Finally, the simulation frame work will be extended to include the new inspection Plaza at the Gordie Howe International Bridge (GHIB).

REFERENCES

1. Aksoy, G., Celikoglu, H., Gedizlioglu, E. 2014. "Analysis of toll queues by micro-simulation: results from a case study in Istanbul". *Procedia - Social and Behavioral Sciences*, 111, pp. 614 – 623
2. Al-Deek, H., Mohamed, A., and Malone, L. 2006. "A New Stochastic Discrete-Event Micro Simulation Model for Evaluating Traffic Operations at Electronic Toll Collection Plazas". *Journal of Intelligent Transportation Systems*. ISSN: 1547-2450 (Print) pp. 1547-2442 (Online)
3. Brijmohan, A., and Khan, A. 2011. "Development of methodology for quantifying the effectiveness of priority crossing programs at land border crossings". *Canadian Journal of Civil Engineering*, 38, pp. 932–943.
4. CBSA 2016a. Ambassador Bridge. Available at: <http://www.cbsa-asfc.gc.ca/do-rb/time-temp/961-eng.html> [viewed April 16, 2016.]
5. CBSA 2016b. Free and Secure Trade. About the FAST program. Available at: <http://www.cbsa-asfc.gc.ca/prog/fast-expres/menu-eng.html> [viewed April 04, 2016]
6. Ceballos, G., and Curtis, O. 2004. "Queue analysis at toll and parking exit plazas: a comparison between multi-server queuing models and traffic simulation". Presented at the Annual Meeting of the Institute of Transportation Engineers, Orlando, Florida, USA
7. Engineering.com 2016. RFID in Transportation. Available at: <http://www.engineering.com/ElectronicsDesign/ElectronicsDesignArticles/ArticleID/7338/RFID-in-Transportation.aspx> [viewed March 03, 2016]
8. Khan, A. 2010. "Prediction and Display of Delay at Road Border Crossings". *The Open Transportation Journal*, 2010, 4, pp. 9-22

9. Kitamura, P., and Kuwahara, M. (editors). 2005. "Simulation Approaches in Transportation Analysis: Recent Advances and Challenges". Springer, New York.
10. Nguyen, T., Vo, Q., and Vu, H. 2012. "A Traffic Simulation Package Based on Travel Demand". World Academy of Science, Engineering and Technology, 61, pp. 8-17
11. PBOA 2016. Public Border Operator Association. Traffic Data: Available at: <http://publicborderoperators.org/index.php/traffic>
12. PTV America 2016. VISSIM. Traffic Micro Simulation Software. <https://company.ptvgroup.com/en/landing-pages/us/ptv-america-en/portfolio/> [viewed January 19, 2016]
13. Wiedemann, R. 1974. "Simulation of the traffic flow". Series of the Institute of Transportation, No. 8, University (TH) Karlsruhe, KIT - Karlsruhe Institute of Technology.
14. Sparmann, U. 1978. "Lane changing operations on two-lane motorway carriageways". Research Road and Traffic Technology, vol. 263, 1978.