Making informed route choices using V2V/V2I communications: The case of Highway401/402 Corridor

Shakil Khan (corresponding author), Cross-Border Institute, University of Windsor, Ontario
Sarah Khalid, Cross-Border Institute, University of Windsor, Ontario
Hanna Maoh, Cross-Border Institute, University of Windsor, Ontario
Kemal Tepe, Department of Electrical Engineering, University of Windsor, Ontario

Introduction

Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) communications rely on exchange of wirelessly transmitted messages among vehicles and, between vehicles and roadside units such as variable road signs. V2V equipped vehicles serve as data sensors and discretely transmit traffic and road condition data to other vehicles equipped with the V2V technology. On the other hand, V2I communications facilitates the direct wireless exchange of information between vehicles and road infrastructure. The wireless exchange of messages can be used to: warn drivers of imminent road safety concerns, inform prevailing traffic conditions and, as well as convey details of alternative route(s).

Typically, V2V/V2I communications use the Dedicated Short Range Communications (DSRC) service. In Canada, the 5850-5925 MHz Band has been designated for dedicated DSRC systems for Intelligent Transportation System (ITS) applications (IC, 2004). Industry Canada classifies DSRC-based ITS applications into 8 groups namely: travel and traffic management, maintenance construction operations, public transit management, electronic payment, commercial vehicle operations, emergency management, advanced vehicle safety systems, and information management (IC, 2018). Both V2V and V2I communications have shown a great potential for improving road safety and streamlining traffic and are considered to be critical elements of any present day ITS.

This research proposes a framework for implementing V2V/V2I communications in a land border crossing corridor to provide en route passenger and commercial vehicles with timely information of the prevailing traffic conditions at the approaching border crossing(s).

Modeling Approach

Traffic microsimulation models are powerful tools widely used by transportation practitioners to model and evaluate the impacts of new transport infrastructure projects and to test various ITS applications. These models focus on microscopic movements of vehicles in a traffic stream (i.e. the movement of individual vehicles). Key characteristics in these models is their ability to represent the interactions of individual vehicles while moving on or through the transportation networks. As such, these movements are simulated digitally in a near-continuous time sequence.

PTV VISSIM is one of the leading agent-based (i.e. microscopic) traffic simulation software around the world (PTV America, 2018). VISSIM provides an accurate and realistic platform for testing various traffic operation scenarios by integrating calibrated *Car Following* and *Lane Change* models. The *Car Following* model is a psycho-physical model developed by Wiedemann (1974). It uses vehicle-driver-units that incorporate several stochastic variations such that no two vehicles have virtually the exact same driving behavior. On the other hand, the *Lane Change* model is a rule-based model originally developed by Sparmann (1978) allowing: *Necessary Lane Change* (executed to reach the next connector of a route) and *Free Lane Change* (executed due the availability of a lane with lower volume and higher operating speed).

VISSIM, by default, does not offer any ready to implement V2V/V2I tools. Typically, these interactions are modeled by developing External Driver and communication modules which together simulate inter-vehicle and vehicles to infrastructure communications. However, the research presented here uses scripts that are developed in the Python programming language to simulate the V2V/V2I interactions in VISSIM.

Proof of Concept Simulations

To test the efficacy of V2V interactions in VISSIM, proof of concept simulations are conducted to model the behavior of connected vehicles (CVs) apperceiving a traffic incident such as an accident or a disabled vehicle on a roadway. The simulations test demonstrates the propagation of V2V messages in a traffic stream under various available rates of CVs warning drivers of the upstream traffic conditions. The objective is to see how the availability (i.e., density) of CVs in a traffic stream can help reduce the overall traffic speed to improve road safety around the incident area. A color codding scheme is used to visualize the effect of V2V communications. The colors of the vehicles are based on the V2V status: status 0 (white): no V2V equipment; status 1 (yellow): no active V2V message; status 2 (green): received V2V message; and status 3 (red): sending V2V message.

Figure 1 shows the network used in the proof of concept simulations. The network consists of a 3-lane stretch of an urban roadway with vehicles, mainly cars travelling at a speed 70 km/h. The network was divided into three segments labelled as S1, S2, and S3, representing the beginning, middle, and end segments of the network, respectively. The highlighted box labelled 'VB' represents the area where the vehicle breakdown takes place. Data collection points were placed at the three sections of the network to record speeds and delays. Multiple simulations were run under various CV rates of: 0%, 5%, 10%, 25%, 50%, and 100%. We anticipate that V2V equipped vehicles, in the wake of an accident, will react to the incident by sending out a reduce speed-alert message to other V2V enabled vehicles that are within the DSRC range. Typically, the DSRC communication range vary from 10 to 1000 meters. For present simulations, a range of 300 meters was assumed.

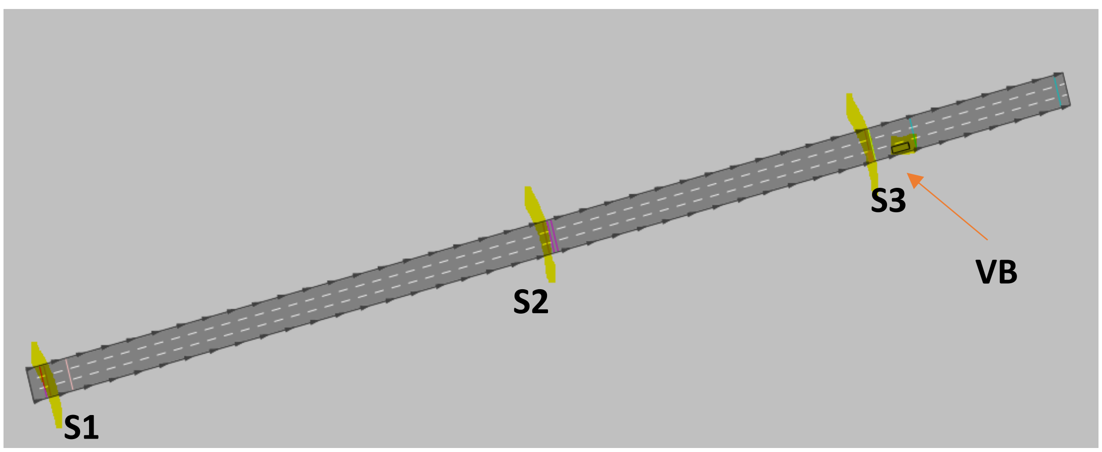

Figure 1: Segmentation of simulated freeway section in VISSIM

The results pertaining to the traffic speed in the conducted simulations are presented in Figure 2. It is evident that the greater CVs rate helps lower the average speed of the vehicles. The effect is more pronounced in segment 3 where the incident occurs. A share of 25% CVs in the simulated traffic volume resulted in reducing the traffic speed from 70km/h to 20km/h (Figure 2d). However, for CV rate of 50% and greater (Figures 2e and 2f), there is no notable reduction in the speed. Also, outside the breakdown incident time period (i.e. before 200 seconds and after 400 simulations seconds), the speeds of the vehicles remain fairly constant at 70 km/h at the beginning, and end of the network.

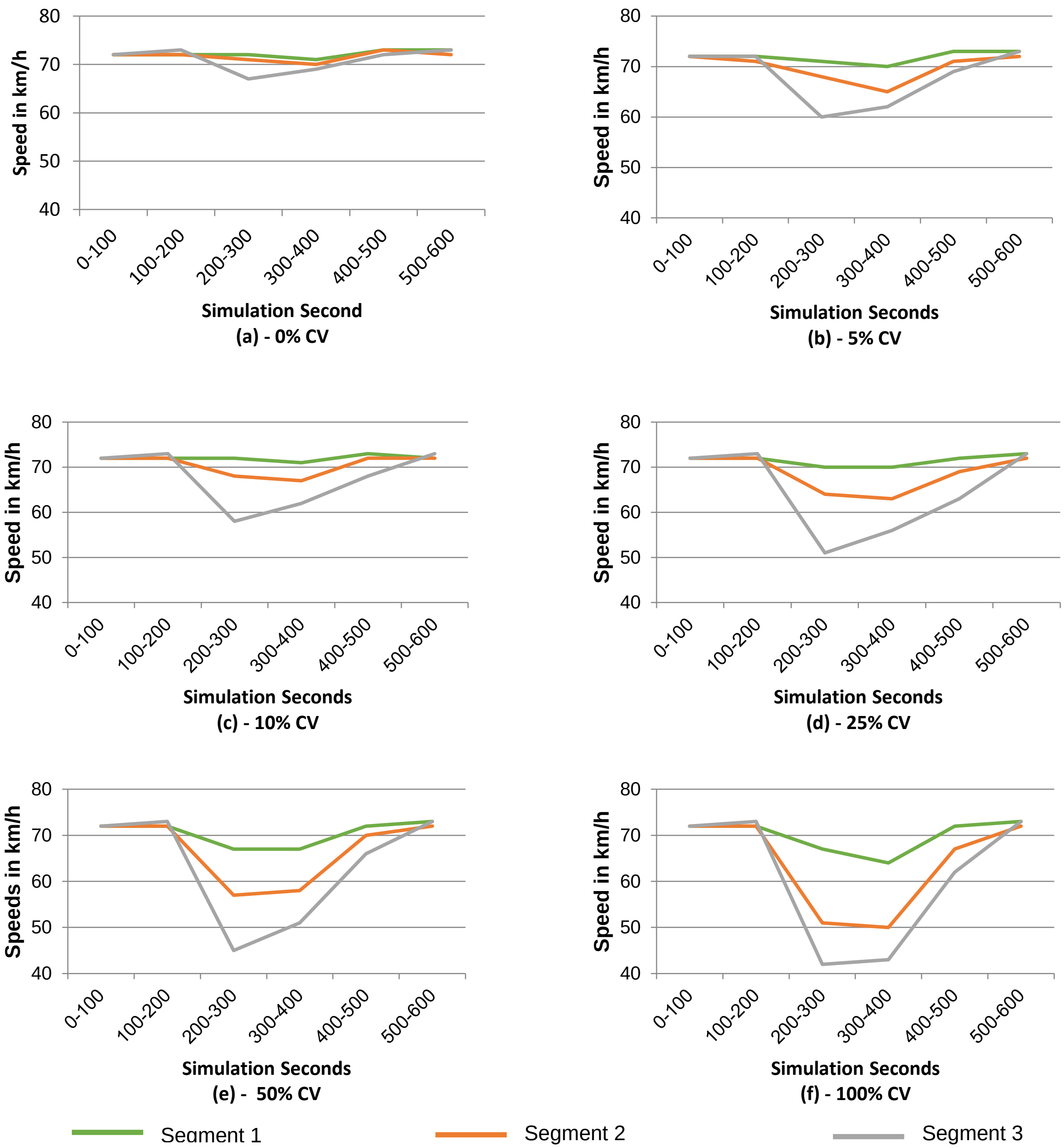

Figure 2: Effect of CV concentration on traffic speed

The results pertaining to the vehicle delay are presented in Figure 3. The “Stop Delay” measurement pertains to the average stopped delay per vehicle in seconds. On the other hand, the “Avg. Delay” is the difference between the free flow travel time (without any incidents and/or traffic) and the actual travel time to traverse the road segment. It is evident from Figure 3 that the delay gradually increases with the CV rate as V2V enabled vehicles reduce their speed from the regular speed of 70 km/h to a cautious speed of 50 km/h while passing through the incident area. However, the delays do not reduce appreciably as the CV rate increase from 50% to 100% (Figures 3e and 3f).

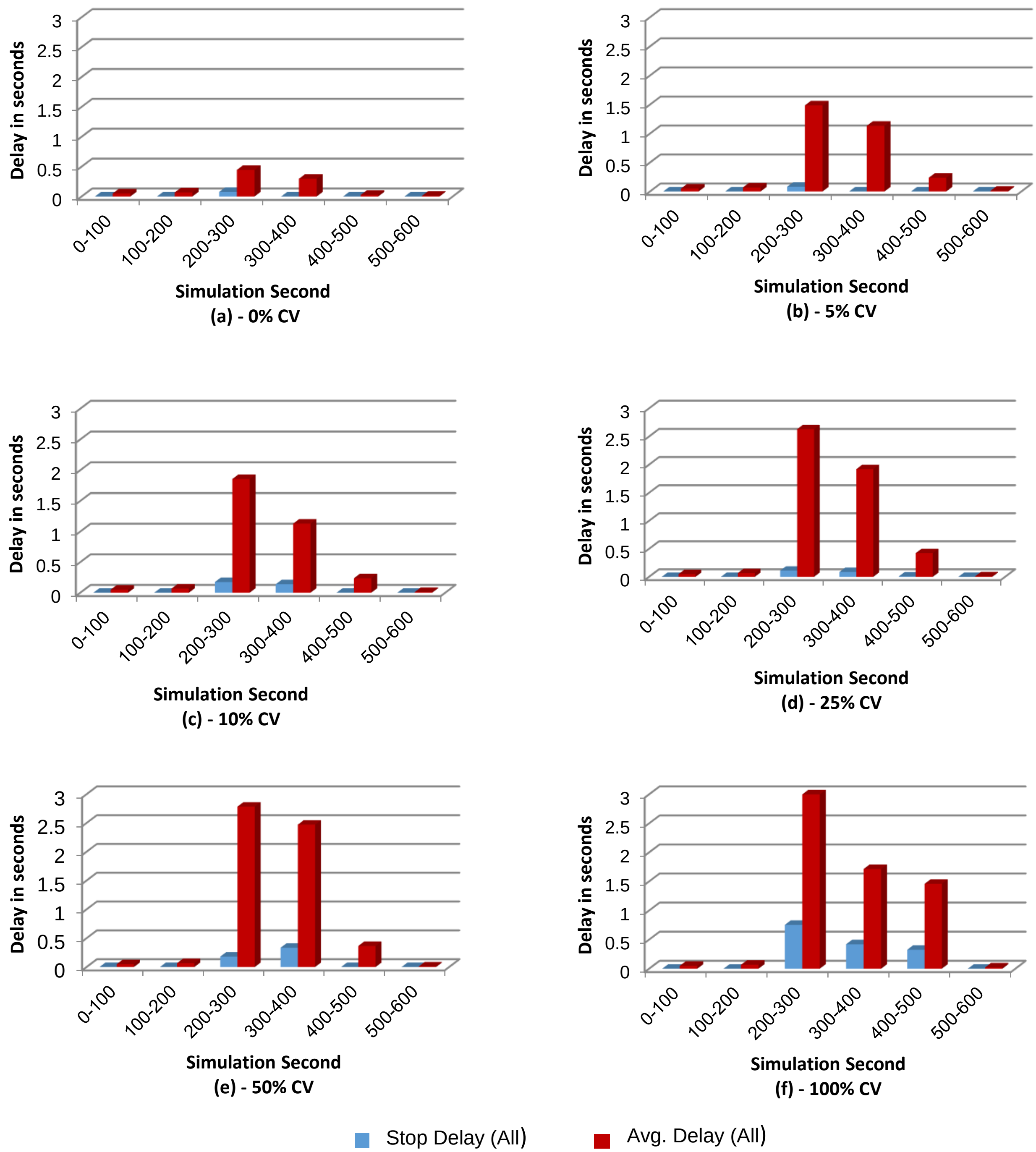

Figure 3: Effect of CV concentration on traffic delays

Implementing V2V/V2I Communications on 401/402 Corridors

The above results paved the way for extending the proof of concept simulation towards devising a mechanism to implement V2V/V2I communications in a land border crossing corridor to provide en route passenger and commercial vehicles timely information of the prevailing traffic conditions at the approaching border crossing(s). More specifically, the developed framework will simulate the V2V and V2I interactions of vehicles on the Highway 401/402 corridors that lead to the two key land border crossings between Ontario and Michigan namely, the Bluewater Bridge and the Ambassador Bridge.

Figure 4 shows a scaled network of the Hwy401/402 corridors that has been developed in VISSIM to conduct the simulations. The updated crossing time information will be collected at source (i.e., at the two data collection points denoted by AMB-0, and BWB-0). The information will be relayed to the CVs via DSRC service and to the roadside units RSU1 and RSU2 via Line of Sight communication technology with extended range offered by such as the 5GHz broadband wireless platform (60km range). Additional RSU's can be used to facilities the communication along the two corridors length. Again, these RSUs will receive and broadcast the traffic information to the CVs in the traffic stream via DSCR service. Once the CVs receive the information which will include the existing crossing time at the two borders, the information will be propagated to the roadside Unit (RSU-DP) which will relay this information to the VMS. The VMS will demark a decision point for the en route vehicles to make an informed choice reading their route depending upon the forecasted crossing time at the two border crossings.

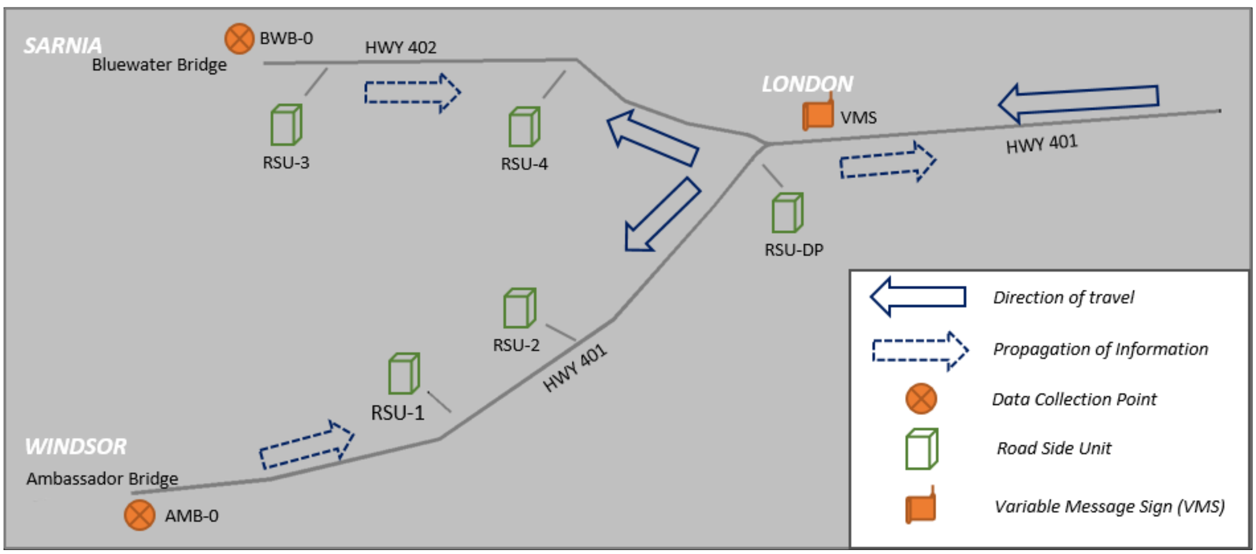

Figure 4 Schematic of the V2V/V2I Simulations network to be used VISSIM

The developed mechanism will simulate how RSUs can be used to enable V2I communications to propagate information in the direction of travel. Also, the effect of CV penetration rates (V2V density in traffic stream) on the effectiveness of V2V communication will be simulated. The conducted analysis will enable us to evaluate the readiness of V2V/V2I communications in reducing congestion and the associated savings in the crossing time by adjusting the relative flow of traffic heading towards these two key land border crossings.

Reference

IC (2018). Industry Canada. Proposed Spectrum Utilization Policy
Available at: https://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf08745.html#s3.1

PTV America (2018). VISSIM. Traffic Micro Simulation Software.
<http://vision-traffic.ptvgroup.com/en-us/products/ptv-VISSIM/>

Sparmann, U. (1978). Lane changing operations on two-lane motorway carriageways. Research Road and Traffic Technology, vol. 263, 1978.

Wiedemann, R. (1974). Simulation of the traffic flow. Series of the Institute of Transportation, No. 8, University (TH) Karlsruhe, KIT - Karlsruhe Institute of Technology.