ASSESSING ADVANCED NON-INTRUSIVE DATA ACQUISITION SYSTEMS IN TRANSPORTATION PLANNING AND RESEARCH

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Introduction

Monitoring road traffic is a critical element of transportation planning and roadside detection has been the most common method of collecting road traffic data. The typically collected traffic parameters include volume, speed and vehicle classification. Convectional data acquisition systems are largely intrusive where they often pose in-field safety concerns. Also, traffic disruption and temporary lane closures usually occur when deploying roadside intrusive technologies. Furthermore, the high installation cost, curved road geometry, extreme environmental conditions and lack of field personnel are factors that limit the appeal of intrusive traffic sensors. The traffic industry has been exploring new alternative and non-intrusive technologies to circumvent the disadvantages of intrusive traffic sensor technologies. As a result, an array of non-intrusive technologies has emerged in recent years. The installation, operation and maintenance of data acquisitions systems featuring non-intrusive technologies cause little disruption to the traffic operation and control.

The presence of an effective and undisruptive data acquisition system is especially vital for corridors subjected to large traffic volumes. The Windsor-Detroit corridor, connecting Ontario and Michigan is one such corridor. The performance of this busy corridor is being improved through the Border Advisory System (BAS). The BAS is a combined initiative of the Government of Canada, the Province of

Ontario and the City of Windsor (City of Windsor, 2014). As part of this initiative, the approaches to the Windsor-Detroit Corridor border-crossings (i.e. the Ambassador Bridge, and the Windsor-Detroit Tunnel) will be equipped with non-intrusive traffic detection technologies. Once in operation, the BAS will provide reliable estimates of border-crossing wait times to the en-route vehicles on Highway 401 and 402 through traffic information signs and web based application. The relayed information will enable drivers in making provisions for awaiting delays at the Bluewater Bridge in Sarnia, Ontario and the Ambassador Bridge/Windsor-Detroit Tunnel in Windsor. The traditional process flow of traffic data utilization from intrusive and non-intrusive technologies is shown in Figure1.

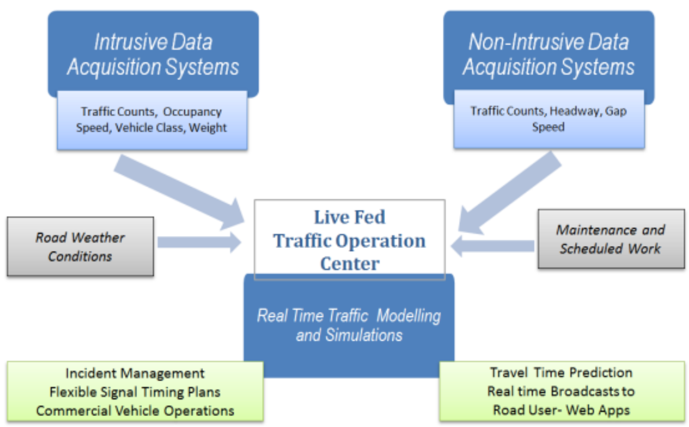

Figure 1. Process Flow of Traffic Data Utilization (Adapted from Leduc, 2008)

This paper provides an assessment of the advanced and emerging non-intrusive data acquisition systems some of which are being deployed in the BAS. The non-intrusive systems identified in this study include *Microwave Traffic Monitoring Radar* and the *Bluetooth Traffic Monitoring Sensor*. These systems are assessed in terms of their ability to gather high quality traffic data under various constraints and conditions.

Evolution of Non-Intrusive of Technologies

Recent advancements in remote sensing have paved the way for advanced non-intrusive technologies. These include but not limited to infrared, microwave radar, Global Positioning System (GPS), Bluetooth and video based detection. In principle, non-intrusive technologies operate by remotely sensing moving vehicles on roadways. Unlike inductive loops (the most common form of intrusive data collection technique) advance non-intrusive systems such as microwave radar and video image processing systems can measure vehicle speed directly while the vehicle passes the detection station. The application of these advance technologies results in a cost-effective design for collecting and processing traffic data in real time. The following sub section provides a description of the non-intrusive technologies that are assessed in this study.

Remote Traffic Microwave Sensor (Autoscope- RTMS G4)

The Remote Traffic Microwave Sensor (RTMS) emits a microwave beam to determine time delay between the transmission and the reflection of microwave slices from a vehicle (Vandervalk-Ostrander, 2009). RTMS have been around for many decades and as a result the technology has noticeably matured. The latest line of RTMS can even provide reliable description of vehicle classification. The RTMS are not significantly affected by adverse weather or lightening conditions (Middleton et al. 2003). The *Autoscope- RTMS G4* has a beam span of 76 m, and is able to detect up to 12 lanes of traffic within that distance. Figure 2 shows the foot print of a RTMS across a multilane highway.

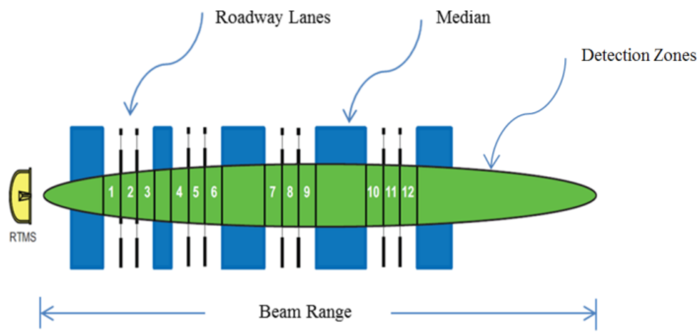

Figure 2. RTMS Detection Foot Print
(Adapted from Image sensing System Inc., 2013)

The extended range of detection span enables RTMS to detect moving and stationary vehicles in multiple detection zones. To detect traffic in multiple traffic zones in a cost effective way, a midblock or side fired configuration is more appropriate. However, due to occlusion between the vehicles, this configuration lowers the accuracy of the collected data. Vehicle occlusion occurs when a vehicle (usually a heavy vehicle) in the detection zone partially or fully blocks other vehicle in adjacent lanes as shown in Figure 3.

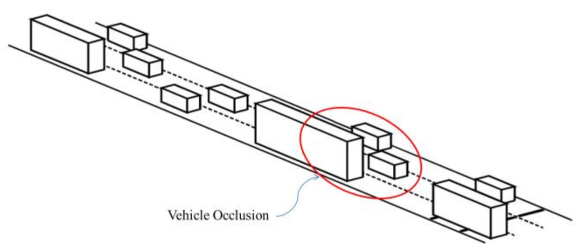

Figure 3. An illustration of Vehicle Occlusion
(Adapted from Versavel, 2007)

The RTMS setup utility is a key component of the RTMS data acquisitions system. The software program provides an interface for the in-field calibration of RTMS. Once in operation, the RTMS calculates traffic volume, occupancy, average speed, and vehicle classifications for each lane and transmit the data packet to the traffic control center via selected medium of communication.

BluFAX Cellular Detection

The Bluetooth traffic Monitoring System (BTMS) is an innovative technology for traffic data collection. In the field of transportation, Bluetooth sensors are often used as an addition to the established traffic data collection systems to provide road users reliable travel time predictions. The success of the traffic data collection through Bluetooth technology is perhaps largely attributed to the increased presence of Bluetooth enabled devices among road users. The Bluetooth wireless technology allows data exchange over short distances using 2.45 GHz radio frequencies (TPA-NA, 2014). Any electronic device such as cellular phone, hands-free systems, portable electronic devices (tablet and/or laptop) etc. equipped with Bluetooth protocol, has a unique electronic identifier called Media Access Control, or MAC ID. After encoding, the MAC ID still remains globally unique and can be utilized to predict traffic related information such as existing and predicted travel times. Bluetooth based traffic sensing devices such as *BluFAX* feature a built-in GPS (Global Positioning System) component for location and common time referencing. It also has an integrated cellular modem and a class III Bluetooth wireless radio which provides a detection range of 333 feet. In its simplest form, the BTMS calculates travel times by matching the MAC ID emitted from Bluetooth enabled device from a vehicle passing two successive detection stations. The distance between the two successive BTMS stations is known beforehand and the time difference between the matched MAC IDs is used to calculate travel time and and travel speed of the moving vehicle as depicted in Figure 4.

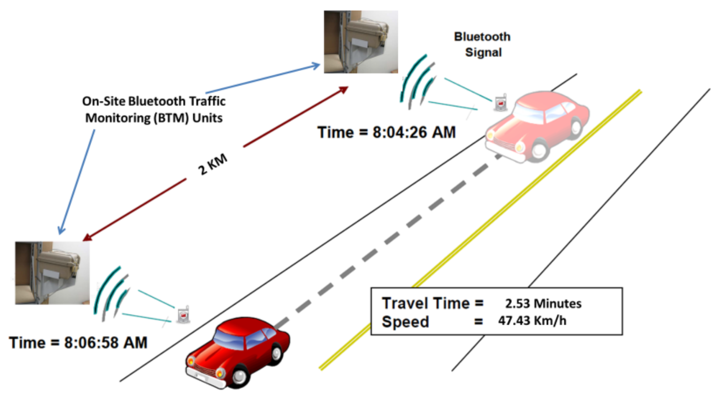

Figure 4. The schematic of Bluetooth data collection (Adapted from Traffax Inc. 2014)

To process the raw data, BTMS is equipped with traffic analysis software which provides a user interface. The interface is developed to match, filter and calculate travel times and speeds derived from the BTMS. BTMS relatively requires low power for its operation and therefore can be powered by environmentally friendly solar energy panels.

Bluetooth sensor technology is also increasingly used in Origin-Destination (OD) studies involving large scale road networks (Blogg et al. 2010). Both RTMS and BTMS are very competitive in providing cost effective solution for monitoring and collecting road traffic data (Middleton 2007; Parma et al. 2013). Table 1 provides a comparison of the functional capabilities of RTMS and BTMS.

Table1. Comparison of Functional Capabilities of Advanced Non-Intrusive Sensor Technologies

Parameter	Sensor Technology	
	Autoscope G4 RTMS	Traffax -BluFAX
Volume/Count	☑	☑ (approximation)
Speed	☑	☑
Occupancy	☑	☒
Vehicle Classification	☑ (6 Classes)	☒
Direct Weight Measurement	☒	☒
Lane Coverage	Up to 12 lanes	Up to 8 lanes
Communication	☑ (5 Modes)	☑
Travel Time	☑	☑
OD Information	☑	☑
Turning Movements	☑	☑

Proposed Framework for Field Testing

A data collection system is being considered by the Cross-Border Institute of the University of Windsor to collect traffic information about trucks crossing the Ambassador bridge between Canada and the United States and vice versa. Developing a robust traffic data collection system requires setting up advanced non-intrusive technologies such as BluFAX and *Autoscope-RTMS G4* data collection systems in the field. It also entails conducting field tests to evaluate the accuracy of the collected information. The functional specification criteria for the field testing require the RTMS to be calibrated at an accuracy of ±10% for both speed and counts. On the other hand, the detection accuracy of Bluetooth technology will be specified at ±15% to ±20% and will be subjected to location shifting to determine the optimal location. Many systematic and random errors along other factors affect the detection of MAC ID of an electronic device present in the vehicle passing a test location (Blogg et al. 2010). The calibrated accuracy levels for both systems will be validated through observed traffic conditions on the ground and the performance of the two systems will be evaluated under various constraints and environmental conditions.

The approaches to the Canadian Custom Plaza (i.e. two entry points and one exit point) will be equipped with both *BluFAx* and *Autoscope- RTMS G4*. A signalized intersection facilitating both in-bound and out-bound traffic to the custom plaza will also be equipped with the two systems as shown in Figure 5.

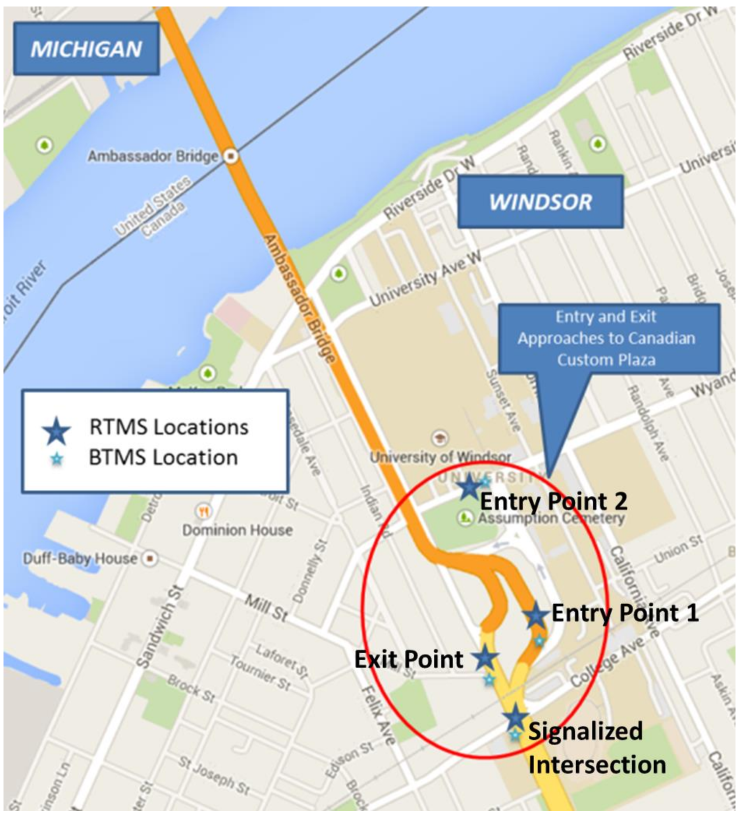

Figure 5. Proposed Test Locations of RTMS and BTMS Installation

The data collected from RTMS and BTMS can be used to develop micro-simulation models for analyzing and predicting the cross-border travel time. The data collected at the signalized intersection can be used to evaluate changes in signal timing plan to minimize control delay at the intersection. Furthermore, the data can also be used for Origin-Destination (OD) estimation to develop *Trip Generation* models for the region.

Excepted Results

The overview suggests that non-intrusive traffic detection systems improve upon the traditional methods by offering a more full-bodied data set beyond the traditionally collected volume and speed parameters. It is expected that *Radar Traffic Monitoring System (RTMS)* would provide reliable estimates of counts, vehicle classifications and average speed on the targeted cross-border corridor. Also, it is expected that the data collected through *Bluetooth Traffic Monitoring Sensor* technology will have a high level of accuracy and will reflect the true extent of variability of speed distribution and travel time and peak hour congestion.

Acknowledgements

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Bibliography

Blogg, M., Semler, C., Hingorani, M., & Troutbeck, R. (2010). Travel Time and Origin-Destination Data Collection using Bluetooth MAC Address Readers. Australasian Transport Research Forum 2010 Proceedings, 2010.

City of Windsor (2014). Windsor/Sarnia Border Advisory System Project.

http://www.citywindsor.ca/cityhall/City-Council-Meetings/
Image Sensing Systems, Inc. (2013). RTMS User Guide. PN A900-1090-1 Rev.D.
Leduc, G. (2008). Road Traffic Data: Collection Methods and Applications. Working Papers on Energy, Transport and Climate Change JRC Technical Notes.
Middleton, D., Parker, R., & Longmire, R. (2007). Investigation of Vehicle Detector Performance and ATMS Interface. Texas Transportation Institute. 0-4750-2.
Middleton, M., Gopalakrishna, D., & Raman, M. (2003). Advances in Traffic Data Collection and Management. Texas Transportation Institute, Cambridge Systematics, Inc.
Parma, K., Koprowski, Y., & Zhang, W. (2013). Origin-Destination and Travel Time Measurement Using Bluetooth Technology: Results and Lessons Learned. ITE Technical Conference and Exhibit.
TPA-NA (2014). TPA North America Inc. Traffic Monitoring System.
http://tpa-na.com/traffic_monitoring.html
Traffax Inc. (2014).User's Manual: Bluetooth Traffic Monitoring Equipment Operating Instructions, December, 2011.
Vandervalk-Ostrander, A. (2009). AASHTO-Guidelines for Traffic Data Programs. American Association of State Highway and Transportation Officials.
Versavel, J. (2007). Traffic data collection: quality aspects of video detection. Proceedings of TRB 2007 Annual Meeting, CR-ROM.