UNIVERSITY OF WATERLOO
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ESTABLISHING INTELLIGENT TRANSPORTATION SYSTEMS PERFORMANCE MEASUREMENT

Ministry of Transportation Ontario
Toronto, Ontario

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Dear Ms. Jarvie:

The title of this report is "**Establishing Intelligent Transportation Systems Performance Measurement**". This was prepared as my 1A term work report for the Ministry of Transportation Ontario, Intelligent Transportation System (ITS) section. This is my first work report. The purpose of this report is to establish performance measures to find project results and identify project benefits.

The Ministry of Transportation Ontario (MTO) is responsible for moving of people and goods across the province. Intelligent Transportation System (ITS) is a section of the MTO. Intelligent Transportation System (ITS) can help deliver an integrated transportation network by using new advanced technologies such as computers, communications and sensors.

I was employed in the Intelligent Transportation System section. The current ITS section head is Fabio Saccon. He manages ITS projects and maps out the ITS strategic plan.

This report was written entirely by me and has not received any previous academic credit at this or any other institution**.** I would like to thank Mr. Fabio Saccon and Mr. Ataur Bacchus for providing me with valuable advice and proofreading my report.

Sincerely,

Hao Xiang Qian
[redacted]

Table of Content

Summary iv
1.0 Background Information 1
2.0 Introduction 2
3.0 Condition Monitoring and Forecasting 3
3.1 Measuring Vehicle Speed and Travel Time 3
3.2 Using Global Positioning System 3
3.3 Field Personnel 5
3.4 Measuring Greenhouse Gas Emissions 6
4.0 Traveller Information 6
4.1 Customer Survey Questionnaire 7
5.0 Traffic Management 9
5.1 Arterial Road Congestion 9
5.2 The Borders 9
5.3 Borders and the Environment 10
5.4 Queuing-Time Modelling 10
6.0 Incident Management 11
7.0 Smart Work Zone and Commercial Vehicle Operations 12
8.0 Conclusion 14
9.0 Recommendations 15
9.1 Management 15
9.2 Technical 15
Reference 16
(Nov. 2007). *Framework for the Application of Intelligent Transportation System (ITS) for Traffic Management.* Markham, Ontario, Canada: Delcan. 17
Appendix B- ITS Deployment Overview 18

List of Figures and Tables

Figure 1 Vehicle speed data on a highway 4

Figure 2 Sample vehicle speed graph 5

Table 1 Survey questionnaire..... 8

Table 3 Sample collision rate on a highway- Measure of the fatality, injury and collision rates per 100 million vehicle kilometres annually 12

Summary

Intelligent Transportation System (ITS) covers a broad range of diverse technologies applied to transportation to make the transportation network safer, more efficient, more reliable and more environmentally friendly, without necessarily having to physically alter existing infrastructure.

This report contains recommendations and suggestions to determine the performance measurements on the Intelligent Border Crossing (IBC) project in Windsor Region. The IBC project uses ITS applications.

The purpose is to discover performance measurement strategies and analyze the recommended strategies.

We are concerned about having scarce evidence and little performance measurements to identify the benefits. In order to provide quality transportation services and perceive border-crossing improvements, we must evaluate the IBC project based on its performance.

A Background Information section provides details about the IBC project. Follow by Introduction, Performance Measurement details, Conclusion and Recommendation.

1.0 Background Information

Traffic volume and congestion have increased significantly at the borders due to rapid increase in trade and personal travel. Therefore, actions must be taken to improve the transportation systems at the borders. The IBC (Intelligent Border Crossing) project is an ITS multi-year deployment plan and a joint initiative between the Ministry of Transportation Ontario and Transport Canada. This plan consists of short-term, medium-term and long-term projects deployment at five different corridors. We will focus on the IBC project deployment near the Windsor Region borders. The main goals of the IBC project are to reduce traffic congestion and greenhouse gas emissions on highways; to enhance safety by informing travellers well in advance about traffic conditions. Various elements which together make up the ITS Tool Kit, are considered. These elements are: **Conditioning Monitoring and Forecasting,** the collection of current information and prediction of future trends on highways using CCTV Camera and Inductive Loops; **Traveller Information,** the provision of current and forecast conditions to travellers through Websites, Dynamic Message Board (See Appendix) and the Media; **Transportation Management,** management of traffic movements through traffic control technologies such as time signals; **Incident Management,** the detection and response to traffic incidents; **Smart Work Zones,** traffic management around construction sites**;** **Commercial Vehicle Operations,** the sharing of commercial vehicle data and tracking of information.

This Tool Kit provides valuable framework for the ITS deployment. Under each element, projects will be planned and technologies will be deployed.

2.0 Introduction

The Intelligent Transportation System established ten years ago with new and innovative technologies and devices implemented on highways. In the province of Ontario, we deployed many ITS related projects, but we lack of information to determine their performance. As for the IBC project, which is nearing completion, ideas of performance strategies need to be established and discussed. We, the ITS department in the Ministry of Transportation must be prepared to present in details if the stakeholders, current managers and executives require this information based on performance measurements and the benefits traveller received from the IBC project in Windsor border. Currently, there is no standard ITS performance measurement available around the world. In order to accomplish this goal, many unique and effective ITS performance strategic plans and ideas must be proposed and specified. After that, actions must be conducted carefully. Under each element from the ITS Tool Kit we will initiate different strategies and ideas for the performance measurement. Therefore, the results obtained from these performance measurements will vary in each element.

These new strategies and ideas are listed under each element.

3.0 Condition Monitoring and Forecasting

Conducting performance measurements on implementation of ITS projects will clearly present the performance evaluations. The performance strategies need to be considered carefully. These essential strategies will measure the ITS application performance under condition monitoring and forecasting.

3.1 Measuring Vehicle Speed and Travel Time

Condition monitoring and forecasting acquires a detailed knowledge of the condition on the roadway network and the vehicles and cargo travelling on it. Thus, the strategies imply finding the vehicle speed, travel time and occupancy data on highways. These data must be measured before and after the ITS implementation. In order to obtain all these data, automated devices to detect the vehicles and calculate the average vehicle speed and time are required on highways. Installing inductive loop sensors (See Appendix) on the asphalt would accurately detect the vehicle speed, travel time and occupancy. Inductive loops, copper wires embedded in the asphalt can measure the vehicle speed, volume, occupancy and classification. However, it would be expensive to implement inductive loops along Highway 401 in the rural region from London to Windsor because of the long distance. Therefore, new strategies are needed to track down vehicle information and detect traffic conditions along Highway 401 in the rural region.

3.2 Using Global Positioning System

Probe vehicles and vehicles equipped with Global Positioning System (GPS) are able to detect vehicle information and condition on highways. Thus, before and after the

implementation of ITS, the vehicle speed, travel time and occupancy data are collected and evaluated. However, privacy needs to be addressed with the individuals. The Ministry of Transportation and individual drivers who possess GPS must negotiate to consolidate an agreement, which allows the Ministry to obtain private vehicle's GPS information. A daily vehicle speed data recorded on a particular highway in British Columbia is given below:

British Columbia Ministry of Transp

Daily Speed Distribution for 03/31/2007 through

	Roadway	Neg DIR	Pos DIR	Neg 1	Pos
0-32.10	0	0	0	0	
32.20-40.10	4	2	2	2	
40.20-48.10	21	7	14	7	
48.20-56.20	121	59	62	59	
56.30-64.20	459	222	237	222	
64.30-72.30	716	316	400	316	
72.40-80.30	632	285	347	285	
80.40-88.40	321	119	202	119	
88.50-96.40	96	41	55	41	
96.50-104.40	28	9	19	9	
104.50-112.50	8	1	7	1	
112.60-120.50	2	0	2	0	
120.60-128.60	0	0	0	0	
128.70-136.60	0	0	0	0	
136.70-144.70	0	0	0	0	
144.80-999	3	2	1	2	
Average	71.8	71.3	72.1	71.3	
Median	70.7	70.1	71.2	70.1	
85th %tile	82.4	80.9	83.3	80.9	
% over 55	93.9	93.6	94.2	93.6	
% over 60	74.9	72.7	76.6	72.7	

Figure 1 Vehicle speed data on a highway

3.3 Field Personnel

Another method of collecting the vehicle speed and travel time is engaging people to carefully and accurately count vehicles on arterial roads, where ITS is installed. They record the speed of each vehicle and the numbers of vehicle passed by at various time periods. One person stands at one corner of an intersection and counts the number of vehicles pass by. Similar to data detection and collection from sensors, the data will be detected and collected by people. All these data will record on the graph. However, this method will begin to conduct once the installation of ITS application is complete and for a short period of time only. Here is a sample of hourly average vehicle speed data recorded from both methods. (Note: values are not accurate)

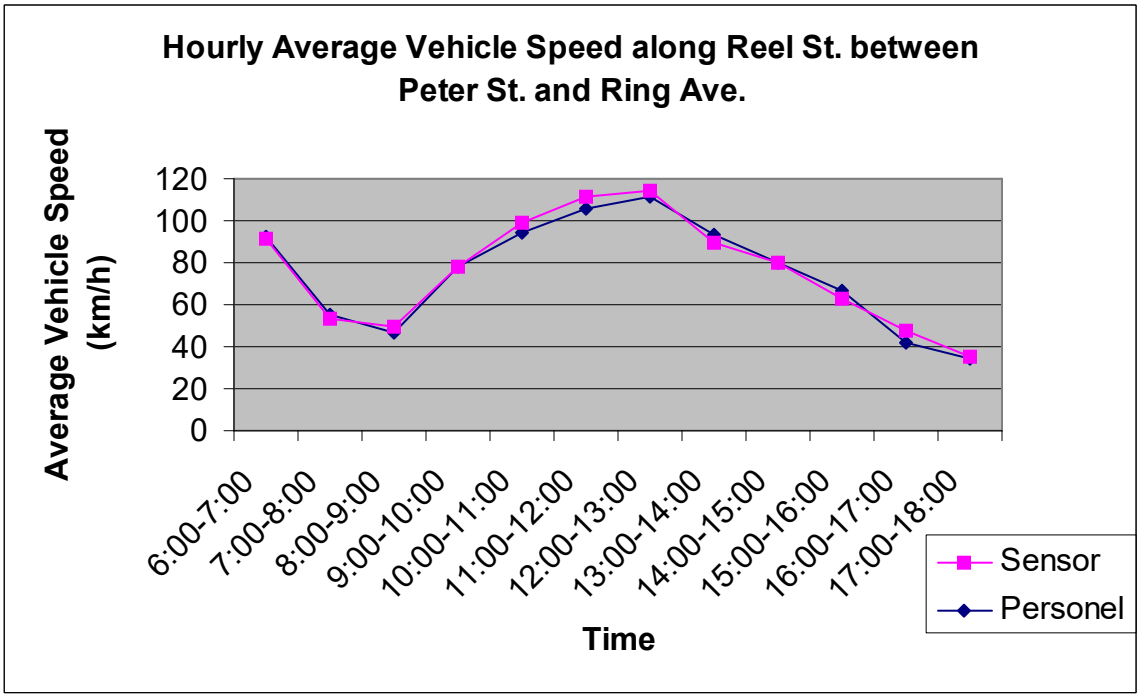

Figure 2 Sample vehicle speed graph

As a result, the comparison between the two graphs on the same arterial road from these two different data collection methods determines the accuracy of the sensors. Another benefit for using both methods confirms the accurate information of the data range. If the two results are different, we carefully calculate the average from the two graphs to determine the final result. The formats of inputting data are tables, charts and graphs. It depends on the data type.

3.4 Measuring Greenhouse Gas Emissions

The reduction in greenhouse gas emissions on highways is the goal to achieve after ITS project completion. Vehicle transportation is the major polluter that causes greenhouse gas emissions. We must coordinate with the Ministry of Environment and measure the greenhouse gas emission rate on highways before and after ITS implementation. This gives us clear and better indication on how the performance of ITS applications creates impact on the environment.

4.0 Traveller Information

Traveller Information is created and distributed to drivers in variety of forms, applications such as the Dynamic Message Board which give drivers advance warning on the traffic conditions ahead, and website which provide up to-date traffic condition and incident information for the corridors and border crossings.

Identification of traveller types is the first step. Each traveller travels for different purposes such as business trips and casual trips. The only method to receive effective

results must be getting valid feedbacks from the travellers. Therefore, in order to provide customer satisfaction after the implementation of IBC project, travelers should be surveyed.

4.1 Customer Survey Questionnaire

The measure of customer satisfaction towards the ITS applications provide constant and up to-date results. After several months of ITS project completion, a survey questionnaire must be written and distributed to various public locations. Drivers should be encouraged to fill out this questionnaire in order to obtain constant feedbacks. The questions on the survey must be carefully considered so that the feedbacks from the drivers will clearly determine whether the benefits are obtained or not. A sample of the survey questionnaire is shown below:

Please circle the best answer. (You don't have to circle all the questions)				
What's your travelling type?	Business Trips	Casual Trips	Other	
How often do you cross the borders in Windsor?	Once or twice per week	Once or twice per month	Once or twice per year	
1. Describe the accuracy of the information on the message boards	Poor	Satisfactory	Good	Excellent
2. Do you find message boards information useful?	Never	Sometime	Most of the time	All the time

3. If you check the traffic condition on the highway before you start your trip, describe the accuracy of the information	Poor	Satisfactory	Good	Excellent
4. Compared to last year, are your trips from within Windsor to the border taking less time, same or more?	Less	Same	More	
5. Compared to last year, is your travel time from outside Windsor to the border more consistent, same or less?	Less	Same	More	
6. Which of the following traveller information services do you regularly use?	Website	Kiosks	Dynamic Message Board	511 and Wireless phone services

Table 1 Survey questionnaire

The survey questionnaire will be placed in the rest stations and kiosks along highways near the Windsor borders. Travellers are asked to fill them out as best as they can. Travellers may even fill the survey questionnaire on the website. Each week, a staff will collect these survey questionnaires in all areas, evaluate them and record the results on the data. At a certain time period, we look at the results in percentage value in each

question and determine whether the benefits have reached or not. Of course, we will distinguish results according to each travel types and travel occurrences.

5.0 Traffic Management

Transportation Management strategies such as adaptive traffic signal controls that can change the signal timing at key intersections and use of queue warning systems near the border based on traffic conditions. By using ITS applications, they improve mobility benefits by reducing traffic congestions for the cars and trucks. On an urban arterial road where ITS applications are installed, gathering data such as vehicle speed and travel time provide satisfactory results. Sensors such as inductive loops are used to detect and collect the data.

5.1 Arterial Road Congestion

The purpose of collecting data is to measure the percentage time that urban roads are experiencing congestion. An urban road network can be divided into segments and the amount of time each segment experiences congestion can be used as a comparison measure before and after ITS deployment. “Congested” can be defined as for example, speeds less than 20 kilometer per hour below posted speed limit.

5.2 The Borders

Sensors and algorithms can estimate border wait times. Dynamic Message Boards are used to display conditions at the border in order to verify the accuracy of the border wait

time messages, actual wait times can be collected by field personnel, and compared with the messages from the border wait time measurement algorithms.

At the borders, measuring border crossing wait time for both cars and trucks demonstrates an essential performance measurement. Once cars and trucks enter the booth, that is the end of their border waiting-time. The border waiting-time starts to count when they stop in front of the booth.

5.3 Borders and the Environment

The greenhouse gas emissions on highways and arterial roads create negative impacts for the environment. ITS applications can reduce the greenhouse gases by smoothing the traffic flows as well as decreasing the border-wait time. At the border gate, the amount of border-wait time for vehicles has a proportional relationship with the amount of greenhouse gas emissions. Hence, we need to coordinate with the Ministry of Environment and detect the greenhouse gas emissions rate at the border before and after ITS implementation. One important issue for finding the data is that the increasing number of hybrid cars. Therefore, the result will vary depending on other factors. If this occurs, finding results that affect ITS might be difficult which in the end becomes vague measurements.

5.4 Queuing-Time Modelling

Once the IBC projects are completed, evaluating queuing-time for vehicles approaching the borders along highways uncovers another result. The queuing-time for average vehicles at certain time period varies significantly. For example, there are more queuing

vehicles during the peak hours. However, calculating queuing-time needs to be researched. Innovative ideas such as queuing system modelling, clear diagrams and charts are required for this research project. Hopefully, in the future, we will be able to simulate a queuing time model and calculate the average vehicle queuing time at intersection on highways. This will be a break-through achievement in terms of finding the results of traffic congestion on highways. A sample of simple model of a queuing system at intersection **Highway 427 along Highway 401** is shown below: (Note: the numbers are incorrect)

Time	AR (Ramp, Hwy427)	AR (Highway, Hwy 427)	PR	QR	Total Delay
12:00	5	10	10	5	25
12:05	2	10	10	7	35
12:10	0	20	15	12	60

AR-Arriving Rate, PR-Processing Rate, QR- Queuing Rate,
Total Delay=QR*Time(5 Minutes)
Table 2 Queuing-time model

The challenge would be implement a queuing-time model that connects all the intersections together (a succession of queues) by using real time data values.

6.0 Incident Management

Information is shared with emergency response agencies to quickly detect, manage and clear collisions and other incidents that can cause serious delays and safety concerns for other motorists approaching the border. The emergency services, police officers and ambulance must carry out uniform actions and decisions in incident management. Installing ITS applications is to provide safety for the vehicles on highways. Our goals are reducing the collision rate and preventing severe injuries.

It is mandatory for us to measure the fatality, injury and collision rates (the number of fatalities, injuries, collisions per 100 million vehicle kilometre) travelled before and after the implementation of ITS.

An example of the data chart based on collision rate Highway 401 between two interchanges: (Note: the data are not accurate)

Year	Target	Actual
2001	1.5	1.64
2002	1.7	1.83
2003	1.6	1.77
2004	1.4	1.68
2005	1.5	1.64
2006	1.7	1.60
2007	1.5	1.57

Table 3 Sample collision rate on a highway- Measure of the fatality, injury and collision rates per 100 million vehicle kilometres annually

We are hoping to get these results as accurate as possible. The Ministry of Transportation must display data on collision rate. If the benefits are achieved that means the numbers from both columns gradually decrease, then ITS applications definitely contribute impact on safety on highways. Also, this brings more satisfaction to the travellers because ITS helps reducing collisions and creating safety on highways.

7.0 Smart Work Zone and Commercial Vehicle Operations

Smart work zone manages and links with the responsibilities of Incident Management and Transportation Management during incidents. We can measure its effectiveness,

especially on Windsor's bridges and tunnels. However, this is a new field and we need to conduct more research.

Obtain results from Commercial Vehicle Operations addresses difficulties.

8.0 Conclusion

Evaluating ITS performance provides a basis for modifying future ITS projects, and technologies to enhance current and future ITS applications on the highway network. The six elements, Conditioning Monitoring and Forecasting, Traveller Information, Traffic Management, Incident Management, Smart Work Zone and Commercial Vehicle Operations support goals for the transportation network, and performance measurements help to gauge how well those goals are met. After all, the ITS program's success must build upon effective ITS project implementation. Smart technologies are deployed on highways to enhance traveller safety and mobility and to reduce congestion and greenhouse gas emissions. Through careful consideration and planning of the IBC project performance strategies, we need to measure the results. Collecting and receiving valid results will provide reliable information to the executive and the ministry on the outcome of ITS. Also, ITS will be able to generate and expand its unique contribution to the transportation network and the public.

9.0 Recommendations

9.1 Management

- Discuss the recommended performance strategies and finalize the plan.
- Once the task starts, keep up-to-date on the process of performance measurement.
- For receiving vehicle information on GPS, negotiate with the private drivers to come up with an agreement.
- Hire staff personnel counting, tracking, and collecting traffic data.
- Set priorities and goals to limit the greenhouse gases emission on highways.
- Evaluate the results and identify whether the benefits reached or not.
- Be ready to prepare the presentation to the Executive in the Ministry.

9.2 Technical

- Research Queuing-Time Modelling.
- Test probe vehicle technology.
- Apply GPS and fully analyze the data.

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Appendix A -Current ITS Technologies

The electrical current causes magnetic field induction. As vehicles pass over the inductive loop, magnetic field changes which detected through the change of loop inductance.

Inductive Loop layout

Provide dynamic messages to travellers. The display message types include traveller information, incident information, safety and public service messages, AMBER alert messages and planned events.

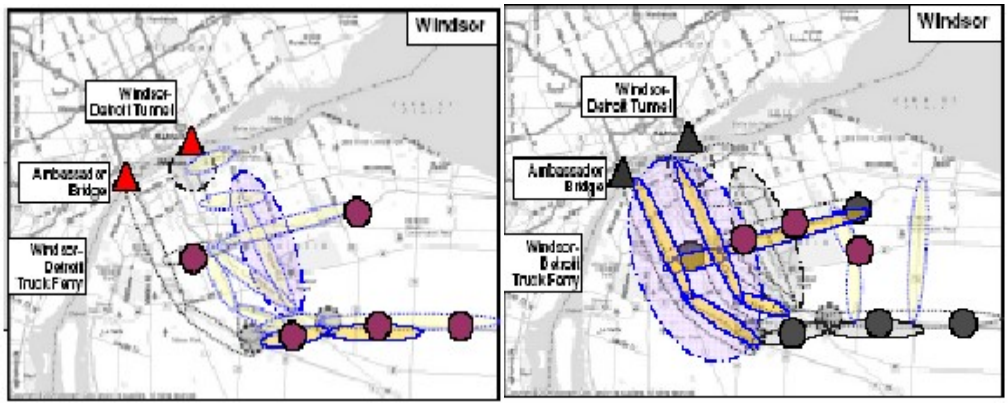
Dynamic Message Sign (DMS)

Monitor and display traffic condition on highways and send video images directly to the traffic operation centre.

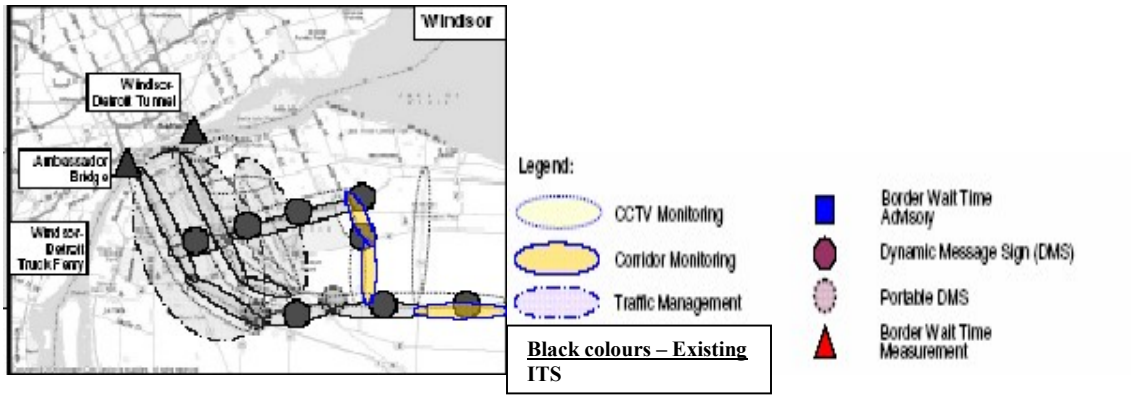
Closed Circuit Television Video (CCTV) Camera

Photo credit:
(Nov. 2007). *Framework for the Application of Intelligent Transportation System (ITS) for Traffic Management.* Markham, Ontario, Canada: Delcan.

Appendix B- ITS Deployment Overview



Short Term **Medium Term**



Long Term

Photo Credit:

- (Sept. 2007). *Action Plan for the Intelligent Border Crossing- Multi-Year Deployment Program.* Markham, Ontario, Canada: Delcan.