IMPROVED ROAD SAFETY THROUGH REAL-TIME ADVANCE WARNING SYSTEMS

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ABSTRACT

Despite significant improvements during the past 20 years, traffic collisions continue to be the biggest transportation safety problem in Canada. Investments in Intelligent Transportation Systems (ITS), including real-time Advance Warning Systems, can help improve safety by informing drivers of unexpected traffic conditions ahead, encouraging them to adjust their vehicle speed, and thereby helping to prevent avoidable collisions.

This paper will examine two case studies were Advance Warning Systems were installed by the Ontario Ministry of Transportation (MTO) on identified freeway sections in Southern Ontario to address current and anticipated traffic safety problems.

In the first case study, a comprehensive traffic study was undertaken to address high collision rates associated with unexpectedly long, standing truck queues on the Queen Elizabeth Way and Highway 405 approaches to the Niagara Region border crossings. The traffic study proposed that a Queue-end Warning System (QWS), designed to inform drivers approaching the end of a vehicle queue, be implemented on these two highway approaches. For each border approach, inductive loop detectors and hybrid dynamic warning systems were install at locations strategically determined to optimize the coverage of the highway approaches. The QWS continuously monitors traffic flows in each of the approach roadway lanes and once a queue is detected, the system automatically activates the warning signs upstream of the end of the queue to warn drivers of the vehicle queue ahead and to be prepared to stop.

In the second case study, as part of the MTO's highway-widening projects, a single high occupancy vehicle (HOV) lane and bypass tunnel were constructed along Highway 404 southbound to westbound Highway 401. The short tunnel (i.e., which is approximately 90 m long) is the end point of the HOV lane, and has a curve to the right that leads traffic to the Highway 401 Westbound Collector. While the tunnel was built to current Ministry standards, the perception of motorists may be distorted or distracted due to the fact that the traffic is travelling from a wide-open roadway to a short enclosed tunnel with a curve, compounded by different light transitions through the tunnel. In order to enhance the safety of motorists approaching the tunnel, an Advanced Warning System (AWS) was deployed to provide advance notice of anticipated ramp queues that can build from the recurring congestion on Highway 401. The system seamlessly integrates detector loop and video image processing vehicle detector technologies to achieve fast and accurate incident and queue detection in all traffic flow conditions. Two dynamic message signs located upstream of the tunnel entrance provide advance appropriate warning messages to drivers.

This paper describes the deployment of these QWS and AWS systems, and provides examples of how ITS can be used to dynamically detect unexpectedly slow vehicles and queues and provide accurate and timely advance warning to drivers of unexpected traffic conditions ahead, encouraging them to adjust their vehicle speed, and thereby reducing rear-end collisions and improving motorist safety.

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INTRODUCTION

Despite significant improvements during the past 20 years, traffic collisions continue to be the biggest transportation safety problem in Canada. Investments in Intelligent Transportation Systems (ITS), including real-time Advance Warning Systems, can help improve safety by informing drivers of unexpected traffic conditions ahead, encouraging them to adjust their vehicle speed, and thereby reducing rear-end collisions and improving motorist safety.

The following two case studies, which were installed by the Ontario Ministry of Transportation (MTO), provide examples of how ITS can be used to dynamically detect unexpectedly slow vehicles and queues, and provide accurate and timely advance warning to drivers of unexpected traffic conditions ahead:

- Queue Warning System (QWS) on the Queen Elizabeth Way (QEW) and Highway 405 approaches to the Niagara Region border crossings; and

- Automated Advanced Warning System (AWS) on the Highway 404 high occupancy vehicle (HOV) lane and bypass tunnel.

QEW / HWY 405 QUEUE WARNING SYSTEM

In recent years, whenever the Peace Bridge Authority and/or the Niagara Falls Bridge Commission were operating at capacity to process commercial vehicles through the US Customs, truck queues of increasing length would develop on the approaches to these respective Niagara Region border crossings. Queues in the order of 3 km to 6 km were reported on the Queen Elizabeth Way (QEW), resulting in the blockage of up to five interchanges; while queues in the order of 2 km to 4 km were reported on Highway 405.

A comprehensive traffic study was undertaken by the MTO to address safety concerns regarding high collision rates, including fatal collisions, associated with the unexpected truck queues on the travelled lanes of these limited access highways. The safety concerns were compounded by the high speed differentials between the normal bus and passenger car traffic and the standing truck queues. The traffic study identified that tactical measures were needed on these roadways to address these safety concerns. The proposed solution was the implementation of a queue warning system, designed to provide advance warning to motorists when they are approaching the end of a vehicle queue, and thereby help to prevent avoidable collisions.

Overview of Queue Warning System

In March 2003, the proposed Queue Warning System (QWS) was fully commissioned on each of the two approaches to the Niagara Region US – Canada border crossings. The system covers approximately 6 km along the QEW, and 4 km along Hwy 405, upstream from the respective border crossing points.

The objective of the QWS is to provide accurate and effective warning messages to motorists of any potentially slow moving and/or stopped vehicles ahead. This is accomplished by automatically identifying slow moving and stopped vehicles in real-time, and then displaying an appropriate warning message on dynamic signs to the inform drivers when they are approaching the end of a vehicle queue.

On each approach, inductive loop detectors and QWS signs were install at locations strategically determined to optimize the coverage of the highway approaches. The QWS continuously monitors traffic flows in each of the approach roadway lanes, and once a queue is detected, the system automatically activates the warning signs upstream of the end of the queue to warn drivers of the vehicle queue ahead and to be prepared to stop.

A typical equipment layout for a single QWS 'node' is shown in the Figure 1 below:

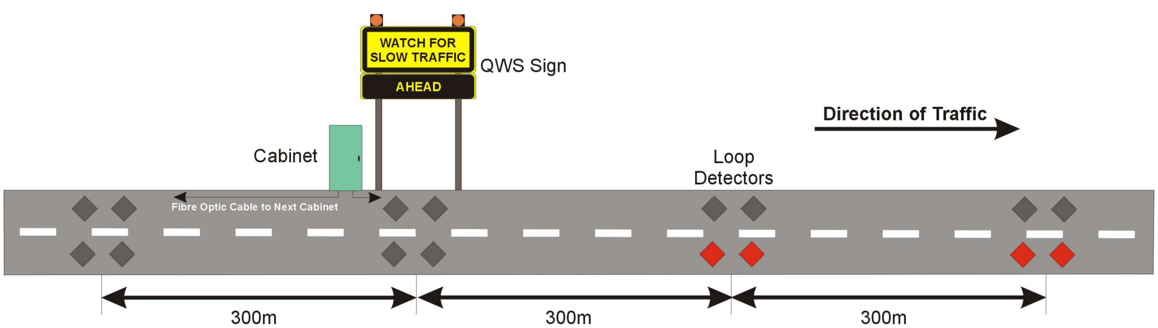

Figure 1 Typical Equipment Layout for QWS Node

Generally, each QWS node monitors a maximum of 4 detector stations. Loop detectors will be installed in the roadway adjacent to each QWS sign location, as well as 300 m upstream, 300 m downstream, and in some cases 600 m downstream. The 300 m spacing for some loop locations may be adjusted to avoid traffic weaving areas.

Each loop detector station will typically have a 'speed detection' configuration, with a pair of diamond-shaped 1.8 m x 1.8 m detector loops installed in each lane to be detected.

The QWS sign display, shown in Figure 2, will consist of a combination of static and dynamic messages with a pair of flashing beacons. The dynamic portion of the sign will show one of the following messages:

- BLANK (with flashing beacons on or off);
- AHEAD (with flashing beacons on);
- NEXT 1 KM (with flashing beacons on); and
- NEXT 2 KM (with flashing beacons on).

Figure 2 Typical QWS Sign

The message to be displayed will be selected by the QWS node based on the location of the detected end-of-queue relative to the sign location. For example, if the queue is downstream from the sign, the sign will show "NEXT 1 KM" or "NEXT 2 KM", as appropriate. If the sign is 'within' the vehicle queue, the dynamic portion of sign will show 'BLANK' with the flashing beacons on.

As illustrated in Figure 3, a cabinet will be placed in the right-hand side highway right-of-way just upstream of each QWS sign, such that the sign dynamic displays can be viewed from the cabinet. The cabinets will house the controllers used for loop counts and system control. The controllers will be inter-connected via fibre optic comm. cable (to be confirmed), and each controller / cabinet will serve as a node on the QWS network.

Figure 3 Typical QWS Cabinet and Warning Sign Site Installation

To determine whether a dynamic queue warning is required, the queue detection algorithm compares and evaluates upstream and downstream traffic parameters collected by the vehicle detector stations – namely, volume, occupancy and speed. Figure 4 summarizes the combinations of volume, occupancy and speed used to identify a queue. In general, detection of low vehicle speed and/or high detector occupancy indicates slow moving traffic and/or a queue, whereas detection of high speed and/or low occupancy indicates no congestion. In Figure 4, 'Levels' 9 to 12 apply in situations where one loop in a traveled lane has failed and vehicle speed data is therefore not available.

Parameter	**Level**	1	2	3	4	5	6	7	8	9	10	11	12
Volume	High	•	•	•	•					•	•		
	Low					•	•	•	•			•	•
Occupancy	High	•	•			•	•			•		•	
	Low			•	•			•	•		•		•
Speed	High	•		•		•		•					
	Low		•		•		•		•				
Admissible?		√	√	√	x	x	√	√	√	√	√	√	√
Queue / No Queue		NQ	Q	NQ			Q	NQ	Q	Q	NQ	Q	NQ

Figure 4 Summary of QWS Detection Algorithms

Delcan was retained to design and build the QWS infrastructure including communications, power, central computer system and other field equipment; to develop the QWS algorithm and software; and to integrate and commission the system as well as the contract management.

Significant Development and Innovations

Since QWS is a stand-alone system without operators, the system must be highly reliable and trustworthy. The system was designed and tested with very strict requirements such as high detection rate, low false alarm rate, fast response time and high system availability.

The spacing of the QWS signs and detector loops is strategically determined to optimize the coverage of the highways based on the highway geometry, sign visibility and existing structures.

The system was built with features and logic that provide fail-safe operations designed to ensure that the system is able to be self-managed and operate in a continuous and credible manner. Such features include:

- *Use of Proven Technologies* – Field equipment was carefully chosen to ensure the high liability of the equipment. Hybrid signs and inductive loop detectors are the proven and accepted technologies for the QWS.

- *Design of the Warning Signs* – The QWS signs are hybrid signs that contain both static and variable message components, as illustrated in Figure 2. The static sign "WATCH FOR SLOW TRAFFIC" message (located above the variable message sign) continuously warn drivers of potential danger ahead. On the occasion when the variable sign is not activated or has failed, the static sign remains effective; reminding motorists to stay alert and watch for slow traffic conditions ahead. The variable message component provides real-time dynamic information with respect to the end position of slow traffic or a vehicle queue, relative to the location of that sign. This real-time slow traffic / queue-end position information gives the drivers an accurate picture of the traffic conditions that will be encountered downstream. The two flashing beacons installed above the static sign also help to attract motorists' attention to the warning sign when slow moving traffic or a queue is detected.

- *Data Collection for Queue Detection* – For real-time data collection, a pair of diamond-shaped loops is installed in each lane of each detector station. The pair of inductive loops is another fail-safe facility. Speed data collected from the double loop is used to detect and clear the queue formation. If one of the loops fails, the detector system loses the capability to measure the vehicle speed. Nonetheless, the remaining loop can measure the traffic flow occupancy and thereby still provide queue detection and clearance capabilities.

- *System Operational Fallback Mode* – During communications or power failures, the system is capable to degrade its mode of operations from a co-ordinated network-wide mode to a local mode where the local operations can be maintained by each QWS node.

The software was designed to be flexible, reliable and intelligent. Enhanced features and functions were integrated in the system to provide accurate and confirmed identification of the end-of queue location. These features include:

- *Rationale Matching Scheme* – The QWS algorithm employs a Rationale Matching Scheme with three major traffic parameters (i.e., volume, occupancy and speed) for automatic queue detection and clearance. Using "Worst Lane" and "Lane-by-Lane" rules, the algorithm identifies the queue-end location farthest from the border crossings among travelled lanes, and activates the corresponding QWS signs with flashing beacons in a co-ordinated manner. Based on pre-determined distance "x" to queue-end location displays, the system automatically chooses the appropriate messages to be displayed on the VMS to alert the motorists whenever a queue has been identified. The QWS algorithm is designed to detect all types of queue conditions, especially truck queues.

- *Queue Tracking System* – On the road, a traffic queue can significantly expand and/or shrink over time. The Queue Tracking System is used to track and handle the compression and expansion of a queue. In addition, faulty detectors can impact on the performance of the system by causing a 'break' to appear in the queue. Therefore, an "implied queue" technique is employed to fill the gap between the detected queues so that a more realistic picture of the vehicle queue formation and clearance can be determined.

- *Persistence Check* – In order to maintain the flexibility and optimum performance of the system, the system allows the user to configure the parameters that control the operation of the system. The parameters were configured and fine-tuned based on the traffic patterns, driver behaviour, and the geometry of the highways. The Persistence Check is applied on the real-time traffic data to verify the occurrence of a queue. These features have effectively improved the ability of QWS to detect and clear the presence of a real queue.

To further enhance the reliability of the system, the QWS is also equipped with a paging service that reports any system problems (i.e., power, communications and equipment failures, and other critical events). The MTO's maintenance crew is paged and notified when the system detects a problem; thereby enabling the problem to be resolved in a quick and efficient manner.

System Fine Tuning

The QWS is a highly flexible and configurable system. It allows the user to configure and fine tune the system parameters (e.g., parameter threshold values, persistence cycles, loop configurations, etc.) that control operation and sensitivity of the system based on the local traffic patterns, driver behaviour, and geometry of the highway to achieve optimum system performance. For example, the recording of queue formation and dissipation by the system were greatly improved by increasing the number of persistence cycles in the queue clearing module.

End Results

The QWS was a pilot project and a new innovative system for the MTO. Site acceptance tests and subsequent anecdotal experience shows that the system operates reliably and consistently, and has been influential in providing accurate and timely advance warning to drivers of unexpected slow traffic conditions ahead, thereby reducing rear-end collisions and improving road safety.

Based on the successful performance of the system, the MTO:

- Have recently expanded the QWS another approx. 4 km to provide full coverage of Hwy 405 upstream to the interchange with the QEW;
- In 2008, are planning to expand the QWS along the QEW upstream to the interchange with Hwy 405; and

are currently proceeding to install similar systems at other border crossings including:

- Highway 402 in Sarnia, Ontario; and
- Thousand Islands in Eastern Ontario (i.e., currently in the Design Stage).

HWY 404 HOV LANE AND BYPASS TUNNEL ADVANCED WARNING SYSTEM

As part of the Ministry of Transportation's highway-widening projects in 2003-2005, shown in Figure 5, a single high occupancy vehicle (HOV) or carpooling lane and bypass tunnel (BT) were constructed along Hwy 404 Southbound from Van Horne Avenue to Hwy 401. This new HOV lane is built to encourage Toronto's daily commuters to carpool and use buses. The lane usage is strictly re-enforced by the traffic patrol to ensure that only HOV vehicles (e.g., cars with more than two occupants, buses, etc.) use the lane. (See Figure 6.) The lanes are intended to provide fast, reliable travel for HOV users at any time of the day, especially during peak travel periods when other lanes can be congested. The HOV lanes and tunnel were officially opened on December 13, 2005.

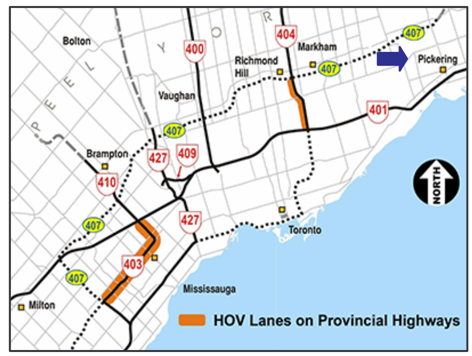

Figure 5 Location Map

Figure 6 HOV Sign

The tunnel is the end point of the Southbound Highway 404 HOV lane. The entrance of the tunnel is located south of Sheppard Avenue. The tunnel has a curve and leads traffic to the Hwy 401 Westbound Collector. The tunnel was built to current Ministry standards, which required an extra wide right shoulder for adequate sight lines and stopping distances at the design speed of 80 km/h. The posted speed limit of 40 km/h provides an ample safety factor. However, the perception of motorists may be distorted or distracted due to the fact that traffic is travelling from a wide-open roadway to a short enclosed tunnel (i.e., approximately 90 m long) with a curve to the right, compounded by different light transitions through the tunnel. In order to enhance the safety of motorists approaching the tunnel, an advanced warning system was developed to provide advance notice of slow or stopped vehicles in the tunnel (e.g., due to anticipated ramp queues building from recurring congestion on Hwy 401).

Overview of Advance Warning System

As illustrated in Figure 7, the effective control area of the Advanced Warning System (AWS) is approximately 400 m, including the 90 m tunnel. The objective of the system is to detect incidents and queues along the HOV lane leading into and out of the tunnel in an accurate and timely manner (i.e., with a targeted response time of less than five seconds). When a traffic problem is detected, the system automatically (i.e., without requiring confirmation from an operator) displays warning messages on upstream Variable Message Signs (VMSs) to alert approaching motorists. Using the same detection algorithms, the system also automatically removes warning messages within five seconds of detected free flow conditions.

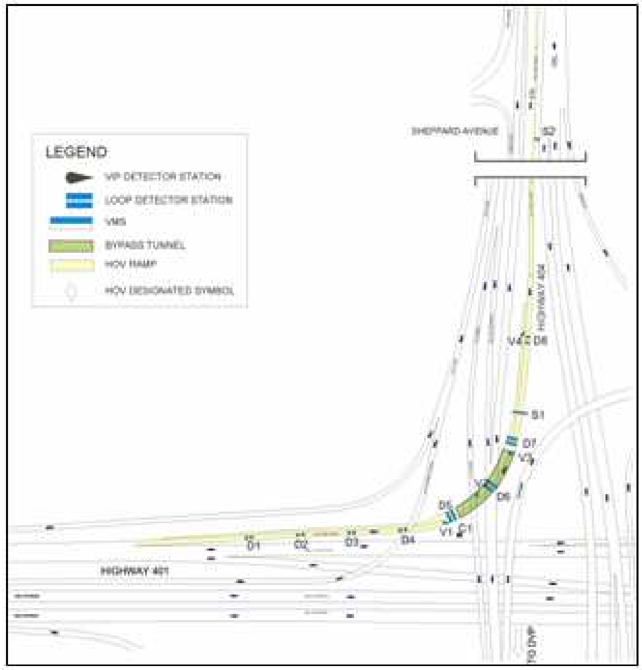

Figure 7 AWS Equipment Layout

Unattended automated warning systems require high reliability and durability (e.g., with built-in diagnostics and logging, in a fully redundant, hot-standby computer configuration). The AWS is designed such that equipment in the field is capable of independently performing all functions, even when the communications to the Ministry's COMPASS Control Centre has failed.

Field Equipment

The AWS is supported by two distinct vehicle detection technologies to ensure the full visibility and detection coverage within the entire scope area. The Ministry installed eight double-loop vehicle detector stations at 50-100 m spacing, and a Video Imaging Processing (VIP) detection system with four fixed colour CCTV cameras with wipers. The VIP detection system is not only used as a traffic incident detection tool, but also as CCTV cameras for operator traffic surveillance. Figure 8 shows a video recorded during a detected incident in the tunnel. Each camera video is FM-modulated to the Ministry-owned single-mode fibre back to the Ministry's Toronto COMPASS Control Centre at located at Hwy 401 and Keele Street.

Figure 8 VIP Video Playback

The system has two NTCIP compliant Variable Message Signs (VMSs) (i.e., a full matrix sign with 3 lines by 12 characters support) installed to forewarn the upstream vehicles of any queue and/or slow moving vehicle(s) approaching and/or within the tunnel. The first sign is installed at the entrance of the tunnel and the second sign is on Hwy 404 Southbound, north of the Sheppard Avenue overpass.

Two ATCs (Advanced Traffic Controllers) were installed in the field. Both controllers are concurrently connected to the central COMPASS system, all loops, VIP cameras and other ancillary equipment. This provides a highly reliable and independent backup facility for the system. One ATC controller is the main controller, which operates in a daily basis, and the second ATC, containing the same configuration, is the redundant hot-standby controller that will automatic take over the operations if the primary controller fails. Fibre Optic Ethernet LAN provides a high-speed communication network and connects all field devices to the central system at the COMPASS Control Centre.

Central System and Capabilities

A user-friendly Browser-Based Graphical User Interface (GUI), shown in Figure 9, was developed for real-time system monitoring, manual override, and data management. According to the designated user types, the system allows the Ministry’s staff to access different functions and features, via a private Intranet website. The GUI consists of a not-to-scale schematic map, with interactive graphical icons representing the current state of equipment and traffic conditions. The system uses J2EE in order to manage the multiple concurrent users.

The Java-based AWS server includes the following system functions:

- Monitoring real-time operations;
- Graphically displaying any on-going incidents, queues, VMS messages and equipment status;
- Receiving VIP detected incidents, and transmitting the alarm messages to the ATC controller to activate/display the responding automatic sign messages;
- Upon receiving incident detections from the loops, triggering the designated cameras to record a 3-minute video clip;
- Managing operator VMS override by selecting pre-composed VMS

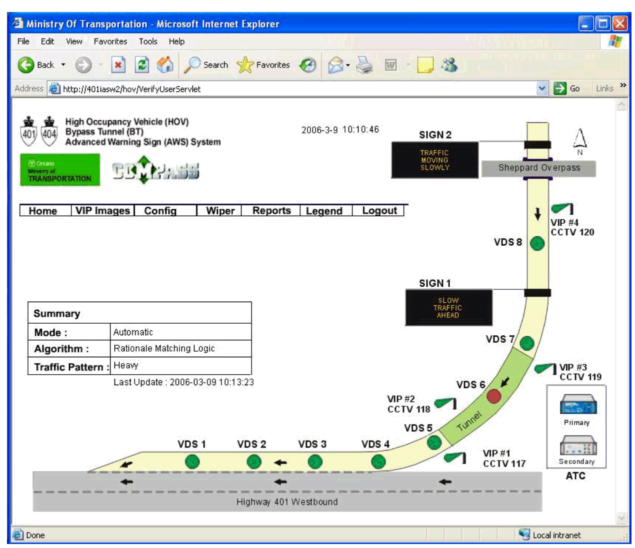

Figure 9 Browser-Based Graphical User Interface

messages from the ATC VMS message library;

- Enabling and disabling any field equipment, including VMS, loop and video detectors;
- Displaying and modifying the system configuration parameters including creating and modifying the ATC VMS message library;
- Triggering CCTV wiper control for cleaning camera lenses;
- Automatically disabling the VIP camera detection function when the wiper is active;
- Managing alarms and event notifications via e-mails to operators when the advanced warning signs are activated and/or field equipment failures occur;
- Logging all events and 5-minute loop data into a database;
- Retrieving all events and 5-minute loop data and generating customizable reports and logs; and
- Retrieving video files for playback.

Algorithms

There are three algorithms that were developed and deployed:

- Rational Matching Logic;
- Vehicle-Tracking Logic; and
- Traffic Pattern Selection Logic.

In order to detect the traffic problems more effectively in different traffic conditions, two traffic detection logics were developed to be applied one at a time, depending on the prevailing traffic conditions. For instance, the system will automatically operate with the Rational Matching Logic (i.e., a heavy traffic detection algorithm) during peak traffic volume periods and switch to Vehicle-Tracking Logic (i.e., a light traffic detection algorithm) when traffic volumes are extremely light. The system will constantly monitor the change of the traffic pattern and

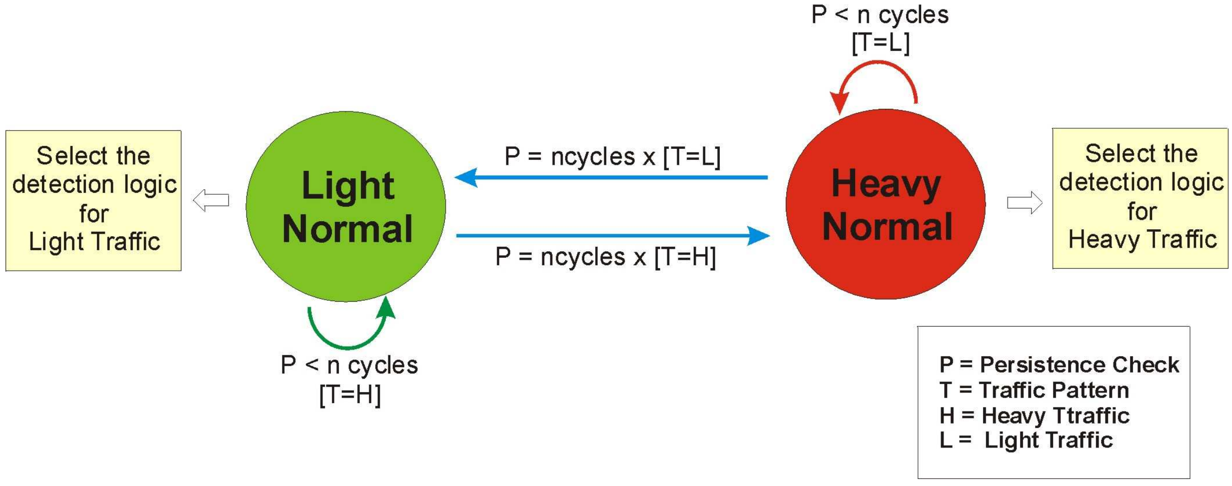

Figure 10 Traffic Pattern Selection Logic Diagram

determine the optimum detection logic that will be used. The selection of which algorithm to be used is handled by the Traffic Pattern Selection Logic. The diagram in Figure 10 illustrates the process of the Traffic Pattern Selection Logic.

As described previously, queue and incident detections in the tunnel are supported by both the loop detector and video detector technologies to enhance the coverage and efficiency of the vehicle detections. A typical detector coverage area is shown in Figure 11.

The deployment of the VIP cameras by the Ministry for a motorist warning system is a pilot implementation intended to illustrate the potential of the VIP cameras for improved detection of slow vehicles and incidents. As shown in Figure 11, the video detection only zone (i.e., green area) and overlapping video and loop detection zone (i.e., yellow area) provide superior detection. Blind spots (i.e., grey area) are minimized by strategically placing the video cameras before and within the tunnel.

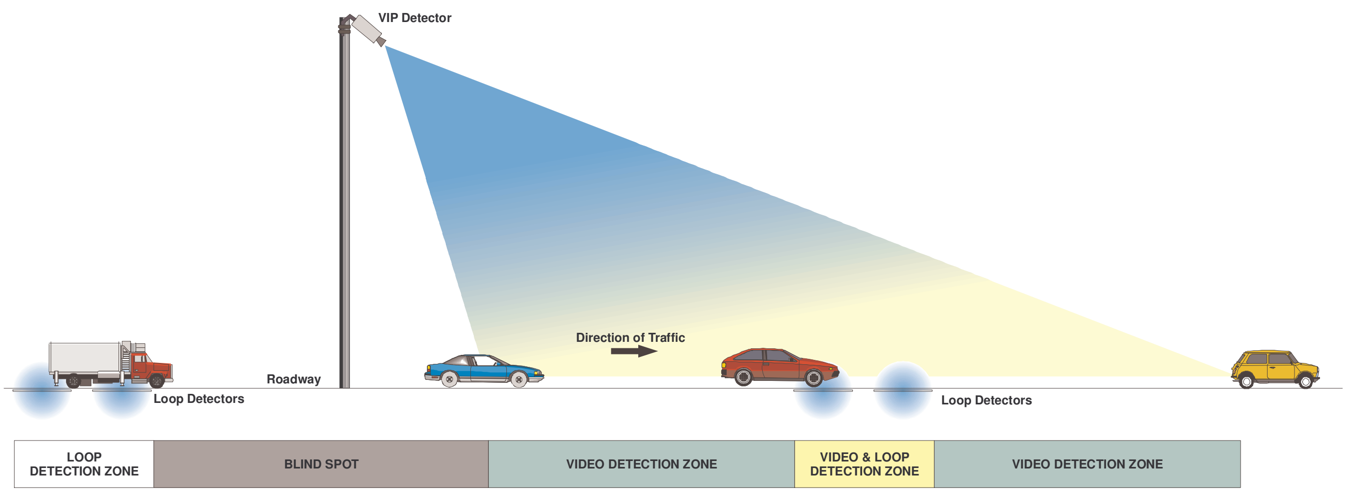

Figure 11 Typical Detection Zone Classification

Sign Messages

Depending on the detected end of queue or incident location, as well as the sign locations, the system automatically displays and removes the following automatic two-phase VMS messages:

- "Prepare to Stop / Slow Traffic Ahead" (used at tunnel entrance VMS, as shown in Figure 12); and
- "HOV Ramp to 401 West Collector/ Traffic Moving Slowly" (used at Sheppard Avenue VMS).

The VMSs display a blank message when there is no queue or incident detected. The operator can manually change and display the desired messages (e.g., Tunnel Closed) anytime based on the prevailing conditions in the tunnel.

Figure 12 Automatic Warning Message

End Results

Since the commencement of operations on December 13, 2005, the AWS has operated independently, reliably and consistently to provide an advance warning to motorists of slow or stopped vehicles in the tunnel, encouraging them to adjust their vehicle speed and thus improving motorist safety.

In the first few months of operations, the speed and occupancy algorithm thresholds were adjusted to match with the live traffic conditions (e.g., filtering out buses that usually travel at a slower speed and can cause short chains of slow moving vehicles, etc). From the system logs, it was observed that the system operates consistently to raise alarms due to slow or stop vehicles. Examples of typical system logs are shown in Figure 13. In the heavy traffic algorithm, the system reacts responsively to slow moving vehicles and raises an alarm once the slow traffic is detected.

In the light traffic algorithm, the system is also able to react promptly upon detection of “missing” cars between loop stations. The system demonstrates that with the combination of the light traffic condition and the high accuracy of loop detectors, the light algorithm delivers satisfactory operations with a low false alarm rate.

An innovative feature is the seamless integration of loop and video detection technologies to achieve faster and more accurate incident and queue detection in all traffic flow conditions. The quick detection performance of the VIP camera detectors complements the detector loop based AWS by detecting slow or stop vehicles quicker and in a more effective manner than traditional loops. The examples of traffic detection, as recorded and included in this paper, using the light and heavy traffic detection algorithm based on the loop technology, show that the key functions of the system to detect traffic problems and provide advance warning have been achieved.

With the user-friendly browser-based graphical user interface, system engineers and operators are able to monitor the AWS in real-time, remotely override field equipment, change system and algorithm parameters, and acquire traffic data and system event logs for analysis purposes.

Date / Time	Event Type	Description of Activity
01/26/06 02:51:21	Zone Status	Zone 7 from CLEAR to INQUEUE
01/26/06 02:51:21	Queue Status	Queue Map ......Q.

						Vehicle Length Bins						Speed Bins												
Date / Time	Location	Occupancy	Headway	Volume	Speed	1	2	3	4	5	6	1	2	3	4	5	6	7	8	9	10	11	12	13
01/26/06 02:55:00	VDS 1	0%	2440s	1v	77k	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
01/26/06 02:55:00	VDS 2	0%	2440s	1v	70k	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
01/26/06 02:55:00	VDS 3	0%	2440s	1v	65k	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
01/26/06 02:55:00	VDS 4	0%	2441s	1v	65k	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
01/26/06 02:55:00	VDS 5	0%	2441s	1v	54k	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
01/26/06 02:55:00	VDS 6	0%	2443s	1v	50k	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
01/26/06 02:55:00	VDS 7	0%	0s	0v	0k	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
01/26/06 02:55:00	VDS 8	0%	2443s	1v	73k	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0

System logs for the activation of queue alarm in the light traffic algorithm the associated 5 minutes traffic data showing the stop vehicle between Detector Station Nos. 6 and 7.

Date / Time	Event Type	Description of Activity
03/10/06 07:43:47	Zone Status	Zone 6 from CLEAR to INQUEUE
03/10/06 07:43:47	Queue Status	Queue Map .....Q..
03/10/06 07:44:02	Sign Status	Sign 1 aspect change from " "(1) to "PREPARE TO STOP SLOW TRAFFIC AHEAD"(2)
03/10/06 07:44:03	Sign Status	Sign 2 aspect change from " "(1) to "HOV RAMP TO 401WEST COLLECTOR TRAFFIC MOVING SLOWLY"(3)

						Vehicle Length Bins						Speed Bins												
Date / Time	Location	Occupancy	Headway	Volume	Speed	1	2	3	4	5	6	1	2	3	4	5	6	7	8	9	10	11	12	13
03/10/06 07:45:00	VDS 1	3%	9s	34v	65k	0	9	25	0	0	0	0	0	0	0	1	5	24	4	0	0	0	0	0
03/10/06 07:45:00	VDS 2	4%	9s	35v	61k	0	19	16	0	0	0	0	0	0	0	2	14	18	1	0	0	0	0	0
03/10/06 07:45:00	VDS 3	5%	9s	36v	53k	0	15	21	0	0	0	0	0	0	0	9	22	5	0	0	0	0	0	0
03/10/06 07:45:00	VDS 4	5%	8s	36v	49k	0	16	20	0	0	0	0	0	0	0	20	16	0	0	0	0	0	0	0
03/10/06 07:45:00	VDS 5	5%	8s	36v	43k	0	34	2	0	0	0	0	0	0	9	25	2	0	0	0	0	0	0	0
03/10/06 07:45:00	VDS 6	8%	8s	37v	33k	0	28	9	0	0	0	0	4	4	21	8	0	0	0	0	0	0	0	0
03/10/06 07:45:00	VDS 7	5%	8s	36v	41k	2	24	10	0	0	0	0	0	0	15	19	2	0	0	0	0	0	0	0
03/10/06 07:45:00	VDS 8	6%	8s	37v	53k	0	0	37	0	0	0	0	0	0	1	9	25	2	0	0	0	0	0	0

System logs for the activation of queue alarm in heavy traffic algorithm and the associated 5 minutes traffic data showing the slow traffic.

Figure 13 Typical System Detection Logs

CONCLUSIONS

To minimizing the potential for rear-end collisions and improve road safety, real-time advance warning systems are designed to ensure that motorists travelling on high-speed highways are warned in an accurate and timely manner of unexpected and imminent slow moving vehicles or vehicle queue and/or incident condition ahead. The warning systems deployed by the MTO on both the Niagara border highway approaches and the Hwy 404 HOV lane operate in a highly reliable, consistent and intelligent manner, and have been influential in warning motorists and encouraging them to adjust their vehicle speed and thereby reduce the potential for rear-end collisions.

REFERENCES

1. The Ministry of Transportation of Ontario web page on High Occupancy Vehicle Lanes http://www.mto.gov.on.ca/english/traveller/hov/

2. Technical Paper "Implementation of the Queue-end Warning System (QWS) along the Approaches to the Canada-U.S. Border" for the Madrid 2003 ITS World Congress

3. Technical Paper "Automated Advanced Warning System (AWS) Concurrently Utilizing Loop and Video Detection Technologies" for the 9th International IEEE Conference on Intelligent Transportation Systems, Toronto, 2006

4. Technical documentation prepared during the respective QWS and AWS system deployments:

   - Concepts of Operation and Algorithm;
   - System Architectures & Software Functional Specifications; and
   - Software Designs.