Project Title»

VARIABLE SPEED LIMIT SYSTEM

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PBX ENGINEERING | IBI | ASSOCIATION OF CONSULTING ENGINEERING COMPANIES

1. Variable Speed Limit System (VSLS)

Posted speed limits are intended to inform drivers of the maximum acceptable and safe speeds allowed under ideal conditions. However, fixed speed limits may not be a reliable indication of safe speeds as roadways are subjected to adverse weather, and poor traffic conditions. It is usually expected that drivers use good judgement, and adjust their speed accordingly. Drivers may recognize that heavy rain, snow or ice require that they lower their speed, yet an appropriate safe speed may not be apparent. Driving too fast for existing road conditions accounts for 7 out of 10 traffic incidents in B.C. By informing motorists of potential hazards, and dynamically adjusting regulatory speed limits, a significant impact on roadway safety could be realized.

Driving the highways of British Columbia can be challenging; often negotiating mountainous terrain with varying topography. Additionally, BC highways pass through multiple climatic zones where significant changes in elevation often result in rapidly changing weather conditions along a single trip.

The Ministry of Transportation and Infrastructure commissioned the Rural Highway Safety and Speed Review (July 2014). This study identified three BC highway corridors that are particularly affected by changing and adverse weather conditions:

Highway 1: Perry Creek Bridge to Highway 23 South Junction (30 km)

This segment of highway bridges the BC interior with Vancouver in the southwest, and the rest of Canada to the East. It contains challenging terrain and can experience heavy snowfall. In the Three Valley Gap area, in particular, eight avalanche zones exist along a 1km segment.

Highway 5: Portia Interchange to former Toll Plaza (40 km)

The Coquihalla corridor runs through mountainous terrain connecting the south coast of BC to the interior. The Coquihalla changes in elevation from 250m in Hope, BC to 1230 m at the summit within 50km (Figure 1). This large elevation change in a short distance results in drastically changing weather conditions. A driver may experience mild rain in Hope, and yet be subjected to blizzard conditions near the summit.

Highway 99: Squamish Valley Rd to Function Junction. (30 km)

The Sea to Sky corridor connects Whistler and Vancouver, winding between the mountains and the ocean. There is 675m change in elevation between Squamish and Whistler, which can result in rapidly deteriorating weather conditions, especially in winter.

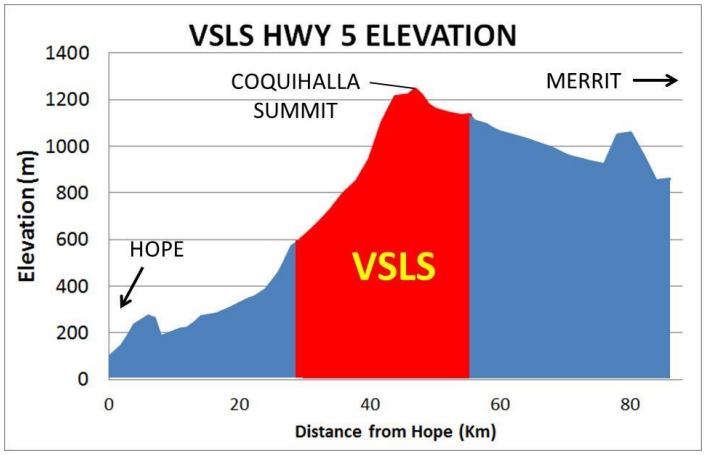


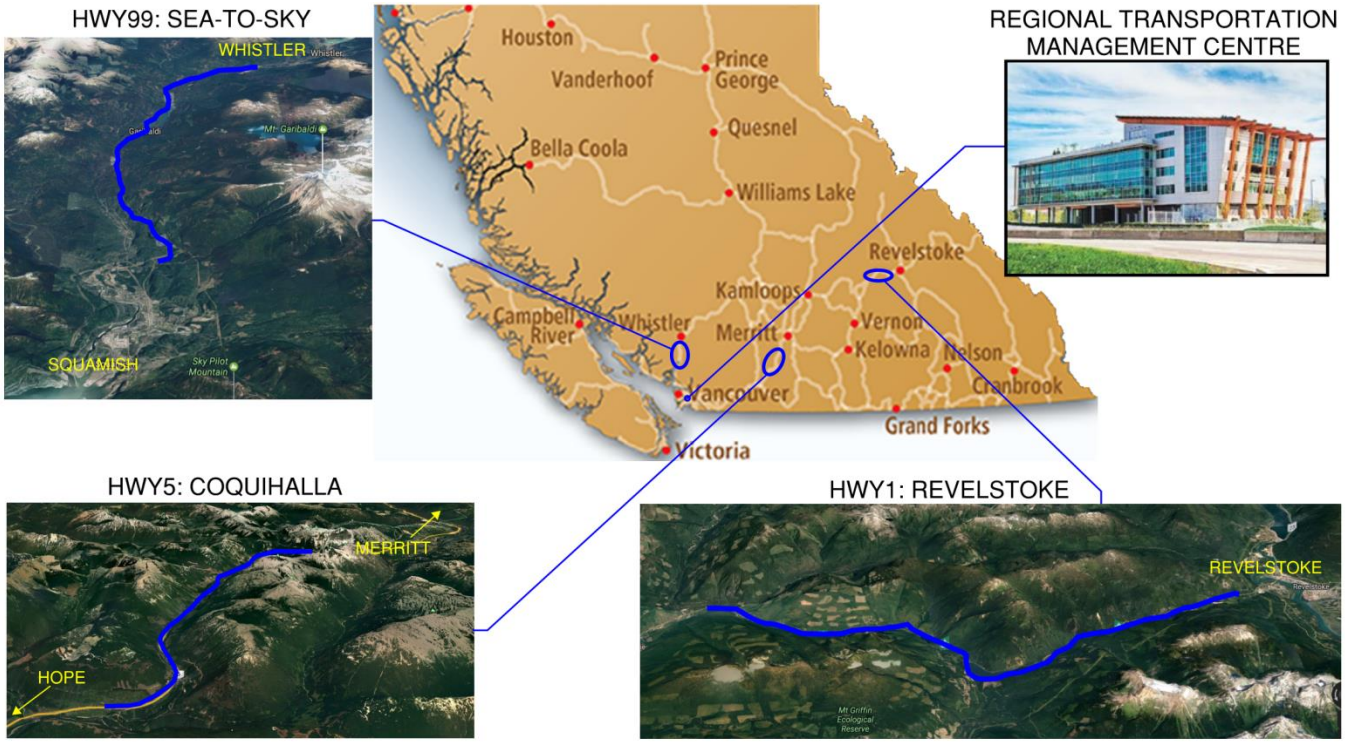
Figure 1: Coquihalla elevation profile and VSLS coverage

The study recommended that these corridors would benefit from emerging technologies that inform motorists of adverse weather conditions, and automatically alter speed limits at any point along the corridor. Such systems are called a Variable Speed Limit Systems (VSLS). A VSLS informs drivers of safe speed limits by updating Variable Speed Limit Signs and Dynamic Message Signs (DMS) strategically placed along the route.

The Ministry turned to PBX Engineering and IBI Group to design and deploy a VSLS across all three identified corridors. VSLS systems have been implemented by other organizations around the world. However, most other systems are located in or near urban areas and are only a few kilometers in length. The VSLS implemented in BC covers over 100km of roadway in remote areas across the province. A total of 54 VSLS sites were installed along the three corridors (Figure 2). The system has been in full operation since May 2016 and is one of largest and most complex implementations of a VSLS of its kind.

The VSLS design was undertaken by applying Intelligent Transportation Systems (ITS) engineering practices. Systems engineering design principles were applied to address challenges of integrating information from disparate and proprietary systems. A diverse complement of expertise was drawn upon, from disciplines in transportation engineering, information technology, and systems engineering in order to address challenges inherent in this live and geographically-expansive system.

Figure 2: Deployment of the British Columbia VSLS



2. VSLS Description

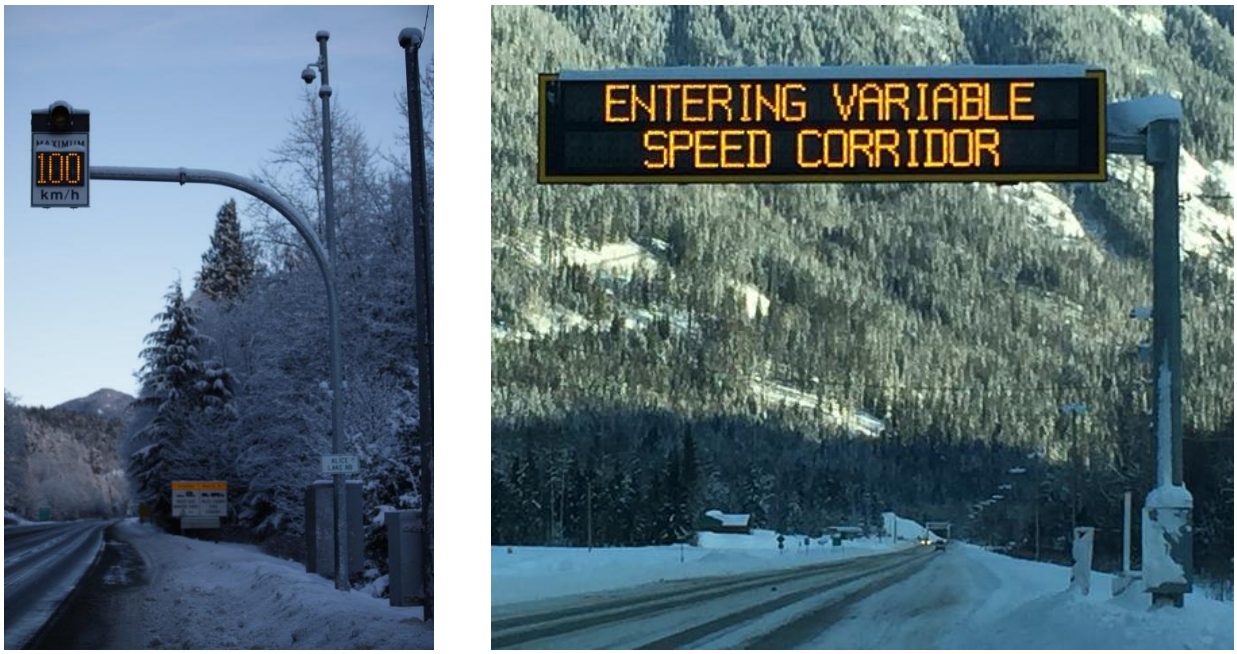
The VSLS measures road-weather and traffic conditions, along three corridors, and that data is transmitted to the Ministry's Advanced Transportation Management System (ATMS) at the Regional Transportation Management Centre (RTMC). The ATMS operations centre analyzes these measurements and appropriate speed limits are calculated. Speed limit reductions normally occur due to adverse weather conditions or traffic incidents. These speed limits are then transmitted to the Variable Speed Limit signs located along the corridors. The VSLS can also be used to adjust speeds through operator control for other incidents and planned construction or maintenance activities.

VSLS Components

Intelligent Transportation System (ITS) components are located at 54 VSLS sites along a total of 100 km of highway. Each site uses a cellular modem to link the ATMS with each ITS component deployed throughout the three corridors.

Variable speed limit signage is the primary means of communicating speed limits to motorists within a VSL corridor. Located at 2 – 7 km intervals along each corridor (Figure 3a). Each sign is linked, via a cellular modem, to the ATMS to enable reduction in the posted speed limits as required. The signs display the maximum posted speed whenever normal conditions prevail. It is the primary method by which the VSLS adjusts the flow of traffic in response to varying downstream conditions. The placement of VSL signs effectively divides a corridor into speed sections and dictates the sections in which speed can be controlled.

Installed at the entrance to each corridor, Dynamic Message Signs (DMSs) advise travelers that they are entering a variable-speed corridor, and of any adverse conditions ahead (Figure 3b). The use of dynamic message signs (DMS) to support speed harmonization is central to promoting public acceptance of the system. The reason for the reduction in speed may not be immediately apparent to a motorist who is unaware of upcoming congestion. They may be required to slow down from what might otherwise be a safe speed for perceived conditions. DMS's provide an opportunity to inform motorists of the reason for reduced speed limits, which in-turn results in greater compliance.



(a) **(b)**

Figure 3: a) MoTI Variable Speed Limit Sign, b) Dynamic Message Sign

To detect adverse road weather conditions, weather sensors were installed along each corridor. Road surface state sensors are non-intrusive instrumentation which uses laser technology to detect water, ice, and snow on road surfaces (Figure 4). With this information, the surface condition sensor is able to calculate a "grip factor". The road surface sensor data is reported in real time, and integrated with the ATMS which uses this information to calculate safe speed limits.

Traffic detecting radar senses the presence of passing vehicles and determines vehicle speed and classification (vehicle lengths) as well as traffic volume and occupancy (congestion). Data from these sensors are used to identify and calculate severity of congestion at a given location (Figure 4).

Figure 4: Road Surface Sensors and Traffic Detecting Radar

Other technologies utilized for the B.C. VSLS include:

- **PTZ Web Cameras:** Pan-Tilt-Zoom web cameras are used for verification of road and traffic conditions and still images are posted to the Ministry's traveler-information web site.
- **Ambient Temperature Sensors:** These sensors tied in with the road weather measurement sensing system
- **Dataloggers:** Each location contains a datalogger to interface with sensors and radars. The datalogger provides pre-processing of the sensor data and is a key part of a distributed computing solution.

Figure 5: PTZ Web Camera and Ambient Temperature Sensor

3. Design Complexity

The VSLS is a large, complex system with multiple hardware and software subsystems. There are many disparate components, in remote locations, distributed throughout the province. Innovative design approaches were employed to incorporate redundancies and robust strategies, in order to ensure this live system maintains a high level of operational effectiveness.

Remote Location Challenges

The three VSLS corridors can experience harsh winter weather conditions with extreme temperatures and large volumes of snow found in mountain passes. All equip equipment used were ruggedized and appropriate for the anticipated weather extremes. Reliable wireless communications approaches were pursued were many VSLS sites are situated in remote and rugged terrain. The design included redundant power systems to ensure live and continuous operation. Should communications dropouts occur, store and forward strategies ensure continuity of incoming sensor data. If one of the VSLS measurement sites drops out for a prolonged period of time the system can utilize data from other sites to ensure continuity of service.

Figure 6: VSLS Cabinets – ruggedized for extreme weather conditions

Road Weather and Traffic Measurements

Processing the measurement data required innovative solutions in order to ensure accuracy and redundancy. Much of the processing of the measurements takes place at each of the VSLS sites. This distributes the computation load of the system as well and reducing the communication bandwidth requirements. Traffic volumes can spike intermittently, therefore optimization of data-processing algorithms within the processing equipment at each site ensures real-time system response filtered out spurious data. As the VSLS is a regulatory system, custom software and design strategies were needed to verify that speed limits are calculated and displayed correctly.

VSLS Software System

The Traffic Responsive subsystem collects traffic speed and occupancy from each VSLS site. The subsystem recommends a speed based on an algorithm that considers the measured speed and occupancy with appropriate data filtering and smoothing.

The Road Weather subsystem aggregates pavement temperature and pavement condition (including the grip factor) in addition to visibility. The subsystem recommends a speed based on an algorithm that considers all of the measured parameters and compares them to thresholds defined in a pre-defined look-up table.

The VSLS has been designed to support future full automation. The VSLS automatically displays pre-configured messages on the DMS at the approaches to each corridor based on traffic and road weather conditions. RTMC Officials have the ability to accept the automatically generated message or override with a high priority message if required.

Speed Limit Validation

As the B.C. VSLS is a regulatory system, it was deemed imperative to verify that speed limits transmitted to the variable speed signs matched what was actually displayed. In addition to traceability for legal enforcement requirements this functionality was needed to ensure proper electrical function of the signs. Customized firmware was created, for the sign control electronics, as well as custom retrieval, display and archiving of messages within the ATMS. This information has proved invaluable for enforcement and maintenance alike.

4. Benefits

Travelling Public

By informing motorists of potential hazards, and adjusting regulatory speed limits, the VSLS is expected to yield direct and immediate socio-economic benefits. The primary benefit of VSLS is, therefore, to the travelling public, where varying regulatory speeds help to reduce speed-related traffic incidents during inclement weather. Real-time road condition information has been made available to the public across each of three corridors. This information is also disseminated to the travelling public using the Ministry's driver-information systems, including the web-based DriveBC site, and highway Dynamic Message Signs (DMS). Commercial vehicles and local regular road users benefit from improved safety. Out-of-town drivers, not familiar with problem areas for adverse weather, benefit from reduced speeds along with advanced notification of road conditions.

Figure 7: Additional Dynamic Message Signs to warn of changing road conditions and assist drivers to adjust speeds

Ministry Staff

Ministry staff benefit from additional real-time and archival data, gathered by the VSLS, to make operational decisions. The data gathered can provide more information about traffic patterns, road weather conditions, and provide more information about crash conditions. The system also provides increased 'visibility' of roads due to enhanced webcam coverage.

Maintenance Contractors

Maintenance Contractors benefit from the increased density of pavement temperature and condition data, and web cam images to aid in their operational decision making. Contractors' operations also benefit from the ability to request an 'operator reduced' speed limit to enhance safety during construction and maintenance activities on the highway.

RCMP

In addition to improving safety, the VSLS provides more information for the Royal Canadian Mounted Police (RCMP) enabling them to provide more targeted and effective enforcement, as well as providing evidentiary information as and when required for legal challenges.

Environmental Benefits

The objectives of the VSLS focus primarily on improving safety and increasing mobility and associated transportation efficiency. The technologies and processes employed by this ITS project foster the added benefit of reducing transportation related environmental impacts. Environmental impacts include pollutant emissions which lead to increased energy consumption and greenhouse gas (GHG) emissions. A key objective of the VSLS is to optimize traffic speeds and harmonize traffic flow. Excessive GHG emissions are generated by vehicles traveling at very low speeds during congested conditions. By reducing traffic incidents and smoothing traffic flow an added benefit of reducing GHG emissions is realized.

The three VSLS corridors pass through remote areas of the province surrounded by diverse ecosystems that support wildlife in abundance. Motor vehicle accidents often result in gas and fluid leaks, emitting harmful chemicals into the environment that can poison grass and neighboring plants and harm wildlife. Major oil spills from wrecked vehicles are one of the biggest problems with transportation incidents, particularly those that happen near water. By reducing the direct impact of traffic incidents and the secondary effects of the resultant congestion and response by emergency services, the VSLS helps to ease these types of negative impacts on the environment.

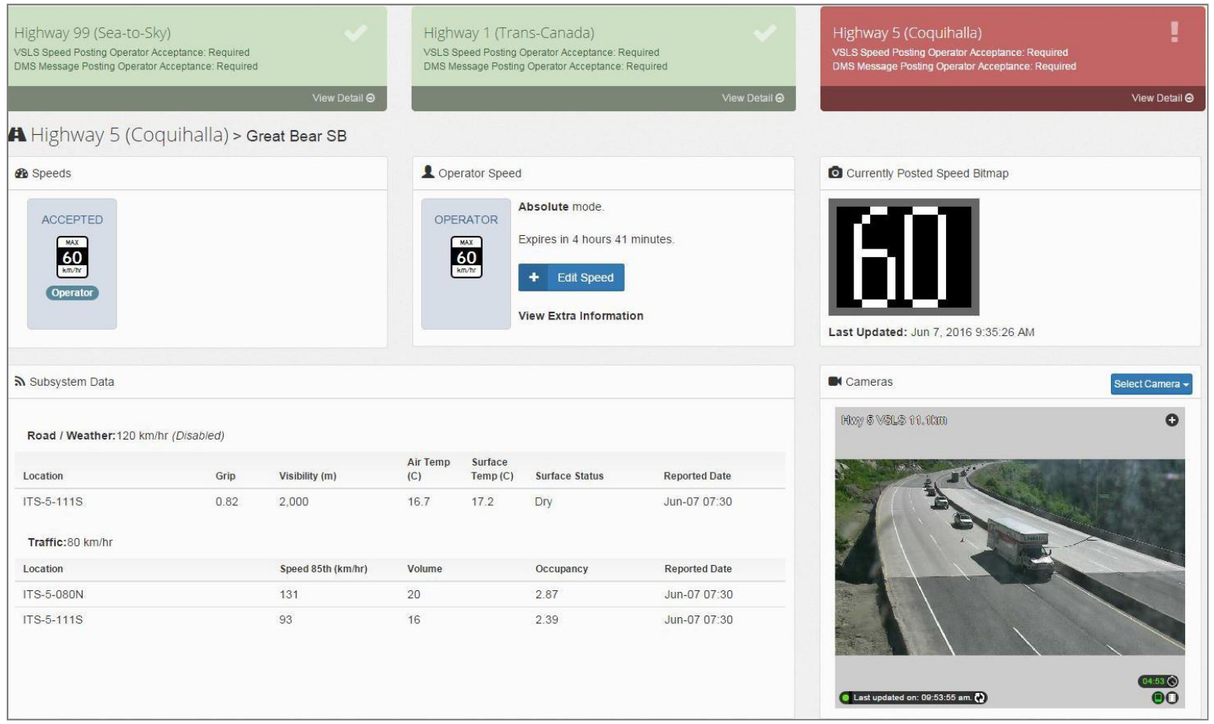
The VSLS design further addressed environmental considerations by using existing infrastructure wherever possible. Road weather and traffic sensors installed in areas without permanent power were designed to use solar power. The VSLS can respond to reports of wildlife on roadways by reducing speed limits and displaying warning messages.

5. Conclusion

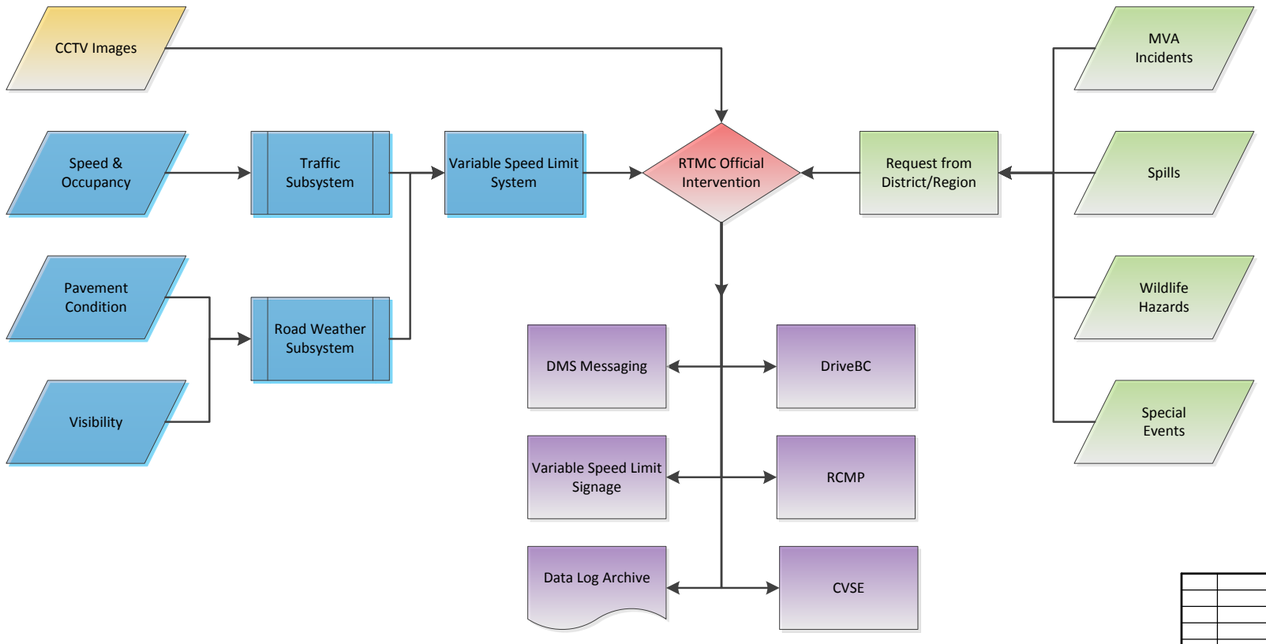
The three BC highway corridors were chosen for implementation of the VSLS because of the severity of changing and adverse weather conditions, and the resultant traffic incidents experienced. At the outset of the VSLS design a number of goals were identified by the Ministry of Transportation and Infrastructure. These include:

- Informing the travelling public of adverse weather and changing traffic conditions.
- Enhancing the Ministry's visibility of the road and weather conditions along the corridors.
- Improving traffic and incident management capability.
- Reducing the frequency and severity of traffic incidents.
- Providing suitable backup to ensure enforceability.

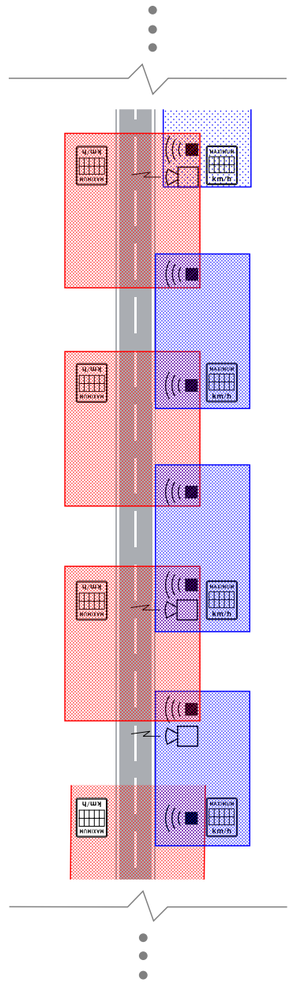
PBX Engineering and IBI Group delivered a fully-functional and robust solution spanning all three corridors. PBX and IBI designed the VSLS such that all ITS components, across the entire system, integrate with the Ministry's ATMS in real-time. There are a total of 43 traffic detecting radar units, and 33 road weather sensors feeding live data to the Ministry's ATMS. The VSLS is now able to set regulatory speed limits of 46 Variable Speed Limit signs at any point along the three corridors. Robust validation algorithms provide evidentiary information that can be used to defend legal challenges. Message signs at the entrance to each corridor automatically provide current traffic and weather information. Better informed drivers are given the opportunity to adjust speeds according to local, current driving conditions. The VSLS enhances the Ministry's traffic and incident management capabilities by providing up-to-date traffic and weather data and providing on-demand video from 38 CCTV cameras along the corridors.



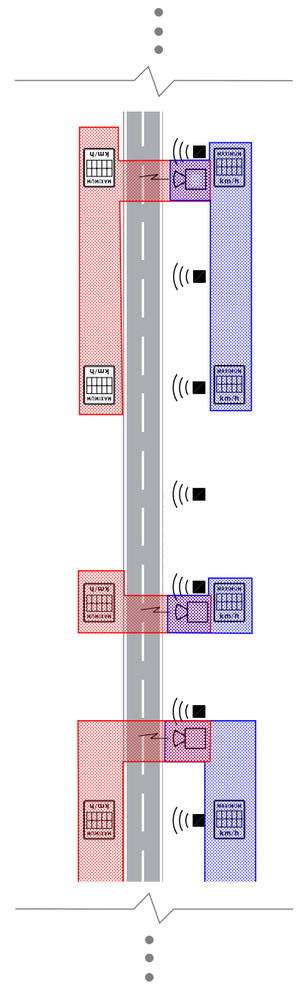
DASHBOARD OF THE ADVANCED TRANSPORTATION MANAGEMENT SYSTEM (ATMS)



HIGH-LEVEL SYSTEM ARCHITECTURE



TRAFFIC DATA RESPONSIVE SUBSYSTEM



ROAD WEATHER RESPONSIVE SUBSYSTEM

Rev.	DATE	ISSUE / REVISION DESCRIPTION	DESN	QC	QA
1	170413	SUBMITTED FOR ACEC-CANADA CONSUTLING ENGINEERING AWARDS	FR	IS	PBX

CLIENT: BRITISH COLUMBIA — MINISTRY OF TRANSPORTATION AND INFRASTRUCTURE, ELECTRICAL ENGINEERING CENTRE

PROJECT: VARIABLE SPEED LIMIT SYSTEM

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TITLE: VARIABLE SPEED LIMIT SYSTEM
ACEC-CANADA
CANADIAN CONSULTING ENGINEERING AWARDS

SCALE	PROJECT NUMBER	DRAWING NUMBER	REV.
AS SHOWN	14203		1

VARIABLE SPEED LIMIT SYSTEM

2017 AWARDS FOR ENGINEERING EXCELLENCE

PROBLEMS

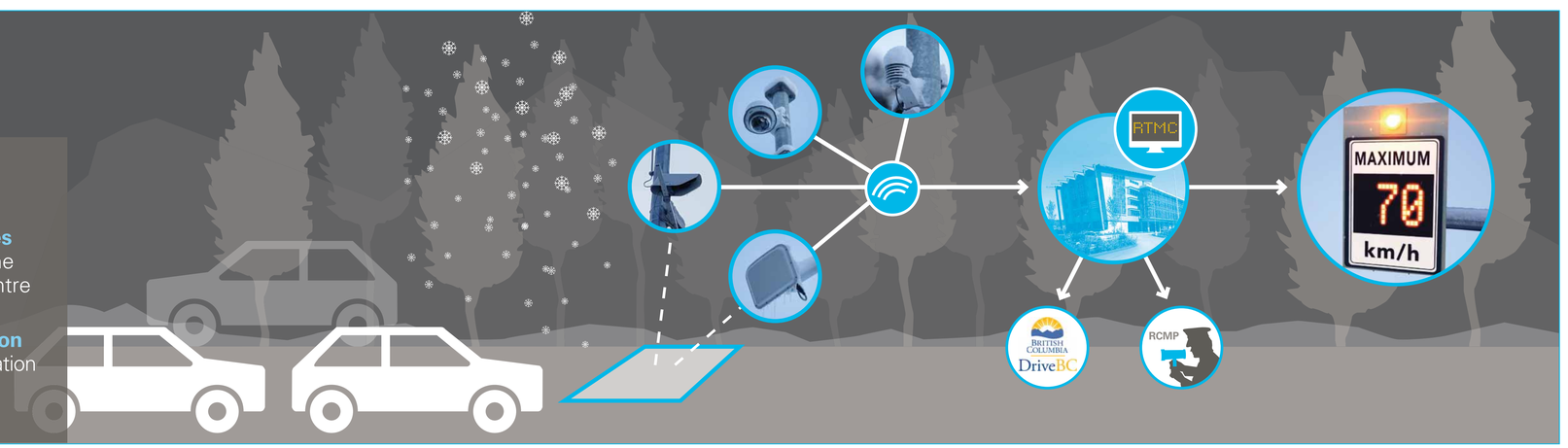
- Beautiful British Columbia attracts a lot of traffic, exposing them to scenic views as well as **varying climate zones**
- **Weather conditions can change rapidly** – it is common to experience sunny and dry conditions, that change to rain, sleet, or full-blown snowstorms along the way
- **Static signs** reflect maximum speeds for ideal driving conditions and cannot adjust to prevailing conditions
- Speeding is the leading cause of fatal car crashes
- **7 out of 10** speed related crashes are related to **driving too fast for the existing road conditions**

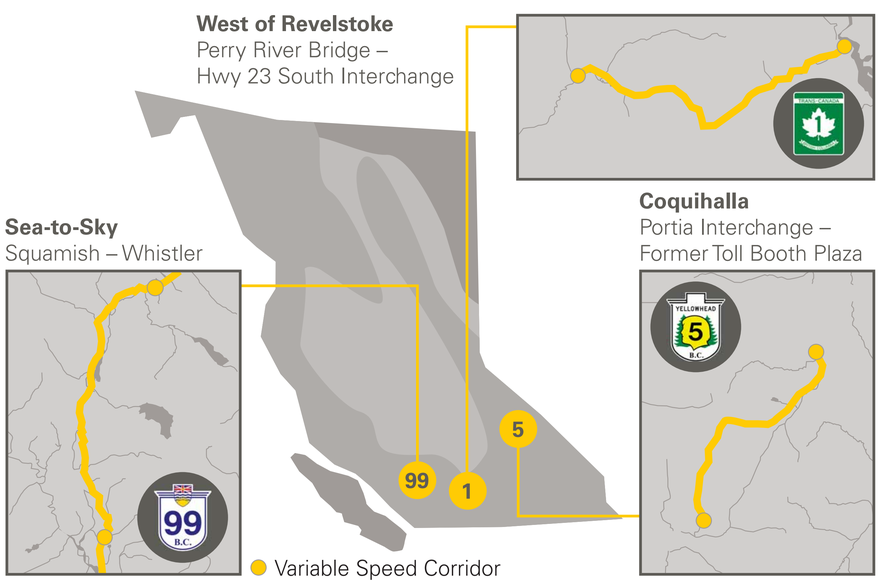
APPROACH

- **Engineer an enforceable solution** that can adjust speed limits to prevailing traffic and weather conditions
- Implement detection and motorist advisory system to help **reduce frequency and severity of weather-related crashes**
- **Urge drivers to be alert, slow down, and adjust their driving** for the conditions

SOLUTION

- Develop innovative and integrated **solution to detect, assess, and respond to changing conditions**
  - Unique business logic to address operational needs
  - Robust custom developed data gathering and field pre-processing application
  - Intelligent central software facilitating automated or operator-confirmed speed limit adjustments
- Extensive system of traffic, pavement, and visibility **sensors calibrated to detect conditions**
- Central **software and algorithm provides recommended speeds** to operators at the Regional Transportation Management Centre through a real-time dashboard
- **Condition-appropriate speeds displayed on electronic signs** and road condition information posted to Dynamic Message Signs
- Deployed on **3 major corridors**





BENEFITS

- Improved driver awareness
- Enhanced corridor safety, positively affecting thousands of motorists each day
- Enhanced traffic and incident management
- Expands operational capabilities and effectiveness of the Ministry's Regional Transportation Management Centre
- Reduce GHG emissions through reduced crashes and associated congestion
- Increase economic productivity through reduced delays associated with post-crash congestion
- Decrease societal costs through fewer property damage, injury, and fatal crashes

INNOVATIONS

- Intelligent approach to traffic management
- Advanced algorithms leveraging proven detection and computer/ software technologies
- Unique and integrated solution developed locally by BC Engineers
- Implemented in challenging physical environment, under tight time constraints

PBX ENGINEERING | IBI GROUP

Submitting Members

Client » BC Ministry of Transportation and Infrastructure

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