The Opportunities for Intelligent Transportation Systems to assist with Spring Load Restrictions and Winter Weight Premiums

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ABSTRACT:

Pavements are especially vulnerable to deterioration throughout the spring thaw. During this time of year, as the thaw progresses, the pavement structure becomes weak due to saturation and differential thaw. Damage can occur in both the surface asphalt layer but also in the base, sub-base and subgrade layers depending on the degree of saturation and the degree of thawing. The effects of frost action and thaw weakening can be both costly and disruptive for transportation agencies and their users. Load restrictions have become a common practice for many Transportation agency Maintenance and Operation departments in Canada, in an attempt to limit damage to the pavement structure. The spring load restrictions and winter weight premiums reduce pavement distress caused by the trucks travelling on the weakened structure. Determining when to implement and lift load restrictions has historically been done through selection of a fixed date, visual inspection by experienced maintenance staff, calculation of a Thaw Index or by monitoring frost depths.

Intelligent Transportation Systems (ITS) include the application of technology to address transportation issues. This paper will discuss the results of the Research and Development project funded by Transport Canada that looked at the use of ITS to assist with variable load restrictions. Variable load restrictions include Seasonal Load Restrictions (SLR) and Winter Weight Premiums (WWP). The paper will outline the process that the project followed and the results of the various stages, including a discussion on the data needs for pavement planning, design and operations and maintenance and illustrate how ITS can assist the provision of data for SLR and WWP as well as other pavement lifecycle requirements. The paper will discuss the type of monitoring equipment required in the field, the central system functionality required to evaluate the data and make recommendations on timing of implementation and lifting and how the information can be disseminated to the various commercial agencies.

1 INTRODUCTION

Intelligent Transportation Systems (ITS) include the application of technology to address transportation issues. A Research and Development (R&D) project was completed for Transport Canada to examine whether there is a role for ITS in the implementation and lifting of Spring Load Restrictions (SLR) and Winter Weight Premiums (WWP). In addition, the scope was expanded to look at how ITS can assist with data provision for pavement planning, design, and operations and maintenance. This paper provides a summary of the results from the R&D project.

2 BACKGROUND

The current asset value of Canada's roads and pavements is in the order of $150 billion, encompassing the national, provincial and municipal road network. Protecting this investment is of critical importance to the movement of goods and the mobility of people. The two biggest sources of deterioration are the environment and traffic loading. It is a major challenge to design a pavement that will withstand very low temperatures in the winter and high temperatures in the summer. In addition to resisting environmental effects, the pavements must be able to withstand the effects of heavily loaded trucks, which are an important source of revenue to our national economy.

Pavements are especially vulnerable to deterioration throughout the spring thaw. During this time of year, as the thaw progresses, the pavement structure becomes weak due to saturation and differential thaw. Damage can occur not only in the surface asphalt layer but also in the base, sub-base and subgrade layers, depending on the degree of saturation and the degree of thawing. Consequently, the pavements will exhibit signs of premature deterioration due to permanent structural damage. This damage can be limited to cracking or it can be more severe, resulting in a full failure that requires immediate repair. Thus it is critical that SLR be applied to those pavements not structurally designed for spring thaw weakening. This includes much of the secondary highway system.

The effects of frost action and thaw weakening can be both costly and disruptive for transportation agencies and their users. Load restrictions have become a common practice for many transportation agencies in Canada, in an attempt to limit damage to the pavement structure. SLR and WWP reduce pavement distress caused by trucks travelling on the weakened structure. This is used as an alternative to designing and constructing a pavement that is capable of carrying the normal legal loads at any time of the year.

3 PROJECT RESULTS

3.1 Task 1 – Market Scan

The first task that was completed was a Market Scan of Canadian and International agencies that utilize spring load restrictions and/or winter weight premiums. The Market Scan consisted of a literature search as well as telephone interviews. The market scan summarized the various methods for determining start and stop dates for restrictions. The following table summarizes the SLR and WWP approaches followed by Canadian agencies in 2004. As the table illustrates, Canadian transportation agencies use a number of quantitative and qualitative approaches, including specified calendar dates, visual observations, air temperature measurements, subsurface temperature measurements and deflection testing. The actual types of restrictions include load limits for certain axle configurations, complete restriction, reduced speed limits and various combinations of the three. Canadian transportation agencies reported that there is pressure from the trucking agencies to reduce the duration of the restrictions; however, they continue to have concerns relating to managing their asset. A quantitative approach presents an opportunity to manage these concerns.

Table 1: Summary of Canadian SLR/WWP Practices

Jurisdiction	SLR – Imposition Method	SLR – Lifting Method	WWP – Imposition Method	WWP – Lifting Method	Contact
National Roads	Based on BC decision	Based on BC decision	Based on BC decision	Based on BC decision	Pat Whidden (250) 774 6957
Newfoundland/ Labrador	N/A	N/A	N/A	N/A	Will Griffin (709) 729 0359
New Brunswick	Fixed date – refined through temperature	FWD, Benkelman beam readings and road condition information	N/A	N/A	Denis Goguen (506) 453 2802 http://www.gnb.ca/0113/Policy/swr2004-e.asp
Nova Scotia	Weather and road condition information. Adding 2 m temperature sensors at ARWIS sites for frost depth readings.	Dynaflect and road condition information	N/A	N/A	Gerrard Lee (902) 424 5582 www.gov.ns.ca
PEI	Frost tubes, Benkelman Beam	Frost tubes, Benkelman Beam, weather conditions	N/A	N/A	Wilfred McDonald (902) 368 5222 http://www.gov.pe.ca/news/getrelease.php3?number=3520
Quebec	Frost tubes, pilot for temperature sensors	Frost tube + fixed duration	N/A	N/A	Denis St- Laurent (418) 643 7740 http://www1.mtq.gouv.qc.ca/en/publications/camionnage/infocam/index.asp
Ontario	Fixed date modified based on temperature and road conditions	Fixed date	N/A	N/A	Becca Lane (416) 235 3513 www.mto.gov.on.ca
Manitoba	Fixed date – modified by Thaw index calculation	Fixed date	Fixed date	Fixed Date	Ray Van Cauwenberghe (204) 945 1934 http://www.gov.mb.ca/tgs/transreg/compreg/spring-restrict.html
Saskatchewan	Thermistor, weather, road condition	Road inspection or max of 6 weeks	Fixed date	Fixed Date	Josh Safronetz (306) 933 5947 http://www.highways.gov.sk.ca/docs/trucking/weight_restriction_transition.asp

Jurisdiction	SLR – Imposition Method	SLR – Lifting Method	WWP – Imposition Method	WWP – Lifting Method	Contact
Alberta	Frost probes (= 30 cm of thaw), weather conditions	FWD, frost probe	> 1 m of freezing	< 30 cm of freezing	Imants Krumins (403) 340 5189 http://www.trans.gov.ab.ca/Content/doctype260/production/RoadBans.pdf
B.C.	Frost probe, weather, historical, judgement	Benkelman beam	N/A	N/A	Mike Oliver (250) 387 3353
Nunavut	N/A	N/A	N/A	N/A	Tom Brigard (867) 975 5381
Northwest Territories	Road inspection	Benkelman Beam, road inspection	# of days of cold weather	Road inspections	Pete Boden (867) 874 5007 http://www.gov.nt.ca/
Yukon Territory	Thermistors	Thermistors	N/A	N/A	Gary Felker (867) 667 5644 http://www.hpw.gov.yk.ca/trans/rr/weight.html

3.2 Task 2 – Data Needs

The second task included an assessment of the data needs for pavement planning, design, and operations and maintenance.

Data requirements for asphalt pavements for Canadian best practices were collected and then consolidated into three data groupings:

- Road Structure
- Traffic
- Environmental

Table 2 provides an overall list of each of the data types required for the planning, design, operations and maintenance, and traveller information function, and groups the requirements into Road Structure, Traffic or Environmental requirements.

Table 2: Data Requirements for Planning, Design, and Operations and Maintenance Functions

	Road Structure	Traffic	Environmental
Planning	Deflection/strength (historic) Strength of weakest structure (i.e., bridge) Pavement age Distress data (surface defects, cracking, rut depth) Material properties for subgrade, sub-base, base, asphalt Roughness	Characterizations of traffic loads: volume, % commercial, axle weight, # of axles, axle spacing, total weight, vehicle classification, vehicle height, vehicle width, vehicle length, speed, occupancy	Frost depth (historic) Daily temperatures (min/max/mean) Precipitation (max, day)
Design	Deflection/strength Pavement age Material properties for subgrade, sub-base, base, asphalt Stress/strain Relative elevation of pavement structure (up or down) Moisture content in subgrade, sub-base and	Characterizations of traffic loads: volume, % commercial, axle weight, # of axles, axle spacing, total weight, vehicle classification, vehicle height, vehicle width, vehicle length, speed, occupancy	Pavement temperature (hourly, daily average, max/min daily, average 7 day max/min) Air temperature (hourly, daily average, max/min daily, average 7 day max/min) Precipitation (hourly) Wind speed (hourly) % Sunshine (hourly or

	Road Structure	Traffic	Environmental
	base Consolidation settlement		W/m^2) Relative humidity (hourly) Frost depth (yearly historic and max) Freeze/thaw cycle Thaw progression Solar radiation
Operations & Maintenance	Deflection/strength Stress/strain Material properties for subgrade, sub-base, base, asphalt Pavement thickness Capillary action Relative elevation of pavement structure (up or down) Moisture content in subgrade, sub-base and base Distress data (surface defects, cracking, rut depth) Roughness Water level table Salinity Recovery period (lag time) Saturation	Characterizations of traffic loads: volume, % commercial, axle weight, # of axles, axle spacing, total weight, vehicle classification, vehicle height, vehicle width, vehicle length, speed, occupancy	Pavement Temperature (hourly, daily average, max/min daily, average 7 day max/min) Air Temperature (hourly, daily average, max/min daily, average 7 day max/min) Precipitation (hourly) Frost depth (daily max/min) Thaw depth (daily max/min) Freeze/thaw cycle Thaw progression Thaw index Solar radiation (current and predictive) Forecast min/max daily air temperatures (5 days in advance)

In addition, data required to disseminate SLR and WWP information to trucking and other agencies were also collected. Data requirements for Information Dissemination included:

- Roads that have SLR or WWP;
- Date of imposition;
- Date of lifting;
- Revised legal load limit; and
- Fax/e-mail addresses for trucking association representative.

It is clear from the lists that there is a lot of duplication between the planning, design, and operations and maintenance functions. Therefore, collection of data to support the imposition and lifting of SLR and WWP, or the operations and maintenance function, will have benefits for the planning and design functions as well.

3.3 Task 3 - System Concept

The next task involved the development of a system concept to address the data requirements, data analysis and information dissemination requirements for an SLR and WWP system. Two quantitative approaches were developed: a basic system that uses algorithms that are currently being used across Canada and an advanced system that reflects current research completed in Quebec. The system concept includes the definition of the system functionality, the hardware required to deliver the functionality and the software requirements necessary to meet the functionality. The system concept was outlined within the context of the Canadian ITS Architecture and a preliminary cost prepared for a basic and an advanced system.

The three primary stages in the determination and implementation/termination of SLR and WWP are:

1. Collection of relevant weather and roadway data;

2. Analysis of data to make decision; and

3. Dissemination of information.

Each of these three stages are described in further detail. In addition, the three stages have been broken down into requirements for a basic system and requirements for an advanced system.

3.3.1 DATA COLLECTION – BASIC

A review of the data necessary to allow quantitative analysis efforts for determining when to implement and lift SLR and WWP, resulted in identification of a subset of this data The following data will be collected through in-situ equipment or derived from collected data:

- Road Structure
- Deflection/strength;
- Stress/strain;
- Moisture content in subgrade, sub-base and base;
- Pavement, base, sub-base thickness; and
- Recovery period (lag time).
- Environmental
- Pavement temperature;
- Air temperature;
- Frost depth;
- Freeze/thaw cycle;
- Thaw depth;

- Thaw indices;
- Solar radiation; and
- Forecast min/max daily air temperatures (5 days in advance).
- Other
- Roads that have SLR or WWP;
- Date of imposition;
- Date of lifting;
- Fax/e-mail addresses for trucking association representative.

The data will be collected in real time and aggregated into configurable resolutions ranging from 5 minutes to 24 hours. The identification of minimums and maximums will also be possible. All raw data will be stored by the system.

This data may be collected by a number of different types of equipment, depending on the preferences of the agency and availability of technology.

3.3.2 DATA COLLECTION – ADVANCED

The data collection requirements for the Advanced System include the requirements for the Basic System plus the following requirements:

- Road Structure
- Displacement or relative elevation of pavement structure (up or down); and
- Consolidation settlement.

3.3.3 ALGORITHMS

An analysis of existing algorithms that are currently used internationally to determine when to implement and lift SLR and WWP was completed. In addition, discussion between the project team members and the technical steering committee resulted in the generation of other potential algorithms. The algorithms that have been suggested for use for this system concept for SLR and WWP implementation and lifting are included below.

3.3.3.1 SLR Implementation

The most commonly used equations are the Thaw Index and the measured depth of thaw. The other equations, such as the MBE, have not been used for operational purposes within Canada. Minnesota completed testing of the MBE [Berg 1997] and the report published in March 1997 compares computer frost depths using MBE to measured frost depths. Further work done by Minnesota in 2000 [Ovik 2000] to define the Thaw Index and Freezing Index did not include use of this equation. Calculation of a thaw weakening index is considered to be at the leading edge of the quantitative analysis of spring road conditions. The equation that has been proposed is in its infancy and may be subject to further modifications with further research. Therefore, the use of this equation has been included in the Advanced System description.

3.3.3.1.1 SLR Implementation – Basic

A combination of algorithms is proposed to address the need adequately and to allow for alarm verification. There will initially be two algorithms used for generating SLR implementation alarms. Algorithm 1 will detect an alarm state. Algorithm 2 will be used to assist with providing 5 day advance notice.

1. SLR implementation will be determined based on the following logic statement:

   If Strain ≥ a and thaw depth ≥ b and moisture content ≥ c then SLR;

-OR-

If Strain ≥ a and 5 day thaw index ≥ b and moisture content ≥ c then SLR

Where:

Strain – measured at the bottom of asphalt (maximum for day);

Thaw Depth – measured

Moisture content – measured

5 Day thaw index - is a computed thawing Index for specific date (where this date is in the future, forecasted air temperatures are used and converted to pavement temperatures using the reference temperature)

a and c are configurable values calibrated in a lab

b is configurable per area but generally within 20-30 cm

NOTE: That Moisture content is also represented by a % moisture content that exists in the subgrade.

2. Advance warning of SLR implementation will be determined by the following logic statements:

If Strain < a and thaw depth ≥ b and Moisture content ≥ c then SLR advance warning;

-OR-

If Strain ≥ a and thaw depth < b and Moisture content ≥ c then SLR advance warning;

-OR-

If Strain ≥ a and 5 Day thaw index < b_1 and Moisture content ≥ c then SLR advance warning;

-OR-

If Strain < a and 5 Day thaw index ≥ b_1 and Moisture content ≥ c then SLR advance warning

Where:

Strain – measured at the bottom of asphalt (maximum for day);

5 Day thaw index - is a computed thawing Index for specific date (where this date is in the future, forecasted air temperatures are used and converted to pavement temperatures using the reference temperature)

Moisture content – measured

a and c are configurable values calibrated in a lab or developed through field observation

b is configurable per area but generally within 20-30 cm

b_1 is configurable per area but generally 13-15 ^{o}C

5 Day Thaw Index details:

$$TI_{date}=TI_{previous\ date} + \text{Reference Temperature} + \text{Daily Mean Temperature}_{date}$$

Where:

$TI_{previous\ date}$ = summation of mean measured pavement temperatures from a specified start date.

Reference Temperature = 1.7^{o}C beginning March 1 and increasing 0.06^{o}C per day (Manitoba) of 1.5^{o}C beginning February 1 and increasing by 0.56^{o} per week (Ottawa)

Daily mean temperature = (maximum + minimum Daily Air Temperatures)/2

This equation is run using measured pavement temperatures from the previous day, along with forecasted air temperatures for the next 5 days. These forecasted air temperatures will be entered into the system by the user. The user will obtain this information from Environment Canada. The reference temperature converts the air temperature to pavement temperature. Alternatively, the TAC conversion could be used.

An alternative for this equation, that would take Solar Radiation measurements into account, would be:

$$TI_{date}=TI_{previous\ date} + \text{Solar Radiation Factor} * \text{Daily Mean Temperature}_{date}$$

Where:

TI_{date} = Thawing Index for specific date (where this date is in the future, forecasted air temperatures are used and converted to pavement temperatures by multiplying by a Solar Radiation Factor)

$TI_{previous\ date}$ = summation of mean measured pavement temperatures from a specified start date.

Solar Radiation Factor = calculated based on historic radiation (either last 5 days or based on previous years information) and factor developed through comparative analysis

Daily mean temperature = (maximum + minimum Daily Air Temperatures)/2

3.3.3.1.2 SLR Implementation – Advanced

If an Advanced System is deployed, the following equation would be run in parallel to the equations defined in SLR Implementation – Basic to determine when to implement SLR.

SLR implementation is determined necessary if the thaw weakening index computed as TWin = (h/D) x (X/S) exceeds a user defined threshold.

Where:

TWin = Thaw weakening index

h = Total heave resulting from frost action in subgrade soil

D = Thickness of subgrade soil affected by frost action

X = Thawing rate (mm/day)

S = Settlement rate (mm/day)

3.3.3.1.3 SLR LIFTING – Basic and Advanced

If Strain ≤ d and thaw depth ≥ e and Moisture content ≤ f then SLR lifting;

Where:

Strain – measured at the bottom of asphalt;

Thaw Depth – measured

Moisture content – measured

d,f are configurable values calibrated in a lab

e is configurable per area but generally within 100-125 cm

NOTE: there are several agencies doing Dynaflect, FWD or Benkelman Beam testing throughout the spring and other periods of the year. There may be value in allowing these measured values to be added to the system, along with the date and time so as to allow a comparison between strain measured at the sensor and the Dynaflect, FWD or Benkelman Beam measurements.

2. Advance warning of SLR lifting will be determined by the following logic statements:

If Strain ≤ d and 5 Day thaw index ≥ e and Moisture content ≤ f then SLR lifting advance warning;

Where:

Strain – measured at the bottom of asphalt;

5 Day thaw index –see Section 2.2.1.1

Moisture content – measured

d, f are configurable values calibrated in a lab

e is configurable per area but generally within 100-125 cm

3.3.3.1.4 WWP IMPLEMENTATION – Basic and Advanced

A combination of algorithms is proposed to address the need adequately and to allow for alarm verification. There will initially be two algorithms used for generating WWP implementation alarms. Algorithm 1 will detect an alarm state. Algorithm 2 will be used to assist with providing 5 day advance notice.

1. WWP implementation will be determined based on the following logic statement:

If Strain ≤j and frost depth ≥ k then WWP;

-OR-

If Strain ≤j and 5 day freeze index ≥ k_1 then WWP

Where:

Strain – measured at the bottom of asphalt (maximum for day);

Frost Depth – measured

5 Day freeze index - is a computed freezing Index for specific date (where this date is in the future, forecasted air temperatures are used and converted to pavement temperatures using the reference temperature)

j, k and k_1 are configurable values calibrated in a lab

2. Advance warning of WWP implementation will be determined by the following logic statements:

If Strain $\leq$j and frost depth < k then WWP;

-OR-

If Strain $\leq$j and 5 day freeze index < k_1 then WWP;

-OR-

If Strain >j and frost depth $\geq$ k then WWP;

-OR-

If Strain >j and 5 day freeze index $\geq$ k_1 then WWP

Where:

Strain – measured at the bottom of asphalt (maximum for day);

Frost Depth – measured

5 Day freeze index - is a computed freezing Index for specific date (where this date is in the future, forecasted air temperatures are used and converted to pavement temperatures using the reference temperature)

j, k and k_1 are configurable values calibrated in a lab

$FI = \sum(0^{o}C - T_{mean})$

Where:

FI = Freezing Index

T_{mean} = mean daily temperature, $^{o}C = \frac{1}{2}(T1 + T2)$

T_1 = maximum daily air temperature

T_2 = minimum daily air temperature

This equation is run using measured pavement temperatures from the previous day, along with forecasted air temperatures for the next 5 days. These forecasted air temperatures will be entered into the system by the user. The user will obtain this information from Environment Canada. The reference temperature converts the air temperature to pavement temperature. Alternatively, the TAC conversion could be used.

3.3.3.1.5 WWP LIFTING – Basic and Advanced

1. WWP lifting will be determined based on the following logic statement:

   If Strain ≥l and frost depth ≤ m then WWP;

   -OR-

   If Strain ≥l and 5 day freeze index ≤ m_1 then WWP

   Where:

   > Strain – measured at the bottom of asphalt (maximum for day);
   >
   > Frost Depth – measured
   >
   > 5 Day freeze index - is a computed freezing Index for specific date (where this date is in the future, forecasted air temperatures are used and converted to pavement temperatures using the reference temperature)
   >
   > l, m and m_1 are configurable values calibrated in a lab

2. Advance warning of WWP lifting will be determined by the following logic statements:

   If Strain ≥l and frost depth > m then warning;

   -OR-

   If Strain ≥l and 5 day freeze index > m_1 then WWP;

   -OR-

   If Strain <l and frost depth ≤ m then WWP;

   -OR-

   If Strain <l and 5 day freeze index ≤ m_1 then WWP

   Where:

   > Strain – measured at the bottom of asphalt (maximum for day);
   >
   > Frost Depth – measured
   >
   > 5 Day freeze index - is a computed freezing Index for specific date (where this date is in the future, forecasted air temperatures are used and converted to pavement temperatures using the reference temperature)
   >
   > l, m and m_1 are configurable values calibrated in a lab

   $FI = \sum(0^{o}C - T_{mean})$

   Where:

   > FI = Freezing Index

T_{mean} = mean daily temperature, $^{o}C = ½ (T1 + T2)$

T_1 = maximum daily air temperature

T_2 = minimum daily air temperature

This equation is run using measured pavement temperatures from the previous day, along with forecasted air temperatures for the next 5 days. These forecasted air temperatures will be entered into the system by the user. The user will obtain this information from Environment Canada. The reference temperature converts the air temperature to pavement temperature. Alternatively, the TAC conversion could be used.

3.3.4 INFORMATION DISSEMINATION

Transportation agencies across Canada use a diverse set of tools to disseminate information to commercial agencies. Integration of the data into a GIS-based central system will assist with electronic dissemination through the various technologies employed by these agencies, including:

- Web site;
- E-mail;
- 511;
- Fax polling service; and
- Interactive Voice Response.

The system will generate responses for the various dissemination devices using the information stored in the central computer. These responses will be developed using predefined templates and will be approved by the users prior to dissemination.

3.3.5 FIELD COMPONENTS

The data that is required to run the algorithms can be delivered by a variety of equipment. Therefore, wherever possible, agencies can make use of their existing infrastructure or their hardware preferences. For example, if there are existing Remote Weather Information Systems (RWIS) or planned RWIS deployments, these sites could be augmented with additional sensors to meet all of the requirements. Alternatively, if an agency has frost probes in place, it may wish to add additional equipment at that location.

The system will also include other checks and balances, using more traditional approaches, to ensure that data is valid. For example, as there is a correlation between pavement temperature and strain, the system will also include a check and backup for the strain measurements. A table will be configured in the system, based on laboratory results, that correlates pavement temperature to strain.

All equipment will be installed in accordance with the equipment manufacturer’s recommendations.

There are two alternatives for how the field data can be processed: field data can be sent to the central system for processing or can be processed locally through field controllers that generate alarms and aggregate data for transmission to the central system. The choice of field or central processing is often driven by communication requirements and infrastructure availability. Regardless of where the data processing for each site is performed, there will always be a central processing function to store, archive and visually display information from all of the sites in a central location.

If the final design architecture identifies a need for distributed processing, then some sort of Advanced Field Controller (AFC) would be deployed that comprises the necessary communication interfaces to consolidate the various sensor devices and perform local processing of data. Software specific to this application would be developed in conjunction with the central software requirements. The AFC will be a rugged, industrial PC custom designed to support the necessary hardware interfaces and that will run the software application. It is generally preferred that a centralized system be used, where all of the data will be sent to the central system for processing.

National Transportation Communications for ITS Protocol (NTCIP) standards will be used wherever possible for communication to field devices.

3.3.6 CENTRAL COMPONENTS

The central system components will comprise the necessary software and hardware elements to collect, analyze and disseminate the SLR and WWP information. The software will be developed to poll each of the AFCs or field device controllers for information (either processed or raw, depending on where the processing is completed) and to display the information graphically on a GIS-based map. The alarms that are generated for warning or for SLR implementation and lifting and WWP implementation and lifting will be graphically displayed here for review and acceptance by a user. The central system will also generate the information for dissemination through e-mail and facsimile and to external systems that may deploy other technologies such as interactive voice and 511. This will allow data to be graphically disseminated, which will be helpful for users to illustrate where there are restrictions in place.

Data will be stored and archived for use by the planning and design departments.

The software requirements of an SLR/WWP automated monitoring system will be referred to as the “Roadway Conditions Watch” application or RCWatch for short.

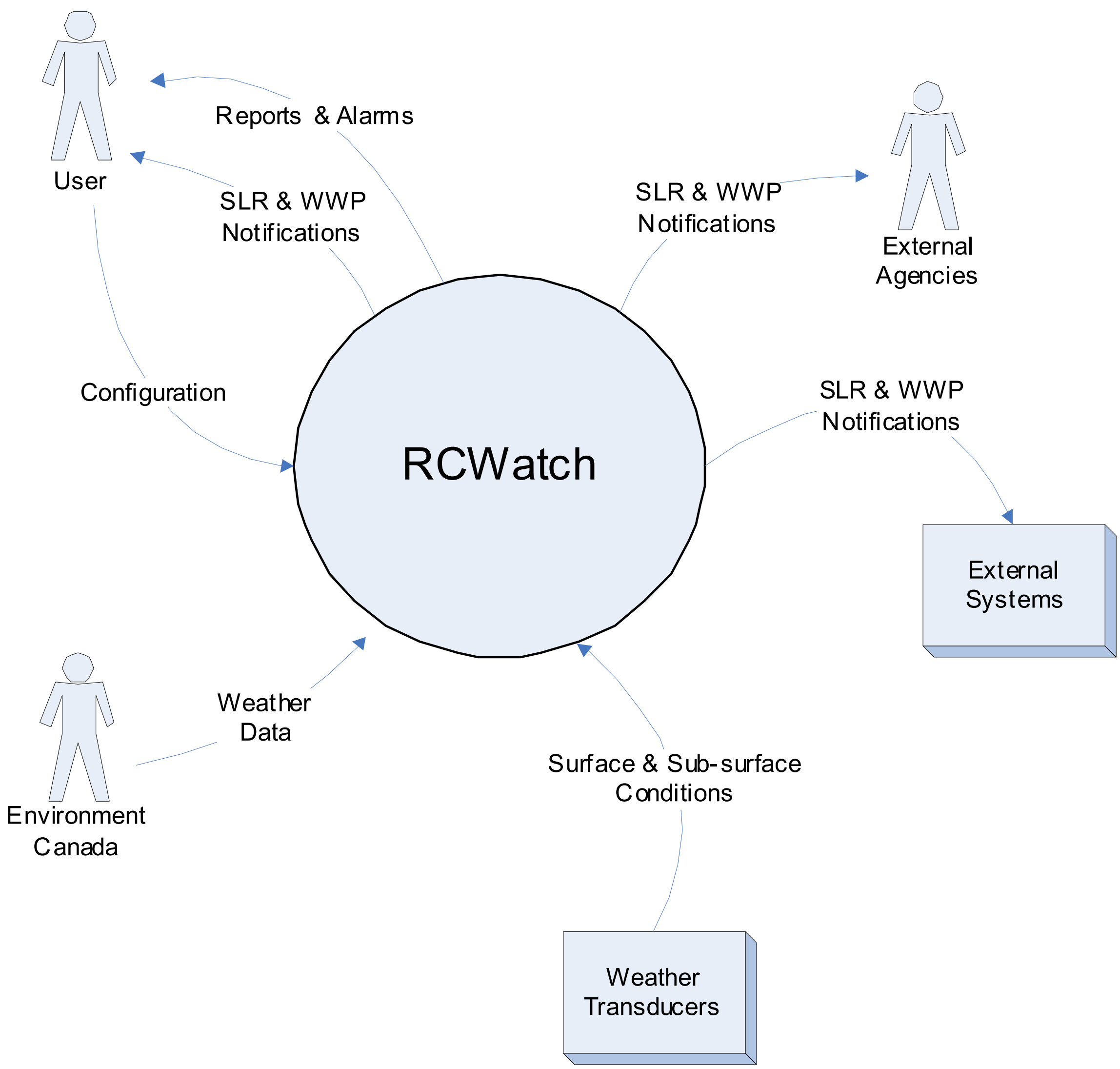
The full set of RCWatch requirements are outlined in the Software Requirements Specification (SRS). The SRS describes the software components of RCWatch that provide the roadway condition monitoring and notification functions for a centralized operations centre. Depending on physical implementation and the capabilities of off-the-shelf field equipment, RCWatch will comprise software that runs on one or more centrally located computers and may additionally include software running on a distributed network of field controllers.

The principal function of the software is to collect and analyze surface and sub-surface data to identify periods for which to implement SLR and WWP.

The primary business process supported by RCWatch is the collection and analysis of surface and sub-surface data for a defined roadway network for the purpose of determining the appropriate periods during which the SLR and WWP programs are to be implemented.

RCWatch will aid operating agencies by automating the process of roadway condition monitoring and the dissemination of these conditions to various other departments and external agencies as required. An overview of RCWatch software is provided in Figure 1.

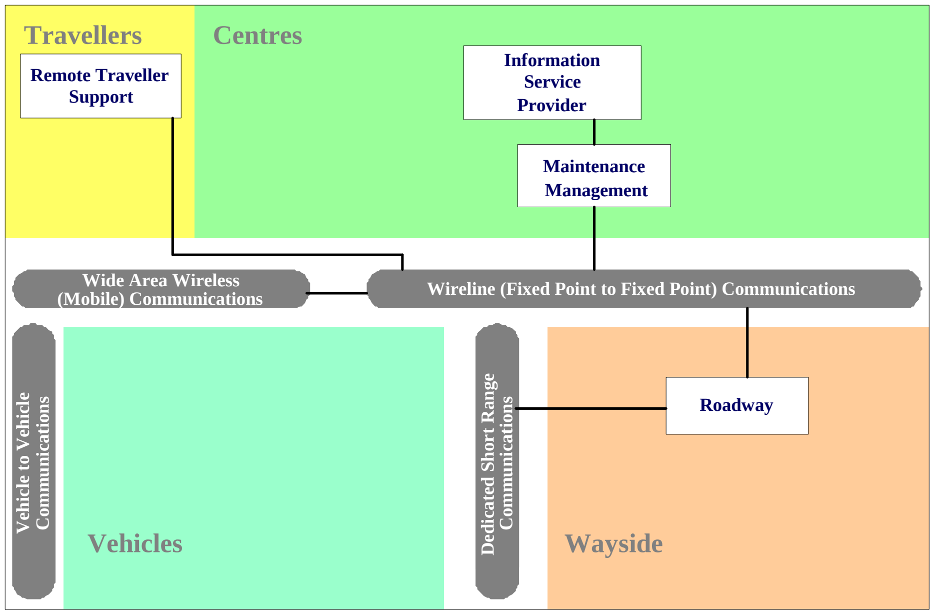
Figure 1: RCWatch Context Diagram



3.4 ITS Architecture

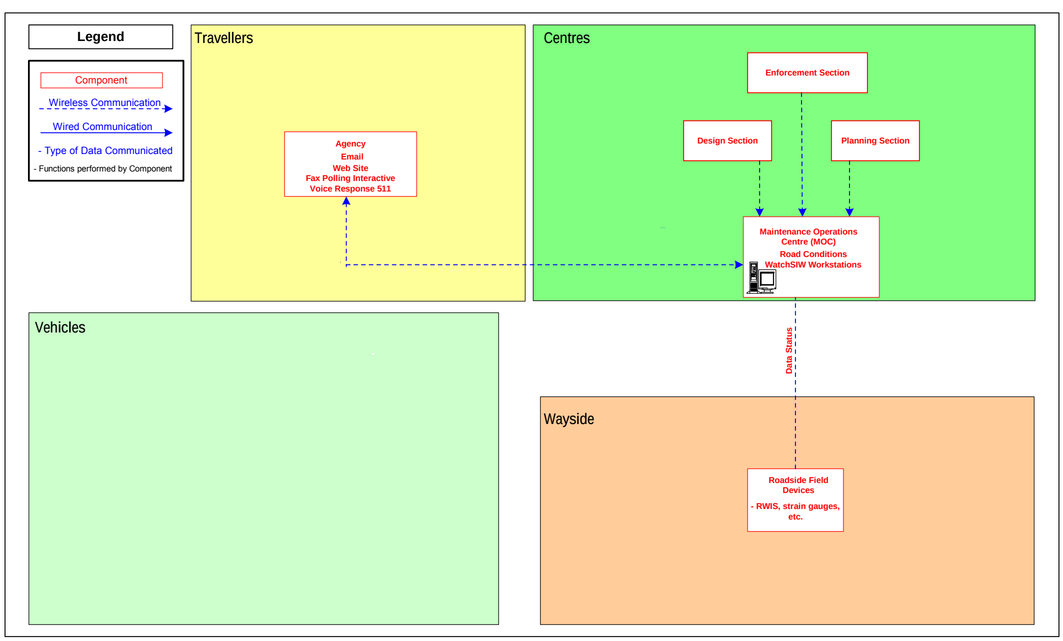
The system concept can be described by the following Physical Architecture (Figure 2) as defined by the Canadian ITS Architecture.

Figure 2: ITS Physical Architecture



The Physical Architecture has been constructed using the "sausage diagram" and shows the physical location of the ITS components and the communications medium used to connect them. For this system concept, there is no interaction with the vehicles. The schematic included in Figure 3 includes a few more details about the particular functions.

Figure 3: ITS Scheme



3.5 Preliminary Costs

Preliminary costs have been prepared for a basic and an advanced system. The costs as well as assumptions are summarized in Table 3 and Table 4.

Table 3: Basic System Pricing

	Data Collected	Equipment Type/Name	Unit Cost (CND)	Quantity	Total Equipment Cost (CND)	Installation Cost (CND)	Net Cost (CND)
Basic	Pavement & Air Temperature	RWIS Road Weather Information System	$41,000.00	1	$41,000.00	$4,000.00	$45,000.00
	Strain	Strain Gauge Pavement Strain Transducer for the measurement of strains in Asphalt Concrete (PAST II AC)	$780.00	10	$7,800.00	$1,500.00	$9,300.00
	% Moisture content	Moisture Sensor ECHO Soil Moisture Smart Sensor (S-SMA-M003)	$180.00	3	$540.00	$200.00	$740.00
	Base, Subbase and Subgrade Temperature (Frost Depth)	Multi-point Temperature Probe TDP Temperature Probe (15 sensor points along 72 inch tube)	$2,280.00	1	$2,280.00	$500.00	$2,780.00
	Other Field Requirements	Data Logger, Modem, Cabinet, Power, etc.					$11,000.00
	Central Requirements	Server, Workstation, Database, Miscellaneous	$6,000.00	1	$6,000.00	$0.00	$6,000.00
		Software Development					$167,750.00
				Total Cost:	$57,620.00	$6,200.00	$242,570.00

Table 4: Advanced System Pricing

	Data Collected	Equipment Type/Name	Unit Cost (CND)	Quantity	Total Equipment Cost (CND)	Installation Cost (CND)	Net Cost (CND)
Advanced	Pavement & Air Temperature	RWIS Road Weather Information System	$41,000.00	1	$41,000.00	$4,000.00	$45,000.00
	Strain	Strain Gauge Pavement Strain Transducer for the measurement of strains in Asphalt Concrete (PAST II AC)	$780.00	10	$7,800.00	$1,500.00	$9,300.00
	% Moisture content	Moisture Sensor ECHO Soil Moisture Smart Sensor (S-SMA-M003)	$180.00	3	$540.00	$200.00	$740.00
	Base, Subbase and Subgrade Temperature (Frost Depth)	Multi-point Temperature Probe TDP Temperature Probe (15 sensor points along 72 inch tube)	$2,280.00	1	$2,280.00	$500.00	$2,780.00
	Displacement	Linear Variable Differential Transformer (LVDT) PIz100 (+/-50mm range) arranged to for a multi-depth deflectometer	$577.50	4	$2,310.00	$800.00	$3,110.00
	Other Field Requirements	Data Logger, Modem, Cabinet, Power, etc.					$11,000.00
	Central Requirements	Server, Workstation, Database, Miscellaneous	$6,000.00	1	$6,000.00	$0.00	$6,000.00
		Software Development					$167,750.00
				Total Cost:	$59,930.00	$7,000.00	$245,680.00

4 NEXT STEPS

Through the development of this document, it became apparent that ITS can play a role in assisting agencies with determining when to implement and lift SLR and WWP. In addition, deployment of ITS equipment to meet this need will also result in data that can assist with other planning and design tasks, thereby increasing the value of this type of system. The system concept discussed herein utilizes existing equipment and proven algorithms, and integrates the data and hardware into a GIS-based central system software package described as RCWatch. The next step will be to develop a pilot project to test the data, algorithms and assumptions, and to ascertain whether there is a value to agencies to deploy this type of system.

In addition, through the research and development that was conducted, it was clear that various academic institutes and government agencies in Canada have established themselves as leaders in various areas relating to research into and application of SLR and WWP. In order to share this information more easily across Canada, it is suggested that steps be taken to develop a Centre of Excellence that would allow all agencies and institutes to share information relating to SLR and WWP, thus helping to advance research in this area.

Central Tire Inflation (CTI) Systems are becoming more widely used across Canada; furthermore, Commercial Vehicle Operations (CVO) systems are also becoming standard. Future opportunities include the ability to dynamically modify the load restrictions based on in-situ measurements and to broadcast that information in real time to trucking companies. This will allow transportation agencies to protect their assets and trucking companies to maximize their productivity. While the largest benefits occur to both agencies during the period of spring thaw, there will also be benefits associated with winter weight premiums.

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