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DEVELOPING A SECOND-GENERATION MOBILE ROAD WEATHER STATION

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SUMMARY

Québec's highway safety record has improved significantly over the past few decades, despite a considerable increase in vehicular traffic.

Table 1 – Vehicular Traffic and Highway Fatalities in Québec in 1973 and 2003

Year	Vehicular Traffic	Fatalities
1973	2,265,471	2,209
2003	5,063,449	621
Variation – 1973-2003	123.5 %	- 71.9 %

Québec's performance places it among the leaders in industrialized countries, where it is ranked as one of the jurisdictions with the lowest fatality rate per billion kilometres. Despite these results, the MTQ and its partners are aware that past efforts must continue in order to maintain and even improve its highway safety record.

In the context of developing highway weather forecasting in Québec, the MTQ resolutely undertook an innovative approach, implementing a variety of technologies in order to provide maintenance personnel with guidance in terms of determining the scope of operations required to ensure the safety of users during the winter.

These technologies include mobile road weather stations, which provide real-time measurements of certain meteorological and road-surface parameters as the patrol vehicle travels along the network. Mobile road weather stations are an innovative concept in terms of collecting data pertaining to the environment, the weather, and pavement conditions that directly influence decision-making during winter maintenance operations. They have led to a significant increase in user safety, more prudent use of de-icing chemicals and abrasives, and better protection of the environment.

KEYWORDS

ITS / MOBILE ROAD WEATHER STATION / SENSOR / WINTER MAINTENANCE / MONITORING / VEHICLE POSITIONING / GPS /

1. INTRODUCTION

With a view to meeting the challenge of highway safety in Québec, the MTQ's strategic plan includes a focus on providing the users of its network with transport infrastructures that are safe, operational and in good condition. One area of intervention that reflects this focus is the prevention or reduction of accidents that result in vehicles leaving the highway. The MTQ's interventions within the highway environment have the greatest impact on highway safety. Roadside accidents represent more than one-third of all accidents with fatalities or serious injuries that occur on the highway network managed by the MTQ, and in all cases this involves vehicles leaving the highway. This reality is even more striking during the winter. The size of its territory, the presence of numerous bodies of water, the harsh climate, and the steady increase in the number of vehicles and trips constitute a major challenge for the MTQ in terms of developing, managing, and especially maintaining its highway network during the winter.

In order to meet its commitments, especially those involving highway safety during the winter, the MTQ has invested a great deal of effort over many years, first in terms of educating users, who share some degree of responsibility for their own safety, and also in terms of developing tools and methods aimed at improving the safety and effectiveness of its interventions on the highway network.

The MTQ has been conducting information and advertising campaigns that address highway safety in winter conditions for a number of years. Based on an informative approach, these campaigns encourage drivers to drive carefully by increasing their awareness of the risks involved in winter driving, which require a change in driving habits.

In addition to these communication activities, the MTQ has developed a winter road condition information service for citizens and drivers, in the form of a website called Québec 511 Web. This service provides all relevant information for planning safe travel on the highway network. In addition, the MTQ has developed specific and unique terminology for informing users of road conditions during the winter.

More recently, the MTQ implemented legislation in the fall of 2008 that made winter tires mandatory for users of the Québec highway network. This measure was intended to help drivers to drive more safely in cold weather.

Following a pilot project that was carried out in 2001, a number of decisional support tools were developed with a view to meeting the expectations of the operational staff who are assigned to network maintenance. These include mobile road weather stations, which allow patrol vehicles to measure a number of meteorological and road parameters in real time as they travel along the network.

The development of this unique tool was based on a needs analysis that was conducted among maintenance personnel and snow removal experts. This approach identified the most relevant meteorological and road parameters that would be of use in terms of supporting decision-making in an operational context.

In addition, the involvement of operational personnel from the very beginning of the tool development process greatly facilitated its implementation in an operational context.

2. PRINCIPLES AND OPERATION OF THE MOBILE ROAD WEATHER STATION

A total of six meteorological and road parameters are now available to help maintenance personnel to anticipate and quantify weather and road phenomena that may impact the scope of operations required on the network.

Table 2 – Meteorological and Road Parameters Measured by the Mobile Station

Type of measurement	Symbol
Pavement Surface Temperature	T_s
Dew Point	T_d
Air Temperature	T_a
Relative Humidity	U
Barometric Pressure	Kpa
Altitude	m

These parameters are measured by sensors that are mounted on the vehicle, and the readings are displayed on a digital screen inside the cab.

In the fall of 2002, after three months of developmental work, the MTQ deployed a first generation of mobile road weather stations in more than 60 patrol vehicles for the benefit of its snow removal staff. These vehicles are used by the staff to direct operations, including snow removal operations.

In light of the interest that was shown in the first generation of the mobile station, the MTQ implemented a second generation of the station within the context of Transport Canada's ITS program. In this version, modifications were made to the device in the areas of ergonomics, immunity against mobile radio waves, data acquisition, on-board data display, and data storage in a database.

The data management system, which was designed entirely by the MTQ, optimizes the collection of measurements taken by sensors that are available on the market, which can be queried remotely and independently. Users can view the data on the vehicle's display screen, retrieve data from the computer memory's database, or transmit measurements over a wireless connection. The data management system also has a visual interface that can be used to configure the parameters without programming knowledge.

The new data acquisition system, which is equipped with a backlit digital display (Figure 1), was installed in each vehicle. This system is connected to four sensors (Figure 2) that measure the desired parameters in real time as the vehicle travels along the road. An infrared thermometer is installed under the vehicle in order to measure pavement temperature (Ts). A thermometer and a hygrometer equipped with digital interface are placed on the roof of the vehicle in order to measure air temperature (Ta) and relative humidity (U). A barometric pressure sensor is installed in the vehicle in order to measure atmospheric pressure (P).

The system calculates the dew point using the values of Ta, U, and P. A GPS system determines the geographic position of the various measurements that are collected.

Figure 1: Backlit display

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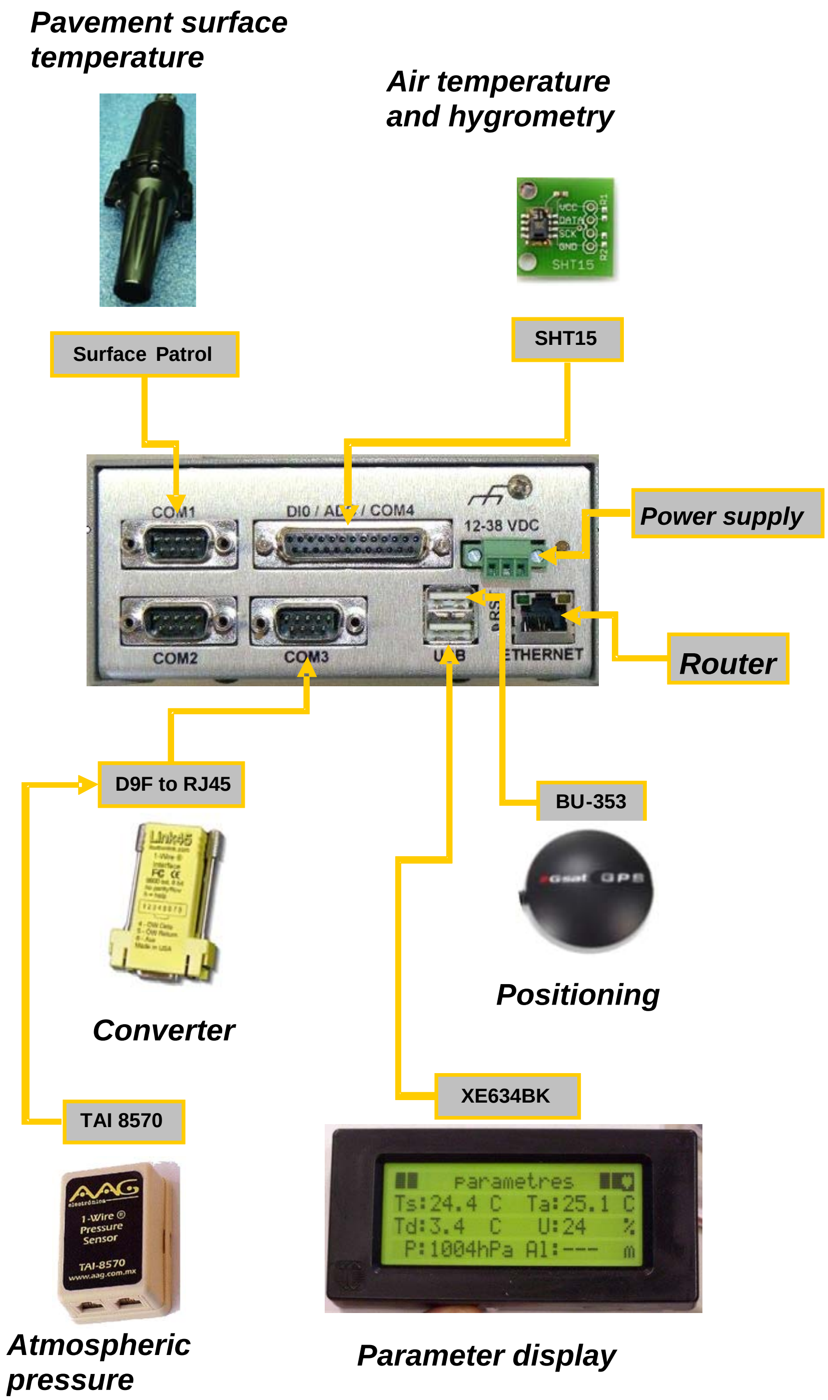

Figure 2: Second-generation data acquisition system

3. TECHNOLOGICAL ARCHITECTURE OF THE SOLUTION

Right form the outset, it was decided to use an open and modular architecture based on open-source software. A technological architecture based on the Linux operating system was selected in order to take advantage of the multi-task operating system and the wide availability of free software in order to reduce the development time for an on-board system. In addition, this choice makes it possible to remain independent of the hardware platform, thanks to the large number of processors supported by this operating system.

The hardware platform that was selected was a small on-board computer with an Intel 486 compatible ELAN SC520 processor, in order to facilitate the development of a workstation with an Intel processor. This equipment has relatively standard features: three RS232C serial ports, two USB ports, an Ethernet network port, a PCMCIA interface, and an 8-gigabyte compact flash memory interface.

With respect to the sensors and peripherals, it was decided to use sensors with digital interfaces in order to avoid magnetic interference problems with the radio transmitters on board the vehicles. Table 3 summarizes the list of sensors and peripherals used:

Table 3 – Selected sensors and peripherals

Description	Brand	Model	Bus
Pavement surface temperature	Quioxe	999J	RS232C
Air temperature and relative humidity	Sensirion	SHT15	Sensirion
Barometric pressure	AAG Electronica	TAI-8570	1-wire
GPS Position	GlobalSat	BU-353	USB
ACL 4 x 20 display	CrystalFontz	XE634BK-YFB-KU	USB
RS232C 1-wire converter	iButtonLink	Link45	1-wire

The data management system that was designed by the MTQ optimizes the collection of measurements taken by the sensors, which can be queried remotely and independently. Users can view the data on the vehicle’s display screen, retrieve data from the computer memory’s SQLite database, or transmit the measurements over a wireless connection. The data management system also has a visual interface that can be used to configure the parameters without programming knowledge

The data acquisition architecture (Figure 3) is based on a series of independent *daemons* – background processes that make it possible to manage queries related to elements of the system in order to read or display the data provided by the sensors. These *daemons* can be queried remotely using the Telnet TCP/IP protocol, providing real-time access to the measurements of the various parameters.

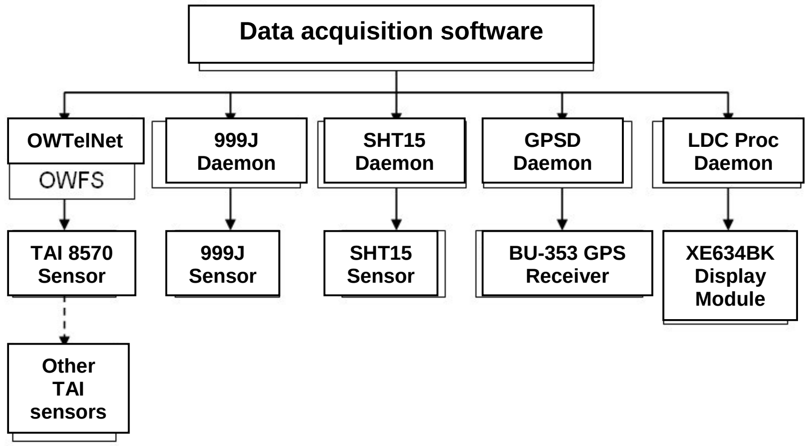

Figure 3: Architecture

Each of the daemons has a different IP port, which allows the sensor measurements to be read independently via the IP address of the computer's Ethernet network card. A PCMCIA Wi-Fi card also allows for collection of the data via a wireless network.

An Ethernet network that allows for the connection of a touch-screen computer for monitoring the network, a mobile road weather station, and a cellular router for data communication is installed in a van. The touch-screen computer can be connected locally to any daemon of the mobile road weather station in order to query the values of the sensors that measure the road and meteorological parameters. The data from the mobile road weather station can be transmitted to a remote server, and a remote connection to the mobile road weather station can be established in order to diagnose the proper operation of the sensors.

Finally, with a view to ensuring that deployment can be carried out rapidly and properly, an installation manual accompanying the various components of the road weather station has been prepared. The purpose of this manual is to standardize installation on the various types of vehicles used by the MTQ, and to highlight the precautions to be taken in order to ensure that this type of equipment will provide long-term service.

4. DEPLOYMENT AND UTILIZATION OF THE TOOL

The second generation of mobile road weather stations was deployed in more than 130 vehicles that are used to monitor the highway network for winter viability. The MTQ’s winter maintenance professionals have completely integrated this innovative tool into their implementation and understanding of the road weather phenomena that may affect highway safety, including ice formation.

The development and use of this tool supports winter road maintenance decision-making processes in real time by helping personnel to plan operations at the proper time and with the proper materials. The cross-referencing among the various parameters is very useful in terms of formalizing the prediction of road weather phenomena and determining the scope of operations aimed at ensuring the safety of the highway network.

As a simple example, the lower value between Ts and Ta can be used to determine whether there is a risk of condensation on the pavement (Ts < Ta). Once this risk (Ts < Ta) has been determined, a comparison between Ts and the dew point (Td) can be used to determine whether the condensation on the pavement will be liquid (water if Ts > 0°C) or solid (white ice if Ts < 0°C) if Ts < Td.

At the present time, operational personnel consider this new tool that was developed by the MTQ to be indispensable for daily operations on the network. They believe that using this tool improves infrastructure operations and ensures quality road maintenance by prioritizing actions that have an impact on safety. In addition, it facilitates the rational and sustainable use of resources such as de-icing chemicals and abrasives, and contributes to sustainable development. This new tool also contributes to the development of human resources by providing operational decision-makers with objective indicators for decision-making and an understanding of road-weather phenomena on the road network.

5. DESCRIPTION OF THE GENERAL APPLICABILITY OF THE INITIATIVE TO TRANSPORTATION

Innovative solutions aimed at protecting highway users and optimizing the maintenance of the highway network has been developed in response to Québec's harsh winter conditions.

Mobile road weather stations meet this dual concern. They represent an innovative concept in terms of the collection of data pertaining to the environment, atmospheric conditions, and pavement conditions that have a direct impact on decision-making for winter maintenance operations. They help to significantly increase user safety, manage de-icing agents and abrasives judiciously, and protect the environment.

This new tool will also make it possible to document the thermal behaviour of the surface temperature of pavement in a specific location as a function of total net radiation (various situations in terms of cloud cover) in order to produce continuous daily road maps that indicate the potential danger of ice formation.