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Introduction

Alberta Transportation (AT) has installed an extensive network of over 100 Road Weather Information Stations (RWIS) throughout the province. AT’s Maintenance Decision Support System (MDSS) utilizes observations from RWIS to provide treatment recommendations for individual plow routes. Locations further away from RWIS observations rely on assumed road conditions to provide treatment recommendations.

Weather sensor technology has recently emerged to provide road weather observations directly from moving vehicles. Traditionally, these road weather observations have been collected by the static RWIS, but Mobile Weather Sensor technology offers many new advantages for improved situational awareness and decision support for road maintenance operations.

Mobile RWIS technology presented AT with the opportunity to provide more geographically specific observations for locations between RWIS, without incurring the cost of installing a full RWIS unit.

Schneider Electric, AT’s RWIS service provider, in conjunction with Traffic Tech 2000, the Canadian distributor for Lufft weather sensors, proposed a pilot with AT to investigate the value of Mobile RWIS technology during the winter of 2015-2016.

Pilot Goals

The following goals were identified by AT for the Mobile RWIS pilot to obtain insight based on actual field usage:

1. How do Mobile RWIS observations compare to existing RWIS observations?
2. Can Mobile RWIS observations be used as a source of additional information between RWIS?
3. Do Mobile RWIS observations have value to a winter maintenance operation? Specifically,
   a. Can treatment be adjusted to better match the actual road conditions by using Mobile RWIS observation information?
   b. What is the value of Mobile RWIS observations in the evaluation of snow and ice control treatments to improve treatment decisions in the future?
Mobile RWIS Technology

Mobile RWIS technology generally has the following characteristics:

- A downward-facing sensor installed on specific road maintenance vehicles collects direct measurements of the pavement condition, pavement temperature, presence of chemicals, friction, etc. of the roadway.

- Targeted observations are collected in locations where road condition information is specifically required for making operational decisions.

- Data collection is controlled directly by the road maintenance agency:
  - Weather observations can be taken before, during and after a storm.
  - Information can be gathered at all times of day through both day and night patrols.
  - Installed sensors on road maintenance vehicles ensures coverage of primary and secondary roads.

Equipment Description

The Mobile RWIS technology chosen for the AT pilot was the Mobile Advanced RWIS (MARWIS-UMB) device from Lufft, Inc. This device utilizes infrared measuring via four emitting and two receiving diodes that capture the reflecting behavior of the road surface at varying wave lengths. Due to the different spectral properties of various substances — e.g. water and ice — the road state can be deduced from the captured values. MARWIS-UMB delivers values for road temperature, dew point temperature, relative humidity at road temperature, water film height, road state, ice percentage and friction.

As ice particles increase on the road surface, the friction coefficient delivered by MARWIS-UMB falls, providing valuable information for the treatment decision-making process.

Due to the open interface protocols, MARWIS-UMB can be easily integrated into existing winter maintenance monitoring networks. Similarly, MARWIS-UMB can communicate directly with the control system of plow vehicles.

MARWIS-UMB sensors have been tested by Lufft for accuracy up to speeds of 85 kilometers per hour, so vehicles traveling in normal traffic are able to obtain accurate road observations.

MARWIS-UMB Observations

The MARWIS-UMB device utilized in the AT pilot collected the following information:

**Road surface temperature**
The road surface temperature is measured with a non-invasive pyrometer which is fully integrated into the sensor.

**Dew point temperature**
The dew point temperature is the temperature where the current partial water vapor pressure equals the saturated vapor pressure, indicating condensation, e.g., in the form of fog.

**Relative humidity at road temperature**
The calculation of the relative humidity at road temperature is based on the absolute humidity and the road temperature. It can be used as an indicator for impending formation of dew or frost.

**Water film height**
The water film height on the road surface is measured with non-invasive optical spectroscopy. The water film height indicates the proportion of liquid water on the roadway.

**Road condition**
The road condition is determined from the measurement of water film height, road surface temperature and ice percentage. The sensor deduces the road conditions of dry, damp, wet, snow / ice as well as critical and chemical wetness. The values which are supposed to be used in the calculation of the road condition can be set, e.g., highest, lowest or average road temperature of the last covered road section. For this purpose, predefined settings are available for selection.

**Ice percentage**
With the data from the optical spectroscopy, the frozen part of the aqueous solution on the road is determined and delivered as ice percentage.

**Friction**
Friction describes the adhesion of tires on the road surface. This can be reduced due to ambient conditions such as rain or snow. The value of the friction is scaled between 0.1 and 1.0. High values indicate high adhesion, low values stand for low adhesion. The highest value (1.0) will be achieved when the road is dry whereas the lowest result (0.1) represents water on ice.

Note: The grip of a road is determined basically by the consistency of its surface. The friction value of the MARWIS-UMB indicates to which degree the maximum possible grip of a specific road is reached, respectively how much it has been reduced by ambient conditions. Therefore, identical friction values of the MARWIS-UMB on different road surfaces mean different grip.
Connected Vehicle vs. Mobile RWIS Technology

Connected Vehicle is a broad term describing a range of technology which allows vehicles to connect with other vehicles and to connect to nearby infrastructure for the purposes of sharing information to support safety and mobility. Connected Vehicle technology collects information from standard sensors commonly installed on the majority of vehicles traveling within the transportation network. The following characteristics generally apply when Connected Vehicle data is used to support winter road maintenance decisions:

- Pavement and weather conditions are inferred rather than directly measured, using observations from ABS, wipers, headlights, etc.
- A large number of public vehicles provide observations, so data must be verified and aggregated.
- Availability of data depends on driver behavior:
  - Most vehicles drive primarily in “good” (dry) weather.
  - The majority of trips occur during the day.
  - Most frequent routes of travel are focused on major routes, leaving less travelled areas without data.

Alberta Transportation is investigating both Mobile RWIS and Connected Vehicle technologies to understand the potential for both types of observations to improve the safety and efficiency of the provincial transportation network.
Mobile RWIS Pilot Description

Alberta Transportation utilizes contracted highway maintenance services throughout the province. Volker Stevin is the Highway Maintenance Contractor (HMC) in southern Alberta, which includes Calgary.

Volker Stevin routinely patrols the roads between October 15 and April 15 of each year as part of their winter road maintenance contract. During the daytime, primary roads (single or double digit highways) are inspected five to seven days a week, depending on weather conditions. Secondary roads (triple digit highways) are inspected at least three times per week during the day. During the night, selected primary roads are checked seven days a week. Road inspections are performed as needed outside of the October 15 and April 15 season.

Since routine road patrols were already being performed by Volker Stevin, patrol vehicles provided an ideal platform to install Mobile RWIS. MARWIS-UMB weather sensors were installed on two Volker Stevin patrol vehicles during the summer of 2015 and were utilized throughout the winter of 2015-2016. Schneider Electric’s primary contract at Volker Stevin for this pilot was Carl Bodkin (CarlBodkin@volkerstevin.ca).

Alberta Transportation Highway Maintenance Contractors (HMCs)

MARWIS-UMB installed on Volker Stevin night patrol vehicle
Components on each truck included a MARWIS-UMB sensor, mounting bracket and an in-cab tablet with a cellular data plan. MARWIS-UMB data was geo-referenced using the tablet’s GPS and distributed through a data cloud. This data was stored in a database hosted by Lufft and made available for display in near real-time within Alberta Transportation’s WeatherSentry Online® Platinum Pavement Forecast Edition (WeatherSentry) application from Schneider Electric.

The tablet installed in the cab of the patrol vehicle displayed real-time data from the MARWIS-UMB sensor directly to the driver.
Should the cell connection experience a low quality signal or break down entirely, the iPad® stores the collected observations and uploads them when connection has been re-established.

This same data was displayed in WeatherSentry, showing both the latest vehicle position, observations from each MARWIS-UMB, and a three-hour history of weather observations for further analysis.

Real-time and historical MARWIS-UMB observations displayed in WeatherSentry

A diagram of the overall MARWIS-UMB data flow is provided below.

MARWIS-UMB data flow diagram
Weather Conditions During MARWIS-UMB Pilot

During the 2015-2016 winter season, Alberta’s winter was warmer and drier than average, particularly in southern Alberta where the MARWIS-UMB were being utilized by Volker Stevin. This pattern resulted in limited opportunities to test the sensors during full winter precipitation events. However, significant information was collected during this pilot to address the project goals.

Alberta winter 2015/16 recap (Nov/Mar)
Mobile RWIS Observations vs. Static RWIS Observations

Alberta Transportation has deployed over 100 RWIS stations throughout the province to collect accurate, timely data to provide intelligence on current road weather conditions. The breadth and scope of Alberta’s RWIS installation makes it one of the largest RWIS networks in North America.

A comparison of MARWIS-UMB observations to existing static RWIS observations was performed during the winter of 2015-16. As a patrol vehicle passed by a static RWIS, MARWIS-UMB weather observations were compared with the RWIS observations.

During the pilot, the two Volker Stevin patrol vehicles typically travelled in and around Calgary. MARWIS-UMB to RWIS comparisons were made along Highway 2 south of Calgary at the OKOTOKS RWIS and east-west through Calgary along Highway 1 at the STONEY TRAIL RWIS. Volker Stevin also purchased a handheld road temperature gauge as an additional data measurement tool. Volker Stevin consistently collected road temperatures via MARWIS-UMB that were within 1-2 degrees Celsius of the static RWIS road temperature observations throughout the winter. Comparisons of MARWIS-UMB vs. RWIS road temperatures utilizing WeatherSentry showed similar consistencies. An example is shown in the following WeatherSentry screen shot:
While it may seem logical to expect an embedded pavement sensor (RWIS) and a remote pavement sensor (MARWIS-UMB) to produce exactly the same pavement temperature readings, due to the differences in how each sensor takes measurements, some differences can and should be expected. A memo produced by micKS (http://micks.de/en/) on this subject identified the following potential differences between embedded and remote pavement temperature observations:

1. A +/- 1C difference between embedded and remote surface temperatures has been measured in optimal and stable conditions.
2. Embedded surface temperatures change more slowly than remote temperatures.
3. Differences in incoming or outgoing solar radiation can result in differences of +/- 3C.
4. Data sampling frequency differences should be considered when comparing temperatures; gradients of +/- 2C per minute are possible.

A qualitative comparison was performed between the pavement condition reported by MARWIS-UMB and camera images taken by RWIS. Overall, there was good agreement between the pavement condition as judged by the RWIS camera image and the pavement condition that was measured by the MARWIS-UMB. One such example is shown below, where MARWIS-UMB observations indicate a wet/chemically wet road condition, which is supported by the RWIS camera image:

Comparison of RWIS camera and MARWIS-UMB pavement condition
Volker Stevin also produced ad-hoc camera images during the pilot to document road conditions, but mostly during timeframes where MARWIS-UMB observations did not match the actual road conditions. These instances were utilized to calibrate the MARWIS-UMB sensors. Future Mobile RWIS implementations would benefit from images collected by installed dashboard cameras to capture regular images with the purpose of corroborating mobile observations with actual road conditions.

The following example shows MARWIS-UMB readings which require further calibration, due to the fact that the pavement condition of DRY from the MARWIS-UMB does not agree with the conditions being observed out the windshield.

In-cab MARWIS-UMB display (reading DRY) in obviously wet conditions
Using Mobile Weather Observations and Existing RWIS

MARWIS-UMB readings were not only taken in and around existing RWIS during the winter of 2015-16, but wherever Volker Stevin patrol vehicles travelled. In doing so, several valuable characteristics of mobile observations were identified as part of this trial, such as providing insight for locations between RWIS, providing additional observation parameters beyond what is currently available from RWIS, covering additional geographies and capturing spatial variations.

In the example below, the start and end points of the MARWIS-UMB pavement condition observations agreed well with the DRY pavement condition readings coming from the RWIS network around Calgary. But as the MARWIS-UMB travelled along Highway 40 from south to north, variations in pavement condition were observed, showing icy conditions (pink and purple) during the first half of the trip, turning to wet conditions (green) during the second half of the trip. This demonstrated that while the RWIS observations were accurate for the locations they represent, spatial variations do exist in-between RWIS that can be identified by MARWIS-UMB.

MARWIS-UMB observations between two RWIS locations:
Colorized breadcrumb trail depicts pavement condition of Highway 40.
Another example showed ICE WARNINGs observed by the RWIS network in Calgary, with the MARWIS-UMB travelling along Highway 2 showing icy conditions (pink dots). The MARWIS-UMB also showed several stretches of dry conditions (brown dots) along Highway 2, demonstrating again that spatial variations can and do exist between RWIS and can be identified by MARWIS-UMB.

![Map of Calgary showing ICE WARNINGs and dry conditions along Highway 2.](image)

**MARWIS-UMB observations between RWIS sites:**
Colorized breadcrumb trail depicts pavement condition of Highway 2.

MARWIS-UMB provided measurements of the spatial variations in pavement temperature that winter maintenance organizations knew existed between RWIS. One such example is show below, where patrol vehicles equipped with MARWIS-UMB drove a section of Highway 68 with elevation gain and loss as well as variations in sun/shade. Over a relatively small distance of less than 15 kilometers, the pavement temperature dropped from 2°C to -8°C as the MARWIS-UMB travelled from east to west. These spatial variations in pavement temperature can have an impact on chemical effectiveness and treatment strategies during winter precipitation events.
MARWIS-UMB also provided additional parameters beyond what was available from the RWIS network. Examples of these additional parameters include ice percentage and friction, shown in the examples below. Ice percent shows promise to more specifically identify smaller sections of pavement where icy conditions may be occurring, allowing a more targeted response by the HMC. Friction provides a summarized green-yellow-red indication of where pavement conditions are deteriorating and accidents may be more likely to occur.
MARWIS-UMB friction observations overlaid on Environment Canada radar
Data Collection for New Roadway Types

MARWIS-UMB also provided weather observations in sections of roadway that may not have had any information available in previous winters. These included secondary highways, on/off ramps, overpasses and in-town roads. Examples of MARWIS-UMB readings taken in these locations are shown below.

![MARWIS-UMB observations for in-town roads](image)

![MARWIS-UMB observations for secondary roads](image)
MARWIS-UMB observations for on/off ramps and overpasses
Winter Maintenance Operation Value

Volker Stevin identified labor scheduling and material costs as major factors to consider in their winter maintenance decision-making to meet Level of Service requirements in the most cost efficient manner. Labor decisions must also be based on maximum timeframes under which employees may work, coupled with the requirement to call in spare operators at any time of the night or day. Chemicals for treating roadways are often over-estimated to ensure that the entire roadway can be treated, even if the conditions are not consistent throughout the plow route.

Case Study: Highway 541 on March 2, 2016

On March 2, 2016, MARWIS-UMB technology was utilized by Volker Stevin decision-makers to utilize their labor and material resources more effectively and efficiently:

- Because there is spotty cell service along Highway 541, the typical procedure for patrol vehicles was to make the 30-minute drive, then phone in the results of the patrol when the truck was back in cellular range. If problem areas were identified anywhere along Highway 541 after the patrol route was travelled, typically two plow trucks and 24 tons of material were dispatched to treat the roadway.

- On March 2, 2016, a patrol vehicle with a MARWIS-UMB patrolled Highway 541. The MARWIS-UMB data was routinely updating in WeatherSentry, since data transmission can be accomplished through a weaker cell signal that a cell phone call requires. A supervisor back at the garage immediately saw the weather observations from the patrol vehicle. The supervisor also saw that weather observations from MARWIS-UMB showed that only a portion of Highway 541 contained problem areas. This information allowed the supervisor to immediately dispatch resources to deal with these problem areas, rather than waiting until the patrol vehicle finished the route. The supervisor decided to dispatch one plow truck with 12 tons of material, since the MARWIS-UMB observations showed that the entire stretch of roadway was not affected. The second plow that would have typically been dispatched to Highway 541 could then be assigned to address a different road with the other 12 tons of material.

What typically occurs (before mobile observations) | What actually occurs (with mobile observations)
---|---
- Pickup checking hwy-541 (spotty cell service) | Pickup checking hwy-541 (spotty cell service)
- Drives route for **30 minutes**, assessing problem areas | Supervisor sees problem area back at the garage as pickup drives
- Contacts supervisor and dispatches **two plow trucks** with **24 tons of material** | **Immediately** dispatches **one plow truck** with **12 tons of material** to problem area
- | Other plow can attend to a different road
By utilizing the various aspects of MARWIS-UMB as described in this document, Volker Stevin summarized the technology as a “key decision-making tool” during the 2015-16 winter season.

**Perspective from AT District Maintenance Engineer**

Dave Gray, P.Eng., is Alberta Transportation’s Maintenance Innovations Engineer, responsible for the Edson District where the MARWIS-UMB pilot was conducted. Dave stated that MARWIS-UMB observations utilized in this pilot successfully contributed to better treatment decisions for specific road conditions. He also said that they provided AT with data to analyze treatment decisions and how they could be improved in the future. However, the mild winter did not provide many opportunities to work with a fully representative set of storms, so he felt additional testing would be warranted.

In the future, Dave would like to see MARWIS-UMB observations collected in more remote locations, such as those far from existing RWIS. Mobile observations would also be valuable within known microclimates, to understand weather conditions that may not be occurring in surrounding areas.
Additional Feedback and Lessons Learned

In utilizing MARWIS-UMB during the winter of 2015-2016, Volker Stevin provided additional feedback regarding the installation, configuration and data characteristics. The following items should be considered when deploying MARWIS-UMB for road maintenance operations decision-making.

MARWIS-UMB Observation Location

Agencies should be cognizant of where the MARWIS-UMB is pointing when it is installed. Volker Stevin originally installed the MARWIS-UMB on the roof of the vehicle and pointed it at the centerline of the roadway. The readings from MARWIS-UMB installed in this fashion were found not to be representative of the actual road conditions, as typically the centerline represented worse road conditions than the rest of the roadway.

MARWIS-UMB Battery Considerations

Volker Stevin also pointed out that it was necessary to remember to unplug the MARWIS-UMB if the patrol vehicle was not moving for long periods of time. Keeping the MARWIS-UMB plugged in to a stationary vehicle drained the truck battery after about one day.

MARWIS-UMB Calibration

Common feedback from Volker Stevin was the necessity to properly set up and configure the MARWIS-UMB before using the data for decision-making. MARWIS-UMB contains a variety of settings to affect the readings coming from the sensor. These calibrations take some time and effort to get settled and an agency should not expect this to be “plug and play”.

The overall conclusion is that once calibrated, MARWIS-UMB provided good in-storm data, but that storm “fringes” (before and after a storm) requires the time and effort to properly calibrate the sensor. Volker Stevin also noted that the MARWIS-UMB sensed very small amounts of moisture and chemicals, which was difficult to confirm just by driving down the road.
Future Uses of Mobile Observations

Mobile observations could be utilized as input into pavement models to produce a more spatially granular pavement forecast in the geographies where mobile observations are taken. As mobile observations are taken throughout a winter season, the pavement forecast would routinely be modified based on this information, allowing small scale changes in treatment and response to be made to keep the road free of snow and ice. The example below shows MARWIS-UMB data in the lower-left part of the screenshot laid over the top of a route-based pavement forecast.

Cameras mounted within the vehicle containing a Mobile RWIS could add significant value to the overall data collected by providing a picture of current road as well as weather conditions. Volker Stevin took pictures to document anomalies during the pilot, however an integrated camera image taken at specific intervals could be displayed against the mobile observations to provide additional context.

Patrol vehicles are routinely deployed before, during and after a storm. As these patrol vehicles visually assess the effectiveness of the applied treatments after a storm, a mobile weather sensor could provide quantitative metrics to use in this performance measurement process. Variables such as friction could be used to support performance measurement across highway maintenance contractors.
MARWIS-UMB-equipped vehicle (right) “following” a plow truck (captured by RWIS camera on left)
Summary and Conclusions

The following conclusions were made during Alberta Transportation’s Mobile RWIS pilot during the winter of 2015-2016:

1. Mobile RWIS observations compared well with existing RWIS observations
   - MARWIS-UMB was more sensitive to moisture and chemical presence than RWIS.
   - Users should be aware of temporal and spatial gradients when comparing MARWIS-UMB to RWIS temperatures.
   - MARWIS-UMB observation target siting considerations are required (i.e., wheel tracks, shoulder, centerline, etc.).

2. Mobile RWIS provided additional information between RWIS observations
   - MARWIS-UMB provided additional parameters beyond what was available from RWIS, such as friction and ice percentage.
   - MARWIS-UMB provided weather observations over areas that may not have had observations, such as on/off ramps, overpasses, secondary highways and in-town roads.
   - MARWIS-UMB provided good in-storm data but storm “fringes” took time and effort to properly calibrate the sensor.

3. Mobile RWIS add value to a winter maintenance operation
   - Volker Stevin called it a “key decision-making tool”.
   - Alberta Transportation gained confidence in the value of mobile sensor technology to assist in making better treatment decisions.
   - MARWIS-UMB technology allows agencies to control their own destiny in weather intelligence gathering, including observations taken at night, during a storm and over sections of roadway where observations are specifically required (ramps, overpasses, etc.).
   - Observations are immediately communicated, providing valuable information directly to decision makers.
   - Cost savings can be realized through a more targeted road treatment plan, leading to labor and resource savings realized by both the highway maintenance contractor and the government.
4. **Future use of Mobile RWIS**

- Due to the mild winter, there were limited opportunities to test the Mobile RWIS under disruptive winter road conditions.
- Additional testing is warranted based on initial results.
- Mobile RWIS data has the potential to influence both pavement forecasts and MDSS treatment recommendations to provide more accurate, location-specific guidance to road maintenance operations.
- Mobile RWIS data has the potential to provide performance measurement and verification of treatment strategies, particularly when the mobile sensors are utilized on a larger number of patrol vehicles.
- Camera images collected in conjunction with Mobile RWIS observations would greatly enhance the situational analysis capabilities of the road conditions.
- The data collected by Mobile RWIS has the potential to be utilized and displayed in additional ways that were not explored in the AT pilot.
- Future use of Mobile RWIS within AT present the opportunity to define best practices.
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Appendix A

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