ASSESSMENT OF DEVICES USED TO MEASURE ROAD FRICTION IN WINTER CONDITIONS

Steve Arsenault, P. Eng.
Ministère des Transports du Québec, Québec City, Canada, G1R 5H1
Steve.Arsenault@mtq.gouv.qc.ca

SUMMARY

Road maintenance personnel do not always know the precise impact of road weather conditions on road friction in winter. In late 2006, the Ministère des Transports du Québec (MTQ) was seeking to supplement its basic mobile road weather instrumentation with a sensor that would allow for a more accurate assessment of this parameter during the winter.

In light of this, a research project pertaining to this subject was initiated in September 2007. The objectives of this project were twofold: to identify devices that are capable of carrying out road friction measurements in winter; and to test the capabilities and limitations of some of these devices.

An analysis of the sensors was carried out using two different approaches, from both an operational and technical perspective.

As a result, this project allowed the MTQ to determine the limitations of each type of device, which was essential in terms of identifying their potential use. From the technical and operational perspectives, the performance of some devices was sufficiently convincing to generate interest among operational personnel who are responsible for carrying out monitoring activities on the road network.

KEYWORDS

ROAD FRICTION / SENSOR / MOBILE / WINTER MAINTENANCE / TESTING

1. INTRODUCTION

Winter road maintenance is particularly complex, and the combination of a number of road weather parameters can create varying road friction conditions. There are a variety of work processes and specific tools that allow road network managers to determine the road weather situation and to anticipate tendencies in order to adapt the actions to be taken. However, the impact of road weather conditions on road friction is not always precisely known, because it varies according to location and over time.

In light of this, measuring this parameter is of particular interest to road network managers, because it allows for precise identification of areas where intervention is required.

Taking into consideration the interest among road administrations in terms of measuring this parameter, the MTQ, with the financial participation of Transport Canada, initiated a research and development project aimed at identifying and assessing sensors that are designed to perform this type of measurement.

2. DESCRIPTION OF THE PROJECT

As a first step, the project involved identifying products that are available on the market and that are fully capable of measuring road friction during the winter. Subsequently, the MTQ sought to assess the technical and operational potential of a certain number of these products.

The ultimate objective of the project was to compare the measurements obtained using these various products in a completely impartial manner, and independent of their method of operation, while focusing on the benefits that they may provide in terms of winter maintenance management as a whole.

In light of this, the project was divided into the following five crucial stages, which were designed to ensure that the MTQ would meet the objectives that it had set for itself in this area:

- Carrying out a technology watch pertaining to the subject
- Selecting and acquiring certain devices that are available on the market and that would not require any development work on the part of MTQ
- Analyzing the technical potential of the selected devices
- Analyzing the operational potential of the selected devices
- Assessing the application potential of the devices

3. TECHNOLOGY WATCH

At the start of the project, a technology watch exercise was initiated in order to identify devices that are capable of measuring road friction during the winter. This exercise, which was carried out on an international scale, revealed the existence of two distinct types of products on the market.

The first type measures road friction using a testing wheel with a slip angle. In addition to the reference device, the following two devices using this principle were selected:

- *Real Time Traction Tool* (RT3), manufactured by the US company Halliday Technologies Inc., and distributed in Canada by the Cargill company
- *IceChek*, designed by the company of the same name based in Canada (Alberta)

The second principle used in measuring road friction is the partial braking of a wheel. The following three devices that use this principle were selected:

- *Traction Watcher One* (TWO), supplied by the PON-CAT company in Norway, and distributed in North America by the TENCO company
- *Winter Friction Trailer 01* (WIFT 01), from the Québec company Nordaxe Innovations Inc.
- *Mk 3 Electronic Decelerometer* (Mk 3), developed by the TES Instruments company in Canada (Ontario)

The last device (Mk 3) was selected more for the purpose of comparison with other studies. This device and the reference device (Sideways-force Coefficient Routine Investigation Machine – SCRIM) were used only for technical analysis. Figure 1 shows photographs of the various devices, with the exception of the SCRIM.

Traction Watcher One (TWO)


Real Time Traction Tool (RT3)


IceChek

Winter Friction Trailer 01 (WIFT 01)

Mk 3 Electronic Decelerometer

Figure 1 – Photographs of the various devices

4. TECHNICAL ANALYSIS

The technical analysis that was conducted was intended to subject the various devices to a series of tests designed to determine their respective limitations. These tests were conducted in a controlled environment on a test track, as well as on location on the road network, with the attendant disparities.

4.1. Analysis in a controlled environment

In order to exercise a reasonable degree of control over the condition of the running surface while analyzing the devices, tests were carried out on a track that was set aside for this purpose, on which precise surface conditions were artificially created. Five lanes were set aside for the purpose of conducting successive tests using the various devices. Figure 2 shows the layout of the test site.

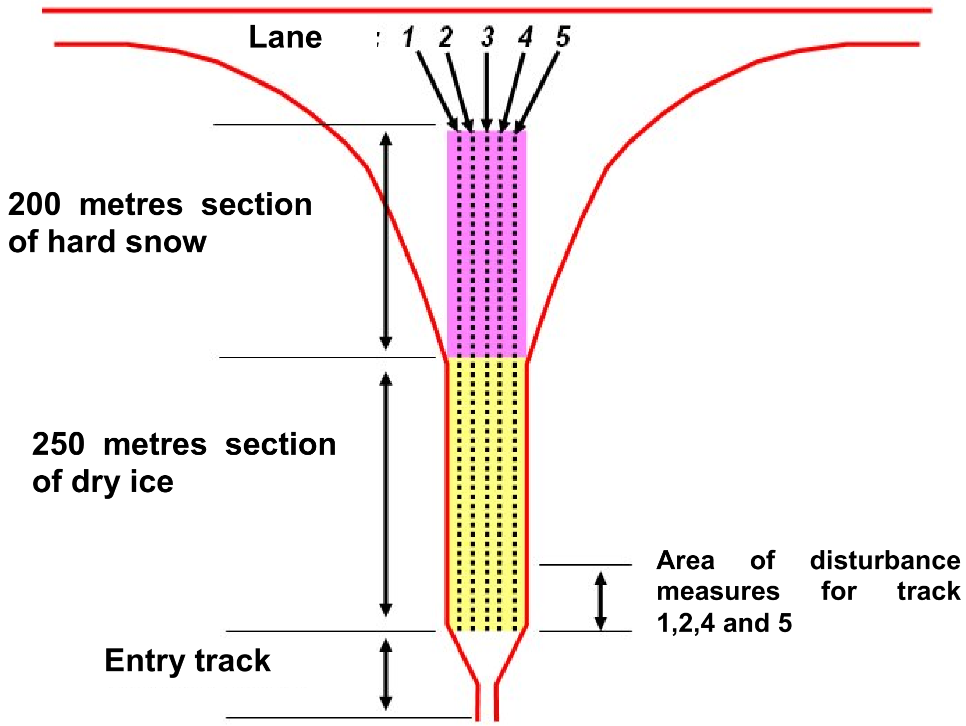

Figure 2 – Layout of the track for testing in a controlled environment

The tests that were carried out on this track on February 21, 2008 made it possible to measure the performance of the devices and their response to changes in the surface condition, because the test sections consisted partly of dry ice and partly of hard snow. The accuracy of the devices was also tested, along with their ability to reproduce the measurements and their ease of operation. Each device was required to complete successive passes on lanes 1, 2, 3, 4, and 5. Dry ice conditions were created over the first 250 metres of each lane, followed by 200-metre sections of hard snow.

4.2. On-location analysis

The on-location analyses were repeated several times on the Québec road network. More than 1500 kilometres of comparative tests were conducted on sections of road where the IRI characteristics (summer and winter) and road friction measurements (summer) have been well documented by MTQ personnel. Figure 3 shows the locations of the main testing sites, which were mainly located in the Québec City region, on roads that represent a variety of traffic volumes, levels of service, and geographic characteristics.

The tests that were carried out at these locations made it possible to assess the in-service performance on the road network under conditions that were sometimes extremely heterogeneous. However, successive passes were carried out with the various devices in all cases, which allowed them to be assessed under similar conditions. On some days, the variability of the pavement conditions severely tested the capacity of these devices to identify changes in surface condition at locations selected by MTQ technical personnel when conditions permitted.

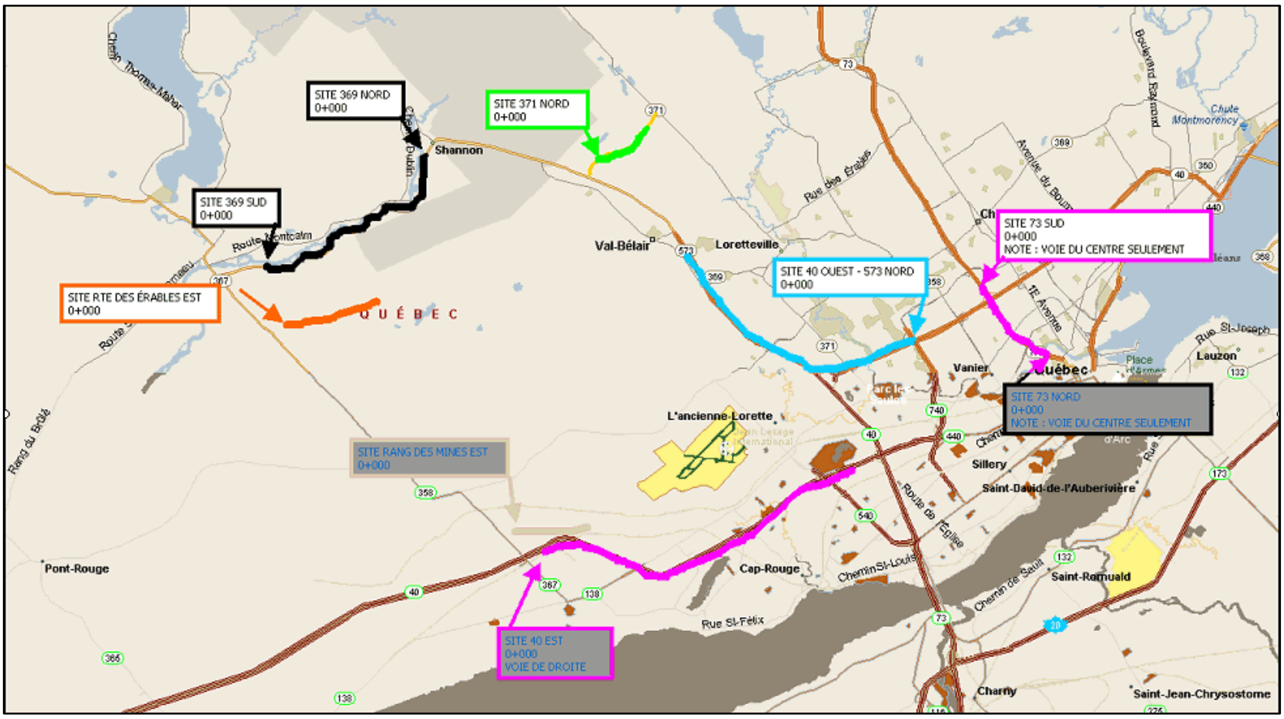

Figure 3 – Location of MTQ test sections in the Québec City region

4.3. Summary of the technical assessment of the devices

Based on all of the data that was collected during the technical assessment campaigns that were conducted in a controlled environment and on location, the MTQ personnel who were assigned to this project were able to draw conclusions pertaining to certain important characteristics of the devices. The following main characteristics were used to compare the devices:

- Ease of calibration
- Measurement scale
- Ability to reproduce measurement results
- Effect of changes in direction on measurements
- Ability to identify changes in surface condition

These characteristics are very important in terms of winter maintenance, because they can severely limit the utilization potential of the devices in some cases.

4.3.1. Ease of calibration

Terminology was defined for this parameter in order to describe both the documentation provided by the supplier for the calibration procedure and the application of the procedure by technical personnel. It is important to note that the MTQ was seeking to acquire functional equipment, and therefore, it expected to receive documentation that was sufficient for making a purchasing decision. This documentation must also describe the calibration procedure. In light of this, the terminology used to describe this characteristic is as follows:

- Easy: the calibration procedure is properly documented, and can be easily carried out by competent technical personnel.
- Fairly easy: the calibration procedure is properly documented, and can be carried out by competent technical personnel.

- Fairly difficult: the calibration procedure is not very well documented, but can be carried out by competent technical personnel.
- Difficult: the calibration procedure is not very well documented, but can be carried out by competent technical personnel with difficulty.

Table 1 shows the results obtained by the various devices with respect to this specific criterion.

4.3.2. Measurement scale

This parameter was analyzed, and it was determined that all of the devices that were assessed had their own measurement scales, ranging from 0 to 1 for all of the devices, with the exception of the RT3, which had a scale ranging from 0 to 150.

These findings made it more difficult to carry out a direct comparison of the values obtained by the various devices. It is important to understand that, unlike the case of equipment that is used to measure road friction during the summer, there is no standardized method for measuring the friction coefficient during the winter.

4.3.3. Ability to reproduce measurement results

This parameter was designed to assess the ability of each device to reproduce the same measurements on successive passes at the same location. In so doing, the MTQ sought to assess the consistency of the measurements produced by the devices.

This was accomplished using the test-track measurements (tests conducted under controlled conditions). Figure 4 shows the profile of some of the data used to assess reproducibility for the RT3 device.

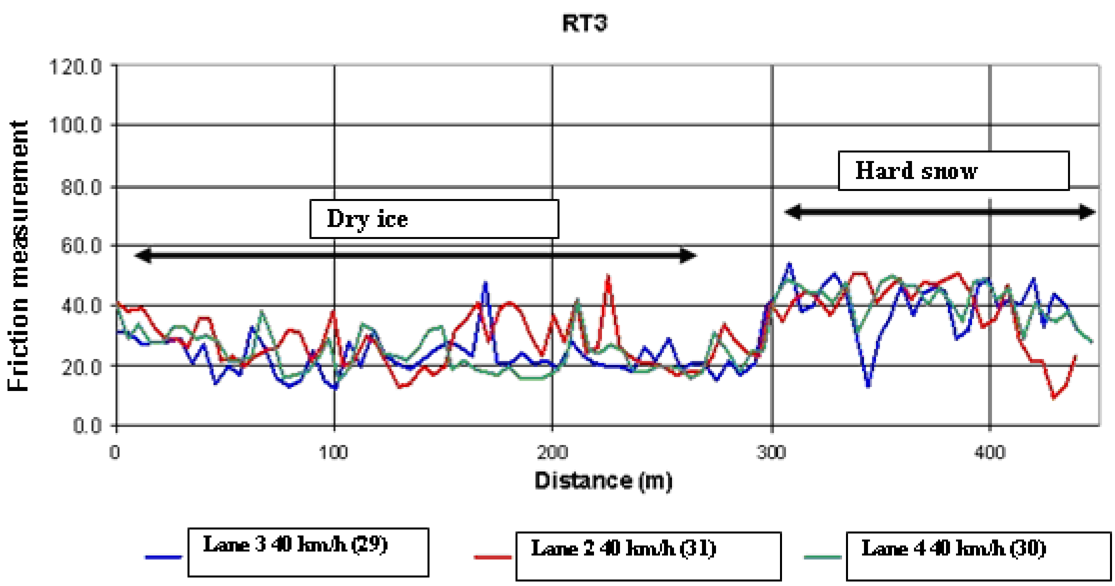

Figure 4 – Reproducibility for the RT3 device
Blainville test track (21/02/2008)

The data collected after successive passes by each device were used to calculate the mean values at certain specific points on the course (MVi), based on the following formula:

$$VMi = \left(\frac{VC2i + VC3i + VC4i}{3}\right)$$

Where: MVi: Mean value of the three curves located i metres from the start of the test section.

VL2i: The point value obtained i metres from the start of the test section on Lane 2.

Next, the relative deviations from the mean (RDMi) of the curves were calculated for each curve using the following formula:

$$ERMi = \left(\frac{VCxi - VMi}{VMi}\right)$$

Where: VLxi: The point value of curve x i metres from the start of the test section (x can be 2, 3, or 4, representing the corresponding test lane).

Finally, the mean absolute value of the relative deviations (MRDMi) was calculated using the following formula, and these values were graphed:

$$MERMi = \left(\frac{|ERM\,2i| + |ERM\,3i| + |ERM\,4i|}{3}\right)$$

Figure 5 shows the final representation of the mean deviation percentage for the RT3 device.

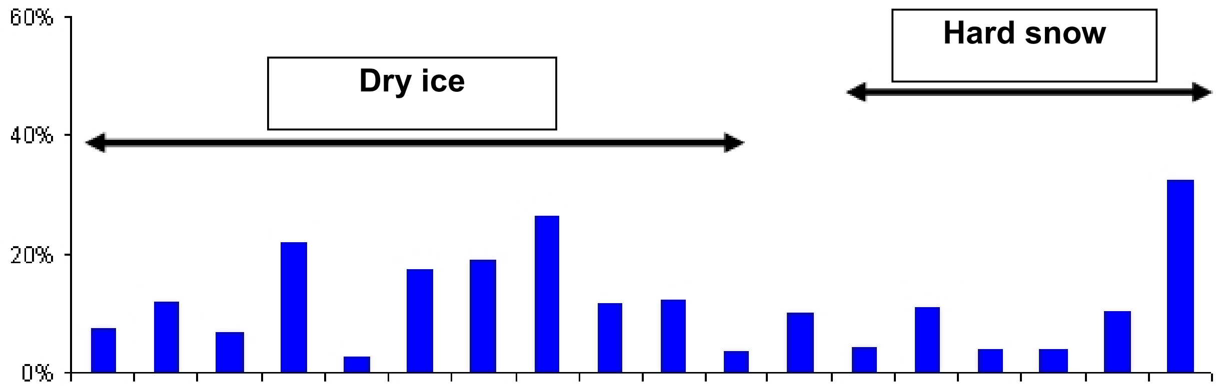

Figure 5 – Mean deviation from the mean measurement / Mean measurement
RT3 – Blainville test track (21/02/2008)

The same process was carried out for all of the devices, with the exception of the WIFT, for which the method of operation did not allow for this type of analysis. The assessment of the results for each device is listed in Table 1, which presents a summary of the technical assessment.

4.3.4. Effect of changes in the direction of the carrier vehicle

The tests that were carried out as part of this project revealed that the impact of a change in the direction of the carrier vehicle is greater in the case of devices that use a testing wheel with a slip angle to take measurements. However, this statement must be qualified somewhat, because the impact of a change in the direction of the carrier vehicle is not as great in the case of devices with a very large slip angle, which is why the SCRIM is a good comparison tool (it has a slip angle of 20°, whereas the RT3 and IceChek have slip angles of less than 3°).

Figure 6 illustrates the type of analysis that was conducted for this parameter on the road network. Major variations in the values are observed after 3 passes with the RT3 over a section of the road network that contains a right curve and a left curve. These variations do not appear in the results obtained on the curves in the same sector after a pass by the SCRIM. The results for all devices for this parameter are shown in Table 1.

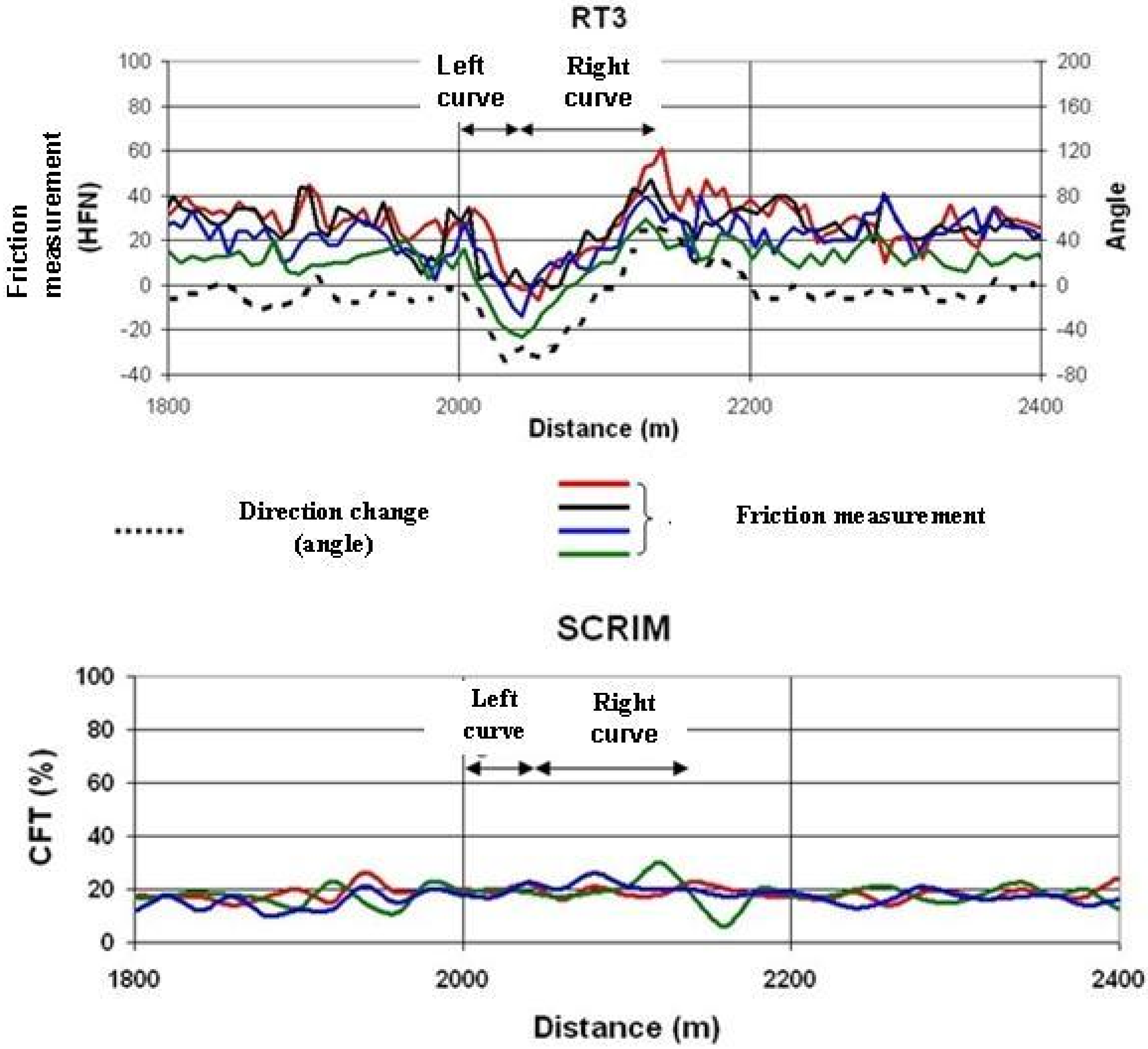

Figure 6 – Representation of the effects of changes in the direction of the carrier vehicle on measurements

4.3.5. Ability to identify changes in surface condition

The ability of devices to identify changes in surface condition is an important criterion for the MTQ. Therefore, this parameter underwent careful evaluation by the project's technical team. Tests were conducted on both the road network and the test track in order to subject each of the devices to a careful analysis with respect to this parameter. Figure 7 shows that the TWO performed well in terms of identifying changes in surface condition. After a first pass on this section of road (black curve), a second pass was carried out at the same location (red curve). In the time between the two passes, abrasives were spread between the 4.5 km and 8.5 km points. This change in surface condition was most accurately detected by the TWO device.

The other devices were subjected to the same type of analysis. The results are shown in Table 1.

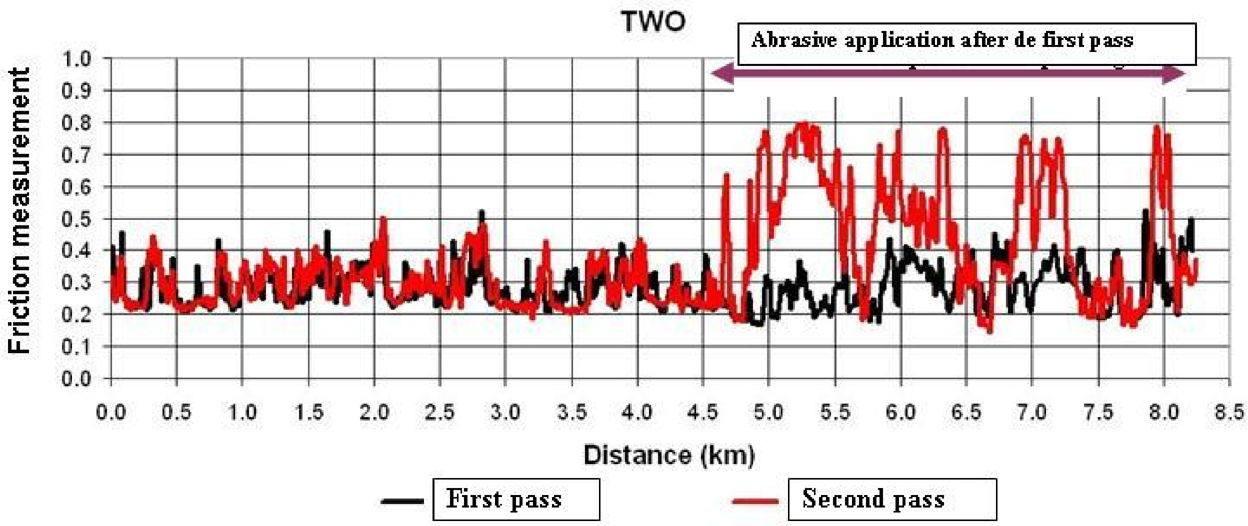

Figure 7 – Ability of the TWO to detect changes in surface condition

Table 1 – Summary of the technical assessment

ASSESSMENT CRITERION	RT3	ICECHEK	WIFT	TWO	VCR 3000
Calibration	Fairly easy	Difficult	Fairly easy	Easy	Easy
Measurement scale	HFN (0 to 150)	0 to 1	WIB (0 to 1)	μ (0 to 1)	0 to 1
Reproducibility	Acceptable	Satisfactory	N/A	Satisfactory	Acceptable
Influence of changes in the direction of the vehicle	Highly affected	Quite affected	Average	Slight	No measurement in a curve
Ability to identify changes in surface condition	Very good in a straight line	Relatively good	Poor	Very good	Poor

5. OPERATIONAL ANALYSIS

A second set of devices was purchased for regular use by MTQ operational personnel. The purpose of this approach was to supplement the technical analysis of the systems with an analysis that focused more on the perceptions of the target users. Each user was invited to make regular use of the same device throughout the testing period.

After several months of using the devices (RT3, IceChek, WIFT, and TWO), the personnel who were using them were asked to pronounce judgment based on certain evaluation criteria that are common to all of them.

In this context, MTQ personnel evaluated the following five criteria:

- Ease of retrieval of the data collected
- Encumbrance of the vehicle caused by the system

- Maintenance burden
- User-friendliness
- Impact of using the measurement device on the driveability of the vehicle

Ease of data retrieval is an important criterion, because the data can be used for various purposes (documentation of complaints or accidents, educational purposes, research and development, etc.). Table 2 presents a personal assessment of each device by the user.

In terms of encumbrance of the vehicle, the MTQ wanted to assess the impact of the presence of the various components of the device inside and outside of the vehicle. The various users rated this aspect of the analysis between moderately cumbersome and cumbersome.

With respect to the maintenance burden of the devices, some of them required a more sustained maintenance effort. For example, the TWO appears to suffer from rapid tire wear when subjected to continuous use.

The user-friendliness of the applications involved in the operation of the devices was specifically assessed. In this category, the IceChek and the TWO received positive comments from users.

The impact of using the device on the driveability of the vehicle is also an important characteristic in a study of this kind, because of its potential impact on user safety.

Some devices have a minor impact on the operation of the carrier vehicle, because the user must take his eyes off the road in order to view the measurements obtained. This applies to the IceChek and the TWO. In the case of the RT3, the heavier-duty design of the device requires the use of larger vehicles in order to minimize the impact of taking measurements on the handling of the carrier vehicle. In the case of the WIFT, the system is not equipped with a lifting apparatus, which was considered to be somewhat restrictive when users attempted to carry out certain manoeuvres. Table 2 presents a summary of the operational assessment of the various devices.

Table 2 – Summary of the operational assessment

Evaluation criterion	**RT3**	**IceChek**	**WIFT**	**TWO**
Data retrieval	Possible	Good	Difficult	Good
Encumbrance of the vehicle	Moderately cumbersome	Cumbersome	Cumbersome	Moderately cumbersome
Maintenance	Average	Traces of rust after 1 season	Frequent brake tests	Rapid tire wear
User-friendliness	Average	Good	Poor	Very good
Impact on driveability of the vehicle	Average	Slight	Average	Slight

6. APPLICATION IN TERMS OF WINTER MAINTENANCE: POTENTIAL OF THE DEVICES TESTED

There are a number of reasons for measuring road friction in winter conditions. The MTQ has identified seven reasons that are of particular interest for its purposes:

- Assisting in decision-making
- Measuring the results of maintenance operations
- Documenting events (complaints, accidents, incidents)
- Documenting critical points (recurring road weather phenomena)
- Research and development studies
- Information for road users
- Educational purposes

In order to assess the potential of the devices, a link was established between possible applications of road friction measurement and the characteristics of the devices. An evaluation grid was developed in order to assess the potential of the various devices in terms of the desired characteristics for each use. A panel of MTQ experts assessed the relative importance of each criterion (on a scale of 0 to 2) for each of the applications identified. The resulting weightings have the following meanings:

- 2: the criterion is essential to the performance of the function
- 1: the criterion is desirable for the performance of the function
- 0: the criterion is not essential to the performance of the function

The same panel of experts was then asked to assess the potential of each device with respect to the seven possible applications. Figure 8 presents the result of the panel's assessment of all of the devices with respect to the application "Assisting in decision-making".

However, it is important for the reader to avoid comparing the assessments of devices that provide continuous readings (RT3, IceChek, and TWO) with the assessments of devices that only take point readings (WIFT and Mk 3). These two types of devices cannot obtain equivalent results.

		Data viewer	Data acquisition	Positionning	Repetability	Calibration	Accuracy when change of direction	Surface condition detection	Sustainability	Usability	Vehicle obstruction	Sensor maintenance	Impact on driving
Mesures continues	TWO	1	1	2	2	2	1	2	1	2	1	0	2
	IceChek	1	1	2	2	0	0.5	1	1	2	0.5	2	2
	RT3	0	0.5	0.5	1	2	0	2	2	2	1	2	1
Mesures ponctuelles	WIFT 01	0	0.5	0.5	1	2	0	2	2	2	1	2	1
	MK3	1	1	0	2	2	-	0	-	-	-	-	-

Figure 8 – Results of the assessment of the potential of the various devices
with respect to assisting in decision-making

7. CONCLUSION

Measuring road friction has great potential for road administrations that are responsible for winter road maintenance. It can provide useful input for network managers in a variety of ways.

Various devices used for measuring road friction were tested within the context of this analysis. All of these devices have a certain utilization potential that partially meets the main specific needs of road administrations.

In light of this, it is important to keep in mind that a road administration may have a diversity of expectations in terms of measuring road friction, and that the choice of device must be based primarily on a precise determination of needs in terms of application. The reliability of the equipment, and more particularly the consistency and ease of calibration, are important criteria to be considered.