

Friction Meter Comparison Study 2011

Abstract

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Original raport (in finnish) can be found:

http://www2.liikennevirasto.fi/julkaisut/pdf3/lts_2011-48_kitkamittareiden_vertailututkimus_web.pdf

This translation is not verified by professional translators.

1. Introduction

The friction requirements are an essential part of the winter maintenance quality requirements in public roads in Finland, Sweden and Norway. The idea behind these frictions requirements are, that all the main roads don't need to be bare, as far as the friction on the road surface is sufficient. This policy minimize the need of various environmentally unfriendly anti-icing materials and chemicals.

In Finland, the road authorities, quality control consultants and the private winter maintenance contractors measure the road friction. The Finnish Transport Agency (= road authority) specifies the instruments and methods to be used in public roads friction measurements.

In Finland, during last 25 years, our road friction measurement is based on the method, where the small electrical in-car accessory determine the deceleration during braking and therefore estimate the friction. Those accessories are intended to be used in ordinary passenger cars or SUV's (Sport Utility Vehicle). When measuring friction, driver brakes the car with full force about 1-2 seconds and then releases the pedal. During the braking, the car speed decreases, but the car won't stop. The measuring cars have been equipped with studded tyres and they have ABS-brakes.

The measurements should be taken on the flat road section and driver should carefully be aware, that no one is behind the car, neither driving from the opposite direction. The measurement should be carried with passenger cars or SUV's, and we haven't heard of any serious accidents connected to that kind of friction measurement during last 25 years. On the contrary, we know about one fatal rear-end accident, when obviously rather non-experienced user tried to measure friction with a lorry.

Because the tyre condition, air drag and brake system of the measuring vehicle has an effect on the friction value, the friction meters have to be calibrated during so called "calibration days" several times during a winter. During those calibration days, the drivers make sure, that all the friction meters give same results in same place and same time. If the friction value is not satisfactory, driver adjust the calibration coefficient until the result is agreeable. According to the guidelines, the friction value should be 0,29 on packed snow, when temperature is -5 °C.

The traditional friction meters, used from 1980's, get their measuring impulses from the vehicle speedometer sensor and brake light wire. The speedometer sensor gives the vehicle speed before and after the braking. The brake lights tell the duration of the braking. This information is enough for the friction meter to calculate the friction value.

These traditional friction meters have one remarkable shortage: the meter installation needs professional expertise and becomes more difficult when electrical systems in the new vehicles are getting more complicated. That's why new friction meters utilizing acceleration sensors are today

so interesting. For these new meters, it's enough to install them firmly near to the dashboard. If the installation is firm enough, the deceleration measured by the acceleration sensor is same as the deceleration of the vehicle during braking. And the friction value displayed is relative to the deceleration.

Thus, the object of this study was to assess if the new friction meters with the acceleration sensors are so reliable and accurate, that these meters can be utilized in winter maintenance quality control in Finland. Furthermore, the object was to determine quality requirements for friction meters, so that the meter manufacturers can directly see, if their meter is suitable for winter maintenance quality control. In the future, when a manufacturer wants his meter to be used in quality control, he must present a report card of the conformity, made by an independent research organization.

This friction meter comparison study included several friction meters intended to use in winter maintenance quality control, as well as some other types of friction meters. The chapter 2 describes these meters more accurately.

2. The devices compared in the study

The devices compared in the study has been classified in table 1. The two uppermost classes represent meters that are intended to be used in the winter maintenance quality control. All the devices, except T2GO and VBOX, have been developed and manufactured in Finland.

Table 1. The devices (compared in the study) classified in the basis of the operational principle (this is not any "official" classification).

Device class	Operational principle	Name
"Traditional friction meters"	Calculates the friction in the basis of vehicle wheel spinning speed and braking time.	Eltrip-45n
Friction meters using acceleration sensor	Calculates the friction in the basis of deceleration measured by acceleration sensor.	μTEC
		Gripman
		Eltrip-7kmb
Optical friction meters	Estimates the friction and road condition in the basis of the reflectivity of the road surface.	DSC111
		RCM411
Mechanical friction meters	Needs additional measuring wheel or wheels, which have a constant or variable slip. The friction is calculated in the basis of slip or forces affecting to the measuring wheel.	T2GO
Vehicle measurement instrument	Measures the vehicle speed and braking distance in the basis of accurate GPS. The instrument doesn't display any friction values, but it can be easily calculated in the basis of speed and braking distance.	VBOX

2.1 Eltrip-45n

Eltrip-45n, so called "Old Eltrip", was the only comparison study device, which represented the traditional measuring technique from the 1980's (figure 1). This friction meter was used as a reference meter in the study. This same device can also be used as an accurate speedometer and odometer (the distance measurement can also be calibrated), thus the information of the speed and distance, as well as the friction, is based on the information of wheel spinning speed. More information can be obtained from the manufacturer internet-pages: http://www.trippi.fi/en_mittari_et45nk.shtml.



Figure 1. Eltrip-45n. Dimensions 118x46x30 mm. Price is about 700 € + VAT and the installation 200 - 300 € + VAT.

2.2 μ TEC

μ TEC is an software, an application for certain mobile phones (figure 2). When we later talk about μ TEC-friction, we mean the friction measured by an cell phone using μ TEC application. μ TEC can only be used in the cell phones, which has already an acceleration sensor inside. When the cell phone is attached firmly to the vehicle, the μ TEC application will register the cell phone deceleration during the braking and calculates the friction. If desired, the results can be sent immediately on the map (can be seen on the internet) in the basis of phone GPS coordinates. The results can also be saved on the cell phone memory. More information:

http://www.teconer.fi/index_tiedostot/Page478.htm.



Figure 2. μ TEC user interface in a cell phone. The μ TEC application license was about 500 € + VAT in the year 2010.

2.3 Gripman

Gripman is an independent friction meter using own acceleration sensor (figure 3). Gripman has no own memory for the results, but results can be send to cell phone or mobile computer via bluetooth connection. More information: <http://www.al-engineering.fi/en/gripman.html>.



Figure 3. Gripman. Dimensions 80 x 130 x 50 mm. Price was about 900 € + VAT in the year 2010.

2.4 Eltrip-7kmb

Trippi Ltd, known before as a manufacture of the "traditional friction meters", announced 2010 a new model using own acceleration sensor (figure 4). The Eltrip-7kmb or "New Eltrip" has no own memory for the results, but results can be send to cell phone or mobile computer via bluetooth connection. More information: http://www.trippi.fi/en_mittari_et7k.shtml.



Figure 4. Eltrip-7kmb. Dimensions 120 x 60 x 25 mm. Price was about 650 € + VAT in the year 2010.

2.5 Mobile DSC111

The mobile Vaisala's DSC111 is a mobile version of the popular fixed roadside sensor DSC111 (figure 5). The optical DSC111 estimates the friction and road condition in the basis of the reflectivity of the road surface. The device should be installed on the vehicle roof, pointing in the 45 degrees angle towards road surface. The device can be installed either backwards or forwards. If installed forwards in the passenger car, device may need a long pole so that device will look on the road, not on the vehicle engine bonnet. On the other hand, the pole should be stiff. When looking forward during snowstorm, the lens get easily covered with snow. When looking backwards, the measurement can be disturbed with snow raised by the vehicle wheels. In this study, the device was decided to use backwards.

In all cases, the device should point on a wheel track (left or right) in order to be sure that device is measuring the road conditions drivers will feel. The operation of the device need an in-vehicle portable computer (wire connection). The computer stores the information 20 times in a minute. More information:

<http://www.vaisala.com/en/roads/products/roadweathersensors/Pages/DSC111.aspx>.



Figure 5. The measuring vehicle in the study. T2GO in front of the vehicle, DSC111 (white box) on the roof and RCM411 in the rear, near the ground.

2.6 RCM411

Teconer Ltd, manufacturer of the μ TEC, has also developed an optical road condition and friction sensor (figure 5). The device should be installed on the vehicle towing hook and should be pointed

in the 90 degrees angle towards road surface. The device will send the information to the in-vehicle mobile phone using bluetooth connection. Because the phone will gather information every 1 second, an extra memory card is usually needed in the phone. If the cell phone has GPS, the coordinates are connected to the data. The price of the device is about 6000 € + VAT. More information: http://www.teconer.fi/index_tiedostot/Page478.htm.

2.7 T2GO

T2GO weighs about 20 kilos and is operated manually when walking on the surface to be measured (figure 5). There is a constant 20 % slip between the two wheels. The friction is calculated by measuring the force needed to achieve the slip. The device displays the real time results on the small screen and saves results to device memory. The device is optimized for the measurement of road markings and sidewalks (and airports). The price is over 10 000 €. More information: <http://www.europlastgroup.com/t2-go.htm>.

2.8 VBOX

VBOX is an international product family offering different kind of measuring instruments for motor sport and vehicle and tyre manufacturers. Those instruments is used for the precise measurement of acceleration, speed and distances using GPS-technology. The prices of these instruments start from 500 €.

In this study, VBOX was used as an reference instrument (figure 6). VBOX doesn't display any friction values, but the friction was calculated in the basis of braking distance and initial speed presented by VBOX (look appendix A). More information: <http://www.velocitybox.co.uk/>.



Figure 6. In the picture one of the cheapest models, Performance Box. The small device can be attached for example on the wind screen using suction pads. Also a small GPS antenna is needed. The antenna should be attached outside, on the vehicle roof, with the magnet. The in-vehicle device and the antenna is connected with a wire.

3. Results from the test tracks

The results from the test tracks are presented in this chapter. The study included also tests on the public roads, presented in chapter 4.



Figure 7. The test on the roughen ice were executed on the ice of the lake. The test on the smooth ice and most of the tests on packed snow were executed on the land track.

On the test tracks, the devices were tested on smooth and roughed ice (figure 7), packed ice and packed snow of different hardness. The results from test tracks include also one test series made on wet asphalt on a public road. The results of the friction meters using acceleration sensors are presented in figures 8-10. The analyses for these results has been carried as follows:

- There were 2 pieces of each meter using acceleration sensors: μ TEC, Gripman and Eltrip-7k. In each of the figures 8-10, these 2 meters have been compared to 2 reference devices: Old Eltrip (Eltrip-45n) and VBOX. **The friction meters with acceleration sensors were not calibrated**, which means that calibration coefficient was 1 (factory setting). Therefore the acceleration sensor meters didn't need to show same results as Eltrip and VBOX, but to be convincing, acceleration sensor meters need to be **comparable** with the reference devices.
- **The Old Eltrip was only calibrated with used (code: "Used") studded tyres.** Also the new (code "New") studded tyres were used, in order to get different kind of test conditions. Also the effect of tyre condition to the friction profile were studied.
- The VBOX friction is the friction calculated in the basis of braking distance measured by VBOX. This friction is determined in a different manner than the official Traffic Agency friction (= Old Eltrip friction with used studded tyres), so the VBOX and Old Eltrip don't need to show same results. But again, Vbox and Old Eltrip should be comparable.

- The results were the averages of 7-8 measurements. All the friction meters used by braking were used exactly at the same time. That means, that in every single braking we got 7 results at the same time: 1 Old Eltrip, 2 μ TEC, 2 Gripman and 2 New Eltrip.
- The tests has been arranged in the order of the friction measured by VBOX (from lowest friction to highest friction).
- Some of the test tracks had small longitudinal inclination. The inclination (0 % or 1 %) has been written also in the test descriptions in figures 8-10. This inclination has a different effect on different meters, but these inclinations were so small, that the effect is minimal.

When looking at figure 9, you can see that the results of Gripman 1 and Gripman 2 were so consistent, that it's difficult to separate the lines of two Gripman's. The results of the Gripman's were also very parallel with the Old Eltrip and VBOX. When looking all the figures 8-10, you can observe surprisingly big differences between different kind of meters.

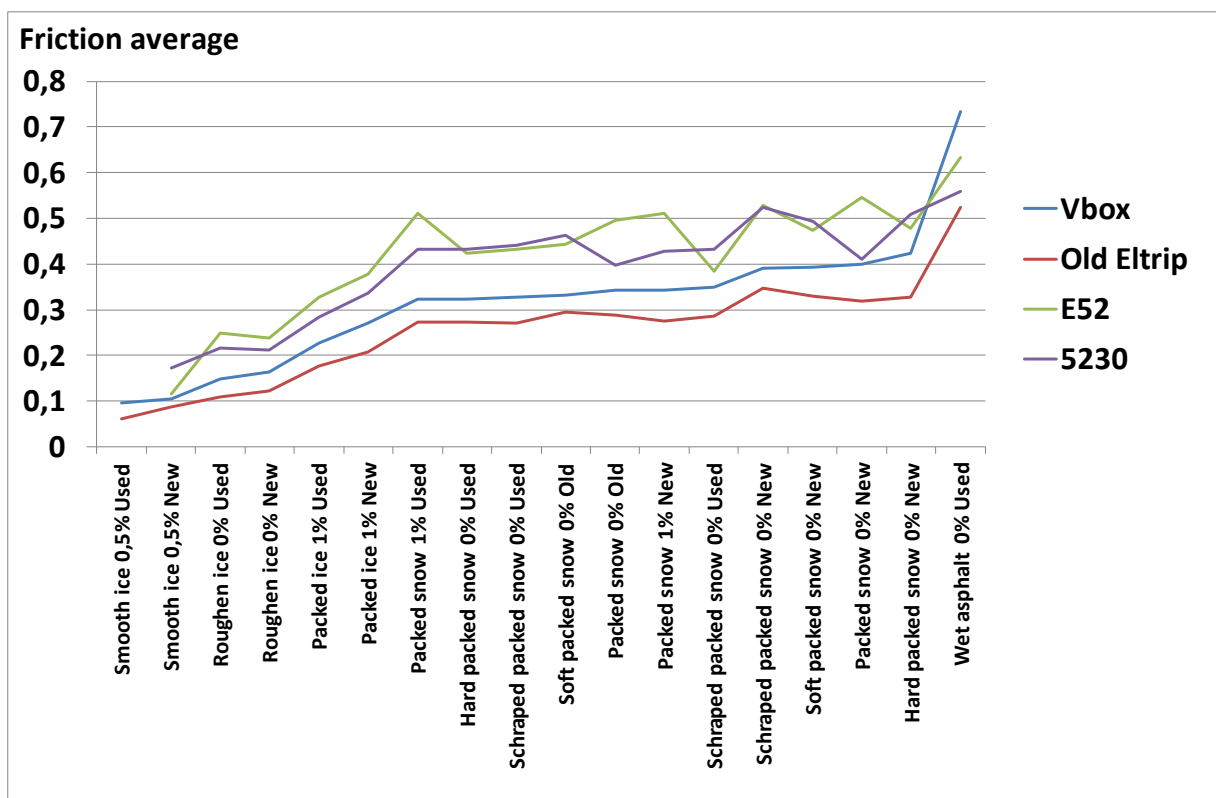


Figure 8. The average friction of the 2 μ TEC's used in Nokia E52 and Nokia 5230 phones. The Old Eltrip and VBOX were the reference meters. The different test track conditions are described on the horizontal axle. Only Old Eltrip was calibrated with old tyres (= the results of the devices don't need to be the same, but they should be consistent).

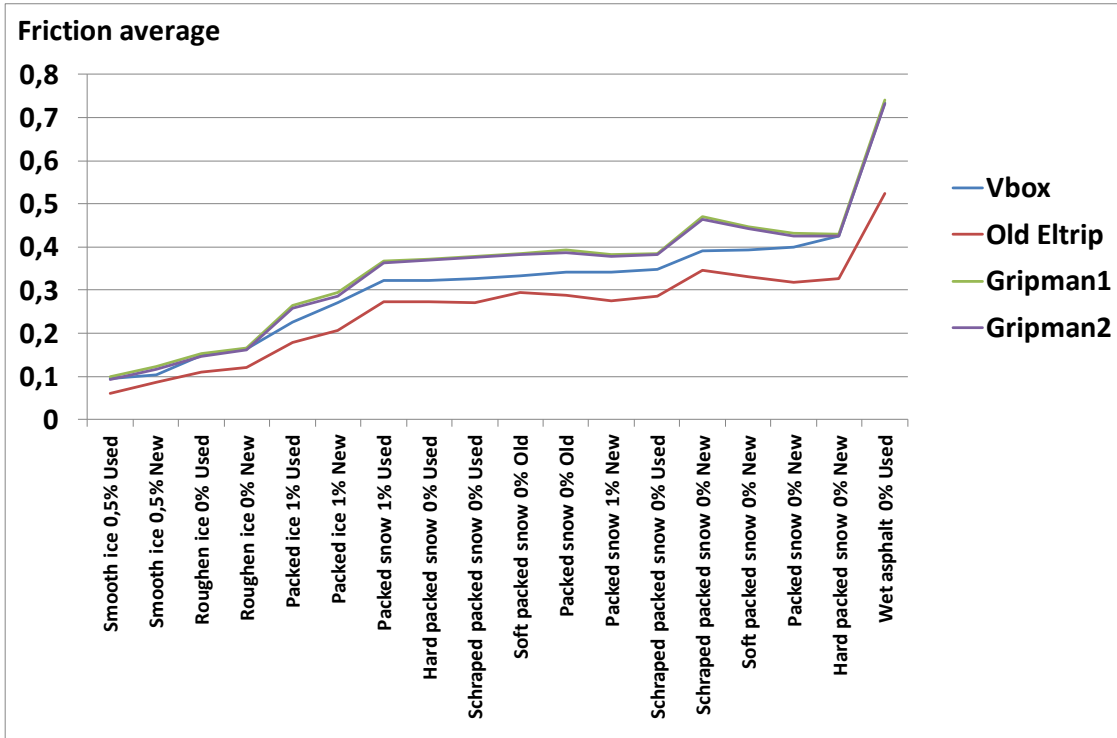


Figure 9. The average friction of the 2 Gripman's. The Old Eltrip and VBOX were the reference meters. The different test track conditions are described on the horizontal axle. Only Old Eltrip was calibrated with old tyres (= the results of the devices don't need to be the same, but they should be consistent).

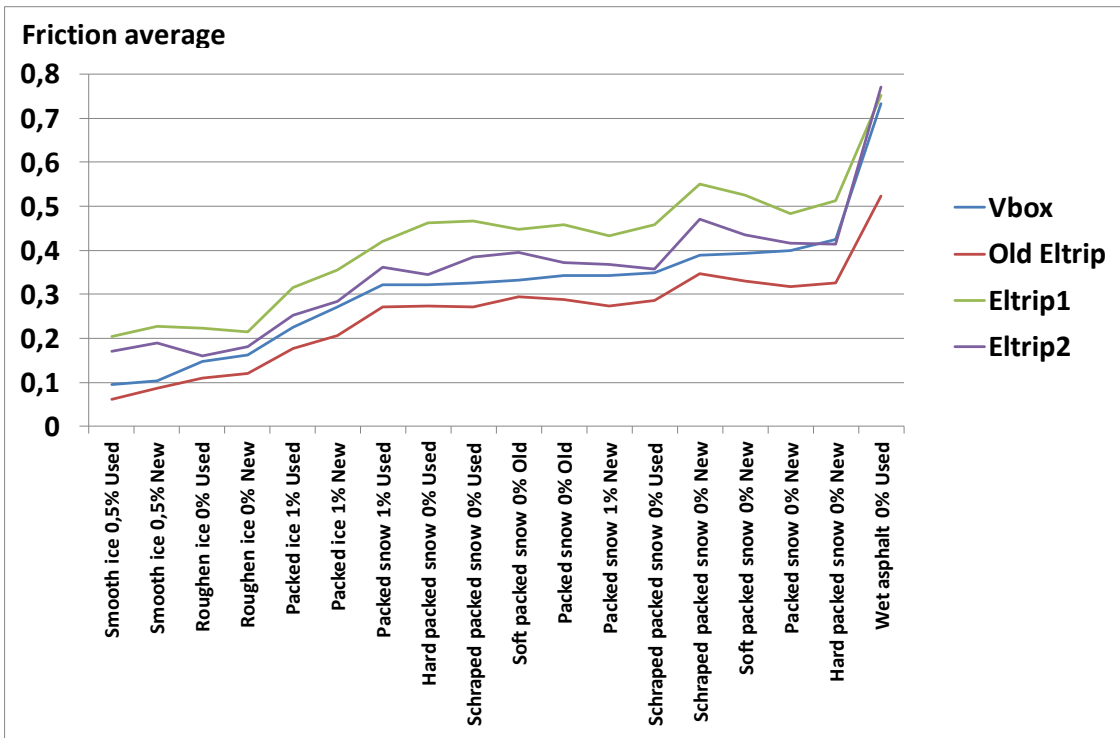


Figure 10. The average friction of the 2 New Eltrip's. The Old Eltrip and VBOX were the reference meters. The different test track conditions are described on the horizontal axle. Only Old Eltrip was calibrated with old tyres (= the results of the devices don't need to be the same, but they should be consistent).

Because the "traditional" friction meters determine the friction in the basis of the speed difference measured from the vehicle wheel, the hilliness of the road affects the results. This "traditional" system gives too low friction on the downhill and too high friction on the uphill. Therefore according to the guidelines, the traditional meters can not be used on the hills bigger than 2 % (2 % = 2 meters upwards or downwards in a 100 m road section).

Because the acceleration sensor meters always measure the direction with is parallel with the longitudinal axle of the vehicle, those sensors don't measure the gravity on a flat road. On the contrary, on the hill those sensors measure the gravity component, which is parallel to the vehicle. If the friction meter process this information from the hills correctly, the effect of the hill can be compensated ,and you get the friction which is same as on a flat road in similar conditions.

The figure 11 presents the results from the special hill tests made on private roads near test tracks. Because the potential energy of the hill was added to the formula of the physical friction (Appendix A), the friction calculated in the basis of VBOX braking distance was almost the same in downhill and uphill in both hills. Also Gripman's gave almost same results when measured downhill and uphill. Presumably also μ TEC's were able to compensate the inclination of the road, but because of the big deviation the result were not exactly same downhill and uphill. On the contrary, New Eltrip didn't compensate the inclination at all.

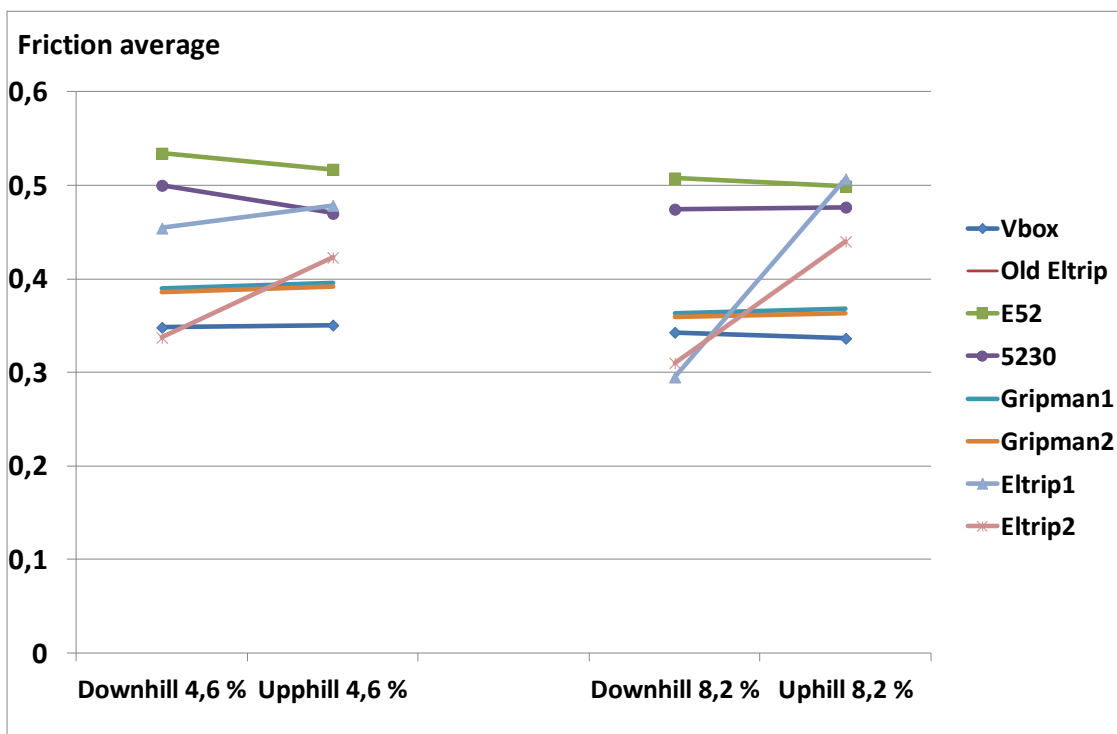


Figure 11. Friction values in two hills, measured downhill and uphill in both hills. For example the 4,6 % inclination means 4,6 meters upwards/ downwards in a 100m road section. Only Old Eltrip was calibrated with old tyres (= the results of the devices don't need to be the same).

The effect of braking time on the friction results was also studied. This effect was tested by using different braking times: short (≈ 1 s), normal ($\approx 1,5$ s) and long (≈ 2 s). According to the results, the braking time seemed to have an effect to all devices studied. This means, that the braking manner do have an effect to friction value, braking should be always as equally long as possible.

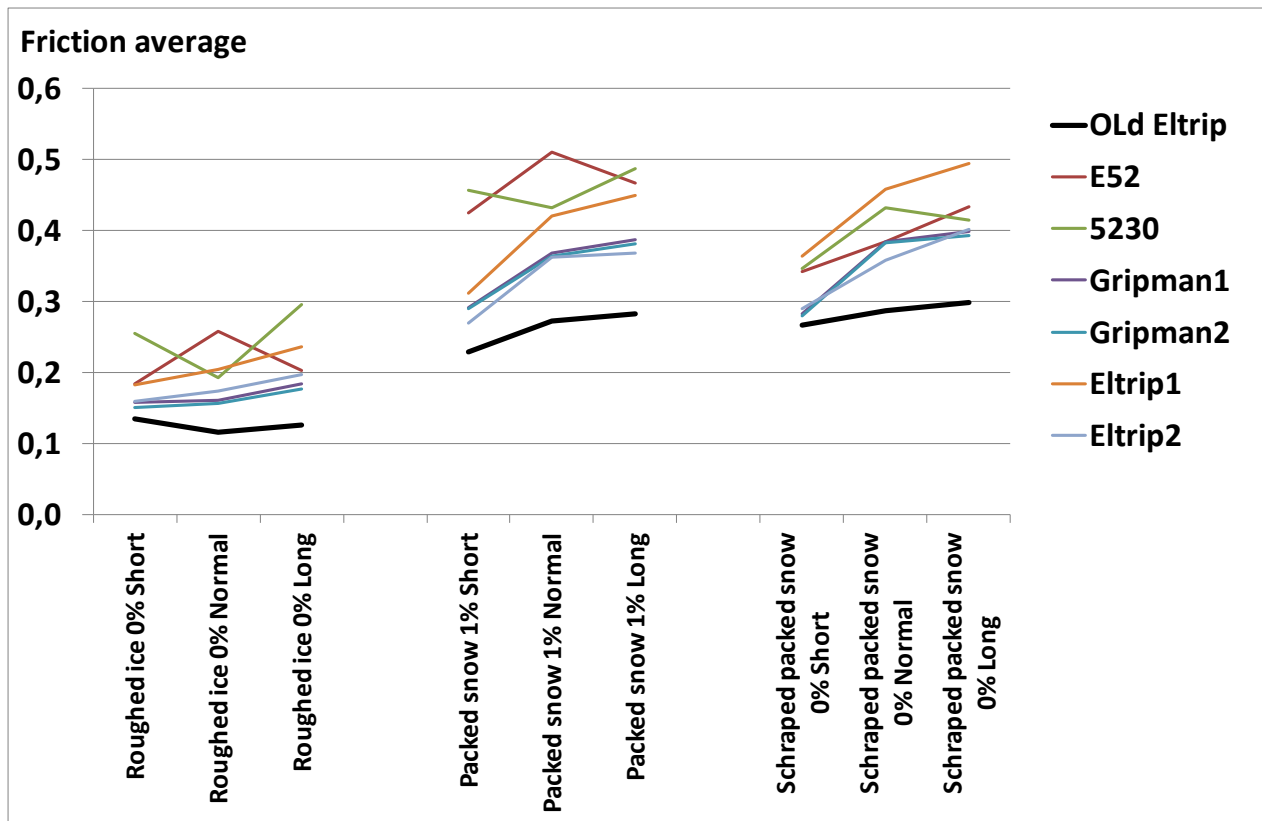


Figure 12. The friction values measured with short (≈ 1 s), normal ($\approx 1,5$ s) and long (2 s) braking. According to Gripman instructions, the braking should be at least 1,5 s. Only μ TEC's has the possibility insert the information of the braking time beforehand, so that the braking time could be taken account in the friction calculation process. Only Old Eltrip was calibrated with old tyres (= the results of the devices don't need to be the same).

Also the effect of the initial braking velocity was studied (figure 13). When using different initial speeds (40, 60 and 80 km/h), it was discovered, that friction values were typically bigger in higher speeds. Probably higher air drag have an effect on higher deceleration in higher speeds. That's why friction should also be measured from the same initial speed (60 km/h, according to the guidelines).

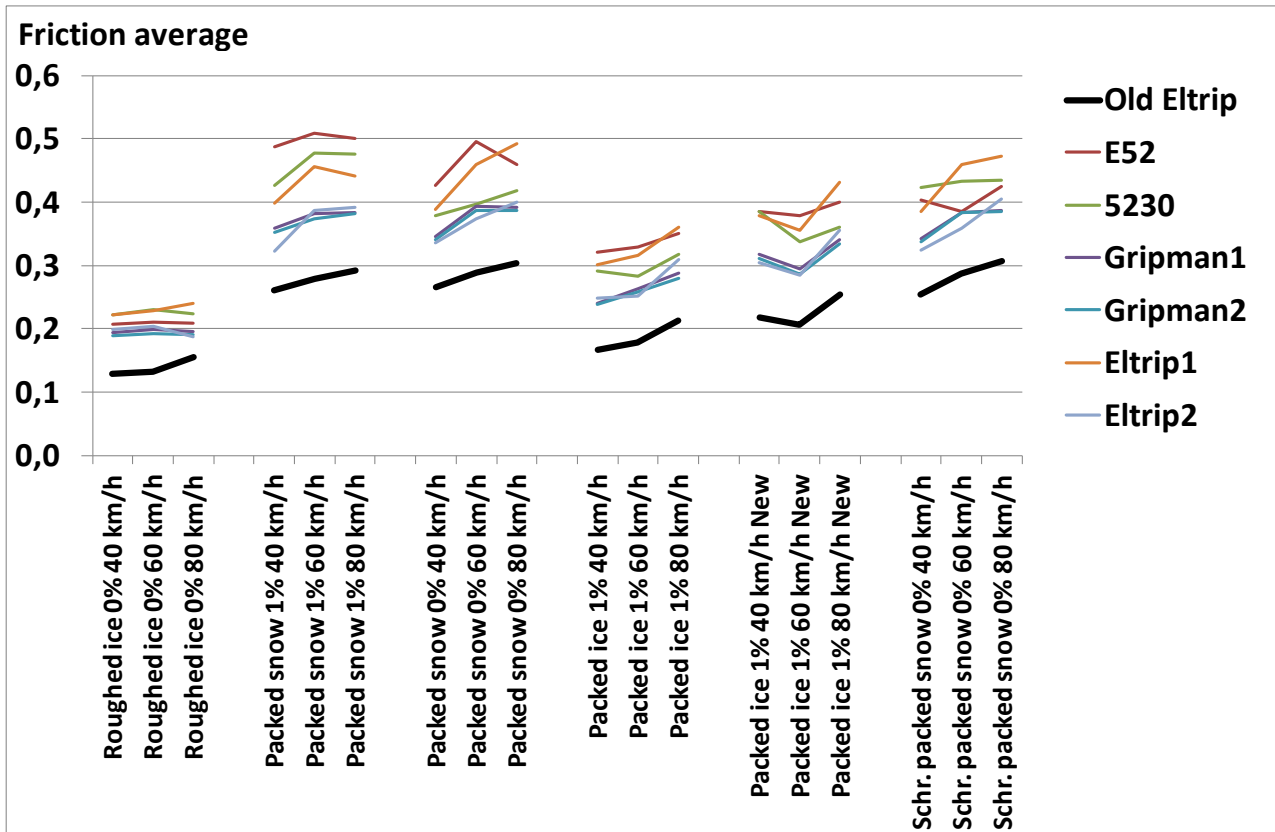


Figure 13. The friction values measured from initial speeds 40, 60 and 80 km/h. Only the Old Eltrip was calibrated with old tyres (= the results of the devices don't need to be the same).

The tyre condition of the measuring vehicle shouldn't affect much on the friction values, because as told on chapter 1, the friction meters are calibrated on the calibration days, in order to get same friction values when using different kind of vehicles and tyres. The fact still is, that different kind of tyres could have slightly different kind of friction profile. That means, that in spite of getting friction value 0,29 in the calibration days with both new and old tyres, user can get lower friction on black ice (friction level 0,10-0,15) with old tyres than new tyres. In this study, we compared new Nokian studded tyre to the used (40 000 km of driving) Nokian tyres. According to the results, the error caused by the different friction profile was only 0,02 on smooth ice (friction level 0,10) (figure 14). That means, that when using studded tyres of good quality, the different service life of the tyres has a minor impact on the results. This applies to tyres where the difference in the tyre condition is not huge. In this case, the groove depth in the new tyres was 10,5 mm and in the old tyres 9,0 - 9,5 mm.

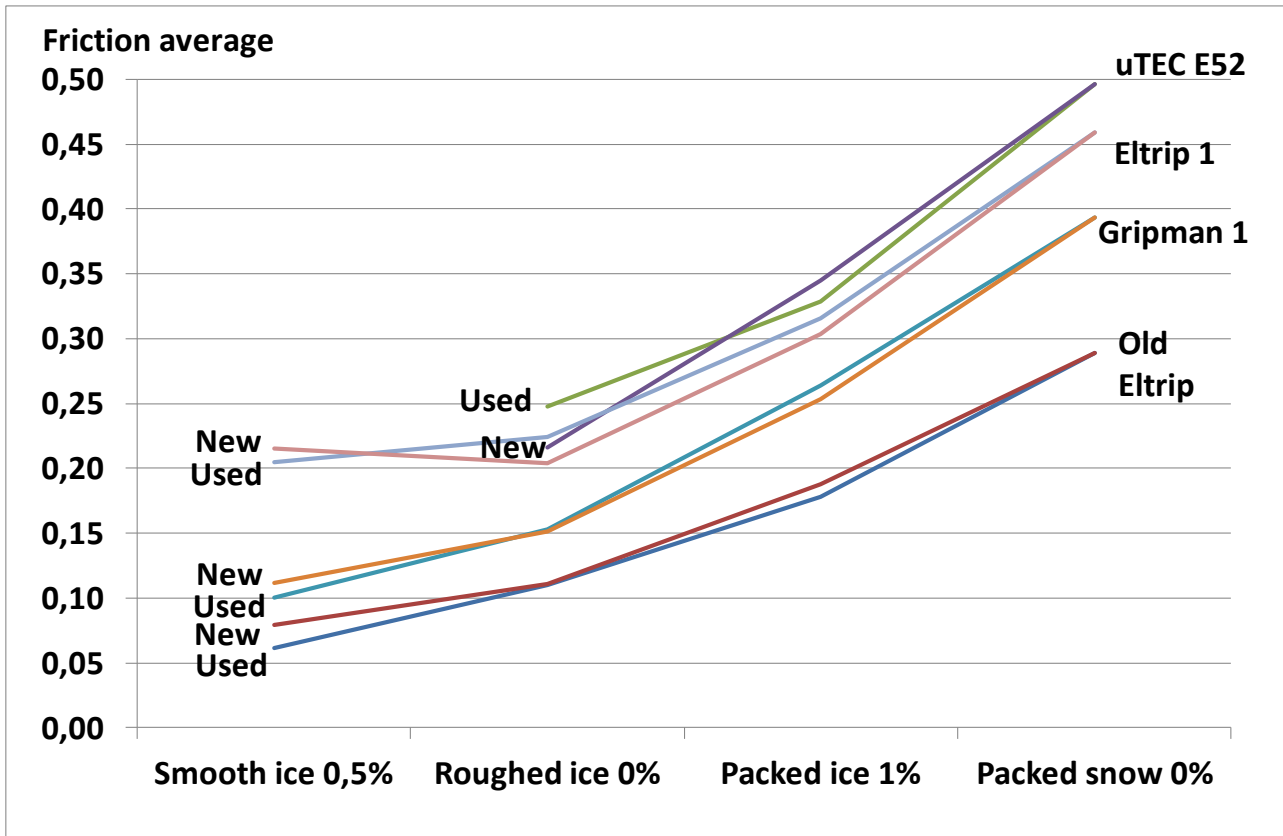


Figure 14. The friction values on used and new tyres when measured with various meters and calibrated to display same results on packed snow.

On the test tracks, both optical sensors identified the most slippery condition (smooth ice) as the most non slippery (figure 15). The reason was probably the ice colour: the test track ice was white, but the black ice is most slippery on public roads. The artificial test track surfaces seemed to bluff both optical sensors (especially DSC111), because the sensors were optimized on real road conditions.

The results of T2GO were quite indicative when measuring solid and hard surfaces. On the contrary, T2GO assessed loose snow to be extremely slippery, but as you may know, the loose snow in a cold weather isn't so slippery when walking or driving.

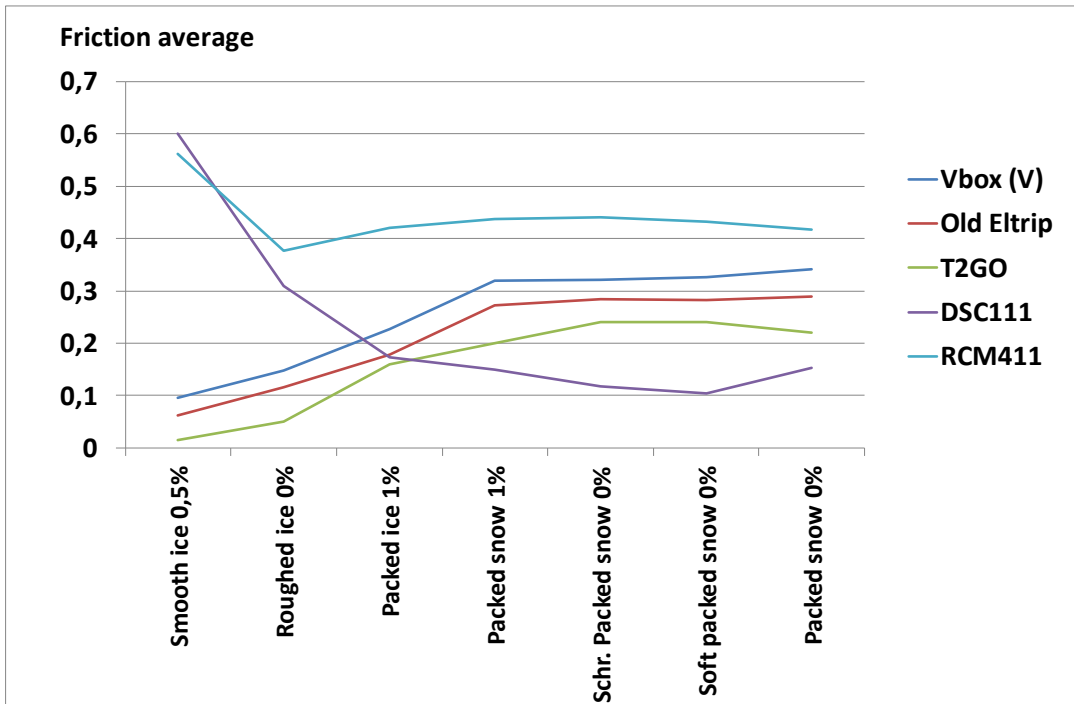


Figure 15. Optical sensors (DSC111 and RCM411) and T2GO compared to VBOX and Old Eltrip. Only Old Eltrip was calibrated (= the results of the devices don't need to be the same, but they should be consistent).

3. Results from the tests on public roads

During this study, the consultant doing the winter maintenance spot check quality control, used all the test devices (except VBOX and T2GO) when making his work. Thus, this part of the test was done by accompanying normal measuring routines and no one needed to wait suitable road conditions because of the study.

The results of the acceleration sensor meters from public roads were quite consistent with the results from the test tracks. When the two meters of each manufacturer were compared, it was revealed again, that the values of Gripman's were most consistent. You can also find on figure 16, that the deviation between two meters of the same manufacturer were always higher on the small friction levels.

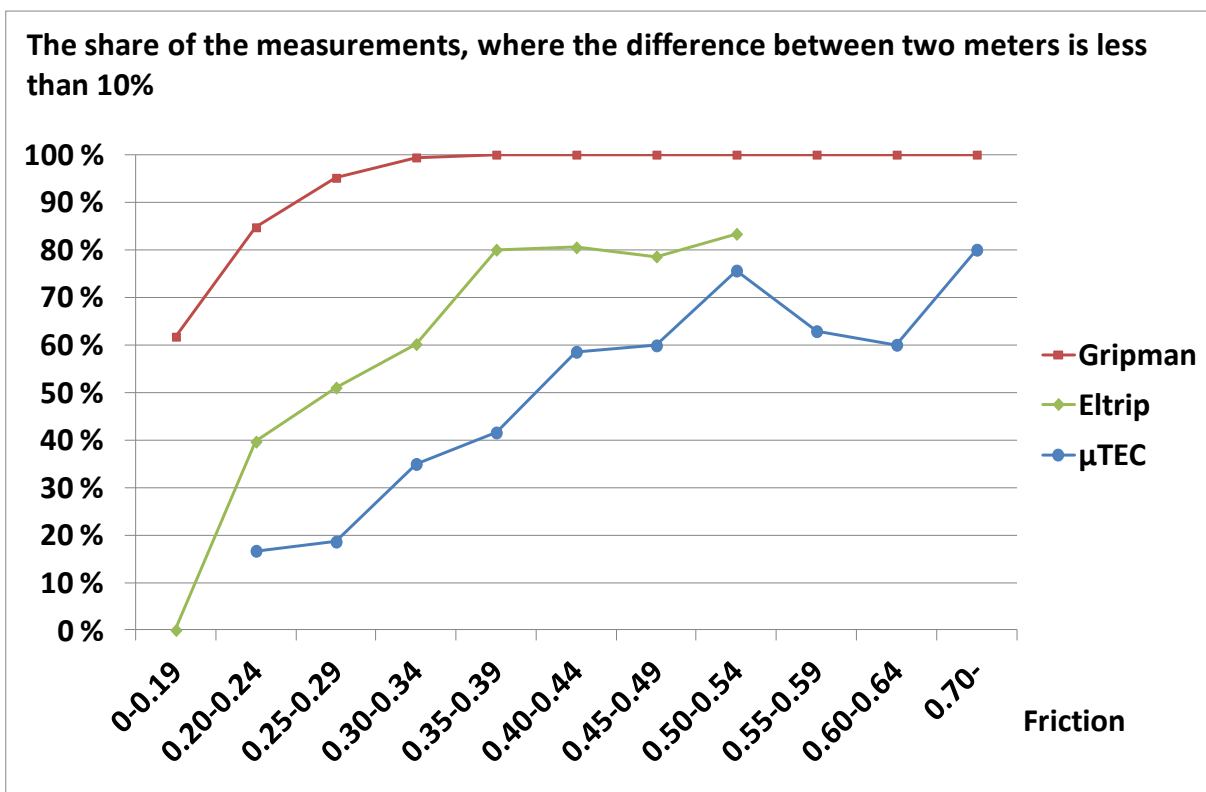


Figure 16. The portion of the measurements, when the difference between 2 meters of the same manufacture was smaller than 10 %. The devices are not calibrated and are used with factory settings.

The measurements with optical sensors were much more fruitful on public roads than on artificial test tracks (figure 17 and 18). The RCM411 were better also in these tests, although the deviation of the both devices were so extensive, that those devices couldn't be used in wintertime quality control.

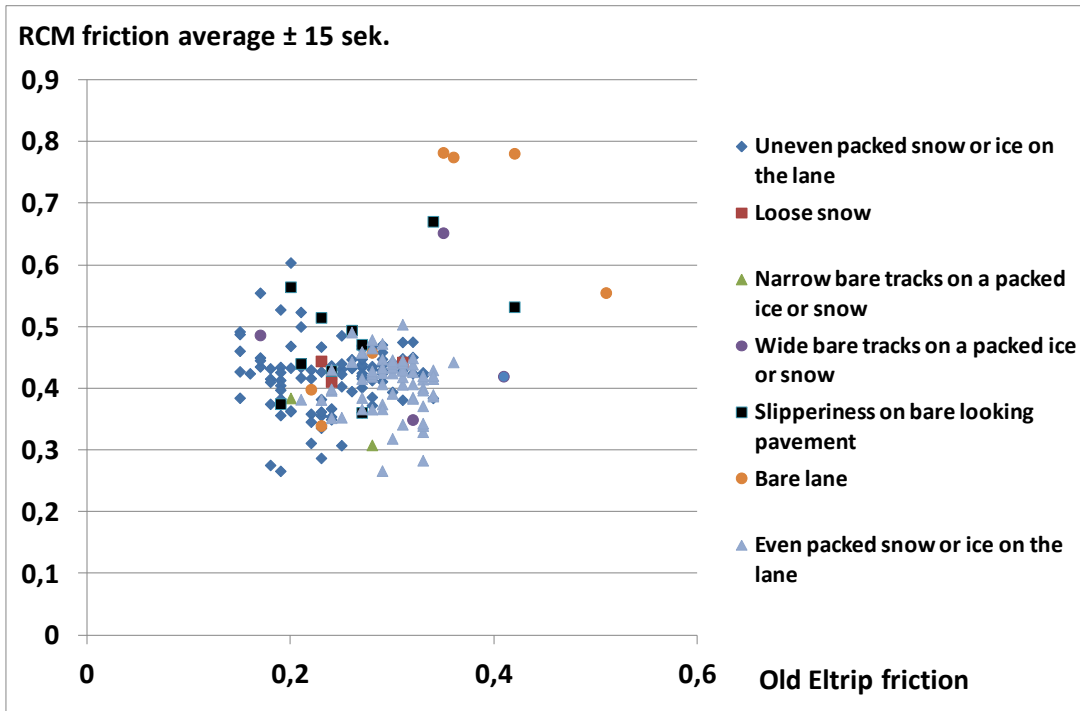


Figure 17. RCM411 average friction in a time frame, which was ± 15 seconds from the Old Eltrip measuring moment. Only Old Eltrip was calibrated (= the results of the devices don't need to be the same, but they should be consistent).

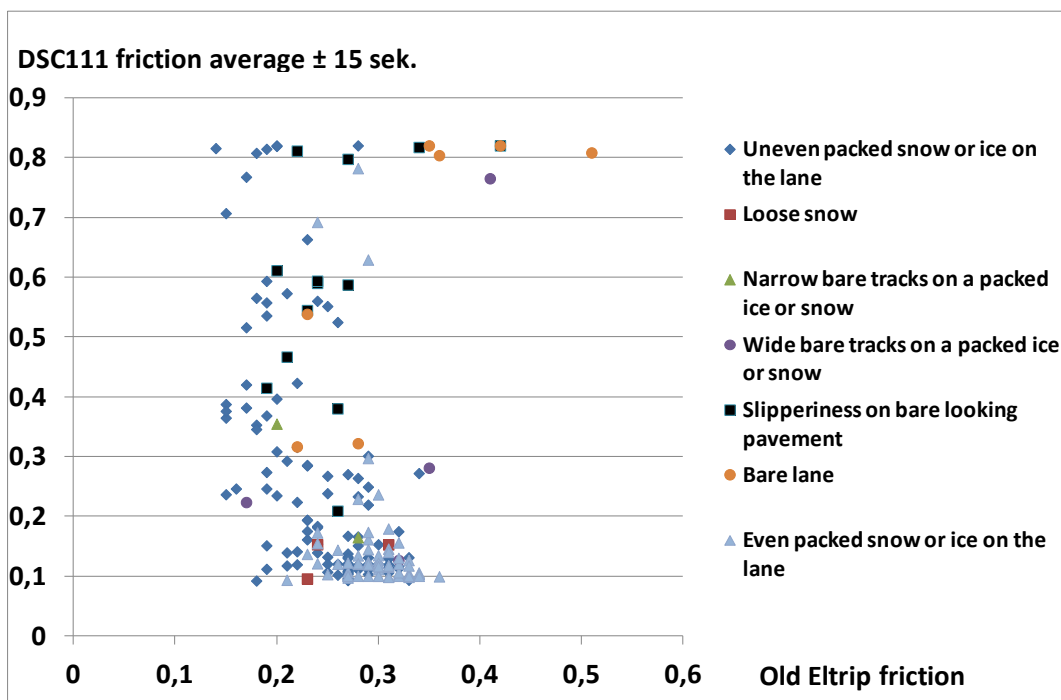


Figure 18. DSC111 average friction in a time frame, which was ± 15 seconds from the Old Eltrip measuring moment. Only Old Eltrip was calibrated (= the results of the devices don't need to be the same, but they should be consistent).

4. Conclusions

The object of this research was to study the reliability and accuracy of various friction meters and assess their suitability in winter maintenance quality control in Finland.

4.1 Conclusions for individual devices

Eltrip-45n, "Old Eltrip"

While the Old Eltrip was intended to be used as a reference device only, it was also revealed, that the accuracy of the Old trip is still so good, that there is no reason to abandon this device, if it can be found on the vehicle. The Old Eltrip's sensitivity for braking time was smallest, but on the other hand, this device is not suitable when measuring friction on a hill.

μ TEC

μ TEC was the most multifunctional application compared, but the deviation was quite large compared to the most accurate devices. While Gripman was designed to be used only in one position in a car, the position of the μ TEC could be changed when ever needed, if so called "position calibration" was made at the same time. The problem with that was, that the position calibration changed μ TEC's friction level $\pm 0,06$. Because the application demanded the position calibration in the beginning of each test day, this position calibration weakened μ TEC's reliability and accuracy considerably.

μ TEC didn't give any results in the most slippery test track condition (smooth ice). μ TEC gave unintentional results on bumpy roads. The deviation was remarkably weaker when μ TEC was used with Nokia 5230 than with Nokia E52. The application has been further developed after the tests.

Gripman

The 2 Gripman's gave very consistent results and the results were also parallel to the reference device (Old Eltrip, VBOX) results. Gripman was the only acceleration sensor meter, which gave reliable results also on the most slippery test track condition (smooth ice). Gripman also operated on the hill faultlessly. Like other acceleration sensor meters, Gripman was quite sensitive for the variation of the braking time.

Eltrip-7kmb, New Eltrip

The extraordinary calibration logic complicated the use of New Eltrip in the tests, and the manufacturer changed the logic to the traditional method soon after the tests. The new Eltrip didn't operate on the hill and gave unreliable results on the most slippery test track conditions.

The accuracy in other road conditions wasn't at the same level as the best devices. New Eltrip gave also unintentional results on bumpy road conditions.

Mobile DSC111

The Vaisala's mobile DSC111 seemed to give quite illogical results across the whole study, and the performance didn't become any better, although the device was examined in the Vaisala headquarters in the middle of the study. Although the device has the same name as the fixed roadside DSC111, the test results of the mobile DSC111 are not applicable to the fixed DSC111.

RCM411

RCM411 was best optical device for the friction measurement in the test. The deviation of the RCM411 results was still so large, that the device is not suitable for the winter maintenance quality control. If the user is able to interpret the results correctly, the device may already give support to the winter maintenance and winter traffic management.

T2GO

T2GO was the only device suitable for the measurement of road markings and sidewalks. According to the tests, T2GO gave indicative results on the solid and hard surfaces, but T2GO considered loose snow much more slippery than observed when walking or driving.

VBOX

VBOX was used as a reference instrument in the study. Although the accuracy of the VBOX wasn't studied, the device convinced with the reliability and ease of installation. We are waiting for the model intended for friction measurement...

4.2 Other

The first version of friction meter demand paper has been made in the basis of the study (Appendix 2). The possibility to change the friction scale used in Finland has been considered. Probably Finland will start using so called physical friction after some other large change in winter maintenance quality requirements. Also some winter maintenance experts in Finland consider, that there would be certain benefits if more northern countries would start to use same friction

scale. Physical friction, in other words friction calculated in the basis of initial speed and braking distance would be a good choice for international standard. The concept of physical friction is presented more widely in appendix 1.

Appendix A

Calculation of physical friction

According to the laws of physics, the friction coefficient determines how the kinetic energy of vehicle effects to the braking distance, in other words:

$$(1) \quad \frac{1}{2} m (v_0)^2 - \frac{1}{2} m (v_i)^2 = \mu m g L$$

where:

- m = vehicle mass
- v_0 = starting speed (where braking starts)
- v_i = end speed (where the measurement ends)
- μ = friction coefficient
- g = gravity; 9,81 m/s²
- L = braking distance

When you want to calculate the friction coefficient, the mass of the vehicle becomes irrelevant.

$$(2) \quad \mu = \frac{(v_0)^2 - (v_i)^2}{2 g L}$$

If you want to measure whole braking distance, v_i will be 0. Therefore:

$$(3) \quad \mu = \frac{v_0^2}{2 g L}$$

If you want to measure the friction on the hill, you must add the potential energy to the formula (see figure 1):

$$(3) \quad \frac{1}{2} m (v_0)^2 - \frac{1}{2} m (v_i)^2 \pm mg \cdot \sin \alpha \cdot L = \mu m \cdot \cos \alpha \cdot g L$$

and therefore the friction on the hill:

$$(4) \quad \mu = \frac{(v_0)^2 - (v_i)^2}{2 \cdot \cos \alpha \cdot g L} \pm \frac{\sin \alpha}{\cos \alpha}$$

, where the term " \pm " is "+" on downhill and "-" on uphill.

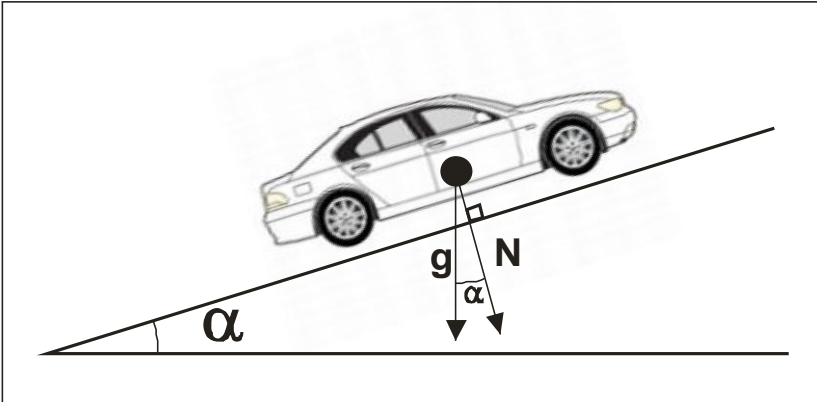


Figure 1 The vehicle and the angles on the hill.

Appendix B

Draft

Method description and demands for the friction meters to be used in public roads winter maintenance quality control in Finland

This paper describes the method and the demands for friction measurement using braking on winter roads. If the method and device complies the demands determined in this paper, the device maybe suitable for the winter maintenance quality control. The winter maintenance quality requirements are determined in a paper "Winter maintenance on public roads, quality requirements, copy 19.1.2009" (<http://www.tiehallinto.fi/pls/wwwedit/docs/27412.PDF>).

1. The method for friction measurement

Friction should be measured using braking method, where the driver brakes the measurement vehicle on the road surface to be studied. During braking, the additional device in the vehicle, on other words "friction meter" will register the deceleration of the vehicle and will calculate the friction value. The measurement should be carried by:

- checking that there is no vehicle behind the measuring vehicle and no vehicles meeting on the same carriageway
- pressing the brake pedal powerfully to the bottom
- as equally as possible. There shouldn't be much variation with the power and the duration of the braking
- using initial speed 60 km/h
- with ABS-brakes and studded tyres
- on a flat road (inclination less than 2 %)

The friction should be measured only with a passenger car suitable for friction measurement. Some new types of friction meters allow the measurements on the hills, where inclination is bigger than 2 %. In those cases there should be a statement "hill" enclosed with the friction value.

Because the vehicles and tyres are different, the friction meters should be calibrated in the "calibration" days to display 0,29 on packed snow with air temperature -5 °C.

2. Quality requirements for the friction meters

2.1 The safety of the use

The following recommendations connected to the safety of the use are introduced:

- the duration of the braking needed should be less than 2 seconds.
- the buttons of the meters should be such, that the use of meter when driving doesn't burden the driver unreasonable. It should be noted, that the driving conditions, when measuring friction, are often demanding. The ergonomics of the meter may be improved with the wired or wireless separate buttons, when the buttons can be brought to the most ergonomic place for the driver.
- the friction meter design should consider the alternating lighting conditions in the vehicle, so that the meter could be read without difficulties both in dark and direct sunshine
- the reliability of the meter should be such, that an experienced user can get a convincing result at least in 95 % of the measurements. On the other hand, the meter should not display results unintentionally (for example on a bumpy road), so that the extra readings need extra action for the driver (for example meter reset).

2.2 Ability to calibrate

The friction level of the friction meter should be able to change using such calibration ratio, which could be seen in the device after calibration. That gives for example the possibility to assess the relation between calibration ratio and tyre mileage. Therefore, it is possible to assess how the road condition on the calibration days equals to the condition of earlier calibration days.

In the case there is also other means to adjust the friction level than friction ratio (for example offset), also those extra terms should be seen afterwards in the device. In the case of extra terms, the manufacturer should present his view of the procedures, how the correlation with the meters approved will be achieved.

2.3 Accuracy

The demands for the accuracy of the friction meters are as follows:

- the difference between two similar friction meters shall be less than 10% in 95 % of the measurements, when measurements are carried out on public roads in quality requirement friction zone 0,20-0,30. This test shall include at least 100 measurements, and measurements should cover equally the whole zone.
- after the meter is calibrated on the packed ice with air temperature -5 °C with the physical friction, the meter should not have a difference more than 15 % with the physical friction in 90 %

of the measurements. The braking distance for the physical friction shall be measured at the same time with the friction meter using accurate continuous distance and speed measurements. The VBOX or Paceler-wheel could be used as a distance and speed meter. This clause should be fulfilled on the whole physical friction zone 0,15-0,70 (equals quality requirement friction zone 0,12-0,55). These measurements should be carried on the test tracks or on the public roads. The measurements should be designed in a way, which allows to compare the deceleration and braking distance at the same time gap than friction measurement.

If the meter is designed in a way, that it could be disconnected and reconnected in a new position whenever needed, the meter should fulfill the requirements when reconnecting the device during tests at least twice.

3. Other

If the friction meter manufacturer wants his meter to be approved for the public roads winter maintenance in Finland, shall manufacturer provide a report paper presenting the conformity with the demands in chapters 2.1-2.3. This report paper shall be made by an independent expert.

The Traffic Agency shall keep the right to disapprove the friction meter, which meets the above requirements, but is not suitable for the intended use because of fault not mentioned above. Respectively, the Traffic Agency shall keep the right to approve the meter, which doesn't completely meet the requirements above, or which accuracy and reliability has been proved in a different manner, but which , assessed as wholeness, is well suitable for intended use.