



Energy use due to traffic and pavement maintenance

The cost effectiveness of reducing rolling resistance

Annelie Carlson
Robert Karlsson
Olle Eriksson

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Preface

The project has been financed by the Swedish Transport Administration and their research programme BVFF. Åsa Lindgren has been the contact person. This work is a part of sub project 3 in the European collaboration MIRIAM (Models for rolling resistance in Road Infrastructure Asset Management Systems). The results from this sub project have been presented at a seminar in Stockholm in May 2015, arranged by the Swedish Transport Administration within the MIRIAM collaboration. It has also been presented at the national conference Transportforum in Linköping January 2016. This documentation is the final report of the project *Energy use due to traffic and pavement maintenance – The cost effectiveness of reducing rolling resistance*.

Linköping, March 2016

Annelie Carlson
Project leader

Quality review

Internal peer review was performed on 28 February 2016 by Iman Mirzadeh. Annelie Carlson has made alterations to the final manuscript of the report. The research director Mikael Johannesson examined and approved the report for publication on 30 March 2016. The conclusions and recommendations expressed are the author's/authors' and do not necessarily reflect VTI's opinion as an authority.

Kvalitetsgranskning

Intern peer review har genomförts 28 februari 2016 av Iman Mirzadeh. Annelie Carlson har genomfört justeringar av slutligt rapportmanus. Forskningschef Mikael Johannesson har därefter granskat och godkänt publikationen för publicering 20 mars 2016. De slutsatser och rekommendationer som uttrycks är författarens/författarnas egna och speglar inte nödvändigtvis myndigheten VTI:s uppfattning.

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Summary

Energy use due to traffic and pavement maintenance – The cost effectiveness of reducing rolling resistance

by Annelie Carlson (VTI), Robert Karlsson (Swedish Transport Administration) and Olle Eriksson (VTI)

Measures in order to reduce GHG exist across a range of policy areas. The transport sector is one of the areas where the potential for a reduction is considered to be of great importance. A large effort has been placed upon making vehicles more fuel efficient and there are regulations within the European Union setting emission standards for new vehicles. However, the impact of the management activities is also an area where there is a potential to reducing energy use of traffic and thereby GHG since almost all fuel used is based on fossil fuel. The reduction can be achieved by performing maintenance measures that lower the rolling resistance, and with the aim of decreasing the total energy use in a life cycle perspective, including energy for both traffic and maintenance.

When choosing maintenance alternative, it is also of importance to consider the costs involved. Pavement management is focused on keeping wide spread road networks in acceptable condition given certain budget constraints. Therefore, the economic constraints need to be addressed and in the case of choosing a maintenance alternative that reduces total energy, it also has to be cost-efficient in order for it to be performed.

The main **scope** of the research presented in this report is to investigate how road management should act to reduce total energy use of roads, including traffic and maintenance induced energy use, while also taking cost efficiency and the aspect of uncertainty into consideration. The **purpose** is to enable a better consideration of the total energy used and maintenance cost when managing the road network. The **objective** is to derive a meaningful instrument for decision making situations such as when selecting and designing maintenance treatments, in which total energy use and maintenance cost is considered.

A general method is developed and presented. A criterion, *CR*, has been identified for how to choose a pavement maintenance strategy in regards to cost and energy efficiency. A cost benefit analysis approach using Benefit to Cost Ratio, BCR, has been adopted. It is shown that the selection between alternatives is straightforward under certain circumstances and if *CR* is significantly lower or higher than 0. If *CR* is close to 0 the variability and uncertainty will be significant and should be taken into account when selecting maintenance alternative.

The study indicates that it is difficult to establish a simple rule of thumb. However, the *CR*-value may be a useful criterion in some circumstances and it is important to have guidelines as decision support where assessments are made of the road surface characteristics, total energy use and maintenance cost and where the different aspects are valued. This is especially important on an object level.

The effect of traffic energy use due to snow and water on the road surface was estimated. The possibility for taking these aspects into consideration when deciding on a strategy for an energy- and cost effective pavement maintenance is limited. In summary, snow should not be accounted for, but the presence of water on the road surface could be a variable to consider. Moist has a non-negligible effect on fuel use and it is also to some extent dependent on the road surface conditions. However, how this should be done is not considered in the report but it could be interesting to investigate further.

It should be emphasized that decision on which maintenance alternative to choose must, in the long run, be based on a broader perspective than just energy and maintenance cost and should also include other aspects of sustainability and safety.

Sammanfattning

Energibehov för trafik och för underhållsåtgärder av vägbeläggning – Kostnadseffektiviteten av att reducera rullmotståndet

av Annelie Carlson (VTI), Robert Karlsson (Trafikverket) och Olle Eriksson (VTI)

Åtgärder för att minska utsläppen av växthusgaser finns inom en rad olika policyområden. Transportsektorn är ett av dessa områden där man anser att det finns stora möjligheter att få till stånd en reduktion då merparten av bränsle som idag används baseras på fossila bränslen. Ett stort arbete har hittills också lagts på att få mer bränsleeffektiva fordon. Det finns dock även en potential att via vägunderhållsåtgärder, som sänker rullmotståndet, kunna minska energianvändningen hos trafiken. Det är i sammanhanget dock viktigt att se till livscykelperspektiv och även inkludera den energi som behövs till underhållet och att det totala energibehovet minskar. När ett underhållsalternativ väljs, är det också viktigt att ta hänsyn till kostnaderna i och med att det finns budgetrestriktioner. Därför behöver åtgärderna också vara ekonomiskt försvarbara.

I denna rapport undersöks hur man kan välja ett vägunderhåll som minskar den totala energi-användningen för trafik och underhåll, samtidigt som det tas hänsyn till kostnadseffektivitet och osäkerheter. Syftet är att göra det möjligt för vägghållaren att bättre ta i beaktande såväl energi som kostnader när de hanterar vägnätet. Målet är att härleda en meningsfull tumregel som kan användas för beslutsfattande när man väljer vilket vägunderhåll som ska utföras där både energi och kostnader ingår.

En generell metod för beslutsstöd har tagits fram och presenteras i rapporten. Ett kriterium, kallat CR, har identifierats vilket kan användas för att bestämma den strategi man ska utgå ifrån när man väljer mellan två underhållsåtgärder. Tillvägagångssättet bygger på en kostnads-nyttoanalys och med hjälp av denna metod har det visats att valet mellan två alternativ är relativt okomplicerat under vissa omständigheter och om CR är betydligt lägre eller högre än 0. Om CR är nära 0 kommer osäkerheter i indata att bli betydande och detta bör beaktas vid val av underhållsalternativ.

Studien visar vidare att det är svårt att fastställa en enkel tumregel. Emellertid kan CR-värdet vara ett användbart kriterium i vissa fall. I rapporten identifieras att det är viktigt att det finns riktlinjer som beslutstöd där man gör bedömningar av energi, kostnader och vägytans egenskaper. Speciellt är detta viktigt på objektnivå.

Effekten av trafikens energianvändning på grund av snö och vatten på vägytan uppskattades också i rapporten. Möjligheten för att ta dessa aspekter i beaktande vid val av strategi för ett energi- och kostnadseffektivt vägunderhåll är begränsad. Kort sammanfattat bör snö inte inkluderas som variabel, medan närvaron av vatten på vägytan kan vara en aspekt att överväga. Vatten har en icke försumbar effekt på bränsleförbrukningen och det är också i viss mån beroende av vägytan. Hur detta kan göras har inte närmare berörts i rapporten men det kan vara intressant att undersöka vidare.

Det bör understrykas att beslut om underhållsalternativ i förlängningen även ska baseras på ett bredare perspektiv än bara energi och underhållskostnader. De bör också omfatta andra aspekter av miljö, hållbarhet och säkerhet.

1. Introduction

1.1. Background

The focus on climate changes has led to attention on actions to reduce greenhouse gas (GHG) emissions from road transport in order to mitigate global warming. Emissions from fossil fuels are an important contributor to GHG emissions and efforts are spent on promoting development of alternative fuels and more fuel efficient engines (European parliament 2009a, European parliament 2009b). Also road management activities themselves contribute to energy use and emissions, but they are in general small compared to traffic fuel use (Karlsson et al. 2012, Carlson 2011, Wang et al. 2012). However, there are reasons to believe that road management can influence the total amount of emissions from road transport by actions influencing rolling resistance. The effect of reducing rolling resistance has for example been shown by Hammarström et al. (2012) where they estimated that a reduction of MPD with 0.5 mm per road link would lead to a decrease in traffic fuel consumption with 1.1% for the road network. Also in Carlson et al. (2013) the effect on energy need due to roughness (IRI) and macrotexture (MPD) was estimated and the evaluation showed that it is possible to lower the traffic fuel consumption by improving IRI and MPD. In Karlsson et al. (2012) the approach of a life cycle perspective on energy use and the importance of rolling resistance was evaluated. The study was performed as a case study of two separate road section with different characteristics and with different maintenance options. It was shown that the total energy use (maintenance and traffic) can be lower by choosing a maintenance alternative that leads to a lower rolling resistance. Also, Wang et al. (2012) used a life cycle approach to analyse the impact of reducing rolling resistance. They concluded that the GHG and energy savings with a reduced rolling resistance can be significantly larger than the energy use and GHG emissions from material production and construction. The savings could also be larger than those from other strategies to reduce traffic energy use, like projected improvements in vehicle fuel efficiency.

The important issue of addressing climate goals is yet to be supported by the current decision making tools and systems. Pavement management today is focused on keeping wide spread road networks in acceptable condition given certain budget constraints. Additional budgets are often released to improve the status of the road network, for example safety and bearing capacity. Therefore, the economic constraints require clear motives in order to choose an alternative taking total energy reduction into account. Pavement management can never achieve one hundred percent optimized decisions with all aspects accounted for. Fair levels of acceptance need to be stated which account for road manager economy (budget constraint), life cycle economy, societal costs, environmental impact, ride quality, traffic safety, health etc. Road manager budget constraints are in practice more rigid than the other aspects, which is one of the reasons for sub optimization, as focus on budgets draws attention from other aspects. Lack of knowledge is another reason. The combination of lack of knowledge and rigid budget constraints may have, as a consequence, that focus shift even more away from aspects difficult to handle to more distinct budget goals and short term quality of pavement performance. Decision makers need to trust the facts presented to them to broaden their focus to a more holistic approach.

This report is a continuation of the international co-operation project MIRIAM (Models for rolling resistance in Road Infrastructure Asset Management Systems). The overall objective of the MIRIAM project is to “provide a sustainable and more environmentally friendly road infrastructure by developing an integrated methodology for improved control of road transport CO₂-emissions”. The Swedish part, initiated and financed by the Swedish Transport Administration, consists of three sub-projects:

- A. Characteristics of the road surface
 - A1 Influence on speed due to road surface characteristics
 - A2 Model to estimate MPD and IRI across the road
- B. The effect on rolling resistance due to wet road surface conditions.
- C. Total material and energy use with respect to rolling resistance and pavement maintenance in a life cycle perspective.

This report covers the results in sub-project C and specifically addresses the topic of the role of rolling resistance on total energy use and if maintenance treatments can be viable option to increase energy efficiency in a life cycle perspective. The work starts from previous outcome of the same sub project in MIRIAM (Karlsson et al. 2012). A general method/model is developed and presented that can make it possible to take the cost effectiveness into consideration when evaluating the pavement maintenance measures to reduce total energy use. The method should enable the user to decide whether one should choose maintenance measure according to cost or total energy use and the findings of more general relationships can be used for decision making planning and design of pavement maintenance. Also, the effect on fuel use due to precipitation is estimated.

1.2. Scope, purpose and objectives

The **scope** is to investigate how road management should act to reduce total energy use of roads, including traffic and maintenance induced energy use. The report focus on how road management can reduce traffic energy by lowering rolling resistance of pavement surfaces by decreased macro texture and increased evenness. The cost efficiency of reducing the total energy use is also assessed including the aspect of uncertainty. The issue of precipitation on the surface that increases rolling resistance is as well included in the report.

The **purpose** of this work is to enable road management to better consider the total energy used and maintenance cost on roads when managing the road network.

The **objective** is to derive a meaningful instrument for decision making situations such as when selecting and designing maintenance treatments, in which total energy use and maintenance cost is considered. A criterion will be formed for choosing a pavement maintenance strategy in regards to cost and energy efficiency. The objective is also to show the importance of water and snow on traffic energy use.

1.3. Disposition

The work is described in Chapter 2 and the results for the statistical analysis and for the climate aspect are presented in Chapter 3 and in Chapter 4 respectively. The discussion is presented in Chapter 5 and in Chapter 6 comprises conclusions, recommendations and support for road managers.

2. Description of work

2.1. Problem formulation

Pavement maintenance can reduce rolling resistance by influencing the road surface properties such as macro texture and evenness. Maintenance activities can also change pavement conditions with respect to drainage conditions (cross fall, rut depth, pavement permeability). Road managers will also have to consider other aspects such as road design, speed limits, traffic safety measures, traffic flow capacity etc.

Energy is used by road users and in activities initiated by road managers. The energy used by road users is dependent on the evenness and texture achieved by road management, which means that the decisions made by road management will influence the amount of energy used by road users during a long period. Therefore, calculations need to reflect the change in condition during several years, including the period when road user energy is affected by pavement management decisions. As pictured below this requires a simulation on a yearly basis to accurately reflect how road condition influence road user energy.

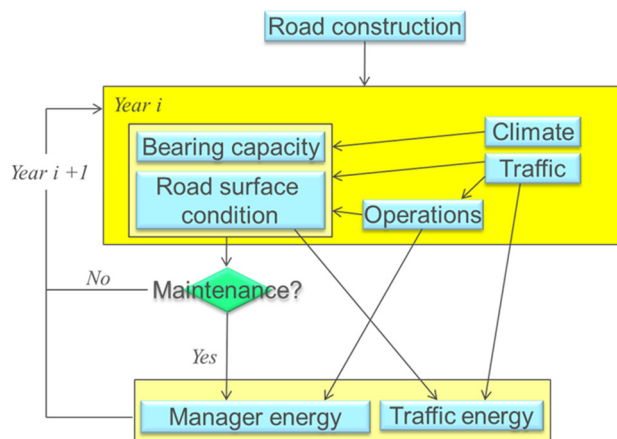


Figure 1. Calculation of energy use in incremental steps.

In Karlsson et al. (2012) two case studies were undertaken in which the energy use for traffic and pavement manager induced actions were investigated using a life cycle inventory approach. The calculations were performed by inventory of all activities down to material flow levels or to aggregated levels if no data is available and the calculation of energies was based on a number of sources. The analysis period was based on the period maintenance measures can contribute to performance. If multiple measures are performed, or if the benefits of a measure will be significant beyond the next maintenance measure, a sufficiently long analysis period was chosen to include the complete benefit.

Some of the general conclusions of the study were:

- Lower rolling resistance saves fuel for each vehicle passing and by lowering the rolling resistance on highly trafficked roads more energy will be saved.
- The larger the influence of rolling resistance is on total fuel consumption, the larger is the influence of a change in rolling resistance. In relation to this, heavy vehicles have more to gain from lower rolling resistance than cars.

- Rolling resistance is relatively more important at lower speed compared to higher speed due to the increased importance of wind forces with higher speed.
- It is more important to have a low rolling resistance where the vehicles are speeding up or maintaining a constant speed.

It was also shown that it is possible to lower the total energy use for a road section by choosing a maintenance alternative that reduces rolling resistance. In some cases, it can be worth to spend more energy on the maintenance stage if it will lead to lower traffic energy use. However, it may not be feasible to perform maintenance at a higher cost even though the total energy use would be minimised. With a prevailing budget constraint, it is important that the road management is also cost efficient.

In order to evaluate the cost effectiveness of reducing the total energy use one can relate the direct cost of reaching the reduction with the social value of the avoided emissions. The direct cost of fuel and a value of the social cost for emission of CO₂ according to ASEK 5 (Trafikverket 2015) was applied in a straightforward way to the case studies in Karlsson et al. (2012). The results are shown in Table 1.

The difference between the total energy used in different maintenance options range from zero (do nothing) to 525 MJ/m (secondary) and the corresponding cost of 56 €/m for Scenario 2, Case 1. A more relevant comparison is to divide energy and cost by service life. The difference between Scenario 1 (preferred) and Scenario 3 (least total energy) is an extra 18 MJ/m per year for maintenance and to an extra cost of €1/m per year. The resulting gain in secondary traffic energy is 94 (169 – 75) MJ/m per year. This means an annual saving of 76 MJ/m per year at a cost of €1/m per year, which corresponds to a cost of 13 €/GJ to save energy for case 1 (170 €/ton CO₂, assuming 0.075 ton CO₂/GJ). For Case 2 Option 1 and 3 can be assessed as the most realistic ones and therefore they are compared. It turns out that Option 1 is both the most cost and energy efficient alternative per year, per meter. However, the difference in cost between the alternatives are very small and a simple sensitivity analysis shows that if the service life of Option 3 would increase from three to four years, the corresponding cost for keeping the more energy efficient Option 1 would be 56 €/GJ.

Table 1. Differences in cost and energy use between alternatives in case 1 and case 2. A sensitivity analysis is included in Case 2 to illustrate effects of small cost difference between alternatives.

Object	Service life	ENERGY USE			COST	COST/ENERGY	
		Maintenance	Traffic	Total		Maintenance	Per Traffic energy
	y	MJ/y,m	MJ/y,m	MJ/y,m	€/yr, m	€/GJ	€/GJ
Case 1 E20 (3-1)	5 and 5	18	-94	-76	1,0	11	13
Case 2 RV47 (1-3)	12 and 3	23	-37	-14	-1,3	-36	-93
Case 2 RV47 (1-3)	12 and 4	32	-37	-5	0,3	8	56

With this example it can be concluded that the gain from less fuel consumption can exceed the extra cost of maintenance. But the results turn out to be sensitive to uncertainties and by assuming a service life of one more year for one of the cases meant there is a problem when assessing energy savings in relation to cost in that very small differences in cost will inevitably lead to low cost per gained energy

ratios. In general, predicting future maintenance cost with this accuracy is not possible. The present models available for traffic and maintenance energy use are able to deliver estimates for traffic energy based on ideal conditions and for maintenance energy based on assumptions on the practice used in material production, service life, resulting performance etc. However, the accuracy of these models is yet to be investigated for the purposes and problems formulated here as well as the way the information is implemented and taken into account in decision-making.

To compare different maintenance alternatives and to decide what strategy to choose; Minimise maintenance cost or minimise energy use, the calculation process described in Figure 1 needs to be amended with the evaluation steps described schematically in Figure 2. The current condition is the same for all alternatives. Each maintenance option leads to its' specific outcome regarding the road surface conditions, cost and energy use. The resulting surface conditions will in turn have an effect on the cost, both direct and societal, and energy use of the traffic. In each of the steps there are also uncertainties to consider.

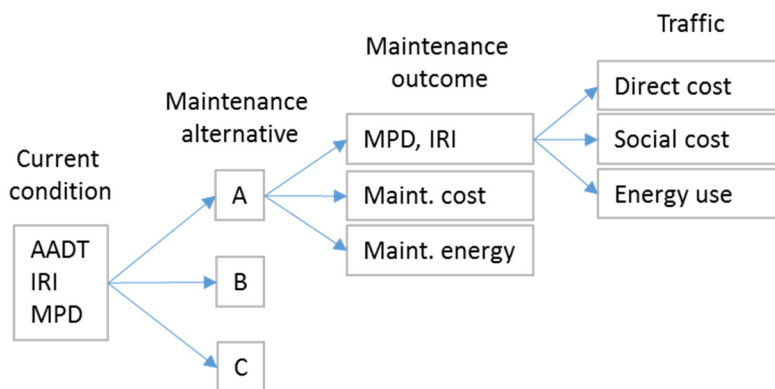


Figure 2. Influence diagram showing how current condition will influence decisions and alternatives and finally the resulting outcome.

This report aims at providing a basis for pavement management decision making with respect to total energy and cost, taking into account uncertainties. This basis can be formed by knowledge, procedures and tools. One of these tools could be to have a guideline or a rule of thumb that tells the pavement management if total energy is a relevant issue in a given situation, if the lowering of the rolling resistance through maintenance is efficient enough.

The climate, with rain and snow, will also have an effect on rolling resistance and hence the energy use of traffic. This is to some extent considered in the Winter maintenance management system (WMMS) where it will be possible to calculate and evaluate the most significant impact on road users, road authorities and society of various policies and measures in winter road maintenance. Water prevailing on the road surface is though not considered. Therefore, the presence of water and snow and the effect on traffic fuel consumption during a year will be evaluated.

2.2. Method for the decision procedure

2.2.1. Criteria for cost efficient maintenance that reduces energy

Since the environmental effects of release of CO₂ can be valued and compared to other costs. The relative cost efficiency (Cost Ratio, *CR*) when comparing two alternatives can therefore be expressed as the difference in total cost (€ Total) divided by the difference in maintenance cost (€ Maint). In other words, if one extra monetary unit cost is used for maintenance, how much is saved in total cost?

$$CR = \frac{(\text{€ Total}_A - \text{€ Total}_B)}{(\text{€ Maint}_A - \text{€ Maint}_B)}$$

Where total cost can be expressed as the sum of maintenance cost and energy related social cost (*€ Energy*) originating from fuel consumption by traffic and energy used in maintenance.

$$CR = \frac{(\text{€ Energy}_A - \text{€ Energy}_B) + (\text{€ Maint}_A - \text{€ Maint}_B)}{(\text{€ Maint}_A - \text{€ Maint}_B)}$$

Which is then formulated as

$$CR = 1 + \frac{(\text{€ Energy}_A - \text{€ Energy}_B)}{(\text{€ Maint}_A - \text{€ Maint}_B)}$$

Where

$$\text{€ Energy} = \text{€ Energy}_{\text{Traffic}} + \text{€ Energy}_{\text{Maint}}$$

$$\text{€ Energy}_{\text{Traffic}} = \text{Direct cost of fuel and environmental cost related to use of fuel.}$$

$$\text{€ Energy}_{\text{Maint}} = \text{Environmental cost related to use of energy during maintenance.}$$

To simplify calculations, it can be assumed that costs are close to those related to the use of diesel only by maintenance and traffic. This means that direct costs of diesel can be used and current pricing of release of CO₂, which can be calculated based on carbon content of diesel per litre. The current pricing in Sweden for direct fuel cost is 14.2 €/GJ and the environmental cost 12 €/GJ, when energy content of diesel (35.1 MJ/litre) is used for normalisation.

2.2.2. Uncertainty and variability and their importance in pavement management

The energy used by traffic can be several orders larger than the energy used during pavement maintenance. This means that small alterations to evenness and texture may render positive effects on both environment and costs, direct and societal. However, the success of selecting the most beneficial maintenance alternative will be dependent on uncertainties in several steps of the assessment and execution of production. Examples of uncertainties are related to:

- Assessment of existing conditions and effects of doing nothing
- Assessment of costs and energy use associated with pavement management alternatives.
- Assessment of pavement condition immediately after maintenance and future development of pavement condition.
- Assessment of energy used and cost associated with traffic as a result of pavement condition.
- Assessment of future need for maintenance.

Since there are many uncertainties included in the assessment it is inevitable that a certain proportion of pavement sections treated with an ambition to save costs or energy will fail in that respect. On the other hand, if the number of treated sections is very large, even small but significant differences in costs and energy may be worth considering to achieve on average a positive outcome. Two questions then arise:

1. What level of significance is needed and is it important to consider size of objects that will be influenced by decision?

2. Can the level of significance or uncertainty and variability be controlled by pavement management efforts?

The second question is a project on its own, for example, to investigate how procurement and production can be carried out in such a manner that rolling resistance can be reduced in a cost effective manner.

The first question is of great importance in this report. For large organisations, such as national road administrations, it might be obvious that stochastic variability is of limited interest since there will be an average difference for the road network as a whole that determine how efficient an alternative is. This view is relevant for making policies for road administrations. However, decisions on maintenance alternatives are made on object/project level, where uncertainties are important to consider. Decisions to select one maintenance alternative before another need to be taken based on project level, balancing objectives of agency costs and societal effects such as road user costs and environmental aspects. Balancing decisions against multiple objectives means greater complexity, hence reducing and focusing decisions towards the most important objectives in each particular project and decision situation is beneficial. A suggested procedure is therefore developed that include a step to determine if rolling resistance is an important factor.

2.2.3. Development of decision making procedure

An example is used to describe the development of the decision making procedure. In this example, it is assumed that a road section needs maintenance and that we compare maintenance alternative (1) to alternative (2). For simplicity, assume that alternative (1) is, more or less, a standard alternative and that we need to discuss the best choice in terms of the properties of alternative (2). Once the procedure is defined, none of the alternatives need to be a standard alternative. Also, for further use, the numbering of the alternatives is arbitrary, i.e. the alternative with the highest cost does not always have to be labelled as alternative (1).

Depending on the difference in price and energy use, we may either prefer alternative (2), find the alternatives equally good or prefer alternative (1). The following procedure will not immediately tell which alternative to use, but it will tell if one should choose with respect to lowest cost or with respect to lowest energy use. A graphic example of the comparison between the alternatives is shown in Figure 3.

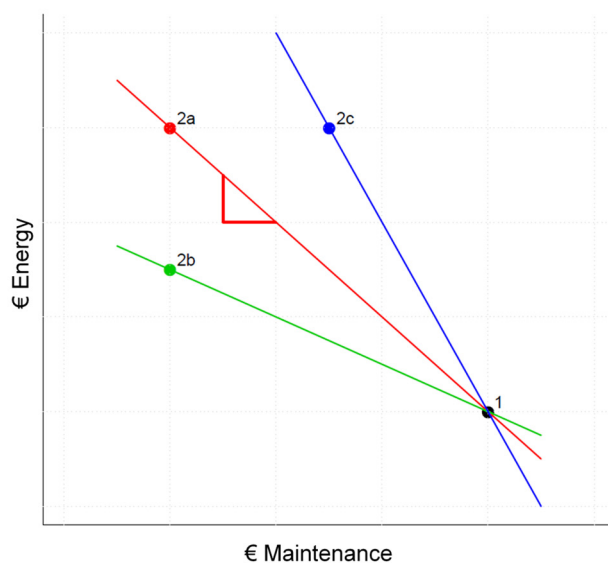


Figure 3. An example of comparison of alternative 1 to alternatives 2a, 2b and 2c.

If the difference in energy cost is of smaller size than the maintenance cost and of opposite sign, (1) and (2b), the green line, alternative (2) is preferred. (2b) has lower maintenance cost but also higher energy cost. The energy cost is however not so much higher that it cancels out the lower maintenance cost of alternative (1).

The red line, (1) and (2a), are equally good if the difference in maintenance costs is of equal size as the difference in energy cost but with opposite sign. The gain in maintenance cost if changing from an alternative with higher cost to one with lower cost is exactly matched to a loss of equal size in energy cost.

If the difference in maintenance cost is of smaller size than the energy cost and of opposite sign, (1) and (2c), the blue line, alternative (1) is preferred. (2c) has lower maintenance cost but the higher energy cost leads to that alternative (1) is preferred.

As can be seen from this example/figure, for a small negative slope (> -1), alternative (2) is preferred and for high negative slope (< -1), alt (1) is preferred. For a slope near -1 the alternatives are equally good.

Because $CR = 1 + \text{slope}$ is means that:

- $CR > 0$ The alternative with lowest maintenance cost is preferred.
- $CR = 0$ The alternatives are equal.
- $CR < 0$ The alternative with lowest energy cost is preferred.

CR does not immediately tell which alternative to choose. It tells if the preferred alternative should be chosen according to maintenance cost or to energy cost.

As a note, it is of course possible to create a special case where one alternative has higher maintenance cost and at the same time higher energy cost than the other, meaning that the slope is positive. In that case it is preferred to use the alternative with lower maintenance cost, or the one with lower energy cost, which is in fact the same. Here $CR > 1$ but the decision rule for $CR > 0$ gives the correct decision and the decision rules do not need to be changed or completed for this special case.

2.2.4. Uncertainty in the decision

The properties of the variables included in the cost functions should be regarded as random variables. If, for instance, we chose between (1) and (2b) according to what we expect of those alternatives, (2b) is the preferred one. With uncertainty added, the outcome (2-dimensional, maintenance cost and energy cost) acts as one observation in the distribution of possible outcomes. Likewise, the outcome if choosing (1) has a distribution and applying (1) only gives one outcome sampled from that distribution. Some possible outcomes are shown as bullet clouds in Figure 4. We choose between the alternatives (1) and (2b) according expectations but the result is the random outcome of a comparison between what we should get if we applied (2b) compared to what we should get if we applied (1).

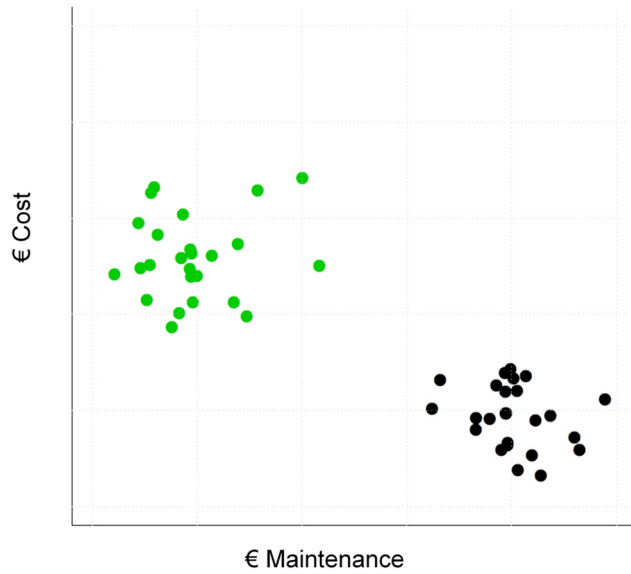


Figure 4. Random outcome of the alternatives (1) and (2b).

With the idea of looking at random outcome, one can connect any pair of one possible outcome of alternative (1) with (2b). Each possible connecting line will have a slope, see Figure 5. This figure shows a sample from the distribution of slopes which can be converted to the distribution of CR. A small proportion of the possible lines have $CR < 0$ in the example. That is, we choose (2b) based on what we know about the expected maintenance costs but there is a probability that the choice turns out afterwards to not be the best. At some occasions, the random variation makes (2b) having so high energy cost and (1) having so low maintenance cost that (1) would be have been a better choice though 2 was preferred and used. The slopes are shown in Figure 6.

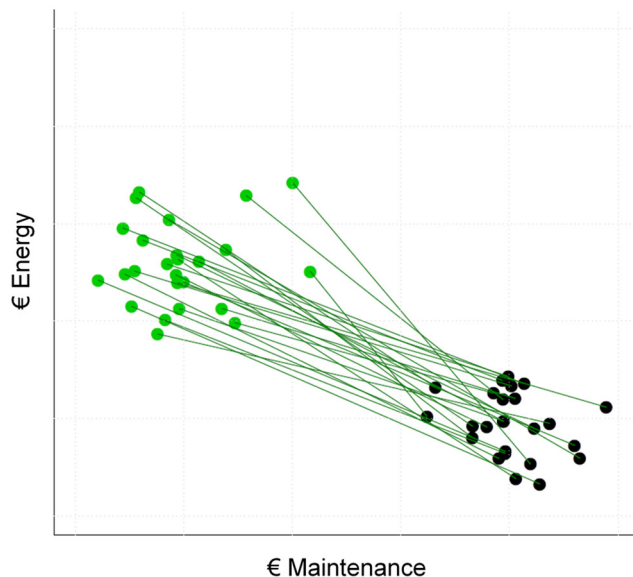


Figure 5. An example of slopes for alternatives (1) and (2b).

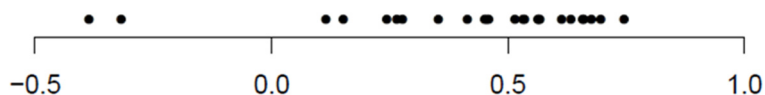


Figure 6. Distribution of slopes between alternative (1) and (2b).

The expected outcome is probably biased, and that may introduce approximations in the decision. Even if expected values of maintenance cost and energy exists together with expected result in IRI and MPD, plugging all these data into the nonlinear *CR* function does not give exactly the expected *CR*. Therefore, the decision is probably based on approximately known expected values, the bullets and slopes in Figure 5.

2.2.5. Design of case studies

It was decided that maintenance cost and maintenance energy should have normal distributions and being defined with expected value and standard deviation and correlation 0.25. Also, the outcome in terms of IRI and MPD should have normal distribution with expectation and standard deviation but uncorrelated to each other and to maintenance cost and energy. The expected total energy is approximately found by inserting the expected IRI etc. into a fuel consumption (FC) model (see section 2.4) and then into *CR*. The decision is then made on that approximation. The distributions of slopes are based on simulation consisting of 100 000 for each comparison.

Comparing alternatives with the same expected maintenance cost does not make much sense. Of course one should choose the one with lowest energy in that case. There is though a problem with the equation for *CR*, that it includes a ratio with a denominator tending to be (at least close to) zero. We did not run any simulation in the case of two alternatives with the same expected maintenance cost.

The simulation compared 12 alternatives with each other in pairs, but some pairs are ignored due to equal expected cost. In total, that means we made 48 comparisons between alternatives, but all these were also run with different speeds, ADC, RF and vehicle mix. The alternatives are presented in the table below. Energy in MJ/m² and cost in SEK/m². The comparisons refer to a road section that is 1 km long, 8 m wide and with an AADT of 8 000. The length cancels out in *CR* but must be mentioned to make it possible to interpret mostly what the standard deviations actually represent. The life times are here regarded as fixed without any random variation.

Table 2. Maintenance alternatives with data used in simulations including expected values and standard deviations.

Alternative	Expectation				Standard deviation				Lifetime
	Energy	IRI	MPD	Cost	Energy	IRI	MPD	Cost	
1	60.1	1.5	1	63	6.01	0.35	0.14	9	10
2	60.1	1.3	0.6005	63	6.01	0.32	0.05276	9	10
3	60.1	1.04	0.7975	63	6.01	0.16	0.05276	9	10
4	40	1	0.5856	54	4	0.9	0.10767	9	7
5	34	1	1.6136	45	3.4	0.6	0.30937	7	7
6	47	1	1.0118	63.45	4.7	0.3	0.12802	7.05	10
7	14	1	1.2	13	1.4	0.2	0.11852	3	5
8	14	2	1.2	13	1.4	0.3	0.11852	3	5
9	14	3	1.2	13	1.4	0.4	0.11852	3	5
10	14	1	1.4	13	1.4	0.2	0.11852	3	5
11	14	2	1.4	13	1.4	0.3	0.11852	3	5
12	14	3	1.4	13	1.4	0.4	0.11852	3	5

The *CR* values are approximations with expected values on each of the variables plugged into the fuel consumption model and the following *CR* calculation. Based on the sign of this value, the decision is made about which alternative is to be preferred (not that at this stage any difference count and the decision cannot be that the alternatives are equal). The Prob values show the probability that the decision becomes correct when uncertainty is introduced.

Table 3. Vehicle mix 96% private cars, 2% trucks, 2% trucks with trailer.

ADC			0.00	1.50	0.00	1.50	0.00	1.50	0.00	1.50
RF			0.00	0.00	29.00	29.00	0.00	0.00	29.00	29.00
Speed			70.00	70.00	70.00	70.00	90.00	90.00	90.00	90.00
	Alt (1)	Alt (2)								
CR	1	4	-1.72	-1.73	-1.74	-1.75	-1.93	-1.94	-1.95	-1.96
Prob	1	4	0.64	0.64	0.64	0.64	0.65	0.64	0.65	0.65
CR	1	5	26.75	26.85	26.92	27.01	25.06	25.20	25.20	25.34
Prob	1	5	0.60	0.61	0.60	0.61	0.61	0.61	0.61	0.61
CR	1	6	-20.19	-20.25	-20.30	-20.36	-26.03	-26.16	-26.16	-26.28
Prob	1	6	0.33	0.33	0.33	0.33	0.35	0.35	0.35	0.35
CR	1	7	0.95	0.95	0.95	0.95	1.02	1.02	1.02	1.02
Prob	1	7	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
CR	1	8	0.47	0.47	0.47	0.46	0.39	0.39	0.39	0.39
Prob	1	8	0.83	0.82	0.82	0.82	0.77	0.76	0.76	0.76
CR	1	9	-0.01	-0.02	-0.02	-0.02	-0.23	-0.24	-0.24	-0.25
Prob	1	9	0.51	0.51	0.51	0.52	0.66	0.66	0.66	0.66
CR	1	10	0.57	0.57	0.57	0.57	0.64	0.63	0.63	0.63
Prob	1	10	0.87	0.88	0.87	0.87	0.89	0.88	0.88	0.88
CR	1	11	0.09	0.08	0.08	0.08	0.01	0.00	0.00	0.00
Prob	1	11	0.57	0.56	0.56	0.56	0.51	0.51	0.50	0.50
CR	1	12	-0.40	-0.40	-0.41	-0.41	-0.62	-0.63	-0.63	-0.64
Prob	1	12	0.77	0.78	0.78	0.78	0.86	0.86	0.86	0.87
CR	2	4	0.52	0.52	0.52	0.52	0.41	0.41	0.41	0.41
Prob	2	4	0.72	0.72	0.72	0.72	0.67	0.67	0.67	0.67
CR	2	5	51.44	51.62	51.75	51.94	50.80	51.08	51.09	51.36
Prob	2	5	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
CR	2	6	50.34	50.53	50.67	50.86	47.52	47.80	47.81	48.08
Prob	2	6	0.60	0.60	0.60	0.59	0.61	0.61	0.61	0.61

Table 3. (Continued)

ADC			0.00	1.50	0.00	1.50	0.00	1.50	0.00	1.50
RF			0.00	0.00	29.00	29.00	0.00	0.00	29.00	29.00
Speed			70.00	70.00	70.00	70.00	90.00	90.00	90.00	90.00
	Alt (1)	Alt (2)								
CR	2	7	0.10	0.09	0.09	0.09	0.13	0.12	0.12	0.12
Prob	2	7	0.59	0.59	0.59	0.58	0.61	0.61	0.61	0.60
CR	2	8	-0.39	-0.39	-0.40	-0.40	-0.50	-0.51	-0.51	-0.52
Prob	2	8	0.81	0.81	0.82	0.82	0.85	0.86	0.86	0.86
CR	2	9	-0.87	-0.88	-0.88	-0.89	-1.13	-1.14	-1.14	-1.15
Prob	2	9	0.97	0.97	0.97	0.97	0.99	0.99	0.99	0.99
CR	2	10	-0.28	-0.29	-0.29	-0.30	-0.26	-0.27	-0.27	-0.27
Prob	2	10	0.75	0.75	0.75	0.76	0.72	0.72	0.72	0.73
CR	2	11	-0.77	-0.78	-0.78	-0.79	-0.89	-0.90	-0.90	-0.91
Prob	2	11	0.96	0.96	0.96	0.96	0.97	0.97	0.97	0.97
CR	2	12	-1.25	-1.26	-1.27	-1.28	-1.51	-1.53	-1.53	-1.54
Prob	2	12	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
CR	3	4	-0.13	-0.13	-0.14	-0.14	-0.15	-0.16	-0.16	-0.17
Prob	3	4	0.38	0.39	0.39	0.39	0.40	0.40	0.40	0.40
CR	3	5	44.26	44.42	44.53	44.69	44.57	44.82	44.83	45.06
Prob	3	5	0.55	0.55	0.56	0.56	0.56	0.56	0.56	0.56
CR	3	6	29.83	29.95	30.03	30.14	29.73	29.90	29.91	30.08
Prob	3	6	0.68	0.68	0.68	0.67	0.68	0.68	0.67	0.67
CR	3	7	0.35	0.34	0.34	0.34	0.34	0.34	0.34	0.34
Prob	3	7	0.80	0.80	0.80	0.80	0.79	0.79	0.79	0.79
CR	3	8	-0.14	-0.14	-0.15	-0.15	-0.28	-0.29	-0.29	-0.30
Prob	3	8	0.63	0.63	0.63	0.64	0.74	0.74	0.74	0.75
CR	3	9	-0.62	-0.63	-0.63	-0.64	-0.91	-0.92	-0.92	-0.93
Prob	3	9	0.92	0.92	0.92	0.93	0.97	0.97	0.97	0.97

Table 3. (Continued)

ADC			0.00	1.50	0.00	1.50	0.00	1.50	0.00	1.50
RF			0.00	0.00	29.00	29.00	0.00	0.00	29.00	29.00
Speed			70.00	70.00	70.00	70.00	90.00	90.00	90.00	90.00
	Alt (1)	Alt (2)								
CR	3	10	-0.04	-0.04	-0.04	-0.05	-0.04	-0.05	-0.05	-0.05
Prob	3	10	0.53	0.54	0.54	0.54	0.54	0.54	0.55	0.55
CR	3	11	-0.52	-0.53	-0.53	-0.54	-0.67	-0.68	-0.68	-0.69
Prob	3	11	0.89	0.89	0.89	0.90	0.93	0.94	0.94	0.94
CR	3	12	-1.01	-1.01	-1.02	-1.02	-1.30	-1.31	-1.31	-1.32
Prob	3	12	0.99	0.99	0.99	0.99	1.00	1.00	1.00	1.00
CR	4	5	-4.57	-4.59	-4.60	-4.62	-4.63	-4.66	-4.66	-4.69
Prob	4	5	0.74	0.74	0.75	0.74	0.73	0.73	0.73	0.73
CR	4	6	-1.11	-1.12	-1.13	-1.13	-1.14	-1.15	-1.15	-1.16
Prob	4	6	0.57	0.57	0.57	0.57	0.55	0.56	0.56	0.56
CR	4	7	0.21	0.21	0.21	0.21	0.21	0.20	0.20	0.20
Prob	4	7	0.67	0.67	0.67	0.66	0.64	0.65	0.64	0.64
CR	4	8	-0.14	-0.14	-0.14	-0.15	-0.25	-0.26	-0.26	-0.26
Prob	4	8	0.61	0.61	0.62	0.62	0.67	0.67	0.67	0.68
CR	4	9	-0.49	-0.49	-0.50	-0.50	-0.70	-0.71	-0.71	-0.72
Prob	4	9	0.84	0.83	0.84	0.84	0.89	0.89	0.89	0.89
CR	4	10	-0.06	-0.07	-0.07	-0.07	-0.07	-0.08	-0.08	-0.09
Prob	4	10	0.55	0.56	0.56	0.56	0.55	0.56	0.56	0.56
CR	4	11	-0.41	-0.42	-0.42	-0.43	-0.53	-0.54	-0.54	-0.54
Prob	4	11	0.80	0.80	0.81	0.81	0.82	0.83	0.83	0.83
CR	4	12	-0.76	-0.77	-0.77	-0.78	-0.98	-0.99	-0.99	-1.00
Prob	4	12	0.94	0.94	0.94	0.94	0.96	0.96	0.96	0.96
CR	5	6	52.03	52.21	52.34	52.52	52.57	52.85	52.86	53.13
Prob	5	6	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57

Table 3. (Continued)

ADC			0.00	1.50	0.00	1.50	0.00	1.50	0.00	1.50
RF			0.00	0.00	29.00	29.00	0.00	0.00	29.00	29.00
Speed			70.00	70.00	70.00	70.00	90.00	90.00	90.00	90.00
	Alt (1)	Alt (2)								
CR	5	7	1.82	1.82	1.83	1.83	1.83	1.83	1.83	1.84
Prob	5	7	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
CR	5	8	1.35	1.35	1.35	1.36	1.22	1.22	1.22	1.22
Prob	5	8	0.96	0.96	0.96	0.96	0.94	0.94	0.93	0.93
CR	5	9	0.88	0.88	0.88	0.88	0.62	0.61	0.61	0.61
Prob	5	9	0.88	0.88	0.87	0.87	0.78	0.77	0.77	0.77
CR	5	10	1.45	1.45	1.45	1.46	1.46	1.46	1.46	1.46
Prob	5	10	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
CR	5	11	0.98	0.98	0.98	0.98	0.85	0.85	0.85	0.85
Prob	5	11	0.91	0.90	0.90	0.90	0.86	0.85	0.86	0.85
CR	5	12	0.51	0.51	0.51	0.51	0.24	0.24	0.24	0.23
Prob	5	12	0.75	0.75	0.75	0.74	0.62	0.62	0.62	0.61
CR	6	7	0.70	0.70	0.70	0.70	0.70	0.69	0.69	0.69
Prob	6	7	0.94	0.94	0.94	0.94	0.93	0.93	0.93	0.93
CR	6	8	0.22	0.22	0.22	0.21	0.08	0.07	0.07	0.07
Prob	6	8	0.69	0.68	0.68	0.68	0.56	0.56	0.56	0.55
CR	6	9	-0.26	-0.26	-0.26	-0.27	-0.54	-0.55	-0.55	-0.56
Prob	6	9	0.70	0.71	0.71	0.71	0.85	0.85	0.86	0.86
CR	6	10	0.32	0.32	0.32	0.32	0.32	0.31	0.31	0.31
Prob	6	10	0.76	0.76	0.76	0.76	0.75	0.74	0.74	0.74
CR	6	11	-0.16	-0.16	-0.16	-0.17	-0.30	-0.31	-0.31	-0.32
Prob	6	11	0.63	0.64	0.63	0.64	0.73	0.73	0.74	0.74
CR	6	12	-0.63	-0.64	-0.64	-0.65	-0.92	-0.93	-0.94	-0.95
Prob	6	12	0.91	0.91	0.91	0.91	0.96	0.96	0.96	0.96

Table 4. Vehicle mix 84% private cars, 8% trucks, 8% trucks with trailer.

ADC			0.00	1.50	0.00	1.50	0.00	1.50	0.00	1.50
RF			0.00	0.00	29.00	29.00	0.00	0.00	29.00	29.00
Speed			70.00	70.00	70.00	70.00	90.00	90.00	90.00	90.00
	Alt (1)	Alt (2)								
CR	1	4	-3.66	-3.67	-3.68	-3.69	-3.90	-3.91	-3.92	-3.93
Prob	1	4	0.72	0.72	0.72	0.72	0.71	0.71	0.71	0.71
CR	1	5	43.96	44.05	44.15	44.23	39.66	39.79	39.81	39.94
Prob	1	5	0.58	0.58	0.57	0.58	0.58	0.58	0.58	0.58
CR	1	6	-35.54	-35.59	-35.67	-35.72	-44.97	-45.09	-45.13	-45.23
Prob	1	6	0.40	0.40	0.40	0.40	0.41	0.41	0.41	0.41
CR	1	7	0.90	0.90	0.89	0.89	1.02	1.02	1.02	1.02
Prob	1	7	0.88	0.88	0.88	0.88	0.90	0.90	0.90	0.90
CR	1	8	0.01	0.01	0.00	0.00	-0.10	-0.10	-0.10	-0.10
Prob	1	8	0.50	0.51	0.50	0.50	0.54	0.55	0.54	0.55
CR	1	9	-0.88	-0.89	-0.89	-0.89	-1.21	-1.22	-1.22	-1.23
Prob	1	9	0.86	0.86	0.86	0.86	0.92	0.92	0.92	0.92
CR	1	10	0.25	0.25	0.25	0.25	0.39	0.39	0.39	0.39
Prob	1	10	0.63	0.63	0.63	0.63	0.69	0.69	0.69	0.69
CR	1	11	-0.64	-0.64	-0.64	-0.65	-0.73	-0.73	-0.73	-0.74
Prob	1	11	0.79	0.79	0.79	0.79	0.81	0.81	0.81	0.81
CR	1	12	-1.52	-1.53	-1.53	-1.54	-1.84	-1.85	-1.85	-1.86
Prob	1	12	0.97	0.97	0.97	0.97	0.98	0.98	0.98	0.98
CR	2	4	0.16	0.15	0.15	0.15	-0.02	-0.02	-0.02	-0.03
Prob	2	4	0.61	0.60	0.60	0.60	0.43	0.42	0.43	0.43
CR	2	5	85.96	86.14	86.33	86.49	82.31	82.57	82.63	82.88
Prob	2	5	0.54	0.54	0.54	0.54	0.54	0.55	0.54	0.55
CR	2	6	84.47	84.65	84.85	85.02	76.90	77.16	77.21	77.46
Prob	2	6	0.56	0.56	0.56	0.56	0.57	0.57	0.57	0.57

Table 4. (Continued)

ADC			0.00	1.50	0.00	1.50	0.00	1.50	0.00	1.50
RF			0.00	0.00	29.00	29.00	0.00	0.00	29.00	29.00
Speed			70.00	70.00	70.00	70.00	90.00	90.00	90.00	90.00
	Alt (1)	Alt (2)								
CR	2	7	-0.56	-0.57	-0.57	-0.57	-0.46	-0.47	-0.47	-0.47
Prob	2	7	0.82	0.82	0.82	0.82	0.76	0.76	0.76	0.76
CR	2	8	-1.45	-1.46	-1.46	-1.47	-1.58	-1.59	-1.59	-1.60
Prob	2	8	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
CR	2	9	-2.34	-2.35	-2.35	-2.36	-2.69	-2.71	-2.71	-2.72
Prob	2	9	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
CR	2	10	-1.21	-1.21	-1.22	-1.22	-1.09	-1.10	-1.10	-1.11
Prob	2	10	0.98	0.98	0.98	0.98	0.95	0.95	0.95	0.95
CR	2	11	-2.09	-2.10	-2.11	-2.11	-2.21	-2.22	-2.22	-2.23
Prob	2	11	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
CR	2	12	-2.98	-2.99	-3.00	-3.01	-3.33	-3.34	-3.34	-3.35
Prob	2	12	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
CR	3	4	-0.89	-0.90	-0.90	-0.91	-0.89	-0.89	-0.89	-0.90
Prob	3	4	0.50	0.51	0.50	0.50	0.50	0.50	0.50	0.50
CR	3	5	74.42	74.57	74.73	74.87	72.80	73.02	73.08	73.29
Prob	3	5	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
CR	3	6	51.48	51.59	51.71	51.81	49.72	49.88	49.92	50.07
Prob	3	6	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
CR	3	7	-0.16	-0.17	-0.17	-0.17	-0.13	-0.13	-0.14	-0.14
Prob	3	7	0.61	0.61	0.62	0.62	0.59	0.59	0.59	0.59
CR	3	8	-1.05	-1.06	-1.06	-1.06	-1.25	-1.25	-1.26	-1.26
Prob	3	8	0.96	0.96	0.96	0.96	0.98	0.97	0.98	0.98
CR	3	9	-1.94	-1.95	-1.95	-1.96	-2.36	-2.37	-2.38	-2.39
Prob	3	9	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table 4. (Continued)

ADC			0.00	1.50	0.00	1.50	0.00	1.50	0.00	1.50
RF			0.00	0.00	29.00	29.00	0.00	0.00	29.00	29.00
Speed			70.00	70.00	70.00	70.00	90.00	90.00	90.00	90.00
	Alt (1)	Alt (2)								
CR	3	10	-0.80	-0.81	-0.81	-0.82	-0.76	-0.77	-0.77	-0.77
Prob	3	10	0.92	0.93	0.92	0.93	0.90	0.91	0.91	0.91
CR	3	11	-1.69	-1.70	-1.71	-1.71	-1.88	-1.89	-1.89	-1.90
Prob	3	11	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
CR	3	12	-2.58	-2.59	-2.60	-2.60	-3.00	-3.01	-3.01	-3.02
Prob	3	12	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
CR	4	5	-8.42	-8.44	-8.46	-8.48	-8.25	-8.28	-8.29	-8.32
Prob	4	5	0.76	0.76	0.76	0.76	0.75	0.75	0.75	0.75
CR	4	6	-2.62	-2.62	-2.63	-2.64	-2.55	-2.56	-2.56	-2.57
Prob	4	6	0.66	0.66	0.66	0.66	0.64	0.63	0.63	0.64
CR	4	7	-0.36	-0.37	-0.37	-0.37	-0.34	-0.34	-0.34	-0.35
Prob	4	7	0.68	0.69	0.69	0.69	0.65	0.65	0.65	0.65
CR	4	8	-1.01	-1.01	-1.02	-1.02	-1.15	-1.15	-1.16	-1.16
Prob	4	8	0.90	0.91	0.91	0.91	0.90	0.90	0.90	0.90
CR	4	9	-1.65	-1.66	-1.66	-1.67	-1.96	-1.96	-1.97	-1.97
Prob	4	9	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
CR	4	10	-0.83	-0.83	-0.84	-0.84	-0.80	-0.80	-0.80	-0.81
Prob	4	10	0.86	0.87	0.87	0.87	0.82	0.82	0.82	0.82
CR	4	11	-1.47	-1.48	-1.48	-1.49	-1.60	-1.61	-1.61	-1.62
Prob	4	11	0.97	0.97	0.97	0.97	0.96	0.96	0.96	0.96
CR	4	12	-2.12	-2.12	-2.13	-2.13	-2.41	-2.42	-2.42	-2.43
Prob	4	12	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
CR	5	6	86.77	86.94	87.13	87.29	85.23	85.49	85.55	85.80
Prob	5	6	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55

Table 4. (Continued)

ADC			0.00	1.50	0.00	1.50	0.00	1.50	0.00	1.50
RF			0.00	0.00	29.00	29.00	0.00	0.00	29.00	29.00
Speed			70.00	70.00	70.00	70.00	90.00	90.00	90.00	90.00
	Alt (1)	Alt (2)								
CR	5	7	2.34	2.34	2.35	2.35	2.32	2.32	2.32	2.33
Prob	5	7	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
CR	5	8	1.48	1.48	1.49	1.49	1.24	1.24	1.24	1.24
Prob	5	8	0.89	0.89	0.89	0.89	0.83	0.83	0.83	0.83
CR	5	9	0.62	0.62	0.62	0.62	0.16	0.16	0.16	0.16
Prob	5	9	0.70	0.69	0.69	0.69	0.55	0.55	0.55	0.55
CR	5	10	1.72	1.72	1.72	1.73	1.71	1.71	1.71	1.71
Prob	5	10	0.92	0.92	0.92	0.92	0.91	0.91	0.91	0.91
CR	5	11	0.86	0.86	0.86	0.86	0.63	0.63	0.63	0.63
Prob	5	11	0.76	0.76	0.76	0.76	0.69	0.69	0.69	0.69
CR	5	12	0.00	0.00	0.00	0.00	-0.45	-0.45	-0.46	-0.46
Prob	5	12	0.50	0.50	0.50	0.50	0.63	0.63	0.64	0.64
CR	6	7	0.46	0.46	0.46	0.45	0.47	0.47	0.47	0.46
Prob	6	7	0.75	0.75	0.74	0.75	0.74	0.74	0.74	0.74
CR	6	8	-0.42	-0.42	-0.43	-0.43	-0.63	-0.64	-0.64	-0.65
Prob	6	8	0.72	0.72	0.72	0.72	0.80	0.80	0.80	0.80
CR	6	9	-1.30	-1.30	-1.31	-1.31	-1.74	-1.75	-1.75	-1.76
Prob	6	9	0.96	0.96	0.96	0.96	0.98	0.98	0.98	0.98
CR	6	10	-0.18	-0.18	-0.18	-0.18	-0.15	-0.16	-0.16	-0.16
Prob	6	10	0.60	0.60	0.60	0.61	0.59	0.59	0.59	0.59
CR	6	11	-1.05	-1.06	-1.06	-1.07	-1.26	-1.26	-1.27	-1.27
Prob	6	11	0.93	0.93	0.93	0.93	0.95	0.95	0.95	0.95
CR	6	12	-1.93	-1.94	-1.94	-1.95	-2.36	-2.37	-2.37	-2.38
Prob	6	12	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00

2.3. Climate

Both snow and water on the road surface will influence the rolling resistance and hence the fuel use. This is due to the need to displace an amount of snow or water in front of the wheel and the size of this extra force is dependent on the volume to displace and also the density in the case of snow.

In Table 5 the climate data retrieved for the two case studies in Karlsson et al.. (2012) is presented. The data is retrieved from RWiS (Road Weather information System) outstations that are nearby the road sections. The data is for October 15 2004 to April 15 2005 and this year was chosen because the precipitation was close to normal (based on statistics 1961–1990). The number of hours with rain or snow fall can be seen for each outstation.

Table 5. Distribution of road surface condition. Number of hours and percentage of time in the winter of 2004/2005.

	Case E20		Case RV47	
	hours	% of time	hours	% of time
Wet road	153	3%	274	6%
Snowy road	360	8%	315	7%
No precipitation		88%		87%

For the calculations of the amount of time the road surface is covered with water or moist, two sub-models of the VTI Winter Model¹ are used, “Splashing from a wet road” and “Drying of a moist road”. The first sub-model describes the variables that control the water disappearing from the road. Significant variables are traffic flow, the ratio between the number of cars and trucks, speed, wind speed and direction, road gradient and texture. This sub-model is used as long as the road is described as wet (>10 g/m²), and when the road turns to be moist the second sub-model take over. In this sub-model calculations are done of the transition from moist to dry surface through evaporation. The parameters taken into account are: road surface temperature, dew point temperature and wind speed, but also traffic flow, the ratio between the number of cars and trucks, speed, and salinity in the moisture.

To evaluate the effect on fuel use due to the presence of water and snow on the road surface the traffic simulation model VETO has been used (see section 2.4). In the evaluation, the amounts of snow and water on the road are varied and the resulting fuel use is compared to a situation with a dry road surface conditions. For dry road surface, fuel use has been estimated for each vehicle categories used in the case studies, with three different outdoor temperatures and with different combinations of IRI and MPD. The estimated fuel use when there is snow or water present on the road surface are presented as relative values, in %, the reference values of a dry road.

The type of snow is altered by using different densities, see Table 6. The densities for the various snow types are defined as intervals (Hjort 2012) and the ones that are used in the calculations are the mid value within each interval. Also, there is a possibility in VETO to define the percentage of how

¹ VINTER is a model for winter maintenance strategies of roads and deals with the effects on accidents, accessibility (speeds and flows), fuel consumption, corrosion, environmental effects, the costs incurred by the road administration for the measures, and the costs of the road administration for wear.

much the first axle of the vehicle are exposed to the snow and water depth respectively. For snow, this has been studied for 100% and 25%, and for water 100% is used.

Table 6. Type of snow and the density.

Type of snow	Density [kg/m ³]	Density used in the estimations [kg/m ³]
New	50-200	125
Powder	500-450	325
Wet	300-700	500
Compact	450-700	575

The yearly average ambient air temperature is set to 8°C for the whole year and is used for estimations of fuel use due to water on the road surface. During wintertime and for the evaluation of snow, the temperature is set to 1.5°C and this represents the average temperature during winter (Nov.–Feb.) in the region where the three roads are situated. To see if the temperature will have an impact, the fuel use during a temperature -5°C was also estimated for snow.

Three roads are used for the case study. One road, called MW, represents a 1 km 2+2 lane motorway with a speed limit of 110 km/h and where the road in each direction is 13 m wide. The second represents a 1 km 1+1 lane rural road with a speed limit of 90 km/h, called RUR_90, with a width of 9 m. These two roads are straight and flat, i.e. both geometrical and vertical alignment is set to 0. The third example is a small rural road with a speed limit of 70 km/h and a width of 6 m. This road is named RUR_70 and it has more curvature and rise and fall than the other two examples. For RUR_70, the geometrical and vertical alignment vary in the estimations throughout the studied stretch.

The IRI and MPD for dry and wet roads are combined using the following values:

- IRI: 1.0; 1.5; 2.0; 2.5; 3.0; 3.5; 4.0
- MPD: 0.5;1.0; 1.5; 2.0

Regarding snowy roads, IRI is varied along with the characteristics of the snow. MPD is in these cases automatically set to 0.5 by VETO. The investigated depth of snow is 1 to 5 cm with 1 cm step, and for water the depths are 0.5 mm, 1mm and up to 7 mm with 1 mm step. These estimations are made the roads and four vehicle types; passenger cars (petrol and diesel), truck and truck with trailer. In total 5 670 estimations of fuel use are calculated.

2.4. VETO

VETO is a simulation model, which can be used to estimate fuel consumption of traffic due to various characteristics of vehicles, roads and driving behaviour. It is a mechanistic model based on physical relationships in which it is possible to describe both vehicles and specific road segments with high precision (Hammarström, Karlsson 1987).

The basic data in VETO consists of the following main parts:

- Road: Geometry, speed limit and surface conditions (IRI and MPD).

- Vehicle: Details about the vehicle such as type of vehicle, air resistance, weight, engine power, fuel type, engine fuel map, tyres and transmission.
- Driving behaviour: Speed can be defined as a function of road width. With gear change one can define the use of max torque during acceleration and for steady state speed, deceleration and gear change decisions.
- Weather: Wind speed, special wind angles, air temperature, air pressure, water depth, and snow depth and density.

The various input parameters can be changed to investigate vehicles energy under different conditions.

VETO has been used to derive the fuel consumption function (Fcs) that is included in the criterion used to choose maintenance alternative. In Hammarström et al. (2012) the Fcs was developed for free flow situation, assuming typical vehicle data, conditions and driving patterns using models implemented in VETO. The function is defined as:

$$Fcs = c1 \times (1 + k5 \times (Fr + Fair + d1 \times ADC \times v^2 + d2 \times RF + d3 \times RF^2))^{e1} \times v^{e2-1}$$

where:

Fcs : Fuel use [liter/10 km]

Fr : Rolling resistance $Fr = m \times g \times (Cr0 + Cr1 \times IRI \times v + Cr2 \times MPD)$

$Fair$: Air resistance $Fair = Cd \times A \times dns \times v^2 / 2$

v : vehicle speed [m/s]

ADC : road curvature [rad/km]

RF : slope [m/km]

IRI : Road roughness [m/km]

MPD : Macrotexture [mm]

m : Mass [kg]

g : Standard gravity [m/s²]

Cd : Air dynamic coefficient

A : Projected front area of the vehicle [m²]

dns : Air density [kg/m³]

$c1, k5, d1, d2, d3, Cr0, Cr1, Cr2$: Parameters, values vary with vehicle type.

VETO has also been used to evaluate fuel use due to the presence of snow and water on the road surface. The vehicles and driving behaviour represent typical Swedish conditions. The fuel use in dm³/10 km is estimated for one type of vehicle according to the defined parameters in the model. To calculate the expected fuel use for one year, the figure in dm³/10 km for each vehicle type is transformed to MJ/(km road section) and multiplied with the AADT for the specific vehicle type. The energy use for the different vehicle types are added together to get the total yearly traffic energy use for the road section in the case study.

3. Statistical analysis

A decision quarter circle is presented in Figure 7. When comparing alternatives, represented by the red and one of the black dots, a CR value is found. The decision circle shows, for different CR values, how the alternatives compare to each other. The CR value and the decision strategy (choose according to energy (E), to cost (C) or being undecisive(U)) are shown for some examples. CR is not calculated for the alternative at “12 o’clock” because CR is not mathematically defined in this point (division by zero).

The figure does not show a complete circle since the CR and decision rule will be the same on the opposite side of any of the shown examples. Problems arise mostly when two alternatives around “12 o’clock” are compared because in that case one should choose according to energy (E) but the slope, and CR can jump between high negative and high positive values after only very small change in cost.

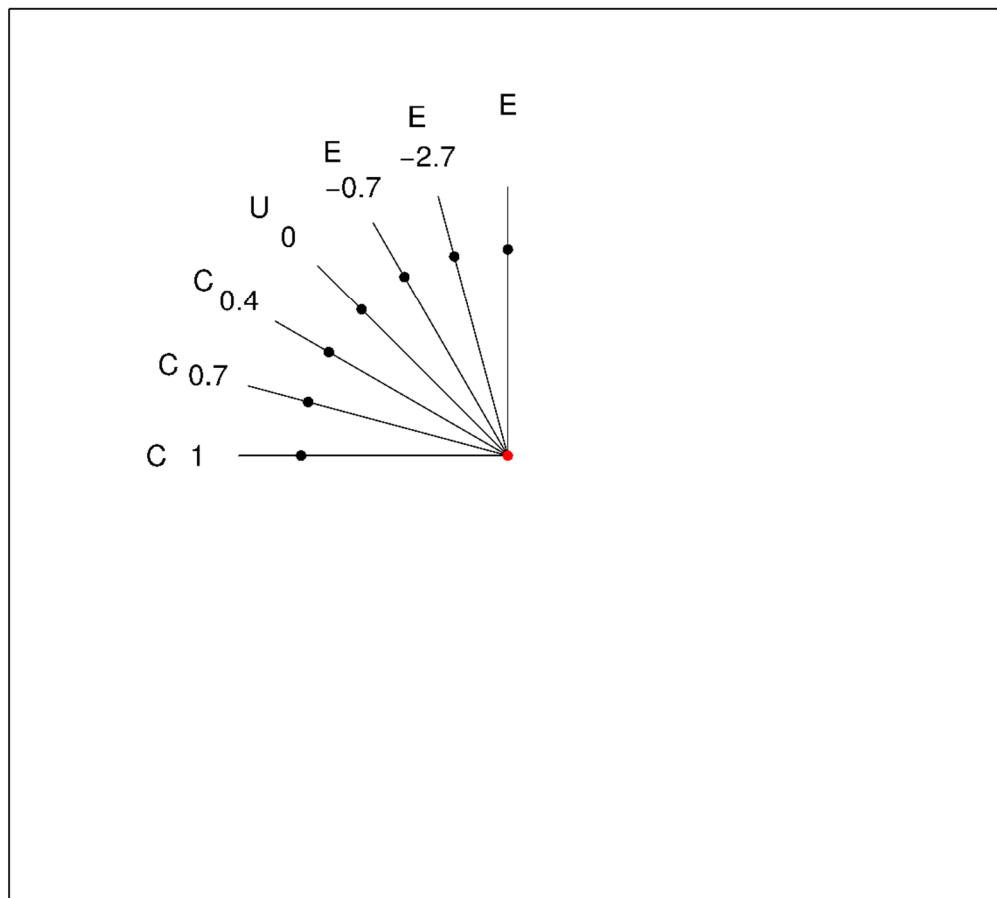


Figure 7. The decision quarter circle.

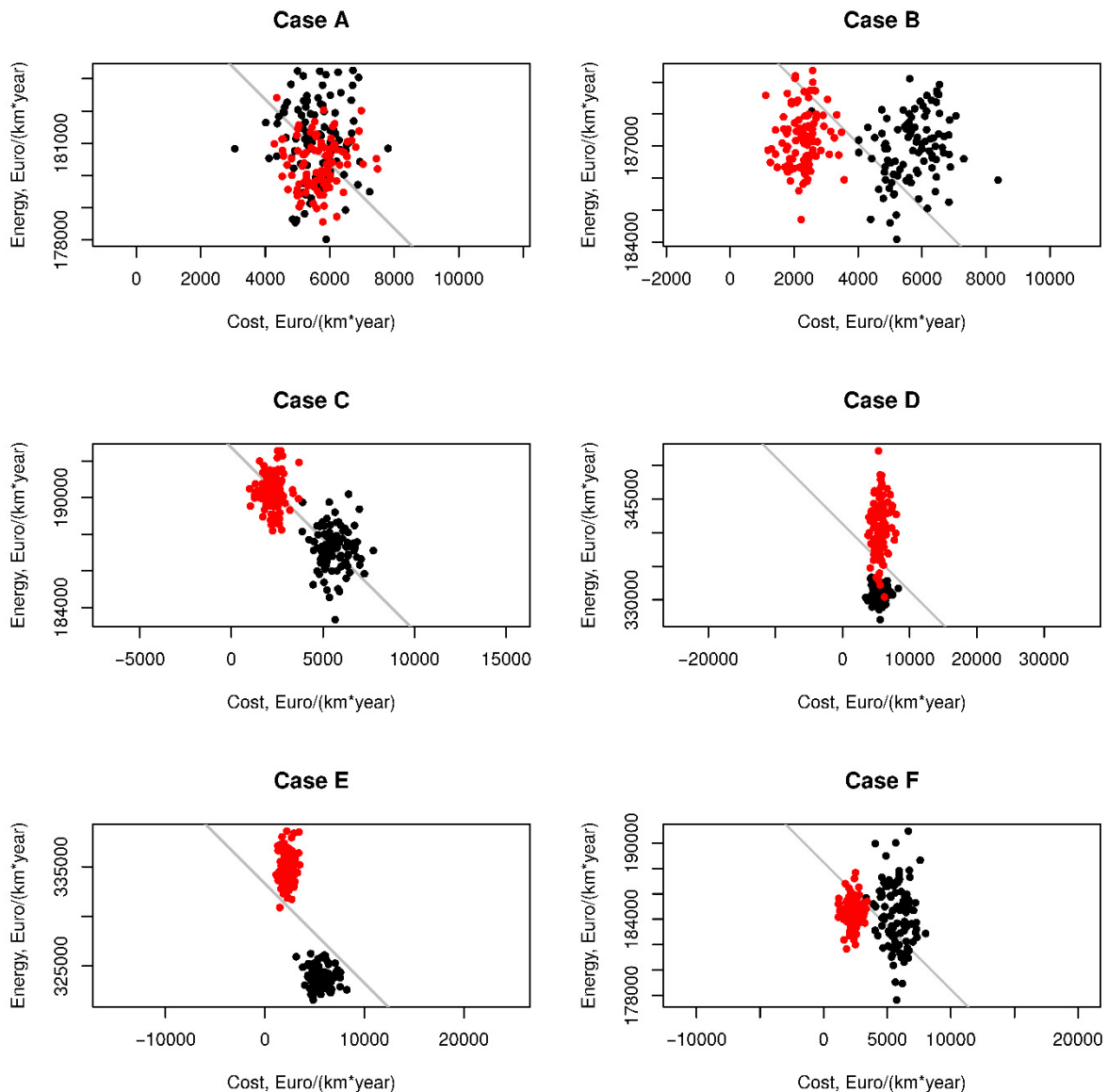


Figure 8. Different cases with two maintenance alternatives in each giving a difference in energy cost and maintenance cost.

The six cases shown in Figure 8 describe possible outcomes and how they can be interpreted. These have been selected as examples with different properties, but of course the outcomes are not limited to only these.

- A. The two maintenance alternatives have almost equal expectation of cost and also of energy. It is not possible to recommend one maintenance method over the other. The main uncertainty depends on the variation between outcomes of the same alternative but not on the difference between alternatives.
- B. The methods have different expected cost but almost the same expected energy. It is probably best to choose the one with lowest cost, but it is an uncertain decision. For the majority of combinations of one red and one black bullet, the red bullet has a better position in the cost/energy-plane, but the probability of making “wrong” decision cannot be neglected.
- C. The two alternatives are clearly separated in cost and in energy, but deciding which one is the “best” is impossible. One alternative has lower cost while the other has lower energy demand

with is expected to almost exactly compensate for the cost. Though the alternatives are separated, the effect of choosing one over the other is unclear. When combining one red and one black bullet, it is only random if it will be more or less steep than the decision line.

- D. The alternatives have almost exactly the same expected cost but quite different energy demand. The slope, when combining a red and a black bullet, varies randomly between a high negative and a high positive slope. *CR* does not clearly support which decision to make but after seeing the figure it is clear that one should choose the alternative with lowest energy demand.
- E. The alternatives are clearly separated. In this case, *CR* shows that the decision strategy must be to choose according to energy.
- F. Most combinations of a red and a black bullet shows that it is better to choose according to cost but the alternatives have different variation in energy demand. The decision can be better supported if one could first of all reduce the uncertainty in the energy dimension for the alternative represented by black bullets.

The six cases above are also noted with the corresponding letter in the tables presenting simulation results in Appendix 1.

4. Climate

In this section, the effect on fuel use due to the presence of snow or water on the road surface is presented. The impact of snow and water is described as relative values in percent of dry road conditions and where the MPD = 1.0 in the case of water. The different roads are shortly described in 2.3.

For a complete list of the effect of water and snow see Appendix 2 and Appendix 3.

4.1. Dry road conditions

In Table 7 to Table 9, and in Figure 9, the absolute values of estimated fuel use for the different vehicle categories and at different IRI and MPD for the three roads in the case studies are presented. As can be seen, the fuel use is in general higher the higher the IRI, MPD and speed. One difference to this can be found for RUR_70, where the fuel use for trucks with trailer greatly differs from the fuel use on MW and RUR_90. This is due to that RUR_70 has more difference in vertical and horizontal alignment whereas MW and RUR_90 are flat and straight. This curvature leads to a driving behaviour that is not as smooth as for a flat and straight road, with more accelerations and breaking which will have a direct influence on fuel use. Also, the RUR_70 represents a road where trucks with trailers normally do not drive and therefore this alternative is left out in the results from here on.

Table 7. Fuel use for Passenger cars (petrol) at different IRI and MPD. Roads MW, RUR_90 and RUR_70. [dm³/10km].

Passenger car (petrol)						
	MW		RUR_90		RUR_70	
IRI	MPD=0.5	MPD=2.0	MPD=0.5	MPD=2.0	MPD=0.5	MPD=2.0
1.0	0.711	0.737	0.600	0.628	0.472	0.487
1.5	0.714	0.740	0.603	0.631	0.473	0.488
2.0	0.717	0.743	0.606	0.634	0.474	0.489
2.5	0.721	0.747	0.609	0.637	0.475	0.490
3.0	0.724	0.750	0.612	0.640	0.476	0.491
3.5	0.727	0.753	0.615	0.642	0.477	0.492
4.0	0.730	0.756	0.618	0.645	0.478	0.493

Table 8. Fuel use for Trucks at different IRI and MPD. Roads MW, RUR_90 and RUR_70. [dm³/10km].

Trucks no trailer						
	MW		RUR_90		RUR_70	
IRI	MPD=0.5	MPD=2.0	MPD=0.5	MPD=2.0	MPD=0.5	MPD=2.0
1.0	2.291	2.408	2.077	2.206	1.910	1.892
1.5	2.307	2.424	2.094	2.222	1.908	1.896
2.0	2.322	2.439	2.110	2.237	1.868	1.899
2.5	2.338	2.453	2.126	2.253	1.874	1.902
3.0	2.353	2.468	2.143	2.269	1.876	1.910
3.5	2.369	2.482	2.159	2.285	1.878	1.913
4.0	2.385	2.497	2.175	2.300	1.889	1.914

Table 9. Fuel use for Trucks with trailer at different IRI and MPD. Roads MW, RUR_90 and RUR_70. [dm³/10km].

Trucks with trailer						
	MW		RUR_90		RUR_70	
IRI	MPD=0.5	MPD=2.0	MPD=0.5	MPD=2.0	MPD=0.5	MPD=2.0
1.0	3.424	3.815	3.355	3.732	5.078	5.109
1.5	3.467	3.864	3.395	3.780	5.084	5.228
2.0	3.509	3.913	3.436	3.827	5.088	5.224
2.5	3.556	3.963	3.476	3.875	5.098	5.226
3.0	3.605	4.013	3.516	3.923	5.099	5.227
3.5	3.655	4.062	3.562	3.971	5.166	5.228
4.0	3.704	4.112	3.611	4.020	5.169	5.230

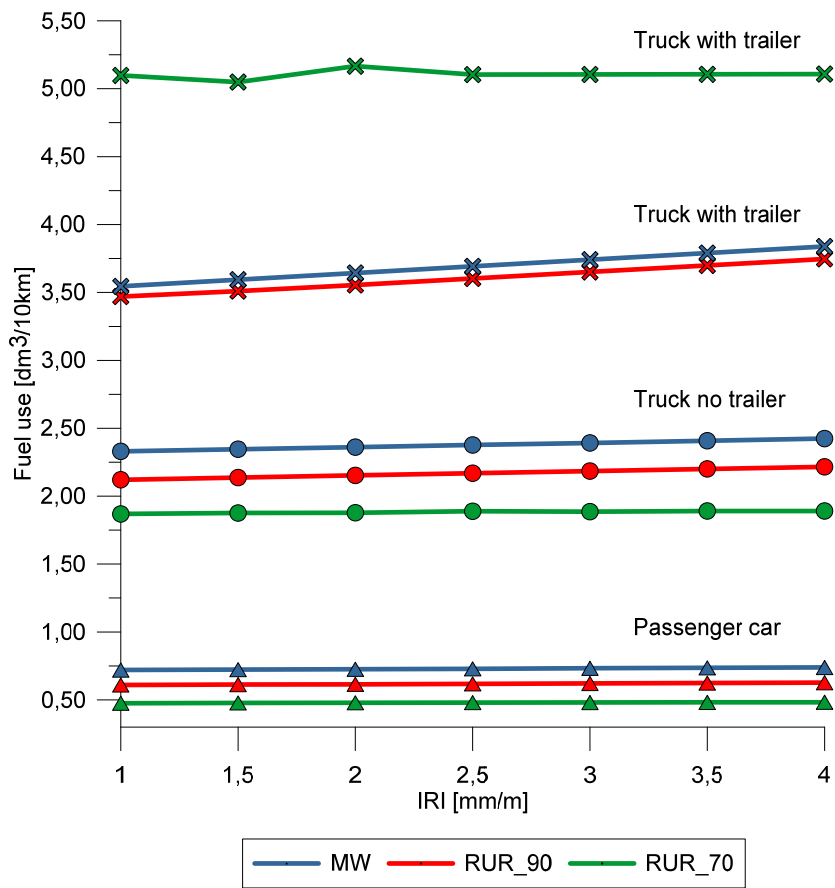


Figure 9. Example of fuel use during dry road conditions of different vehicle categories and roads. IRI = 1.0 to 4.0 and MPD = 1.0.

4.2. Water

In Figure 10 to Figure 12, examples of VETO simulation results for fuel use at different water film thickness on the road surface are presented.

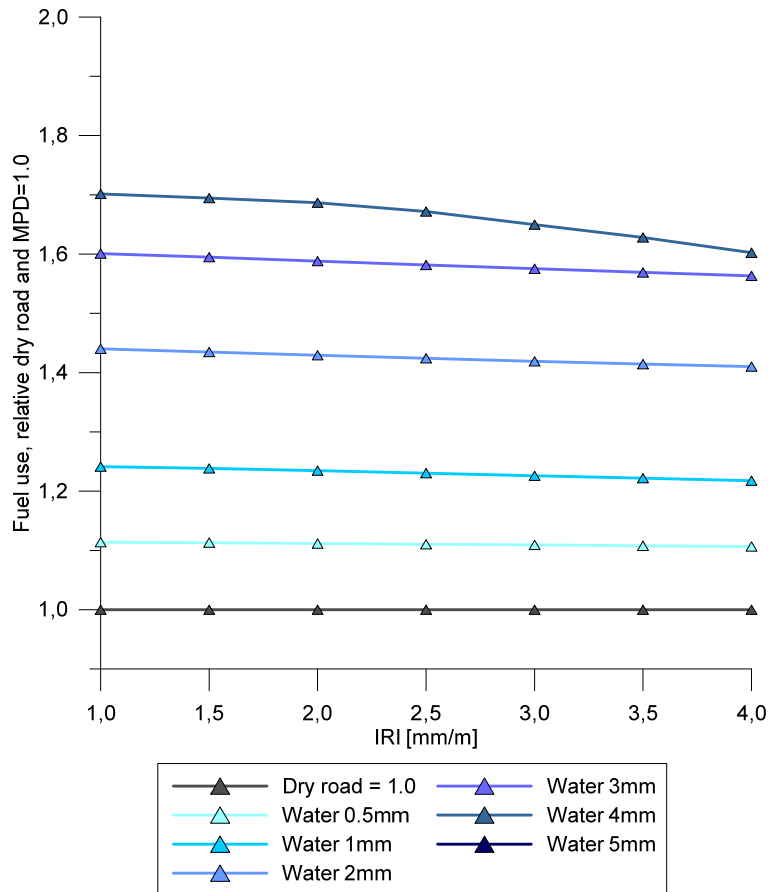


Figure 10. Example of fuel use relative a dry road, MW, Truck with trailer. Different water film thickness. IRI = 1.0 to 4.0, MPD = 1.0.

As can be seen in Figure 10, the relative fuel use is fairly constant for the different IRI and for most water depths. A slightly negative slope can be noticed, which means that the importance of water on the road surface is decreasing with an increase in IRI, i.e. a high IRI is more dominant in regards of the impact on fuel use. This is especially visible where the water depth is 5 mm. Between an IRI of 2.5 and 3 there is a shift. This is to some extent also explained by that the increased resistance will lead to a reduction in speed that will further reduce the relative difference to a dry road surface.

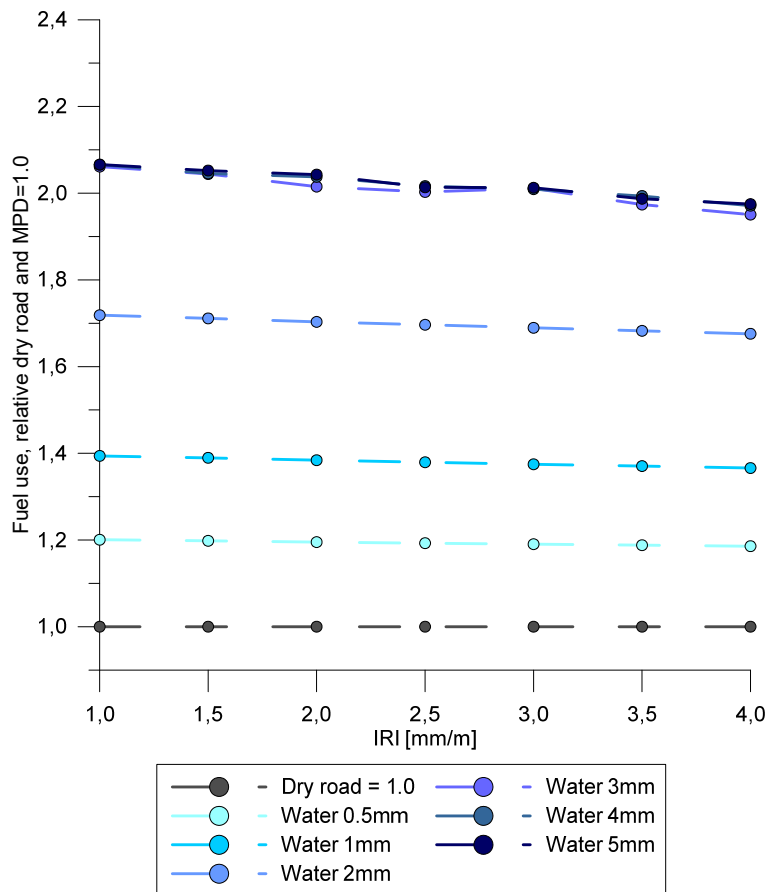


Figure 11. Example of fuel use relative a dry road, *RUR_90*, Truck. Different water film thickness. *IRI = 1.0 to 4.0*, *MPD = 1.0*.

At a water depth of 3 mm, the speed is lower relative the alternatives with less water. This has an influence on the fuel use, which is shown in the presence of indents in the fuel use curve. This is also the case with 4 and 5 mm water, where the increased rolling resistance is offset by a lower speed. As also can be seen in Figure 11, the relative fuel use has a somewhat negative slope for all water depths. The absolute fuel use does increase with a higher IRI but the relative fuel use, i.e. the difference between a dry and wet road surface decreases.

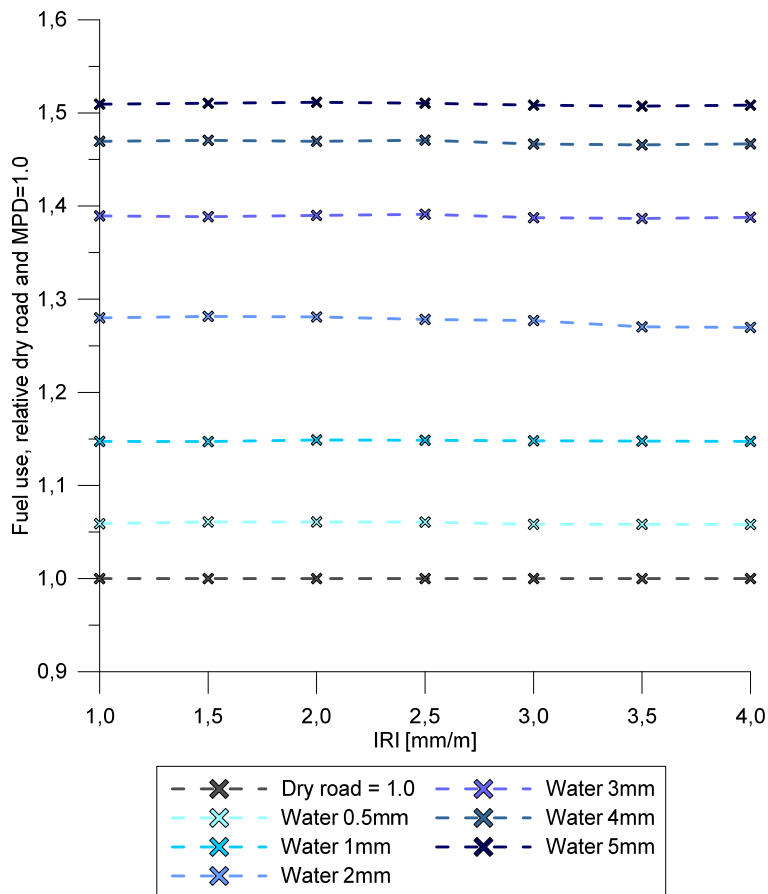


Figure 12. Example of fuel use relative a dry road, *RUR_70*, Passenger car (petrol). Different water film thickness. Fuel use relative a dry road. *IRI* = 1.0 to 4.0 and *MPD* = 1.0.

For a passenger car on a *RUR_70*, the relative fuel use is fairly constant for the different *IRI*. As can be expected it is relatively larger the more water on the road surface since it affects the rolling resistance. However, the change in fuel use gets smaller for each extra mm thickness which to some extent is explained by a slight decrease in speed.

4.3. Snow

When simulating the level of snow on the roads, the value of *MPD* of the road surface is not important since the snow is assumed to cover the macrotexture. Figure 13 to Figure 15 is examples of the impact on fuel use due to snow on the road surface with regards to different snow densities, snow depth and 1st axle exposure to the snow.

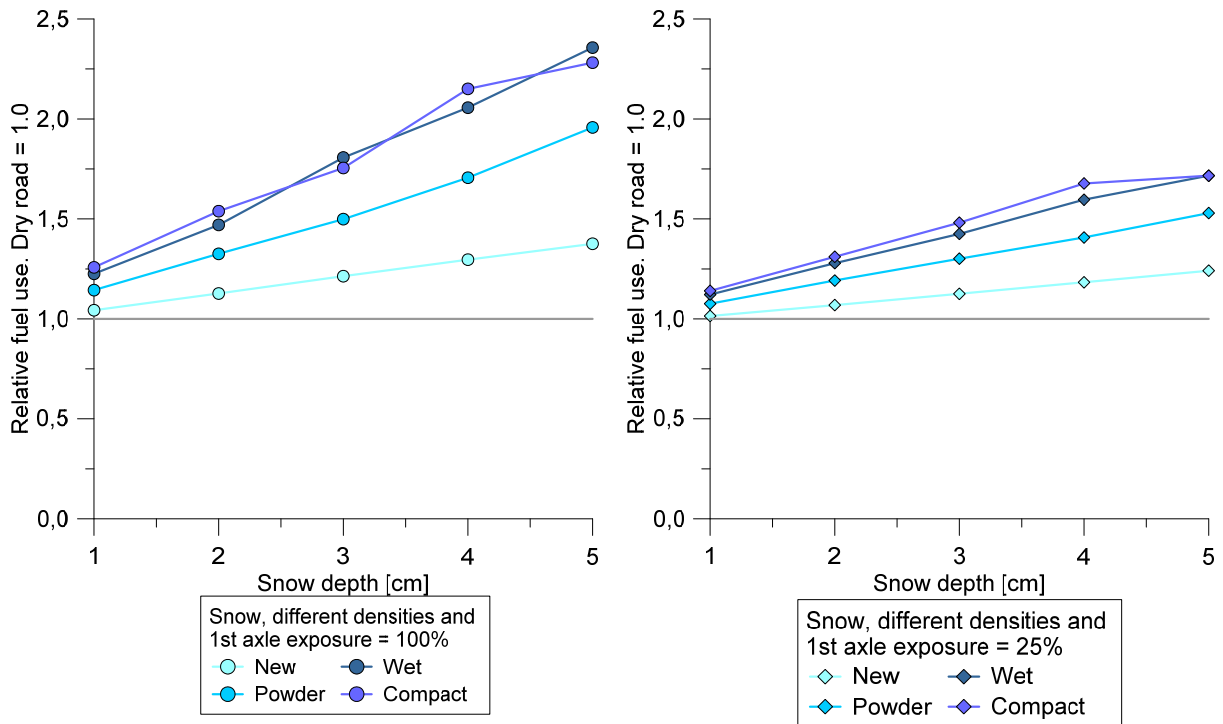


Figure 13. Example of fuel use relative a dry road. MW, Truck with trailer. Different snow densities, snow depth and 1st axle exposure. IRI = 1.0

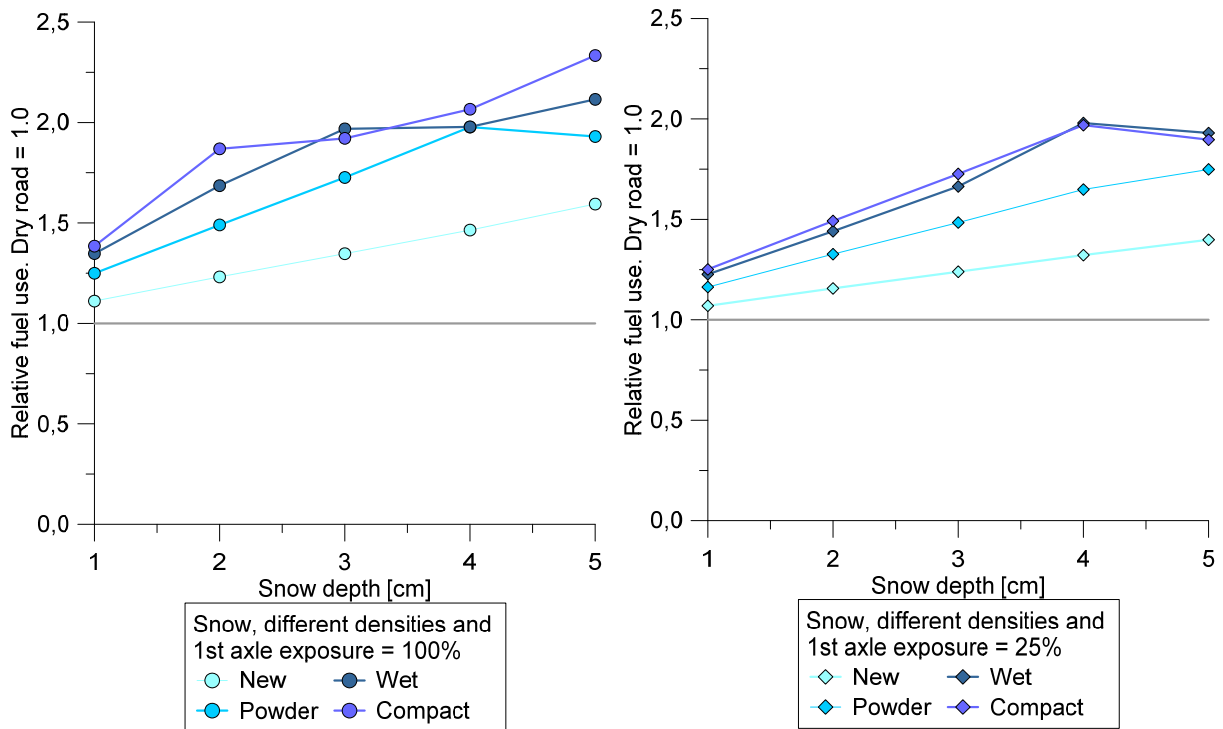


Figure 14. Example of fuel use relative a dry road. RUR_90, Truck. Different snow densities, snow depth and 1st axle exposure. IRI = 2.0

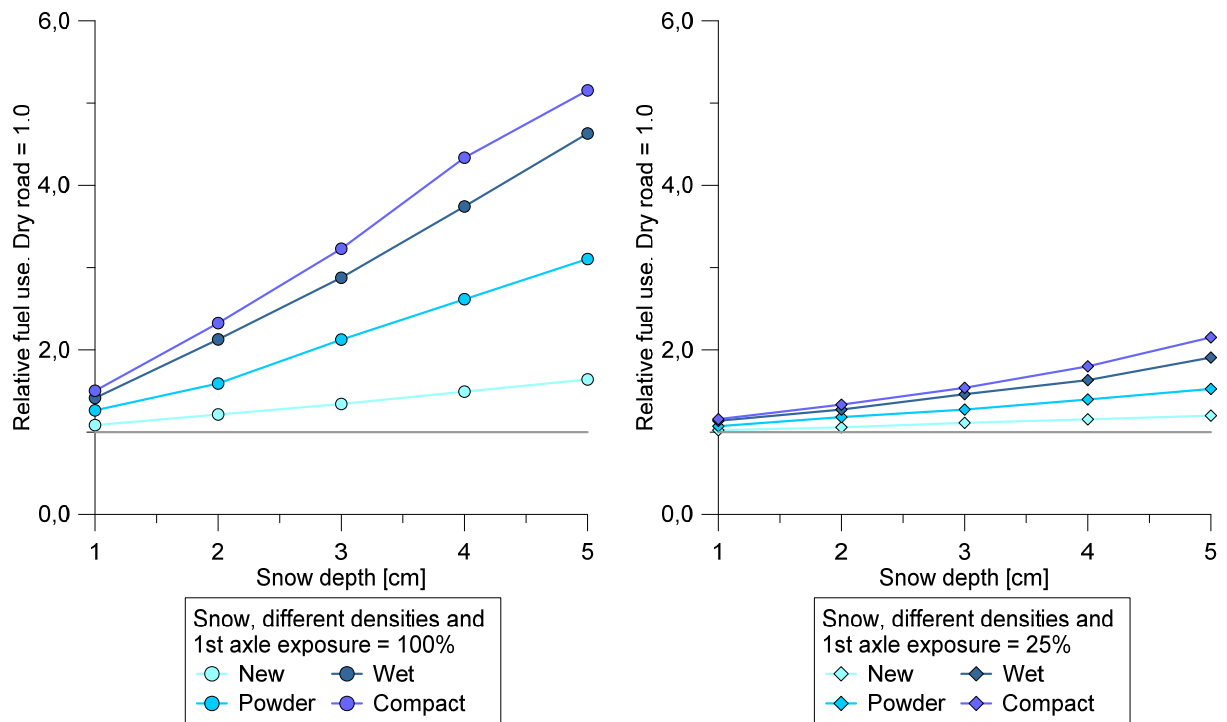


Figure 15. Example fuel use relative a dry road. RUR_70, Passenger car (petrol). Different snow densities, snow depth and 1st axle exposure. IRI = 2.0

One difference between the various vehicle categories is that passenger cars seems to be relatively more sensitive to snow in regards to the extra fuel use needed to overcome the increased rolling resistance. Especially, with the assumption of 100% exposure to the snow depth of the first axle.

5. Discussion

5.1. Valuation of CO₂

One of the main objectives with reducing energy use is to reduce the emissions of GHG. In order to evaluate the cost effectiveness of reducing the energy use one can relate the direct cost of reaching the reduction with the social value of the avoided emissions.

There are several valuations of the cost of GHG emissions that can be used. Three alternatives using different methods for the evaluation are presented below:

1. European Union Emission Trading System (EU ETS)
2. Swedish value of CO₂ in transport planning
3. The social cost of carbon (SCC) used by federal agencies in the US

The EU ETS represents the market prices of emissions rights. It was established in 2005 and is an important part of the climate policy in the European Union. It covers about 45% of the GHG emissions in the EU. There is a limited amount of emission rights forming a cap of CO₂-emissions. Within the cap, companies receive or buy emission allowances that can be traded. The limit on the total number of available allowances ensures that they have a value. Since the launch the price has fluctuated from over 30 €/ton to just below 3 €/ton. The present price level is about 5 to 6 €/ton². One reason why the cost of emissions in EU ETS is relative low is that there is a large surplus of emission rights in the market (EU commission 2012).

The value of CO₂ used for cost benefit analysis in the transport sector in Sweden is set to be equivalent to the carbon tax of fuel and the current evaluation is 160 €/ton CO₂ (Trafikverket 2015). It does not reflect the cost of the impact of climate change. Rather it reflects actual policy, i.e a tax, and not just the stated policy objectives and it is a measure already expressed in monetary terms, which is the reasons why this is the chosen method.

The SCC is an estimate of the monetised damages associated with an incremental increase in carbon emissions in a given year (United States Government 2013). Three integrated assessment models has been used to estimate the SCC for a number of scenarios. The value includes, but is not limited to, changes in net agricultural productivity, human health, property damages from increased flood risk, and the value of ecosystem services due to climate change. The central value is the average SCC across the models at the 3%. For the year 2015 this value was app. 28 € /ton CO₂.

The estimated values of the three different methods varies substantially, where the highest is around 30 times as high as the lowest estimate. In the analysis the estimates 5 and 160 €/ton CO₂ will be used. This means that we have a price range of between 0.75 €/GJ (average EU ETS at 10 €/ton) and 12 €/GJ (Sweden) on savings of CO₂ emissions related to diesel (a rough but reasonable assumption). This can be compared to the direct cost of diesel fuel, which accordingly cost about 14 €/GJ³. The first note is that comparing the direct cost of fuel for traffic to the valued cost of CO₂ release, being between the same order of magnitude and one magnitude lower.

To investigate if it would ever be feasible to correspond with the EU ETS valuation of CO₂ emissions for the pavement conditions and maintenance options presented in Table 1 on page 14 is to use the fact that the traffic energy savings are proportional to the traffic volume, AADT. If we then also consider

² <http://www.svenskenergi.se/Elfakta/Elpriser-och-skatter/Handel-med-utslappsraetter/>

³ One litre of diesel cost about €0.5 before taxes, contains 35.1 MJ/litre, and creates in total about 2.65 kg CO₂/litre when combusted.

low energy maintenance solutions (approximate to zero energy use) at the same price as traditional we get a best case scenario. For case 1 the gain in traffic energy was 94 MJ/m per year at a cost of €1/m per year, which corresponds to 11 €/GJ at a total AADT of 36 800. If the traffic was more than ten times higher the cost per energy saving would reach the lower levels of EU ETS price, but such high traffic volumes are not possible for the road type in question. For case 2 Option 1 is the best alternative with respect to both cost and energy depending on that Option 3 has a short service life of only three years. Similar to above a sensitivity analysis using a service life of four years gain in traffic energy was 37 MJ/m per year at a cost of €0.3/m per year, which corresponds to 8 €/GJ at a total AADT of 4 280. If the traffic was about ten times higher the cost per energy saving would reach below the lower levels of EU ETS price. Also in this case, this amount of traffic is not very common for the road type in question. The sensitivity analysis also shows a problem when assessing energy savings against cost in that very small differences in cost will inevitably lead to low cost per gained energy ratios. In general, predicting future maintenance cost with this accuracy is not possible. To conclude, EU ETS on its own is not an argument for public spending in pavement maintenance on lowering rolling resistance in general, but possible in some cases.

However, the Swedish valuation of CO₂ emissions from a societal perspective (160 €/ton CO₂), together with the direct cost of fuel (190 €/ton CO₂), renders a different picture, see Table 1. With a total cost of 350 €/ton CO₂ from traffic we get a price per energy saving of 26 €/GJ on savings related to diesel. We can then conclude that for case 1 the gain from less fuel consumption exceed the extra cost of maintenance. Also for Case 2 there is a possibility that lowering rolling resistance could be beneficial given that adequate service life can be achieved.

When assessing the above stated conclusions, it must be noted that the present models available for traffic and maintenance energy use are able to deliver estimates for traffic energy based on ideal conditions and for maintenance energy based on assumptions on the practice used in material production, service life, resulting performance etc. However, the accuracy of these models is yet to be investigated for the purposes and problems formulated here as well as the way the information is implemented and taken into account in decision-making.

5.2. Decision support

Variability and uncertainty of costs and energy use arises both in the perspective of production and operation (during expected service life) and in the perspective of effects on society (cost related to fuel and CO₂). Furthermore, variability and uncertainty can be handled by efforts related to research, management and procurement. It is of great importance that a decision on which alternative to choose is followed up by control measures to increase likelihood of success. Parameters to control are maintenance costs, energy used during production, achieved road surface properties during service life and service life of pavement. The questions then remain how to assess variability and uncertainty and how to define what level of significance that is needed?

In this report a cost benefit analysis approach using Benefit to Cost Ratio, BCR, has been adopted. This allows assessment of cost effectiveness of energy reduction measures by other means, even across organisations, if a common value of return on investment is imposed. Here the Swedish common pricing of release of CO₂ and fuel is used. This pricing level render a total cost of energy of 26 € per GJ as previously described. Using this approach, it is assumed that the selection between alternatives can be assigned to one of four categories:

1. If no important difference in cost or energy between alternatives exist, the situation is unclear and other aspects should be considered when selecting maintenance alternative.
2. If *CR* is close to zero and the difference in cost and energy between alternatives is greater than the variability and uncertainty, the situation is clear but the alternatives are about

equally good, making the decision unclear. Other aspects should be considered when selecting maintenance alternative.

3. If CR is lower than zero and the difference in cost and energy between alternatives is greater than the variability and uncertainty, then the total energy aspect should be considered. The same decision should be made if the alternatives are about equal in cost but separated in energy, though CR does not behave stable under this conditions.
4. If CR is higher than zero and the difference in cost and energy between alternatives is greater than the variability and uncertainty, then the energy aspects should not be a major factor to consider. The same decision should be made if the alternatives are about equal in energy but separated in cost.

In Section 3, six different cases were identified in which stochastic outcomes in energy use and cost of maintenance alternatives was compared. If the above suggested criteria is applied on each case the result is:

- A. The maintenance alternatives are too similar in cost and energy use to be separated and consequently falls into category 1 where other aspects than costs and energy should be taken into account.
- B. Since CR is positive mainly cost should be regarded in the decision. This falls into category 4.
- C. Since CR is close to zero other aspects need to be included in the decision, for example if the outcome in expected pavement service life or road condition could be better controlled. This falls into category 2.
- D. There is no significant difference in cost and the CR criteria is approaching infinity. The obvious option is to consider energy use since there is a significant difference between the alternatives in this aspect. This falls into category 3.
- E. Falls into category 3. The energy aspect should be considered.
- F. No significant difference in energy use. This falls into category 4.

The level of significance needed to promote a decision to reduce rolling resistance can be debated. The case study shows the complexity of proving that individual projects successfully contribute to reduction of energy use and emission of CO_2 . However, if policies involving a large number of projects are the intended use of the analysis, failure of reaching a positive outcome in individual projects is of less importance if the majority of projects reach their goals. As previously stated, this require control over individual projects. This leads to the conclusion that policies should involve many projects but control of critical parameters is required in all projects covered by the policy.

5.3. Climate

Since the presence of water or snow will influence fuel use, it is of importance to know the proportions of these conditions. To find out how much water is left on the road surface, we need to know how much precipitation that actually falls on each test site. The precipitation on the road surface is affected by evaporation, run-off and traffic induced splash and spray. This should be considered when estimating the effect on rolling resistance and, hence, increased fuel use. The roads are constructed to facilitate run-off of water and with this in mind, the presence of water on the road surface will most likely be low.

Regarding snow, the traffic induced splash and displacement will have a similar effect on the amount of snow present on the road surface. Therefore, low estimates of both water and snow it used to calculate the effect of precipitation of the total energy use by traffic.

The precipitation data used for the calculation are those presented in Table 5 and for RV47. Since this data only represents a winter period and not a whole year, it is assumed that the wet road condition is valid for a year. This results in road conditions according to:

- Wet: 550 h (6%)
- Snowy: 315 h (4%)
- No precipitation: 7 895 h (90%)

The water and snow depth during the respective road condition, are in the calculations assumed to be 1 mm for water and 10 mm for snow. The AADT is assumed to be 40 000 for MW, 4 300 for RUR_1 and 1 100 for RUR_2. Using these rough estimations, the effect on direct traffic energy use during one year is presented in Table 10. The figures for snow are calculated for the various qualities and for a 1st axle exposure of 25%. The number of hours during a year when there is some sort of rain or snowfall is small during a year, in total 10%. This leads to that the overall effect on fuel use due to precipitation is relatively low, even though it can have a large effect in the short time perspective, i.e. during a heavy snow or rainfall.

Table 10. The effect of rain and snow on traffic energy during a year. Estimated values, GJ/yr, km and % of traffic energy relative dry road conditions.

	MW		RUR_90		RUR_70	
Road condition	[GJ/yr, km]	[% increase]	[GJ/yr, km]	[% increase]	[GJ/yr, km]	[%]
Dry only	45 999		5 399		723	
Dry/Wet/Snowy						
<i>New snow</i>	47 027	2.2%	5 503	1.9%	730	1.0%
<i>Powder snow</i>	47 130	2.5%	5 517	2.2%	731	1.2%
<i>Wet snow</i>	47 210	2.6%	5 528	2.4%	733	1.4%
<i>Compact snow</i>	47 245	2.7%	5 532	2.5%	733	1.5%

As can be seen from the results, taking into account the precipitation on the road can lead to an increased energy use from traffic with around 1 to 3% compared to just considering a dry road only. The importance of water and snow is lower for lower speeds, which is in accordance with the results presented in chapter 4. Earlier studies show that reducing rolling resistance can lead to reduced fuel consumption with app. 1% if MPD decreased by 0.5 mm (Hammarström et al. 2011) or between 0.5 to 2% depending on what maintenance is performed (Karlsson et al. 2012). Compared to these results the presence of precipitation on the road is in the same range of importance. Therefore, it would be of interest to include these aspects in the decision making process when looking at the effect on traffic fuel use. To bear in mind is that in the calculation above, it is assumed that the water and snow are equally distributed over the road section, which is not valid for real conditions. A further evaluation of how to more realistically include precipitation is needed so the effect is not over- or undervalued.

6. Conclusions and recommendations and support for road managers

Optimisation of pavement maintenance has to consider a wide range of aspects, including reduced fuel consumption from lower rolling resistance and life cycle cost of road management. In a previous report it was concluded that the expected variation in the achieved rolling resistance was generally too large to be neglected. Reduced rolling resistance from selecting a certain alternative maintenance treatment can reduce a fraction of the fuel consumption, in the order of one percent, that should be compared to the extra energy and cost spent on the alternative maintenance treatment. Furthermore, in order to ensure cost effectiveness of energy reduction by lowering rolling resistance a common ground for cost benefit analysis of rolling resistance measures needed to be established. It is suggested in the report that the same valuation of CO₂ and fuel consumption is used as in the cost benefit analysis of infrastructure investments, since this would mean that investments in lower rolling resistance would be compared to for example shorter roads (with less fuel consumption).

The study indicate that it is difficult to establish a simple rule of thumb. A decision support procedure comparing two maintenance alternatives has been developed. It categorizes maintenance treatment alternatives for a road object in one of four categories depending on expectation and uncertainty in the maintenance cost and total energy.

The *CR* value (total cost difference / maintenance cost difference) was established to assess if the decision should be based on reducing rolling resistance or reducing maintenance cost. Using the *CR*-value may be a useful criterion, even though that it has its' limits. However, it is important to have a rule of thumb for decision support where assessments are made of the road surface characteristics, energy use and maintenance cost and where the different aspects are valued. On an object level, the assessment of the variables is of great importance and the uncertainties should be minimized. On a policy level, the need for having precise values of the variables are less important since the uncertainties tend to level out.

The case study indicate that simulations are more or less necessary to make solid decisions. To have a method for decision making that is easier to use and that does not require extensive simulation there is a need for simplifications. One such simplification could be a criterion that do not use ratios, however there are also limitations for a ratio-less method.

The presence of snow is mainly a concern for direct maintenance in the form of salting and snow clearing of the roads. Also, snow and its' effect on traffic fuel use is to some extent taken into consideration with regards to direct maintenance measures since it is included in the VTI Winter Model. Therefore, and in the context of this report, snow on the road surface is not considered to be a variable to consider in choosing a strategy to get an energy- and cost effective road pavement maintenance.

Water on the road surface lead to a higher rolling resistance than snow and the presence of it is dependent on the road surface conditions. Normally, roads are designed to let rain run off but rutting and in combination with insufficient or incorrect cross fall could lead to standing water. The database called PMSV3, contains description of the roads in Sweden, and there is a measurement for "calculated water area" in dm² per 20 m road section (Sjögren, Lundberg 2011). This measure is mainly developed for safety issues and for identifying road sections where there is an increased risk for aquaplaning. "Calculated water area", combined with information about rise and fall, could also be used for identifying sections where maintenance could have a benefit for reducing rolling resistance and hence fuel consumption. How to take this into consideration in the decision making process of maintenance alternatives are not investigated in this report. However, it would be an interesting aspect to include as one criterion in a future tool. Furthermore, a field for further study would be to investigate whether the effect of water, ice and snow is mainly through their effect on road surface temperature or on rolling resistance or both.

Finally, cost and energy use are not the only parameters to consider. It should be emphasized that decision on which maintenance alternative to choose must be based on a broader perspective including also all aspects of sustainability and safety.

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Appendix 1. Simulation results

	RF	0.00	0.00	1.50	1.50	0.00	0.00	1.50	1.50
	ADC	0.00	0.00	0.00	0.00	29.00	29.00	29.00	29.00
	SPEED	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00
	MIX	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Alt 1	Alt 2								
1	4	-1.72	0.64	-1.73	0.64	-1.74	0.64	-1.75	0.65
1	5	26.75	0.60	26.85	0.60	26.92	0.61	27.01	0.60
1	6	-20.19A	0.33A	-20.25	0.33	-20.30	0.33	-20.36	0.33
1	7	0.95	0.97	0.95B	0.97B	0.95	0.97	0.95	0.97
1	8	0.47	0.82	0.47	0.82	0.47	0.82	0.46	0.82
1	9	-0.01	0.51	-0.02C	0.52C	-0.02	0.52	-0.02	0.52
1	10	0.57	0.88	0.57	0.87	0.57	0.87	0.57	0.87
1	11	0.09	0.57	0.08	0.57	0.08	0.56	0.08	0.56
1	12	-0.40	0.78	-0.40	0.77	-0.41	0.78	-0.41	0.78
2	4	0.52	0.72	0.52	0.72	0.52	0.72	0.52	0.72
2	5	51.44	0.55	51.62	0.55	51.75	0.55	51.94	0.55
2	6	50.34	0.60	50.53	0.60	50.67	0.60	50.86	0.59
2	7	0.10	0.59	0.09	0.59	0.09	0.58	0.09	0.58
2	8	-0.39	0.81	-0.39	0.81	-0.40	0.81	-0.40	0.82
2	9	-0.87	0.97	-0.88	0.97	-0.88	0.97	-0.89	0.97
2	10	-0.28	0.75	-0.29	0.75	-0.29	0.76	-0.30	0.76
2	11	-0.77	0.96	-0.78	0.96	-0.78	0.96	-0.79	0.96
2	12	-1.25	1.00	-1.26	1.00	-1.27	1.00	-1.28	1.00
3	4	-0.13	0.38	-0.13	0.38	-0.14	0.38	-0.14	0.39
3	5	44.26	0.55	44.42	0.55	44.53	0.55	44.69	0.56
3	6	29.83	0.68	29.95	0.68	30.03	0.67	30.14	0.67
3	7	0.35	0.80	0.34	0.80	0.34	0.80	0.34	0.80
3	8	-0.14	0.63	-0.14	0.63	-0.15	0.63	-0.15	0.64

3	9	-0.62	0.92	-0.63	0.92	-0.63	0.92	-0.64	0.92
3	10	-0.04	0.54	-0.04	0.54	-0.04	0.54	-0.05	0.55
3	11	-0.52	0.89	-0.53	0.90	-0.53	0.90	-0.54	0.90
3	12	-1.01	0.99	-1.01	0.99	-1.02	0.99	-1.02	0.99
4	5	-4.57	0.75	-4.59	0.74	-4.60	0.74	-4.62	0.74
4	6	-1.11	0.56	-1.12	0.57	-1.13	0.57	-1.13	0.57
4	7	0.21	0.67	0.21	0.67	0.21	0.67	0.21	0.67
4	8	-0.14	0.61	-0.14	0.61	-0.14	0.61	-0.15	0.62
4	9	-0.49	0.84	-0.49	0.84	-0.50	0.84	-0.50	0.84
4	10	-0.06	0.55	-0.07	0.55	-0.07	0.56	-0.07	0.56
4	11	-0.41	0.80	-0.42	0.80	-0.42	0.80	-0.43	0.81
4	12		0.94	-0.77	0.94	-0.77	0.94	-0.78	0.94
5	6	52.03	0.57	52.21	0.57	52.34	0.57	52.52	0.56
5	7	1.82	0.99	1.82	0.99	1.83	0.99	1.83	0.99
5	8	1.35	0.96	1.35	0.96	1.35	0.96	1.36	0.96
5	9	0.88D	0.88D	0.88	0.88	0.88	0.88	0.88	0.88
5	10	1.45	0.97	1.45	0.97	1.45	0.97	1.46	0.97
5	11	0.98	0.90	0.98	0.90	0.98	0.90	0.98	0.90
5	12	0.51	0.75	0.51	0.75	0.51	0.75	0.51	0.75
6	7	0.70	0.94	0.70	0.94	0.70	0.94	0.70	0.94
6	8	0.22	0.69	0.22	0.68	0.22	0.68	0.21	0.68
6	9	-0.26	0.70	-0.26	0.71	-0.26	0.71	-0.27	0.71
6	10	0.32	0.77	0.32	0.76	0.32	0.76	0.32	0.76
6	11	-0.16	0.63	-0.16	0.63	-0.16	0.64	-0.17	0.64
6	12	-0.63	0.91	-0.64	0.91	-0.64	0.91	-0.65	0.91

	RF	0.00	0.00	1.50	1.50	0.00	0.00	1.50	1.50
	ADC	0.00	0.00	0.00	0.00	29.00	29.00	29.00	29.00
	SPEED	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00
	MIX	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Alt 1	Alt 2								
1	4	-1.93	0.64	-1.94	0.64	-1.95	0.65	-1.96	0.65
1	5	25.06	0.61	25.20	0.61	25.20	0.61	25.34	0.60
1	6	-26.03	0.35	-26.16	0.35	-26.16	0.35	-26.28	0.35
1	7	1.02	0.97	1.02	0.97	1.02	0.97	1.02	0.97
1	8	0.39	0.77	0.39	0.76	0.39	0.76	0.39	0.76
1	9	-0.23	0.66	-0.24	0.66	-0.24	0.66	-0.25	0.66
1	10	0.64	0.89	0.63	0.89	0.63	0.88	0.63	0.88
1	11	0.01	0.51	0.00	0.50	0.00	0.50	0.00	0.50
1	12	-0.62	0.86	-0.63	0.86	-0.63	0.86	-0.64	0.87
2	4	0.41	0.67	0.41	0.68	0.41	0.67	0.41	0.67
2	5	50.80	0.55	51.08	0.55	51.09	0.55	51.36	0.55
2	6	47.52	0.61	47.80	0.61	47.81	0.61	48.08	0.61
2	7	0.13	0.61	0.12	0.60	0.12	0.60	0.12	0.60
2	8	-0.50	0.85	-0.51	0.86	-0.51	0.86	-0.52	0.86
2	9	-1.13	0.99	-1.14	0.99	-1.14	0.99	-1.15	0.99
2	10	-0.26	0.71	-0.27	0.72	-0.27	0.72	-0.27	0.72
2	11	-0.89	0.97	-0.90	0.97	-0.90	0.97	-0.91	0.97
2	12	-1.51	1.00	-1.53	1.00	-1.53	1.00	-1.54	1.00
3	4	-0.15	0.40	-0.16	0.40	-0.16	0.40	-0.17	0.41
3	5	44.57	0.56	44.82	0.56	44.83	0.56	45.06	0.56
3	6	29.73	0.67	29.90	0.68	29.91	0.67	30.08	0.67
3	7	0.34	0.79	0.34	0.79	0.34	0.79	0.34	0.79
3	8	-0.28	0.74	-0.29	0.74	-0.29	0.74	-0.30	0.75
3	9	-0.91	0.97	-0.92	0.97	-0.92	0.97	-0.93	0.97
3	10	-0.04	0.54	-0.05	0.55	-0.05	0.54	-0.05	0.55

3	11	-0.67	0.93	-0.68	0.94	-0.68	0.94	-0.69	0.94
3	12	-1.30	1.00	-1.31	1.00	-1.31	1.00	-1.32	1.00
4	5	-4.63	0.73	-4.66	0.73	-4.66	0.73	-4.69	0.73
4	6	-1.14	0.55	-1.15	0.56	-1.15	0.56	-1.16	0.56
4	7	0.21	0.65	0.20	0.64	0.20	0.64	0.20	0.64
4	8	-0.25	0.67	-0.26	0.67	-0.26	0.67	-0.26	0.68
4	9	-0.70	0.89	-0.71	0.89	-0.71	0.89	-0.72	0.89
4	10	-0.07	0.56	-0.08	0.56	-0.08	0.56	-0.09	0.56
4	11	-0.53	0.83	-0.54	0.83	-0.54	0.83	-0.54	0.83
4	12	-0.98	0.96	-0.99	0.96	-0.99	0.96	-1.00	0.96
5	6	52.57	0.57	52.85	0.57	52.86	0.57	53.13	0.57
5	7	1.83	0.99	1.83	0.99	1.83	0.99	1.84	0.99
5	8	1.22	0.94	1.22	0.94	1.22	0.94	1.22	0.94
5	9	0.62	0.77	0.61	0.77	0.61	0.77	0.61	0.77
5	10	1.46	0.97	1.46	0.97	1.46	0.97	1.46	0.97
5	11	0.85	0.86	0.85	0.85	0.85	0.85	0.85	0.85
5	12	0.24	0.61	0.24	0.61	0.24	0.61	0.23	0.61
6	7	0.70	0.93	0.69	0.93	0.69	0.93	0.69	0.93
6	8	0.08	0.56	0.07	0.56	0.07	0.56	0.07	0.56
6	9	-0.54	0.85	-0.55	0.85	-0.55	0.85	-0.56	0.86
6	10	0.32	0.75	0.31	0.74	0.31	0.75	0.31	0.74
6	11	-0.30	0.73	-0.31	0.74	-0.31	0.74	-0.32	0.74
6	12	-0.92	0.96	-0.93	0.96	-0.94	0.96	-0.95	0.96

	RF	0.00	0.00	1.50	1.50	0.00	0.00	1.50	1.50
	ADC	0.00	0.00	0.00	0.00	29.00	29.00	29.00	29.00
	SPEED	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00
	MIX	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Alt 1	Alt 2								
1	4	-3.66	0.72	-3.67	0.72	-3.68	0.72	-3.69	0.72
1	5	43.96	0.57	44.05	0.58	44.15	0.58	44.23	0.57
1	6	-35.54	0.40	-35.59	0.40	-35.67	0.40	-35.72	0.40
1	7	0.90	0.88	0.90	0.89	0.89	0.88	0.89	0.88
1	8	0.01	0.50	0.01	0.50	0.00	0.50	0.00	0.50
1	9	-0.88	0.86	-0.89	0.86	-0.89	0.86	-0.89	0.86
1	10	0.25	0.63	0.25	0.63	0.25	0.63	0.25	0.63
1	11	-0.64	0.79	-0.64	0.79	-0.64	0.80	-0.65	0.80
1	12	-1.52	0.97	-1.53	0.97	-1.53	0.97	-1.54	0.97
2	4	0.16	0.60	0.15	0.61	0.15	0.61	0.15	0.61
2	5	85.96	0.54	86.14	0.54	86.33	0.54	86.49F	0.54F
2	6	84.47	0.56	84.65	0.56	84.85	0.56	85.02	0.56
2	7	-0.56	0.82	-0.57	0.82	-0.57	0.83	-0.57	0.83
2	8	-1.45	0.99	-1.46	0.99	-1.46	0.99	-1.47	0.99
2	9	-2.34	1.00	-2.35	1.00	-2.35E	1.00E	-2.36	1.00
2	10	-1.21	0.97	-1.21	0.98	-1.22	0.98	-1.22	0.98
2	11	-2.09	1.00	-2.10	1.00	-2.11	1.00	-2.11	1.00
2	12	-2.98	1.00	-2.99	1.00	-3.00	1.00	-3.01	1.00
3	4	-0.89	0.50	-0.90	0.51	-0.90	0.50	-0.91	0.51
3	5	74.42	0.54	74.57	0.55	74.73	0.55	74.87	0.55
3	6	51.48	0.61	51.59	0.61	51.71	0.61	51.81	0.61
3	7	-0.16	0.61	-0.17	0.62	-0.17	0.62	-0.17	0.62
3	8	-1.05	0.96	-1.06	0.96	-1.06	0.96	-1.06	0.96
3	9	-1.94	1.00	-1.95	1.00	-1.95	1.00	-1.96	1.00
3	10	-0.80	0.93	-0.81	0.92	-0.81	0.93	-0.82	0.93

3	11	-1.69	1.00	-1.70	1.00	-1.71	1.00	-1.71	1.00
3	12	-2.58	1.00	-2.59	1.00	-2.60	1.00	-2.60	1.00
4	5	-8.42	0.76	-8.44	0.77	-8.46	0.77	-8.48	0.76
4	6	-2.62	0.66	-2.62	0.66	-2.63	0.66	-2.64	0.66
4	7	-0.36	0.69	-0.37	0.69	-0.37	0.69	-0.37	0.69
4	8	-1.01	0.91	-1.01	0.90	-1.02	0.91	-1.02	0.91
4	9	-1.65	0.98	-1.66	0.98	-1.66	0.98	-1.67	0.98
4	10	-0.83	0.86	-0.83	0.87	-0.84	0.87	-0.84	0.87
4	11	-1.47	0.97	-1.48	0.97	-1.48	0.97	-1.49	0.97
4	12	-2.12	1.00	-2.12	1.00	-2.13	1.00	-2.13	1.00
5	6	86.77	0.55	86.94	0.55	87.13	0.55	87.29	0.55
5	7	2.34	0.97	2.34	0.97	2.35	0.97	2.35	0.97
5	8	1.48	0.89	1.48	0.89	1.49	0.89	1.49	0.89
5	9	0.62	0.69	0.62	0.69	0.62	0.69	0.62	0.69
5	10	1.72	0.92	1.72	0.92	1.72	0.92	1.73	0.92
5	11	0.86	0.76	0.86	0.76	0.86	0.76	0.86	0.76
5	12	0.00	0.50	0.00	0.50	0.00	0.50	0.00	0.50
6	7	0.46	0.75	0.46	0.75	0.46	0.75	0.45	0.74
6	8	-0.42	0.72	-0.42	0.72	-0.43	0.72	-0.43	0.72
6	9	-1.30	0.96	-1.30	0.96	-1.31	0.96	-1.31	0.96
6	10	-0.18	0.60	-0.18	0.60	-0.18	0.60	-0.18	0.60
6	11	-1.05	0.93	-1.06	0.93	-1.06	0.93	-1.07	0.93
6	12	-1.93	1.00	-1.94	1.00	-1.94	0.99	-1.95	1.00

	RF	0.00	0.00	1.50	1.50	0.00	0.00	1.50	1.50
	ADC	0.00	0.00	0.00	0.00	29.00	29.00	29.00	29.00
	SPEED	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00
	MIX	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Alt 1	Alt 2								
1	4	-3.90	0.71	-3.91	0.71	-3.92	0.71	-3.93	0.71
1	5	39.66	0.58	39.79	0.58	39.81	0.58	39.94	0.58
1	6	-44.97	0.41	-45.09	0.41	-45.13	0.41	-45.23	0.41
1	7	1.02	0.90	1.02	0.90	1.02	0.90	1.02	0.90
1	8	-0.10	0.55	-0.10	0.55	-0.10	0.55	-0.10	0.55
1	9	-1.21	0.92	-1.22	0.92	-1.22	0.92	-1.23	0.92
1	10	0.39	0.69	0.39	0.69	0.39	0.69	0.39	0.68
1	11	-0.73	0.81	-0.73	0.81	-0.73	0.81	-0.74	0.81
1	12	-1.84	0.98	-1.85	0.98	-1.85	0.98	-1.86	0.98
2	4	-0.02	0.43	-0.02	0.43	-0.02	0.43	-0.03	0.43
2	5	82.31	0.54	82.57	0.54	82.63	0.55	82.88	0.54
2	6	76.90	0.57	77.16	0.57	77.21	0.57	77.46	0.57
2	7	-0.46	0.76	-0.47	0.76	-0.47	0.76	-0.47	0.76
2	8	-1.58	0.99	-1.59	0.99	-1.59	0.99	-1.60	0.99
2	9	-2.69	1.00	-2.71	1.00	-2.71	1.00	-2.72	1.00
2	10	-1.09	0.95	-1.10	0.95	-1.10	0.95	-1.11	0.95
2	11	-2.21	1.00	-2.22	1.00	-2.22	1.00	-2.23	1.00
2	12	-3.33	1.00	-3.34	1.00	-3.34	1.00	-3.35	1.00
3	4	-0.89	0.50	-0.89	0.50	-0.89	0.50	-0.90	0.50
3	5	72.80	0.55	73.02	0.55	73.08	0.55	73.29	0.55
3	6	49.72	0.60	49.88	0.61	49.92	0.61	50.07	0.61
3	7	-0.13	0.59	-0.13	0.59	-0.14	0.59	-0.14	0.60
3	8	-1.25	0.97	-1.25	0.98	-1.26	0.97	-1.26	0.98
3	9	-2.36	1.00	-2.37	1.00	-2.38	1.00	-2.39	1.00
3	10	-0.76	0.91	-0.77	0.91	-0.77	0.91	-0.77	0.91

3	11	-1.88	1.00	-1.89	1.00	-1.89	1.00	-1.90	1.00
3	12	-3.00	1.00	-3.01	1.00	-3.01	1.00	-3.02	1.00
4	5	-8.25	0.75	-8.28	0.75	-8.29	0.75	-8.32	0.75
4	6	-2.55	0.63	-2.56	0.64	-2.56	0.63	-2.57	0.64
4	7	-0.34	0.65	-0.34	0.65	-0.34	0.65	-0.35	0.66
4	8	-1.15	0.90	-1.15	0.90	-1.16	0.90	-1.16	0.90
4	9	-1.96	0.98	-1.96	0.98	-1.97	0.98	-1.97	0.98
4	10	-0.80	0.82	-0.80	0.82	-0.80	0.82	-0.81	0.82
4	11	-1.60	0.96	-1.61	0.96	-1.61	0.96	-1.62	0.96
4	12	-2.41	1.00	-2.42	1.00	-2.42	1.00	-2.43	1.00
5	6	85.23	0.55	85.49	0.55	85.55	0.55	85.80	0.55
5	7	2.32	0.97	2.32	0.97	2.32	0.97	2.33	0.97
5	8	1.24	0.83	1.24	0.83	1.24	0.83	1.24	0.83
5	9	0.16	0.55	0.16	0.55	0.16	0.55	0.16	0.55
5	10	1.71	0.91	1.71	0.91	1.71	0.91	1.71	0.91
5	11	0.63	0.69	0.63	0.69	0.63	0.69	0.63	0.69
5	12	-0.45	0.63	-0.45	0.63	-0.46	0.63	-0.46	0.64
6	7	0.47	0.74	0.47	0.74	0.47	0.74	0.46	0.74
6	8	-0.63	0.80	-0.64	0.80	-0.64	0.80	-0.65	0.80
6	9	-1.74	0.98	-1.75	0.98	-1.75	0.98	-1.76	0.98
6	10	-0.15	0.58	-0.16	0.59	-0.16	0.59	-0.16	0.59
6	11	-1.26	0.95	-1.26	0.95	-1.27	0.95	-1.27	0.95
6	12	-2.36	1.00	-2.37	1.00	-2.37	1.00	-2.38	1.00

Appendix 2. Relative fuel use due to water on the road surface

MW - Passenger cars (petrol)

Water [mm]	MPD=0.5							MPD=1.0						
	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
0.5	1.17	1.17	1.17	1.17	1.16	1.17	1.16	1.17	1.16	1.16	1.16	1.16	1.16	1.16
1.0	1.36	1.36	1.35	1.35	1.35	1.35	1.35	1.35	1.35	1.35	1.35	1.35	1.35	1.35
2.0	1.68	1.68	1.68	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.66	1.66	1.66
3.0	1.92	1.92	1.92	1.92	1.91	1.91	1.91	1.92	1.91	1.91	1.91	1.91	1.91	1.91
4.0	2.12	2.12	2.12	2.12	2.12	2.12	2.12	2.12	2.12	2.12	2.12	2.12	2.12	2.12
5.0	2.20	2.21	2.20	2.19	2.18	2.17	2.16	2.19	2.18	2.17	2.16	2.11	2.10	2.09
Water [mm]	MPD=1.5							MPD=2.0						
	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
0.5	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16
1.0	1.35	1.35	1.35	1.35	1.35	1.34	1.34	1.35	1.35	1.35	1.34	1.34	1.34	1.34
2.0	1.67	1.67	1.66	1.66	1.66	1.66	1.65	1.66	1.66	1.66	1.65	1.65	1.65	1.65
3.0	1.91	1.91	1.91	1.91	1.91	1.91	1.91	1.91	1.91	1.91	1.91	1.91	1.91	1.91
4.0	2.12	2.12	2.12	2.12	2.12	2.12	2.11	2.12	2.12	2.12	2.11	2.10	2.09	2.08
5.0	2.17	2.11	2.10	2.09	2.08	2.07	2.06	2.09	2.09	2.08	2.06	2.06	2.05	2.03

MW - Passenger cars (diesel)

Water [mm]	MPD=0.5							MPD=1.0						
	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
0.5	1.21	1.21	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
1.0	1.43	1.43	1.43	1.43	1.42	1.42	1.42	1.43	1.42	1.42	1.42	1.42	1.41	1.41
2.0	1.81	1.81	1.80	1.79	1.79	1.79	1.78	1.80	1.79	1.79	1.78	1.78	1.77	1.77
3.0	2.05	2.04	2.02	2.07	2.06	2.05	2.03	2.01	2.07	2.05	2.04	2.02	2.01	2.00
4.0	2.01	2.00	1.99	1.97	1.96	1.95	1.94	1.98	1.97	1.95	1.94	1.93	1.92	1.91
5.0	2.01	2.00	1.99	1.98	1.95	1.94	1.93	1.98	1.95	1.94	1.93	1.92	1.90	1.89
Water [mm]	MPD=1.5							MPD=2.0						
	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
0.5	1.20	1.20	1.20	1.20	1.19	1.19	1.19	1.20	1.20	1.20	1.19	1.19	1.19	1.19
1.0	1.42	1.42	1.42	1.41	1.41	1.41	1.40	1.41	1.41	1.41	1.41	1.40	1.40	1.40
2.0	1.78	1.78	1.78	1.77	1.76	1.76	1.76	1.77	1.77	1.76	1.76	1.75	1.75	1.75
3.0	2.04	2.03	2.02	2.00	1.99	1.97	1.96	2.01	1.99	1.98	1.97	1.95	1.94	1.84
4.0	1.95	1.93	1.92	1.91	1.90	1.89	1.86	1.91	1.90	1.89	1.88	1.85	1.84	1.83
5.0	1.93	1.92	1.91	1.90	1.88	1.87	1.86	1.90	1.89	1.88	1.87	1.86	1.84	1.83

MW - Trucks

Water [mm]	MPD=0.5							MPD=1.0						
	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
0.5	1.19	1.19	1.19	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.17	1.17
1.0	1.38	1.38	1.38	1.37	1.37	1.37	1.36	1.38	1.37	1.37	1.37	1.36	1.36	1.36
2.0	1.65	1.64	1.63	1.61	1.60	1.59	1.58	1.62	1.61	1.60	1.59	1.58	1.57	1.56
3.0	1.66	1.65	1.61	1.62	1.59	1.59	1.59	1.64	1.61	1.58	1.58	1.59	1.58	1.57
4.0	1.74	1.73	1.72	1.72	1.70	1.70	1.69	1.72	1.70	1.70	1.69	1.68	1.67	1.66
5.0	1.76	1.76	1.74	1.73	1.72	1.71	1.71	1.74	1.73	1.71	1.71	1.70	1.68	1.68
Water [mm]	MPD=1.5							MPD=2.0						
	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
0.5	1.18	1.18	1.18	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.16
1.0	1.37	1.36	1.36	1.36	1.36	1.35	1.35	1.36	1.36	1.35	1.35	1.35	1.35	1.34
2.0	1.59	1.58	1.57	1.56	1.55	1.54	1.53	1.57	1.56	1.55	1.54	1.53	1.52	1.51
3.0	1.60	1.59	1.57	1.59	1.59	1.58	1.57	1.59	1.58	1.57	1.57	1.58	1.57	1.56
4.0	1.69	1.68	1.67	1.66	1.66	1.65	1.64	1.67	1.67	1.65	1.65	1.64	1.63	1.61
5.0	1.72	1.70	1.69	1.68	1.67	1.66	1.66	1.68	1.67	1.66	1.66	1.65	1.63	1.63

MW - Trucks with trailer

Water [mm]	MPD=0.5							MPD=1.0						
	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
0.5	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11
1.0	1.24	1.24	1.24	1.24	1.24	1.23	1.23	1.24	1.24	1.23	1.23	1.23	1.22	1.22
2.0	1.45	1.45	1.44	1.44	1.43	1.43	1.42	1.44	1.43	1.43	1.42	1.42	1.41	1.41
3.0	1.61	1.61	1.60	1.60	1.59	1.59	1.58	1.60	1.59	1.59	1.58	1.58	1.57	1.56
4.0	1.72	1.71	1.71	1.70	1.69	1.73	1.67	1.70	1.69	1.69	1.67	1.65	1.63	1.60
5.0	1.77	1.76	1.80	1.74	1.71	1.69	1.66	1.74	1.72	1.69	1.67	1.64	1.62	1.60
Water [mm]	MPD=1.5							MPD=2.0						
	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
0.5	1.11	1.11	1.11	1.11	1.11	1.10	1.10	1.11	1.11	1.10	1.10	1.10	1.10	1.10
1.0	1.23	1.23	1.22	1.22	1.21	1.21	1.21	1.22	1.22	1.21	1.21	1.20	1.20	1.20
2.0	1.43	1.42	1.42	1.41	1.41	1.40	1.40	1.41	1.41	1.40	1.40	1.40	1.39	1.39
3.0	1.58	1.58	1.57	1.56	1.56	1.55	1.59	1.57	1.56	1.56	1.55	1.54	1.52	1.50
4.0	1.68	1.65	1.63	1.61	1.59	1.57	1.55	1.62	1.59	1.57	1.55	1.53	1.51	1.50
5.0	1.67	1.65	1.63	1.61	1.59	1.57	1.55	1.61	1.59	1.57	1.55	1.53	1.69	1.68

RUR_90 - Passenger cars petrol

Water [mm]	MPD=0.5							MPD=1.0						
	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
0.5	1.15	1.15	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14
1.0	1.30	1.30	1.30	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.28
2.0	1.57	1.57	1.56	1.56	1.56	1.56	1.55	1.56	1.56	1.56	1.55	1.55	1.55	1.55
3.0	1.77	1.77	1.76	1.76	1.75	1.75	1.75	1.76	1.76	1.75	1.75	1.75	1.74	1.74
4.0	1.89	1.88	1.88	1.88	1.87	1.87	1.86	1.87	1.87	1.87	1.87	1.86	1.86	1.85
5.0	1.94	1.94	1.94	1.93	1.93	1.92	1.92	1.93	1.93	1.92	1.92	1.92	1.91	1.91
Water [mm]	MPD=1.5							MPD=2.0						
	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
0.5	1.14	1.14	1.14	1.14	1.14	1.14	1.13	1.14	1.14	1.14	1.13	1.14	1.13	1.13
1.0	1.29	1.29	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28
2.0	1.55	1.55	1.55	1.55	1.54	1.54	1.54	1.55	1.54	1.54	1.54	1.54	1.54	1.53
3.0	1.75	1.74	1.74	1.74	1.74	1.73	1.73	1.74	1.73	1.73	1.73	1.73	1.72	1.72
4.0	1.86	1.86	1.86	1.86	1.85	1.85	1.84	1.85	1.85	1.85	1.84	1.84	1.84	1.83
5.0	1.92	1.91	1.91	1.91	1.90	1.90	1.90	1.91	1.90	1.90	1.89	1.89	1.89	1.88

RUR_90 - Passenger cars diesel

Water [mm]	MPD=0.5							MPD=1.0						
	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
0.5	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.17	1.17
1.0	1.39	1.38	1.38	1.38	1.38	1.37	1.37	1.38	1.37	1.37	1.37	1.37	1.37	1.36
2.0	1.73	1.73	1.72	1.72	1.71	1.71	1.70	1.72	1.71	1.71	1.70	1.70	1.69	1.69
3.0	1.97	1.96	1.96	1.95	1.94	1.94	1.93	1.95	1.94	1.94	1.93	1.92	1.92	1.91
4.0	2.11	2.10	2.10	2.09	2.08	2.08	2.07	2.09	2.08	2.07	2.07	2.06	2.05	2.05
5.0	2.17	2.16	2.16	2.15	2.14	2.14	2.13	2.15	2.14	2.14	2.13	2.12	2.11	2.11
Water [mm]	MPD=1.5							MPD=2.0						
	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
0.5	1.18	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17
1.0	1.37	1.37	1.37	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.35	1.35	1.35
2.0	1.70	1.70	1.69	1.69	1.68	1.68	1.68	1.69	1.68	1.68	1.67	1.67	1.67	1.66
3.0	1.93	1.92	1.92	1.91	1.91	1.90	1.90	1.91	1.91	1.90	1.89	1.89	1.89	1.88
4.0	2.07	2.06	2.05	2.04	2.04	2.03	2.03	2.04	2.04	2.03	2.02	2.02	2.01	2.01
5.0	2.13	2.12	2.11	2.10	2.10	2.09	2.08	2.10	2.10	2.09	2.08	2.08	2.07	2.06

RUR_90 - Trucks

Water [mm]	MPD=0.5							MPD=1.0						
	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
0.5	1.21	1.21	1.20	1.20	1.20	1.19	1.19	1.20	1.20	1.20	1.19	1.19	1.19	1.19
1.0	1.41	1.40	1.40	1.39	1.39	1.38	1.38	1.39	1.39	1.38	1.38	1.37	1.37	1.37
2.0	1.74	1.73	1.72	1.72	1.71	1.70	1.69	1.72	1.71	1.70	1.70	1.69	1.68	1.68
3.0	2.11	2.10	2.09	2.06	2.04	2.03	1.99	2.06	2.04	2.02	2.00	2.01	1.97	1.95
4.0	2.11	2.09	2.07	2.06	2.04	2.02	2.01	2.07	2.05	2.04	2.02	2.01	1.99	1.97
5.0	2.10	2.11	2.07	2.06	2.04	2.05	2.01	2.07	2.05	2.04	2.01	2.01	1.99	1.97
Water [mm]	MPD=1.5							MPD=2.0						
	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
0.5	1.19	1.19	1.19	1.19	1.18	1.18	1.18	1.19	1.19	1.18	1.18	1.18	1.18	1.17
1.0	1.38	1.38	1.37	1.37	1.36	1.36	1.35	1.37	1.36	1.36	1.36	1.35	1.35	1.34
2.0	1.70	1.69	1.68	1.68	1.67	1.66	1.66	1.68	1.67	1.67	1.66	1.65	1.65	1.64
3.0	2.02	2.00	1.97	1.97	1.95	1.93	1.93	1.97	1.95	1.94	1.92	1.92	1.91	1.89
4.0	2.01	2.01	1.99	1.97	1.97	1.95	1.94	1.99	1.98	1.95	1.94	1.93	1.92	1.90
5.0	2.03	2.01	1.99	1.99	1.96	1.94	1.94	1.99	1.96	1.96	1.95	1.92	1.92	1.90

RUR_90 Trucks with trailer

Water [mm]	MPD=0.5							MPD=1.0						
	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
0.5	1.10	1.10	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.10
1.0	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.22	1.22	1.22
2.0	1.44	1.43	1.43	1.42	1.42	1.42	1.41	1.42	1.42	1.42	1.41	1.41	1.40	1.40
3.0	1.58	1.58	1.58	1.57	1.57	1.57	1.56	1.57	1.57	1.57	1.56	1.55	1.55	1.54
4.0	1.69	1.68	1.68	1.67	1.67	1.66	1.66	1.67	1.67	1.66	1.66	1.65	1.64	1.64
5.0	1.74	1.73	1.73	1.72	1.72	1.71	1.76	1.72	1.72	1.71	1.71	1.69	1.67	1.65
Water [mm]	MPD=1.5							MPD=2.0						
	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
0.5	1.11	1.11	1.11	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
1.0	1.23	1.22	1.22	1.22	1.21	1.21	1.20	1.22	1.21	1.21	1.21	1.20	1.20	1.19
2.0	1.41	1.41	1.40	1.40	1.39	1.39	1.38	1.40	1.39	1.39	1.38	1.38	1.38	1.37
3.0	1.56	1.56	1.55	1.54	1.54	1.53	1.53	1.54	1.54	1.53	1.53	1.52	1.52	1.51
4.0	1.66	1.65	1.65	1.64	1.67	1.61	1.59	1.64	1.68	1.61	1.59	1.57	1.55	1.53
5.0	1.71	1.69	1.67	1.65	1.62	1.60	1.58	1.65	1.63	1.61	1.59	1.57	1.55	1.53

RUR_70 - Passenger cars petrol

Water [mm]	MPD=0.5							MPD=1.0						
	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
0.5	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06
1.0	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15
2.0	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.27	1.28
3.0	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39
4.0	1.46	1.45	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47
5.0	1.51	1.51	1.51	1.50	1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51
Water [mm]	MPD=1.5							MPD=2.0						
	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
0.5	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.07
1.0	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15
2.0	1.28	1.27	1.27	1.27	1.27	1.28	1.28	1.27	1.28	1.28	1.28	1.28	1.28	1.28
3.0	1.39	1.39	1.39	1.39	1.39	1.38	1.39	1.39	1.39	1.39	1.38	1.38	1.38	1.38
4.0	1.47	1.47	1.47	1.47	1.46	1.46	1.46	1.47	1.47	1.46	1.47	1.47	1.47	1.47
5.0	1.51	1.51	1.51	1.51	1.51	1.51	1.49	1.51	1.51	1.49	1.49	1.49	1.49	1.49

RUR_70 - Passenger cars diesel

Water [mm]	MPD=0.5							MPD=1.0						
	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
0.5	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06
1.0	1.14	1.13	1.13	1.13	1.14	1.13	1.14	1.13	1.14	1.14	1.13	1.13	1.13	1.13
2.0	1.26	1.26	1.26	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27
3.0	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37
4.0	1.44	1.44	1.44	1.43	1.44	1.43	1.43	1.43	1.43	1.43	1.44	1.43	1.43	1.43
5.0	1.48	1.47	1.47	1.47	1.48	1.47	1.47	1.48	1.47	1.48	1.48	1.48	1.48	1.47
Water [mm]	MPD=1.5							MPD=2.0						
	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
0.5	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06
1.0	1.13	1.14	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.12	1.12
2.0	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.26	1.26	1.27
3.0	1.37	1.37	1.37	1.37	1.37	1.37	1.36	1.36	1.37	1.36	1.37	1.36	1.36	1.36
4.0	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43
5.0	1.48	1.48	1.47	1.47	1.47	1.48	1.47	1.48	1.48	1.48	1.48	1.47	1.47	1.47

RUR_70 - Trucks

Water [mm]	MPD=0.5							MPD=1.0						
	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
0.5	1.06	1.06	1.07	1.06	1.08	1.08	1.08	1.06	1.08	1.08	1.08	1.08	1.08	1.08
1.0	1.15	1.14	1.15	1.15	1.22	1.22	1.22	1.15	1.22	1.22	1.22	1.15	1.14	1.15
2.0	1.28	1.28	1.28	1.28	1.35	1.42	1.42	1.29	1.36	1.42	1.42	1.42	1.39	1.40
3.0	1.46	1.48	1.48	1.49	1.52	1.51	1.50	1.49	1.52	1.51	1.50	1.50	1.49	1.50
4.0	1.51	1.54	1.54	1.52	1.54	1.54	1.54	1.52	1.54	1.54	1.54	1.54	1.53	1.53
5.0	1.53	1.52	1.52	1.62	1.66	1.65	1.65	1.63	1.66	1.65	1.65	1.65	1.64	1.64
Water [mm]	MPD=1.5							MPD=2.0						
	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
0.5	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.07	1.07
1.0	1.22	1.15	1.14	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.16	1.15	1.15
2.0	1.42	1.39	1.39	1.40	1.40	1.39	1.39	1.40	1.39	1.40	1.40	1.39	1.42	1.43
3.0	1.50	1.50	1.49	1.50	1.51	1.51	1.51	1.50	1.51	1.51	1.51	1.51	1.56	1.56
4.0	1.54	1.54	1.53	1.53	1.54	1.59	1.53	1.53	1.54	1.53	1.53	1.53	1.62	1.62
5.0	1.65	1.65	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.63	1.63	1.63

Appendix 3. Relative fuel use due to snow on the road surface

MW - Passenger cars (petrol), 1st axle 100%

Snow [cm]	NEW 125 kg/m ³							POWDER 325 kg/m ³							
	IRI							IRI							
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0	
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1	1.11	1.11	1.11	1.11	1.11	1.10	1.11	1.27	1.27	1.27	1.27	1.27	1.26	1.26	1.26
2	1.24	1.24	1.24	1.24	1.24	1.24	1.24	1.58	1.58	1.57	1.57	1.57	1.57	1.57	1.57
3	1.39	1.39	1.39	1.39	1.39	1.38	1.38	1.94	1.94	1.94	1.94	1.94	1.94	1.94	1.94
4	1.56	1.56	1.56	1.56	1.55	1.55	1.55	2.52	2.51	2.55	2.51	2.48	2.47	2.51	2.51
5	1.74	1.74	1.74	1.73	1.73	1.73	1.72	2.79	2.78	2.77	2.50	2.49	2.48	2.47	2.47
Snow [cm]	WET 500 kg/m ³							COMPACT 575 kg/m ³							
	IRI							IRI							
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0	
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1	1.41	1.41	1.41	1.41	1.40	1.40	1.40	1.47	1.47	1.47	1.47	1.47	1.46	1.46	1.46
2	1.88	1.88	1.88	1.88	1.87	1.87	1.87	2.09	2.09	2.10	2.09	2.09	2.09	2.09	2.09
3	2.76	2.75	2.74	2.72	2.71	2.70	2.69	2.79	2.77	2.76	2.75	2.74	2.72	2.71	2.71
4	2.48	2.47	2.46	2.29	2.28	2.27	2.27	2.88	2.67	2.68	2.63	2.65	2.64	2.62	2.62
5	3.29	3.29	3.37	3.36	3.34	3.33	3.29	3.57	3.55	3.53	3.51	3.49	3.47	3.45	3.45

MW - Passenger cars (diesel), 1st axle 100%

	NEW 125 kg/m ³							POWDER 325 kg/m ³						
Snow [cm]	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.33	1.33	1.32	1.32	1.32	1.32	1.32
2	1.30	1.30	1.30	1.29	1.29	1.29	1.29	1.69	1.68	1.68	1.67	1.67	1.67	1.66
3	1.48	1.48	1.47	1.47	1.47	1.47	1.47	1.95	1.94	1.93	1.92	1.90	1.89	1.87
4	1.68	1.68	1.67	1.67	1.66	1.66	1.66	2.27	2.26	2.24	2.23	2.21	2.20	2.18
5	1.89	1.89	1.88	1.87	1.87	1.87	1.86	2.25	2.24	2.22	2.27	2.25	2.98	2.97
	WET 500 kg/m ³							COMPACT 575 kg/m ³						
Snow [cm]	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1	1.49	1.49	1.48	1.48	1.48	1.47	1.47	1.56	1.56	1.55	1.55	1.54	1.54	1.54
2	1.99	1.98	1.96	2.01	2.00	1.89	1.88	1.87	1.86	1.84	1.83	1.82	1.81	1.80
3	2.26	2.25	2.23	2.21	2.20	2.19	2.17	2.25	2.24	2.22	2.21	2.20	2.18	2.17
4	3.13	3.11	3.09	3.07	3.05	3.03	3.01	3.15	3.13	3.10	3.08	3.07	3.05	3.03
5	3.17	3.15	3.12	3.11	3.09	3.07	3.05	3.86	3.95	3.92	3.90	3.88	3.86	3.84

MW – Trucks, 1st axle 100%

	NEW 125 kg/m ³							POWDER 325 kg/m ³						
Snow [cm]	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1	1.10	1.09	1.09	1.09	1.09	1.09	1.09	1.22	1.21	1.21	1.21	1.21	1.20	1.20
2	1.20	1.20	1.20	1.20	1.20	1.19	1.19	1.44	1.44	1.43	1.43	1.42	1.42	1.42
3	1.31	1.31	1.31	1.30	1.30	1.30	1.30	1.60	1.59	1.58	1.57	1.56	1.55	1.54
4	1.43	1.42	1.42	1.42	1.41	1.41	1.41	1.62	1.61	1.60	1.58	1.58	1.55	1.54
5	1.54	1.54	1.53	1.53	1.52	1.52	1.51	1.62	1.60	1.59	1.58	1.57	1.57	1.55
	WET 500 kg/m ³							COMPACT 575 kg/m ³						
Snow [cm]	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1	1.30	1.30	1.30	1.29	1.29	1.29	1.29	1.34	1.33	1.33	1.33	1.33	1.32	1.32
2	1.58	1.57	1.56	1.55	1.54	1.53	1.52	1.60	1.59	1.58	1.57	1.56	1.55	1.54
3	1.62	1.59	1.57	1.57	1.56	1.56	1.54	1.64	1.62	1.61	1.60	1.59	1.58	1.57
4	1.71	1.70	1.70	1.69	1.68	1.67	1.67	1.81	1.80	1.79	1.78	1.77	1.76	1.75
5	1.88	1.87	1.86	1.85	1.84	1.83	1.82	2.00	1.99	1.98	1.98	1.97	1.96	1.95

MW - Trucks with trailer, 1st axle 100%

	NEW 125 kg/m ³							POWDER 325 kg/m ³						
Snow [cm]	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.14	1.14	1.14	1.14	1.14	1.14	1.13
2	1.13	1.13	1.12	1.12	1.12	1.12	1.12	1.32	1.31	1.31	1.30	1.30	1.29	1.29
3	1.21	1.21	1.21	1.20	1.20	1.20	1.19	1.50	1.49	1.49	1.48	1.48	1.47	1.47
4	1.30	1.29	1.28	1.28	1.27	1.27	1.26	1.70	1.74	1.67	1.65	1.63	1.61	1.59
5	1.38	1.37	1.36	1.36	1.35	1.35	1.35	1.93	1.92	1.92	1.90	1.88	1.86	1.85
	WET 500 kg/m ³							COMPACT 575 kg/m ³						
Snow [cm]	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1	1.22	1.22	1.22	1.21	1.21	1.20	1.20	1.25	1.25	1.24	1.24	1.23	1.23	1.23
2	1.47	1.46	1.45	1.45	1.45	1.44	1.44	1.53	1.53	1.52	1.52	1.51	1.51	1.50
3	1.72	1.70	1.67	1.65	1.63	1.61	1.59	1.72	1.69	1.87	1.85	1.84	1.84	1.83
4	2.03	2.00	1.98	1.96	1.94	1.93	1.92	2.09	2.06	2.03	2.02	2.00	2.11	2.09
5	2.27	2.24	2.19	2.16	2.12	2.08	2.04	2.07	2.02	2.01	1.94	1.93	1.88	1.85

RUR_90 - Passenger cars (petrol), 1st axle 100%

	NEW 125 kg/m ³							POWDER 325 kg/m ³						
Snow [cm]	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1	1.04	1.04	1.04	1.04	1.04	1.03	1.03	1.10	1.10	1.10	1.10	1.10	1.10	1.10
2	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.22	1.22	1.22	1.22	1.22	1.21	1.21
3	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.34	1.33	1.33	1.33	1.33	1.33	1.33
4	1.20	1.20	1.20	1.20	1.20	1.20	1.19	1.46	1.46	1.46	1.46	1.46	1.45	1.45
5	1.26	1.26	1.26	1.25	1.26	1.25	1.25	1.60	1.59	1.59	1.59	1.59	1.58	1.58
	WET 500 kg/m ³							COMPACT 575 kg/m ³						
Snow [cm]	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.19	1.18	1.18	1.18	1.18	1.18	1.18
2	1.33	1.33	1.33	1.32	1.32	1.32	1.32	1.38	1.38	1.37	1.37	1.37	1.37	1.37
3	1.51	1.51	1.50	1.50	1.50	1.50	1.50	1.59	1.59	1.58	1.58	1.58	1.58	1.57
4	1.70	1.70	1.69	1.69	1.69	1.69	1.68	1.81	1.81	1.80	1.80	1.80	1.79	1.79
5	1.90	1.89	1.89	1.88	1.88	1.88	1.88	2.04	2.04	2.03	2.03	2.03	2.02	2.02

RUR_90 - Passenger cars (diesel), 1st axle 100%

	NEW 125 kg/m ³							POWDER 325 kg/m ³						
Snow [cm]	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.13	1.13	1.13	1.13	1.13	1.12	1.12
2	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.28	1.28	1.28	1.28	1.27	1.27	1.27
3	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.44	1.43	1.43	1.43	1.43	1.42	1.42
4	1.26	1.26	1.26	1.25	1.25	1.25	1.25	1.60	1.59	1.59	1.58	1.58	1.58	1.57
5	1.34	1.34	1.34	1.33	1.33	1.33	1.33	1.76	1.75	1.75	1.74	1.74	1.73	1.73
	WET 500 kg/m ³							COMPACT 575 kg/m ³						
Snow [cm]	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1	1.20	1.20	1.20	1.20	1.20	1.19	1.19	1.23	1.23	1.23	1.23	1.23	1.22	1.22
2	1.42	1.42	1.42	1.41	1.41	1.41	1.41	1.48	1.48	1.48	1.47	1.47	1.47	1.47
3	1.65	1.64	1.64	1.63	1.63	1.63	1.62	1.74	1.73	1.73	1.73	1.72	1.72	1.71
4	1.88	1.87	1.86	1.86	1.85	1.85	1.84	2.00	1.99	1.99	1.98	1.98	1.97	1.96
5	2.10	2.09	2.09	2.08	2.08	2.07	2.06	2.26	2.25	2.24	2.24	2.23	2.22	2.21

RUR_90 - Trucks, 1st axle 100%

	NEW 125 kg/m ³							POWDER 325 kg/m ³						
Snow [cm]	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.16	1.16	1.16	1.16	1.15	1.15	1.15
2	1.16	1.15	1.15	1.15	1.15	1.15	1.14	1.33	1.32	1.32	1.31	1.31	1.31	1.30
3	1.24	1.24	1.23	1.23	1.23	1.23	1.22	1.48	1.48	1.47	1.47	1.47	1.46	1.46
4	1.32	1.32	1.31	1.31	1.31	1.30	1.30	1.65	1.64	1.63	1.63	1.62	1.62	1.61
	WET 500 kg/m ³							COMPACT 575 kg/m ³						
Snow [cm]	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1	1.23	1.22	1.22	1.22	1.22	1.21	1.21	1.25	1.25	1.24	1.24	1.24	1.24	1.23
2	1.44	1.44	1.43	1.43	1.42	1.42	1.42	1.49	1.49	1.48	1.48	1.47	1.47	1.47
3	1.66	1.66	1.65	1.64	1.64	1.63	1.62	1.73	1.72	1.71	1.70	1.70	1.80	1.68
4	1.98	1.96	1.95	1.95	1.90	1.92	1.87	1.97	1.96	1.93	1.93	1.91	1.89	1.88
5	1.93	1.92	1.90	1.89	1.88	1.86	1.84	1.89	1.87	1.87	1.86	1.84	1.83	1.82

RUR_90 - Trucks with trailer, 1st axle 100%

	NEW 125 kg/m ³							POWDER 325 kg/m ³						
Snow [cm]	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.08	1.08	1.07	1.07	1.07	1.07	1.07
2	1.07	1.07	1.07	1.07	1.07	1.06	1.06	1.19	1.19	1.19	1.19	1.18	1.18	1.18
3	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.30	1.30	1.29	1.29	1.28	1.28	1.27
4	1.18	1.18	1.18	1.18	1.17	1.17	1.17	1.41	1.40	1.40	1.39	1.39	1.38	1.38
5	1.24	1.24	1.23	1.23	1.23	1.22	1.22	1.53	1.52	1.52	1.51	1.51	1.50	1.50
	WET 500 kg/m ³							COMPACT 575 kg/m ³						
Snow [cm]	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.14	1.14	1.14	1.14	1.14	1.13	1.13
2	1.28	1.28	1.27	1.27	1.26	1.26	1.25	1.32	1.31	1.31	1.30	1.29	1.29	1.28
3	1.43	1.42	1.42	1.41	1.41	1.40	1.40	1.48	1.48	1.47	1.47	1.46	1.46	1.45
4	1.60	1.59	1.59	1.58	1.57	1.57	1.56	1.68	1.68	1.67	1.66	1.70	1.63	1.61
5	1.74	1.71	1.69	1.67	1.65	1.63	1.61	1.74	1.91	1.90	1.88	1.87	1.85	1.84

RUR_70 - Passenger cars (petrol), 1st axle 100%

	NEW 125 kg/m ³							POWDER 325 kg/m ³						
Snow [cm]	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1	1.09	1.09	1.09	1.09	1.09	1.09	1.10	1.27	1.27	1.27	1.26	1.27	1.26	1.25
2	1.22	1.21	1.22	1.21	1.21	1.22	1.22	1.59	1.59	1.59	1.59	1.59	1.59	1.59
3	1.34	1.34	1.34	1.34	1.34	1.34	1.34	2.13	2.12	2.13	2.13	2.13	2.13	2.13
4	1.49	1.49	1.49	1.49	1.49	1.49	1.49	2.63	2.62	2.62	2.62	2.62	2.60	2.60
5	1.64	1.64	1.64	1.64	1.67	1.67	1.67	3.12	3.11	3.10	3.10	3.10	3.11	3.11
	WET 500 kg/m ³							COMPACT 575 kg/m ³						
Snow [cm]	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1	1.42	1.42	1.42	1.41	1.42	1.42	1.42	1.51	1.50	1.50	1.51	1.51	1.50	1.50
2	2.13	2.13	2.13	2.13	2.14	2.14	2.14	2.29	2.28	2.33	2.33	2.32	2.33	2.33
3	2.89	2.88	2.88	2.88	2.87	2.87	2.87	3.25	3.23	3.23	3.23	3.23	3.22	3.22
4	3.64	3.72	3.74	3.75	3.78	3.77	3.77	4.36	4.35	4.34	4.33	4.27	4.26	4.25
5	4.60	4.63	4.63	4.61	4.59	4.59	4.58	5.19	5.17	5.15	5.15	5.14	5.13	5.13

RUR_70 - Passenger cars (diesel), 1st axle 100%

	NEW 125 kg/m ³							POWDER 325 kg/m ³						
Snow [cm]	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.25	1.25	1.25	1.25	1.25	1.25	1.25
2	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.55	1.55	1.55	1.55	1.55	1.55	1.54
3	1.33	1.33	1.33	1.33	1.33	1.33	1.32	1.98	1.98	1.97	1.98	1.97	1.97	1.97
4	1.46	1.46	1.46	1.46	1.46	1.46	1.47	2.56	2.55	2.54	2.59	2.59	2.58	2.58
5	1.61	1.61	1.61	1.61	1.61	1.62	1.62	3.13	3.12	3.12	3.10	3.11	3.11	3.10

	WET 500 kg/m ³							COMPACT 575 kg/m ³						
Snow [cm]	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1	1.40	1.40	1.39	1.39	1.39	1.39	1.39	1.47	1.46	1.46	1.47	1.46	1.47	1.47
2	1.98	1.97	1.97	1.97	1.97	1.97	1.97	2.21	2.20	2.19	2.19	2.20	2.20	2.19
3	2.84	2.83	2.83	2.83	2.82	2.82	2.81	3.20	3.19	3.16	3.18	3.18	3.18	3.15
4	3.62	3.59	3.59	3.59	3.58	3.60	3.59	4.08	4.06	4.05	4.05	4.04	4.01	4.02
5	4.41	4.39	4.34	4.33	4.32	4.31	4.30	6.06	6.03	6.04				

RUR_70 - Trucks, 1st axle 100%

	NEW 125 kg/m ³							POWDER 325 kg/m ³						
Snow [cm]	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1	1.03	1.07	1.08	1.07	1.08	1.07	1.07	1.14	1.14	1.14	1.14	1.15	1.15	1.13
2	1.11	1.10	1.10	1.10	1.10	1.10	1.13	1.30	1.28	1.29	1.29	1.32	1.32	1.33
3	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.53	1.58	1.58	1.57	1.57	1.56	1.56
4	1.26	1.25	1.25	1.24	1.25	1.25	1.25	1.70	1.69	1.71	1.70	1.70	1.70	1.70
5	1.40	1.40	1.40	1.39	1.44	1.44	1.44	1.81	1.79	1.79	1.78	1.78	1.75	1.75

	WET 500 kg/m ³							COMPACT 575 kg/m ³						
Snow [cm]	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1	1.17	1.17	1.17	1.17	1.21	1.21	1.21	1.23	1.23	1.23	1.24	1.24	1.25	1.25
2	1.50	1.50	1.50	1.50	1.51	1.51	1.56	1.61	1.61	1.59	1.58	1.58	1.58	1.58
3	1.74	1.73	1.73	1.72	1.73	1.72	1.73	1.80	1.80	1.79	1.78	1.77	1.77	1.82
4	1.93	1.93	1.92	1.92	1.93	1.96	1.97	2.08	2.12	2.12	2.11	2.12	2.11	2.12
5	2.28	2.27	2.27	2.26	2.28	2.27	2.28	2.53	2.52	2.52	2.52	2.52	2.52	2.54

MW - Passenger cars (petrol), 1st axle 25%

	NEW 125 kg/m ³							POWDER 325 kg/m ³						
Snow [cm]	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.09	1.09	1.09	1.09	1.08	1.09	1.09
2	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.19	1.19	1.19	1.19	1.18	1.18	1.18
3	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.30	1.29	1.29	1.29	1.29	1.29	1.29
4	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.41	1.41	1.41	1.41	1.40	1.40	1.40
5	1.24	1.24	1.24	1.24	1.24	1.24	1.24	1.53	1.53	1.52	1.52	1.52	1.52	1.52
	WET 500 kg/m ³							COMPACT 575 kg/m ³						
Snow [cm]	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.15	1.15	1.15	1.15	1.15	1.15	1.15
2	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.32	1.32	1.32	1.32	1.32	1.32	1.32
3	1.44	1.44	1.44	1.43	1.43	1.43	1.43	1.50	1.50	1.50	1.50	1.50	1.49	1.49
4	1.60	1.59	1.59	1.59	1.59	1.59	1.58	1.68	1.68	1.68	1.68	1.67	1.67	1.67
5	1.75	1.75	1.75	1.75	1.74	1.74	1.74	1.89	1.89	1.89	1.89	1.88	1.88	1.88

MW - Passenger cars (diesel), 1st axle 25%

	NEW 125 kg/m ³							POWDER 325 kg/m ³						
Snow [cm]	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.11	1.11	1.10	1.10	1.10	1.10	1.10
2	1.10	1.10	1.09	1.10	1.09	1.09	1.09	1.23	1.23	1.23	1.23	1.23	1.22	1.22
3	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.36	1.36	1.36	1.35	1.35	1.35	1.35
4	1.23	1.23	1.23	1.23	1.23	1.22	1.22	1.49	1.49	1.49	1.48	1.48	1.48	1.48
5	1.31	1.31	1.30	1.30	1.30	1.30	1.30	1.63	1.63	1.62	1.62	1.61	1.61	1.61
	WET 500 kg/m ³							COMPACT 575 kg/m ³						
Snow [cm]	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1	1.16	1.16	1.16	1.16	1.16	1.16	1.15	1.19	1.18	1.18	1.18	1.18	1.18	1.18
2	1.34	1.34	1.33	1.33	1.33	1.33	1.33	1.39	1.38	1.38	1.38	1.38	1.38	1.37
3	1.52	1.52	1.51	1.51	1.51	1.50	1.50	1.59	1.59	1.58	1.58	1.58	1.57	1.57
4	1.70	1.70	1.69	1.69	1.68	1.68	1.68	1.80	1.79	1.79	1.78	1.78	1.77	1.77
5	1.89	1.88	1.87	1.87	1.86	1.86	1.85	1.99	1.98	1.96	2.01	1.90	1.89	1.88

MW - Trucks, 1st axle 25%

	NEW 125 kg/m ³							POWDER 325 kg/m ³						
Snow [cm]	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.14	1.14	1.14	1.13	1.13	1.13	1.13
2	1.14	1.14	1.13	1.13	1.13	1.13	1.13	1.29	1.28	1.28	1.28	1.28	1.27	1.27
3	1.21	1.21	1.21	1.21	1.20	1.20	1.20	1.44	1.43	1.43	1.42	1.42	1.42	1.41
4	1.29	1.29	1.28	1.28	1.28	1.28	1.27	1.58	1.69	1.57	1.56	1.55	1.53	1.52
5	1.37	1.37	1.36	1.36	1.36	1.35	1.35	1.60	1.59	1.58	1.57	1.56	1.55	1.54
	WET 500 kg/m ³							COMPACT 575 kg/m ³						
Snow [cm]	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1	1.19	1.19	1.19	1.19	1.19	1.18	1.18	1.21	1.21	1.21	1.21	1.21	1.20	1.20
2	1.39	1.39	1.39	1.38	1.38	1.38	1.37	1.43	1.43	1.43	1.42	1.42	1.42	1.41
3	1.70	1.58	1.57	1.56	1.54	1.53	1.52	1.58	1.58	1.57	1.56	1.56	1.55	1.54
4	1.61	1.60	1.59	1.58	1.57	1.56	1.55	1.62	1.61	1.60	1.59	1.58	1.57	1.56
5	1.63	1.61	1.61	1.58	1.57	1.56	1.56	1.64	1.63	1.62	1.61	1.60	1.57	1.55

MW - Trucks with trailer, 1st axle 25%

	NEW 125 kg/m ³							POWDER 325 kg/m ³						
Snow [cm]	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.08	1.07	1.07	1.07	1.07	1.07	1.07
2	1.07	1.07	1.07	1.07	1.07	1.07	1.06	1.19	1.19	1.19	1.18	1.18	1.18	1.17
3	1.13	1.12	1.12	1.12	1.12	1.12	1.12	1.30	1.30	1.29	1.28	1.28	1.27	1.27
4	1.18	1.18	1.18	1.18	1.17	1.17	1.17	1.41	1.40	1.40	1.39	1.39	1.38	1.38
5	1.24	1.24	1.23	1.23	1.22	1.22	1.22	1.53	1.52	1.52	1.51	1.51	1.50	1.50
	WET 500 kg/m ³							COMPACT 575 kg/m ³						
Snow [cm]	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1	1.12	1.12	1.12	1.12	1.12	1.11	1.11	1.14	1.14	1.14	1.14	1.13	1.13	1.13
2	1.28	1.27	1.27	1.26	1.26	1.25	1.25	1.31	1.30	1.30	1.29	1.29	1.28	1.28
3	1.43	1.42	1.41	1.41	1.40	1.40	1.40	1.48	1.48	1.47	1.47	1.46	1.46	1.45
4	1.60	1.59	1.58	1.58	1.57	1.56	1.56	1.68	1.67	1.66	1.70	1.63	1.61	1.59
5	1.72	1.69	1.67	1.65	1.63	1.61	1.59	1.72	1.89	1.88	1.86	1.87	1.85	1.83

RUR_90 - Passenger cars (petrol), 1st axle 25%

	NEW 125 kg/m ³							POWDER 325 kg/m ³						
Snow [cm]	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.10	1.10	1.10	1.10	1.10	1.10	1.10
2	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.22	1.22	1.22	1.22	1.22	1.22	1.22
3	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.34	1.34	1.34	1.34	1.33	1.33	1.33
4	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.46	1.46	1.46	1.46	1.46	1.46	1.45
5	1.26	1.26	1.26	1.26	1.26	1.26	1.25	1.60	1.60	1.60	1.59	1.59	1.59	1.59
	WET 500 kg/m ³							COMPACT 575 kg/m ³						
Snow [cm]	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.19	1.18	1.19	1.18	1.18	1.18	1.18
2	1.33	1.33	1.33	1.33	1.33	1.32	1.32	1.38	1.38	1.38	1.38	1.37	1.37	1.37
3	1.51	1.51	1.51	1.51	1.50	1.50	1.50	1.59	1.59	1.59	1.59	1.58	1.58	1.58
4	1.70	1.70	1.70	1.70	1.69	1.69	1.69	1.81	1.81	1.81	1.81	1.80	1.80	1.80
5	1.90	1.90	1.90	1.89	1.89	1.88	1.88	2.05	2.04	2.04	2.04	2.03	2.03	2.02

RUR_90 - Passenger cars (diesel), 1st axle 25%

	NEW 125 kg/m ³							POWDER 325 kg/m ³						
Snow [cm]	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.13	1.13	1.13	1.13	1.13	1.13	1.13
2	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.28	1.28	1.28	1.28	1.28	1.28	1.27
3	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.44	1.44	1.43	1.43	1.43	1.43	1.43
4	1.26	1.26	1.26	1.26	1.26	1.25	1.25	1.60	1.60	1.59	1.59	1.59	1.58	1.58
5	1.34	1.34	1.34	1.34	1.34	1.33	1.33	1.76	1.76	1.75	1.75	1.75	1.74	1.74
	WET 500 kg/m ³							COMPACT 575 kg/m ³						
Snow [cm]	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.23	1.23	1.23	1.23	1.23	1.23	1.22
2	1.43	1.43	1.42	1.42	1.42	1.41	1.41	1.49	1.49	1.48	1.48	1.48	1.47	1.47
3	1.65	1.65	1.65	1.64	1.64	1.63	1.63	1.75	1.74	1.74	1.73	1.73	1.73	1.72
4	1.88	1.88	1.87	1.87	1.86	1.86	1.85	2.01	2.00	2.00	1.99	1.99	1.98	1.97
5	2.11	2.11	2.10	2.09	2.09	2.08	2.07	2.27	2.27	2.25	2.25	2.24	2.23	2.23

RUR_90 - Trucks, 1st axle 25%

	NEW 125 kg/m ³							POWDER 325 kg/m ³						
Snow [cm]	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.17	1.16	1.16	1.16	1.16	1.16	1.16
2	1.16	1.16	1.16	1.15	1.15	1.15	1.15	1.33	1.33	1.33	1.32	1.32	1.31	1.31
3	1.25	1.24	1.24	1.24	1.23	1.23	1.23	1.49	1.49	1.48	1.48	1.48	1.47	1.47
4	1.33	1.33	1.32	1.32	1.31	1.31	1.31	1.66	1.66	1.65	1.64	1.64	1.63	1.62
5	1.41	1.40	1.40	1.39	1.39	1.39	1.38	1.77	1.76	1.75	1.74	1.72	1.71	1.97
	WET 500 kg/m ³							COMPACT 575 kg/m ³						
Snow [cm]	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1	1.23	1.23	1.23	1.22	1.22	1.22	1.22	1.26	1.25	1.25	1.25	1.24	1.24	1.24
2	1.45	1.45	1.44	1.44	1.43	1.43	1.43	1.50	1.50	1.49	1.49	1.48	1.48	1.47
3	1.68	1.67	1.66	1.66	1.65	1.64	1.64	1.74	1.73	1.73	1.72	1.71	1.70	1.70
4	2.01	2.00	1.98	1.96	1.96	1.95	1.90	2.00	1.98	1.97	1.96	1.93	1.93	1.91
5	1.97	1.95	1.93	1.92	1.90	1.89	1.88	1.95	1.94	1.90	1.87	1.87	1.86	1.84

RUR_90 - Trucks with trailer, 1st axle 25%

	NEW 125 kg/m ³							POWDER 325 kg/m ³						
Snow [cm]	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.07	1.08	1.08	1.07	1.07	1.07	1.07
2	1.07	1.07	1.07	1.07	1.07	1.07	1.06	1.19	1.19	1.19	1.19	1.19	1.18	1.18
3	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.31	1.30	1.30	1.29	1.29	1.28	1.28
4	1.18	1.18	1.18	1.18	1.18	1.17	1.17	1.41	1.41	1.40	1.40	1.39	1.39	1.38
5	1.24	1.24	1.24	1.23	1.23	1.22	1.22	1.53	1.53	1.52	1.52	1.51	1.50	1.50
	WET 500 kg/m ³							COMPACT 575 kg/m ³						
Snow [cm]	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.14	1.14	1.14	1.14	1.14	1.14	1.13
2	1.29	1.28	1.28	1.27	1.27	1.26	1.26	1.32	1.32	1.31	1.30	1.30	1.29	1.29
3	1.43	1.43	1.42	1.42	1.41	1.41	1.40	1.49	1.48	1.48	1.47	1.47	1.46	1.46
4	1.60	1.60	1.59	1.59	1.58	1.57	1.57	1.69	1.68	1.68	1.67	1.66	1.65	1.63
5	1.76	1.74	1.71	1.69	1.67	1.65	1.63	1.76	1.74	1.91	1.90	1.88	1.87	1.85

RUR_70 - Passenger cars (petrol), 1st axle 25%

	NEW 125 kg/m ³							POWDER 325 kg/m ³						
Snow [cm]	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1	1.03	1.02	1.02	1.02	1.02	1.02	1.02	1.08	1.07	1.07	1.07	1.07	1.07	1.07
2	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.19	1.18	1.18	1.19	1.19	1.19	1.19
3	1.10	1.11	1.11	1.11	1.11	1.11	1.11	1.28	1.28	1.28	1.28	1.28	1.28	1.28
4	1.16	1.15	1.16	1.16	1.16	1.16	1.16	1.40	1.40	1.40	1.40	1.40	1.39	1.40
5	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.53	1.53	1.53	1.53	1.53	1.52	1.53
	WET 500 kg/m ³							COMPACT 575 kg/m ³						
Snow [cm]	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.16	1.16	1.16	1.16	1.16	1.16	1.16
2	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.34	1.33	1.33	1.33	1.33	1.33	1.33
3	1.45	1.46	1.46	1.46	1.46	1.46	1.46	1.54	1.54	1.54	1.52	1.52	1.52	1.52
4	1.63	1.63	1.63	1.63	1.67	1.67	1.67	1.79	1.80	1.80	1.79	1.80	1.79	1.80
5	1.91	1.90	1.91	1.91	1.91	1.91	1.91	2.16	2.15	2.15	2.15	2.11	2.11	2.09

RUR_70 - Passenger cars (diesel), 1st axle 25%

	NEW 125 kg/m ³							POWDER 325 kg/m ³						
Snow [cm]	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.08	1.07	1.08	1.08	1.08	1.08	1.08
2	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.17	1.16	1.16	1.16	1.16	1.16	1.16
3	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.27	1.27	1.27	1.27	1.27	1.27	1.27
4	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.38	1.38	1.37	1.38	1.38	1.38	1.37
5	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.50	1.49	1.49	1.49	1.50	1.49	1.49
	WET 500 kg/m ³							COMPACT 575 kg/m ³						
Snow [cm]	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.14	1.14	1.14	1.14	1.14	1.14	1.14
2	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.32	1.31	1.31	1.31	1.31	1.31	1.31
3	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.51	1.50	1.50	1.50	1.50	1.50	1.50
4	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.70	1.69	1.69	1.69	1.69	1.69	1.69
5	1.80	1.80	1.80	1.80	1.79	1.79	1.78	1.99	1.98	1.98	1.98	1.99	1.99	1.97

RUR_70 - Trucks, 1st axle 25%

	NEW 125 kg/m ³							POWDER 325 kg/m ³						
Snow [cm]	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1	1.01	1.02	1.02	1.01	1.01	1.01	1.02	1.09	1.08	1.08	1.08	1.08	1.08	1.08
2	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.16	1.15	1.16	1.15	1.15	1.16	1.16
3	1.10	1.10	1.10	1.10	1.10	1.10	1.14	1.28	1.28	1.28	1.28	1.29	1.29	1.32
4	1.22	1.22	1.22	1.22	1.15	1.15	1.15	1.45	1.45	1.46	1.46	1.46	1.49	1.49
5	1.22	1.22	1.22	1.22	1.22	1.22	1.24	1.61	1.59	1.59	1.58	1.59	1.53	1.53
	WET 500 kg/m ³							COMPACT 575 kg/m ³						
Snow [cm]	IRI							IRI						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1	1.11	1.10	1.10	1.10	1.13	1.13	1.14	1.15	1.15	1.15	1.15	1.16	1.13	1.13
2	1.26	1.25	1.25	1.25	1.25	1.26	1.27	1.31	1.29	1.33	1.33	1.38	1.38	1.38
3	1.51	1.51	1.51	1.49	1.49	1.49	1.49	1.58	1.57	1.57	1.56	1.57	1.56	1.59
4	1.65	1.65	1.67	1.65	1.65	1.65	1.65	1.72	1.71	1.71	1.70	1.71	1.71	1.73
5	1.80	1.79	1.79	1.78	1.78	1.78	1.76	1.81	1.81	1.81	1.81	1.81	1.81	1.84

VTI, Statens väg- och transportforskningsinstitut, är ett oberoende och internationellt framstående forskningsinstitut inom transportsektorn. Huvuduppgiften är att bedriva forskning och utveckling kring infrastruktur, trafik och transporter. Kvalitetssystemet och miljöledningssystemet är ISO-certifierat enligt ISO 9001 respektive 14001. Vissa provningsmetoder är dessutom ackrediterade av Swedac. VTI har omkring 200 medarbetare och finns i Linköping (huvudkontor), Stockholm, Göteborg, Borlänge och Lund.

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HEAD OFFICE
LINKÖPING
SE-581 95 LINKÖPING
PHONE +46 (0)13-20 40 00

STOCKHOLM
Box 55685
SE-102 15 STOCKHOLM
PHONE +46 (0)8-555 770 20

GOTHENBURG
Box 8072
SE-402 78 GOTHENBURG
PHONE +46 (0)31-750 26 00

BORLÄNGE
Box 920
SE-781 29 BORLÄNGE
PHONE +46 (0)243-44 68 60

LUND
Medicon Village AB
SE-223 81 LUND
PHONE +46 (0)46-540 75 00

