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TNO report

TNO 2014 R10735

Potential benefits of Triple-A tyres in the Netherlands

Date	12 June 2014
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Copy no	2014-TM-RAP-0100007423
Number of pages	55 (incl. appendices)
Number of appendices	2
Sponsor	Ministry of Infrastructure and the Environment
Project name	Potential benefits of Triple-A tyres in the Netherlands
Project number	060.08195/01.05.03

Management summary

The quality of a tyre has a large influence on fuel consumption and CO_2 emissions, vehicle safety and noise emissions. Therefore, the use of high-quality tyres could contribute in making vehicles more economic, safer and quieter. For this reason, the ministry of Infrastructure and Environment in the Netherlands has asked TNO and M+P to perform a 'quick-scan' study to evaluate the potential of high-quality tyres in terms of energy, safety and noise.

Tyres in the European Union are labelled on each of these three criteria. High-quality tyres are tyres that rate 'A' on the topic at hand, and are therefore also referred to as A-rated tyres. Tyres that rate an A on each of the topics energy, safety and noise are referred to in this study as AAA-rated or triple-A tyres. The study assesses the potential benefits of A-rated as well as triple-A tyres. It assumes all currently-used tyres in the Netherlands are replaced by A-rated tyres and compares this situation with a baseline representing the current tyre distribution of the Dutch vehicle fleet.

Replacing the currently-used tyres by A-rated tyres would have a large impact on energy consumption, safety and vehicle noise. The use of A-rated tyres in the Netherlands would **save nearly 506 million litres of fuel** and would **reduce CO_2 emissions by approximately 1.3 Mton** annually. Yearly, **43 less people would be killed in traffic accidents**, and high-quality tyres would result in **260 less serious injuries** and **364 less slight injuries**. And due to the favourable noise characteristics of A-rated tyres, each year **216000 less people would be highly-annoyed by road traffic** and **the number a highly sleep-disturbed people would be reduced by 204000.**

Assuming the characteristics of A-rated tyres could be combined into one 'Triple-A' tyre would lead to the sum of all benefits described above. From a **societal perspective,** t**he associated annual cost savings would then amount to nearly one billion Euros**. For the end-user, annual cost savings would range from 117€ for passenger cars to 2418€ for long-haul vehicles.

Given the large potential benefits of high-quality tyres, an accelerated market uptake could help in making road transport more environmentally friendly, safer and quieter.

Summary

The quality of a tyre has a large influence on fuel consumption and CO_2 emissions, vehicle safety and noise emissions. Therefore, the use of high-quality tyres could contribute in making vehicles more economic, safer and quieter.

For this reason, the ministry of Infrastructure and Environment in the Netherlands has asked TNO and M+P to perform a 'quick-scan' study to evaluate the potential of high-quality tyres in terms of energy, safety and noise.

Tyres in the European Union are labelled on each of these three criteria. High-quality tyres are tyres that rate 'A' on the topic at hand, and are therefore also referred to as A-rated tyres. Tyres that rate an A on each of the topics energy, safety and noise are referred to in this study as AAA-rated or triple-A tyres.

Goals of the study
This study assesses the benefits of A-rated as well as triple-A tyres. It provides a first-order estimate of the monetary and non-monetary benefits, highlighting the following aspects:

- the *energy savings* expressed in reduced amount of fuel consumption, costs and CO_2 emissions;
- the *safety improvement potential* expressed in reduced amount of injuries, (fatal) injuries and costs, and;
- the *noise reduction potential* expressed in reduced amount of annoyed and sleep-disturbed people and monetary benefits.

Approach
The study compares two scenarios of tyre distribution in the Netherlands. The first scenario, which acts as a baseline scenario, represents the tyre distribution as it currently exists in the Dutch vehicle fleet. The second scenario assumes that all currently-used tyres in the Netherlands are replaced by A-rated tyres. After calculating fuel consumption and CO_2 emissions, the number of injuries and the number annoyed and sleep-disturbed people for each of the scenarios, a comparison is made between the scenarios. Based on this comparison, the energy savings potential, the safety improvement potential and the noise reduction potential of high-quality tyres can be derived.

Results
The current tyre distribution in the Netherlands constituting the baseline is shown in Table 1. On average vehicles in the Netherlands drive with a D-label for energy, a C-label for wet grip and a B-label for noise.

Table 1: Average tyre label per tyre class and criterion, assuming A=1, B=2, C=3, etc.

	Fuel Efficiency	Wet Grip	Noise	Noise (dB)
C1	4.4 ('D-label')	2.6 ('C-label')	1.9 ('B-label')	69.9
C2	4.3 ('D-label')	2.7 ('C-label')	2.0 ('B-label')	71.6
C3	3.7 ('D-label')	2.5 ('C-label')	1.8 ('B-label')	72.2

Energy savings potential of a shift towards A-rated tyres for energy

Table 2 and Table 3 show that A-rated tyres for energy have a large energy savings potential. Replacing the currently-used tyres by A-label tyres for energy results in a considerable amount of fuel and cost savings for the end-user with fuel cost savings ranging from 117€ to 2418€ per year (Table 2). On a societal level, annual savings of nearly 506 million litres (506Ml) of fuel, 365M€ of fuel costs and a reduction of as much as nearly 1.3Mton in CO_2 emissions can be achieved (Table 3).

Table 2: End-user perspective: Annual fuel and cost savings associated with a switch to A-rated tyres for energy

Vehicle group	Annual fuel savings	Annual cost savings
[]	[l]	[€]
Passenger cars (family, petrol)	67	117
Passenger cars (lease, diesel)	114	171
Service/delivery (diesel)	300	449
Urban delivery/collection (diesel)	449	674
Municipal utility (diesel)	507	761
Regional delivery/collection (diesel)	574	862
Long haul (diesel)	1612	2418
Construction (diesel)	526	790
Bus (diesel)	691	1036
Coach (diesel)	566	849

Table 3: Societal perspective: Annual fuel and cost savings and CO_2 reduction associated with a switch to A-rated tyres for energy

Vehicle group	Annual fuel savings	Annual cost savings	Annual CO_2 reduction
[]	[Ml]	[M€]	[MtCO_2]
Passenger cars (petrol)	249	170	0.59
Passenger cars (diesel)	95	72	0.25
Service/delivery (diesel)	61	46	0.16
Distribution (diesel)	1	1	0.00
Heavy duty (diesel)	92	70	0.24
Bus (diesel)	7	6	0.02
TOTAL	506	365	1.26

Safety improvement potential of a shift towards A-rated tyres for safety

Table 4 shows the considerable safety improvement potential of high-quality tyres. A shift toward A-rated tyres for safety yearly leads to 43 less fatalities, 260 less serious injuries and 364 less people slightly injured in traffic accidents. In total this saves the society a 183 M€ each year.

Table 4: Annual reduction in number of fatalities, serious and slight injuries and resulting monetary benefits associated with a switch to A-rated tyres for safety

	C1	C2	C3	TOTAL	Monetary benefits [M€]
Reduced number of fatalities	37	4	2	43	107.5
Reduced number of serious injuries	218	29	13	260	72.8
Reduced number of slight injuries	323	10	30	364	3.3
Monetary benefits [M€]	156.5	18.2	8.9	183.6	183.6

<u>Noise reduction potential of a shift towards A-rated tyres for noise</u>

A shift towards A-rated tyres for noise results in an average reduction of the noise impact by 2 dB and a subsequent reduction of annoyed and highly-annoyed people by road traffic by 361000 and 216000 respectively. The number a sleep-disturbed and highly sleep-disturbed people is reduced by 310000 and 204000 respectively. The corresponding annual societal savings amount to 389M€.

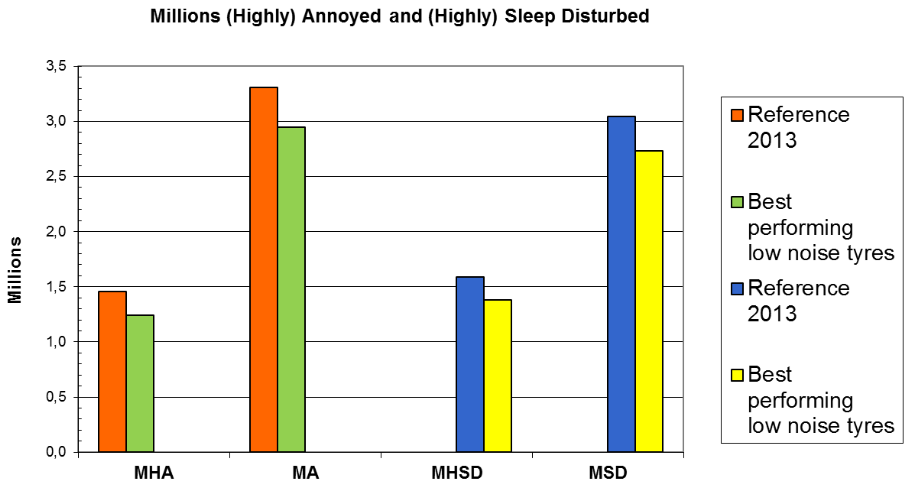


Figure 1: Reduction of Millions of (Highly) Annoyed and (Highly) Sleep Disturbed people resulting from a shift towards the best performing low noise tyres.

<u>Theoretical benefits of a shift towards AAA-rated tyres</u>

Currently, it is unknown whether tyres exist that rate 'A' on energy <u>and</u> safety <u>and</u> noise. In other words: AAA-rated tyres might currently not be available on the Dutch market. Nevertheless, as the above clearly shows, the potential of such tyres would offer significant benefits, to end-users as well as the society. Assuming the characteristics of A-rated tyres could be combined into one 'Triple-A' tyre and applying them to all vehicles of the Dutch fleet, annually nearly one billion Euros (938M€) could be saved. Moreover, this would lead to the sum of all benefits the A-rated tyres would yield separately.

Table 5: Annual improvement potential of A-rated tyres from a societal perspective. The benefits of a shift towards tyres that are A-rated for *either* energy, safety or noise are stated separately. It is assumed that the savings potential of AAA-rated tyres can be calculated as the sum of the savings potential of respective A-rated tyres.

	Energy savings potential	Safety improvement potential	Noise reduction potential	TOTAL
Annual fuel savings [Ml]	506	-	-	506
Annual CO_2 reduction [$MtCO_2$]	1.3	-	-	1.3
Reduced number of fatalities	-	43	-	43
Reduced number of serious injuries	-	260	-	260
Reduced number of slight injuries	-	364	-	364
Reduced number of highly annoyed people	-	-	216000	216000
Reduced number of annoyed people	-	-	361000	361000
Reduced number of highly sleep disturbed people	-	-	204000	204000
Reduced number of sleep disturbed people	-	-	310000	310000
Annual cost savings [M€]	365	184	389	938

Contents

1 Introduction

1.1 Background

Parameters such as fuel consumption and CO_2 emissions, vehicle safety and noise emissions are highly dependent on the type and quality of the tyre. The use of high-quality tyres can therefore potentially make road transport cleaner, safer and less noisy. The Dutch ministry of Infrastructure and the Environment asked TNO to perform a 'quick-scan' study to estimate the potential benefits of those so-called 'A-rated tyres', tyres that are rated best in terms of energy, safety and noise.

1.2 Goal of the study

The goal of this study is to estimate the potential benefits of a shift to A-rated tyres. The potential benefits are categorized in the following manner:

- Energy savings potential: expressed in reduced amount of fuel consumption, costs and CO_2 emissions;
- Safety improvement potential: expressed in reduced amount of injuries, fatal injuries and costs;
- Noise reduction potential: expressed in reduced amount of annoyed and sleep-disturbed people and monetary benefits due to reduced noise impact.

Apart from a separate estimate of abovementioned potential, this study will also address the sum of all benefits, i.e. it also evaluates the benefits of a shift towards tyres that rate best in all three categories. Tyres rating best in all three categories are designated AAA-rated tyres.

1.3 Approach and scope of this study

This 'quick-scan' study is performed in order to provide an overview of the benefits that could be realized with A-rated tyres. It should not be compared to the full scope of an impact assessment where the feasibility, potential and cost-effectiveness are assessed. This study provides a first order estimate of monetary and non-monetary benefits and can act as an indication for further research.

The goal of this study is approached in three steps by addressing the following research questions:

- What is the current tyre label distribution in the Netherlands? With which tyres do consumers currently drive?
- What are the potential benefits of better tyre labels in terms of energy, safety and noise?
- What would be the overall savings potential for the Netherlands if all tyres were switched to A-rated (AAA-rated) tyres?

As a first step in this study, the current distribution of tyre labels are determined. In this study, the distribution of tyre labels is based on the tyre labels available in the retail database of VACO (VACO is the Dutch industry association for tyres and wheels). This provides the baseline for the calculation of the potential improvements for the shift to A-rated tyres.

The potential energy savings, safety improvements and noise reductions are assessed for all vehicle types, i.e. passenger cars (C1 tyres); vans (C2 tyres) and heavy-duty vehicles (C3 tyres). Hereby it is made use of available literature like publications, legislation by the European Commission and other relevant public information.

The overall savings potential for the Netherlands is calculated as the difference of the current distribution as determined in the VACO database and the potential distribution on A-rated tyres.

1.4 Structure of the report

This report is structured as follows. Chapter 2 provides information on the current tyre distribution in the Netherlands. More specifically, it shows how this distribution is determined and how this is relevant for the following chapters. In Chapters 3, 4 and 5, the potential benefit of A-rated tyres is calculated respectively for the parameters energy, safety and noise. Chapter 6 gives an overview of the overall benefit that could be reached for a shift towards AAA-rated tyres, i.e. for tyres with highest performance in all three categories. Chapter 7 closes with the discussion and recommendations.

2 The current distribution of tyres in the Netherlands

In this chapter, the distribution of tyres as currently used in the Netherlands is estimated. Tyres are classified according to the EU Regulation EC1222/2009. Since it is relevant for the following research, some background information is provided about tyre labelling in general in section 2.1. In section 2.2, the method to calculate the current tyre distribution is described. The results are given in the last section 2.3.

2.1 The tyre label

The EU Regulation [EC1222, 2009] prescribes the labelling of tyres with respect to fuel efficiency and other essential parameters and is introduced with the aim to inform consumers and subsequently make road transport

- more energy efficient,
- safer and
- less noisy.

The EU Regulation harmonises the information concerning the tyre performance in terms of fuel consumption, wet braking and external rolling noise, presented on a tyre label (Figure 2). Effectively, it should promote consumers that buy new tyres to choose actively for better tyres.

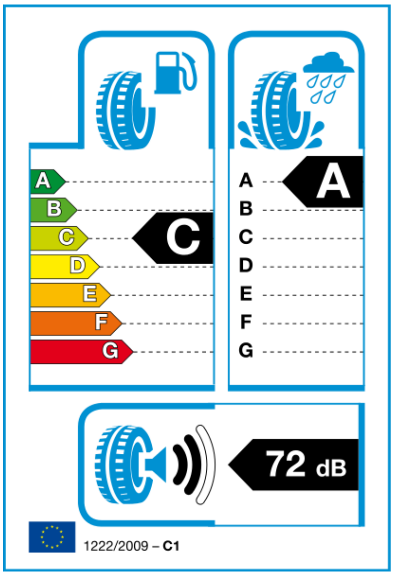


Figure 2: Example of a tyre label according to EC1222, 2009.

The tyre label applies to all tyres, C1 for passenger cars, C2 for vans and C3 tyres for heavy duty trucks and buses. Excluded from tyre labels are tyres for special uses (see appendix A).

C1, C2 and C3 tyres can be allocated to different and more than one tyre class. In this study, the allocation of tyres is done in such a way as to fit passenger cars (C1), distribution vehicles (C2) and heavy duty vehicles (C3).

2.2 Method

The distribution of tyre labels as used in this report is based on the tyre labels available in the retail database of VACO. VACO is the Dutch tyre and rim branch organization. This database contains all tyres currently available for sale in the Netherlands. The database is normally used by retail companies to support their sales and ordering administration. The status of 1 November 2013 is used. By using this database, the following assumptions are made:

- The study focusses on new tyres coming into the market, rather than existing tyres already mounted on vehicles;

- Tyres coming into the market via other channels (e.g. tyres mounted on new vehicles, tyre bought on internet) are assumed to have the same label distribution.

This approach was chosen because it is believed that this leads to a larger stability of the dataset (in time and location). Over time and location, the distribution can be dominated by the effect of several tyres with a large market share.

A method flow diagram of the approach is shown in Figure 3. From all the tyres available in the database a subgroup was used as data set. This set is based on the 7 brands and the 7 sizes with the highest market share. This smaller data set was used for the following reasons:

- The focus of this study is the mass production tyre, with significant market share and significant coherence with real-life situation on the road;
- The statistics of this control data set is not to be influenced by rare special purpose tyres or niche market products, with little market share and little influence on the real-life situation on the road;
- It is assumed that this control data set of tyres and its tyre label values is well correlated to the group of tyres found on new vehicles and the group of tyres that is sold via internet and other channels;
- This control data set is thought to be well representative for the tyres found in other EU countries;
- This data set is thought to be more reliable and stable over time when future regular evaluations are made.

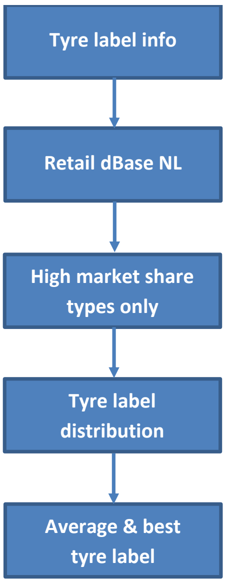


Figure 3: Method flow diagram – current distribution of tyres in the Netherlands

2.3 Current distribution of tyres in the Netherlands

Figure 4 shows the distribution of tyre label data for the control group, split into C1, C2 and C3 tyres. From this distribution a theoretical average tyre can be calculated. Table 6 shows this average value. For the further analysis the control data set is split down into summer/winter (C1 and C2), axle designation (C3), tyre width (C1), and load capacity (C1), as all of these indications influence the boarders of the label classes and therefore the actual performance. Further tables with this data are given in Appendix A.

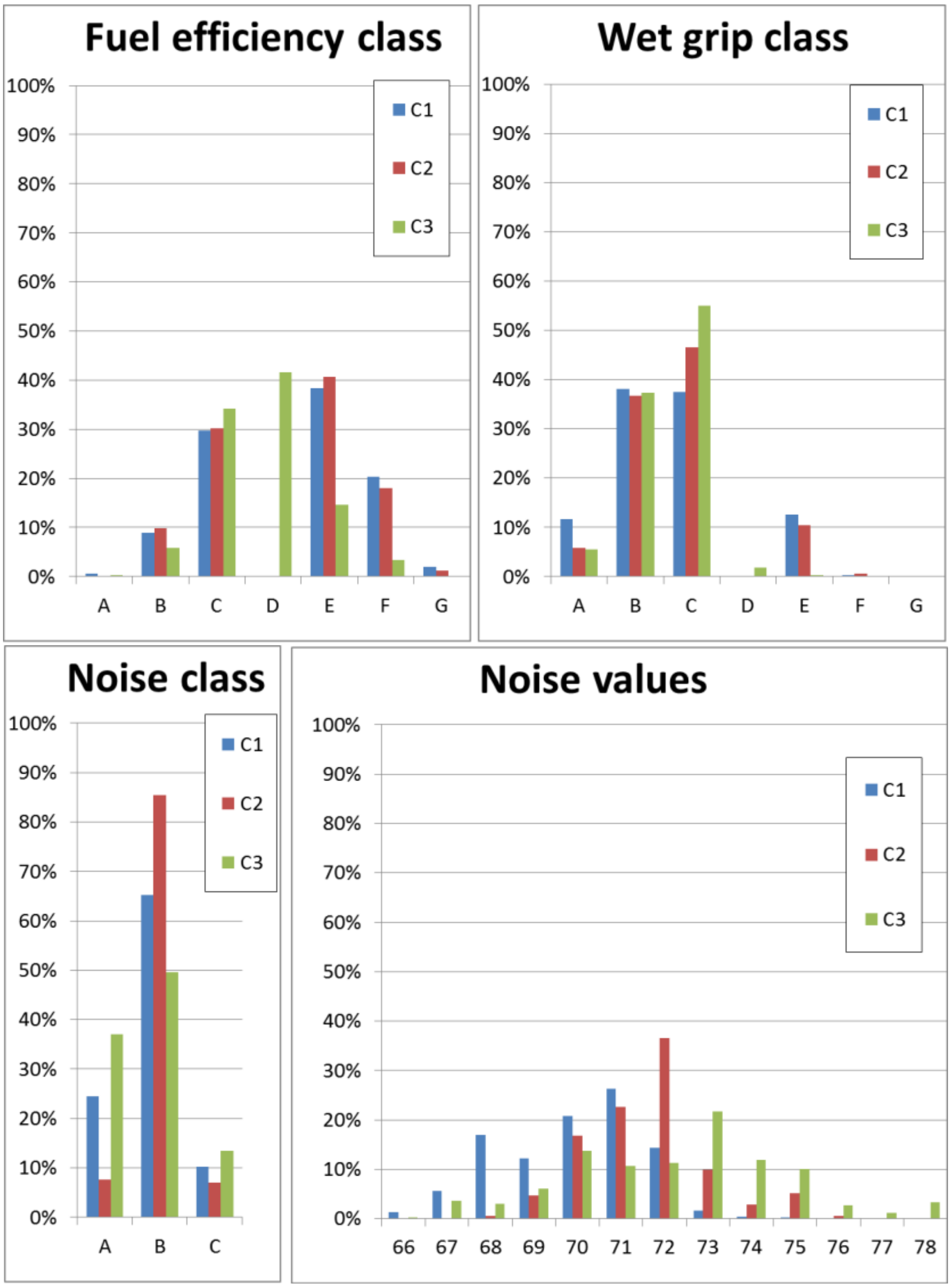


Figure 4: Distribution of tyre label data in the investigated control group. This control group is based on the 7 tyre brands and 7 tyre sizes with the biggest market share in the Netherlands.

Table 6: Average tyre label per tyre class and criterion, assuming A=1, B=2, C=3, etc.

	Fuel Efficiency	Wet Grip	Noise	Noise (dB)
C1	4.4	2.6	1.9	69.9
C2	4.3	2.7	2.0	71.6
C3	3.7	2.5	1.8	72.2

3 Energy savings potential

In this chapter, the energy savings potential of a shift to A-rated tyres for energy is evaluated for different vehicle types and tyre classes. The potential annual energy savings are calculated from an end-user and societal perspective in terms of fuel consumption (in litres), costs (in Euros) and CO_2 emissions (in tons).

In section 3.1 the method to determine the energy savings potential is described, followed by the calculations in section 3.2. The results are given in section 3.3.

3.1 Method

Figure 5 shows a method flow diagram of the steps taken to calculate the potential annual energy savings for A-rated tyres for energy.

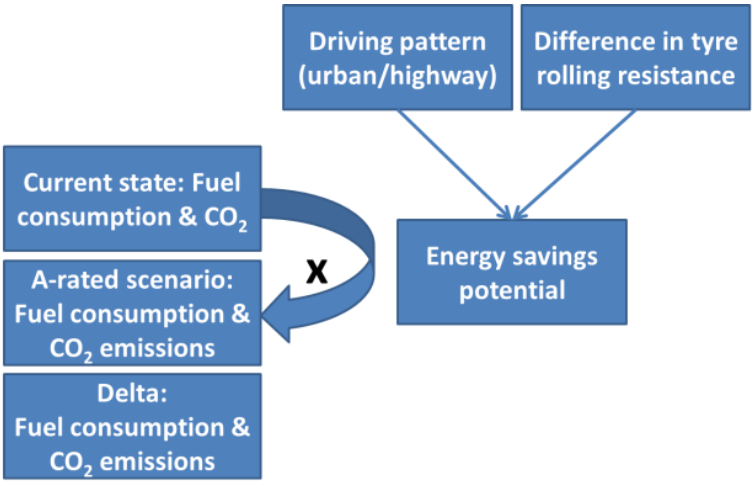


Figure 5: Method flow diagram

The energy savings potential related to switching tyre classes is calculated for different vehicle classes based on:
- the relative reduction in rolling resistance between the tyre X and tyre Y;
- the driving pattern, e.g. predominantly urban or highway.

The energy efficiency of road transport vehicles is largely determined by the vehicle's driving resistance, i.e. the sum of its air resistance, rolling resistance and inertia – the work required to overcome road gradients. The higher the resistance, the more work, and therefore fuel, is required to keep the vehicle in motion.

The rolling resistance of a vehicle depends on many factors of different sources: the vehicle (wheel load and wheel configuration), the road (texture, condition, evenness) and the tyre itself. The rolling resistance of a tyre depends on its geometry (rim width, tyre exterior radius, tyre cross section ratio), material (radial tyre stiffness), design, pressure and temperature.

While the rolling resistance is proportional to the vehicle weight and independent of the speed, the total amount of work required by the engine to overcome its driving resistances increases with speed. This is due to the fact that the vehicle's air resistance increases exponentially with speed and is 0 at 0 km/h. Effectively, the share of air resistance in the vehicle's total driving resistance increases with speed.

For the reasons mentioned above, the savings potential is dependent not only of the reduction in rolling resistance between tyre X and tyre Y, it also depends on the driving pattern. The energy savings potential is calculated as the relative difference in rolling resistance times the share of rolling resistance in overall driving resistances. For example: If rolling resistance accounts for 20 to 30% of the vehicle's fuel consumption and if tyre Y has a 10% lower rolling resistance than tyre X, the overall fuel consumption is reduced by roughly 2 to 3% (10% of 20-30%).

The annual energy savings are calculated in terms of:

- the fuel consumption (in litres);
- the cost savings due to reduced fuel consumption (in Euros) and
- the CO_2 emissions[1] (in tons).

For the calculation of the annual energy savings from an end-user perspective it is differentiated between the following vehicle groups, see Table 7.

Table 7: Assumption for the end-user perspective: tyre classes and vehicle segment

Tyre class	Vehicle segment
C1	Passenger cars (family, petrol)
	Passenger cars (lease, diesel)
	Service/delivery (diesel)
	Urban delivery/collection (diesel)
C2	Municipal utility (diesel)
	Regional delivery/collection (diesel)
C3	Long haul (diesel)
	Construction (diesel)
	Bus (diesel)
	Coach (diesel)

For the calculation of the annual energy savings from a societal perspective the savings potential of all vehicles in the Netherlands are summed up. The vehicle population is categorized into the following vehicle groups, see Table 8.

For both calculations, the end-user perspective as well as the societal perspective, passenger cars on petrol as well as passenger cars on diesel are regarded. Since the share of distribution and heavy duty vehicles driving on petrol are relatively small (close to 0% of all vehicles), all other vehicle segments are expected to drive on diesel. As already discussed above, tyres can be allocated to more than one tyre class foreseen that it complies to the relevant regulations. For the calculation of reduction potentials, the tyre classes are assumed to be such that C1 is typically for

[1] CO_2 emissions are directly proportional to fuel consumption. Based on a typical chemical composition of petrol or diesel fuel, the CO_2 mass emissions can be calculated by multiplication of the mass based fuel consumption with a factor of 3.05. The correlation factor between kg CO_2 and fuel consumption in litres is 2.609 for diesel and 2.365 for petrol.

passenger cars, C2 for urban vans and distribution vehicles and C3 for heavy duty vehicles and buses.

Table 8: Assumption for the societal perspective: tyre classes and vehicle segment

Tyre class	Vehicle segment
C1	Passenger cars (petrol)
	Passenger cars (diesel)
	Service/delivery (diesel)
C2	Distribution (diesel)
C3	Heavy duty (diesel)
	Bus (diesel)

3.2 Calculations

For the calculation of the energy savings potential related to switching tyre classes, assumptions are made for the following parameters:

- the relative reduction in rolling resistance;
- the driving pattern, e.g. predominantly urban or highway.
- the fuel consumption, mileage and fuel costs.

3.2.1 Relative reduction in rolling resistance

The tyre label for energy efficiency is classified in 7 categories, A to G. Each tyre label corresponds to a specific range of rolling resistances RRCs (see Table 9). The label differentiates between three tyre classes C1, C2 and C3. Since the exact values for the rolling resistance of tyres are not retraceable from their label, the relative difference in rolling resistance is calculated based on the average of the range of RRCs.

Table 9: Coefficient of rolling resistance (RRC) in kilograms per ton in %, RRC [EC1222, 2009]

Tyre label	Coefficient of rolling resistance (RRC) [in kilograms per ton in %]		
	C1	C2	C2
A	RRC ≤ 6.5	RRC ≤ 5.5	RRC ≤ 4.0
B	6.6 ≤ RRC ≤ 7.7	5.6 ≤ RRC ≤ 6.7	4.1 ≤ RRC ≤ 5.0
C	7.8 ≤ RRC ≤ 9.0	6.8 ≤ RRC ≤ 8.0	5.1 ≤ RRC ≤ 6.0
D	None	None	6.1 ≤ RRC ≤ 7.0
E	9.1 ≤ RRC ≤ 10.5	8.1 ≤ RRC ≤ 9.2	7.1 ≤ RRC ≤ 8.0
F	10.6 ≤ RRC ≤ 12.0	9.3 ≤ RRC ≤ 10.5	RRC ≥ 8.1
G	RRC ≥ 12.1*	RRC ≥ 10.6*	None

* will not be allowed for use after 01.11.2014

Table 10 shows the relative difference in rolling resistance when comparing tyre labels to A-rated tyres, respectively for the tyre classes C1, C2, C3. The relative difference can be very high as can be seen for example for C3 tyres: changing from F-rated tyres to A-rated tyres results in a 51% improvement of the tyres rolling resistance.

However this does not mean that fuel efficiency is improved by 51%. The fuel efficiency of a vehicle is determined by the energy savings potential. The energy savings potential of A-rated tyres is calculated by multiplying the relative reduction in rolling resistance (i.e. 51%) with the share of rolling resistances in overall driving resistances. The share of rolling resistance in overall driving resistances largely depends on the velocity of the vehicle and thus the vehicle's driving pattern (i.e. mostly urban vs mostly highway). In the following, the energy savings potential is calculated by use of a dedicated calculator designed by (order of) the European Commission [EC, 2013]. The resulting savings potential is shown in Table 11. Depending on the driving pattern, e.g. 100% urban or 100% highway, and the label level at which the tyre is switched, e.g. from label F to label A. the savings potential slightly differs. When relating to the earlier example, it is seen that an energy savings potential of 5.4-6% is possible when switching C3 tyres from F to A. This is still a conservative estimate when considering that the EC fuel calculator makes use of shares of rolling resistance to overall driving resistance of 10 to 18%. However, under certain circumstances this ratio can be as high as 30%. Effectively, this could result in a doubling of the energy savings potential.

Table 10: Relative reduction in rolling resistance (RRC) when switching to an A-rated tyre

Tyre label	Relative difference in rolling resistance [in %]		
	C1	C2	C3
A	0%	0%	0%
B	9%	11%	12%
C	23%	26%	28%
D	None	None	39%
E	34%	36%	47%
F	42%	44%	51%
G	46%	48%	None

Table 11: Energy savings potential when switching to an A-rated tyre

Tyre label	Energy savings potential [in %]		
	C1	C2	C3
A	0%	0%	0%
B	1.3-1.7%	1.2-1.3%	1.3-1.4%
C	3.3-4.1%	2.8-3.2%	3.0-3.3%
D	None	None	4.1-4.6%
E	4.9-6.2%	4.0-4.6%	5.0-5.5%
F	6.2-7.8%	4.8-5.6%	5.4-6.0%
G	6.7-8.5%	5.2-6.0%	None

3.2.2 *Driving patterns*

The driving patterns of different vehicle types in the Netherland are well researched and segmented into the categories urban, rural and highway [PBL, 2013]. The EC fuel consumption calculator only differs between the driving patterns urban and highway. Rural driving patterns are therefore equally (50%/50%) distributed over urban and highway driving patterns. The effective share of the driving patterns is shown in Table 12 together with an estimate for the energy savings potential for summer tyres and winter tyres. Hereby, the current tyre use is assumed for C1, C2 and C3 tyres as previously discussed in chapter 2. For the calculation of the energy savings potential from the societal perspective, the same approach is taken as for an end-user perspective (compare with Table 13).

Table 12: Estimated driving pattern and the resulting energy savings potential from an end-user perspective

Tyre class	Vehicle segment	Driving pattern	Energy savings potential (summer)	Energy savings potential (winter)	Energy savings potential (average)
		[%] urban / [%] highway	[%]	[%]	[%]
C1	Passenger cars (family, petrol)	43 / 57	4.80%	5.65%	5.23%
	Passenger cars (lease, diesel)	43 / 57	4.80%	5.65%	5.23%
	Service/delivery (diesel)	32 / 68	4.92%	5.78%	5.35%
	Urban delivery/collection (diesel)	32 / 68	4.92%	5.78%	5.35%
C2	Municipal utility (diesel)	80 / 20	3.27%	4.08%	3.68%
	Regional delivery/collection (diesel)	60 / 40	3.36%	4.21%	3.78%
C3	Long haul (diesel)	20 / 80	4.05%	4.05%	4.05%
	Construction (diesel)	50 / 50	3.93%	3.93%	3.93%
	Bus (diesel)	73 / 27	3.84%	3.84%	3.84%
	Coach (diesel)	50 / 50	3.93%	3.93%	3.93%

Table 13: Estimated driving pattern and the resulting energy savings potential from a societal perspective

Tyre class	Vehicle segment	Driving Pattern	Energy savings potential (summer)	Energy savings potential (winter)	Energy savings potential (average)
		[%] urban / [%] highway	[%]	[%]	[%]
C1	Passenger cars (petrol)	43 / 57	4.80%	5.65%	5.23%
	Passenger cars (diesel)	43 / 57	4.80%	5.65%	5.23%
	Service/delivery (diesel)	32 / 68	4.92%	5.78%	5.35%
C2	Distribution (diesel)	20 / 80	3.55%	4.45%	4.00%
C3	Heavy duty (diesel)	20 / 80	4.05%	4.05%	4.05%
	Bus (diesel)	73 / 27	3.84%	3.84%	3.84%

3.2.3 *Fuel consumption, mileage and fuel costs*

Further assumptions are made for the different vehicle categories in terms of:

- the average annual mileage;
- the average fuel consumption;
- the average fuel cost (petrol and diesel).

For the end-user perspective, the average annual mileage as well as the average fuel consumption for different vehicle segments is provided in Table 14, as given for LCVs and HDVs in [TIAX, 2011]. Estimates for passenger cars are taken from [CBS, 2012].

Table 14: Estimates for fuel type, annual mileage and fuel consumption [TIAX, 2011][CBS, 2012]

Tyre class	Vehicle group	Annual mileage	Fuel consumption
		[km]	[l/100 km]
C1	Passenger cars (family, petrol)	17000	7.5
	Passenger cars (lease, diesel)	35000	6.3
	Service/delivery (diesel)	35000	16.0
	Urban delivery/collection (diesel)	40000	21.0
C2	Municipal utility (diesel)	25000	55.2
	Regional delivery/collection (diesel)	60000	25.3
C3	Long haul (diesel)	130000	30.6
	Construction (diesel)	50000	26.8
	Bus (diesel)	50000	36.0
	Coach (diesel)	52000	27.7

For the societal perspective, the average annual mileage and fuel consumption of all vehicles is taken from [PBL, 2013] (see Table 15).

Table 15: Estimates for annual mileage and fuel consumption [PBL, 2013]

Tyre class	Vehicle group	Annual mileage	Fuel consumption
		[Mkm]	[l/100 km]
C1	Passenger cars (petrol)	74724	6.4
	Passenger cars (diesel)	33200	5.5
	Service/delivery (diesel)	17599	6.5
C2	Distribution (diesel)	270	13.2
C3	Heavy duty (diesel)	7073	32.1
	Bus (diesel)	624	31.1

When calculating costs savings, different fuel prices are used for the societal and the end-user perspective. Societal costs do not include the VAT or any excise duty. The used fuel prices are derived from the average national fuel prices, the GLA (Gemiddelde Landelijke Adviesprijs = Average National Price Advice), given in Table 16 [ANWB, 2014].

Table 16: Fuel prices used for societal and end-user perspective [ANWB, 2014]

	Fuel price – end-user perspective (incl. excise duty, incl. VAT)	Fuel price – societal perspective (excl. excise duty, excl. VAT)
	[€/l]	[€/l]
Diesel	1.50	0.76
Petrol	1.75	0.68

3.3 Potential Benefits Energy

Beneath, the results of energy savings are discussed for an end-user and a societal perspective.

3.3.1 End-user perspective

End-users can expect to save a considerable amount of fuel, costs and CO_2 switching to A-rated tyres (see Table 17). For all vehicle groups, the estimated energy savings potential is on average between 3.5 to 5.5%. Fuel cost savings range from 117€ per year for an average passenger car on petrol to 2418€ per year for long-haul trucks.

Table 17: End-user perspective: Annual fuel, cost and CO_2 reduction in case of changing to A-labelled tyres.

Tyre class	Vehicle group	Energy savings potential (average)	Annual fuel savings	Annual cost savings	Annual CO_2 reduction
	[]	[%]	[l]	[€]	[tCO_2]
C1	Passenger cars (family, petrol)	5.23%	67	117	0.2
	Passenger cars (lease, diesel)	5.23%	114	171	0.3
	Service/delivery (diesel)	5.35%	300	449	0.8
	Urban delivery/collection (diesel)	5.35%	449	674	1.2
C2	Municipal utility (diesel)	3.68%	507	761	1.3
	Regional delivery/collection (diesel)	3.78%	574	862	1.5
C3	Long haul (diesel)	4.05%	1612	2418	4.2
	Construction (diesel)	3.93%	526	790	1.4
	Bus (diesel)	3.84%	691	1036	1.8
	Coach (diesel)	3.93%	566	849	1.5

3.3.2 Societal perspective

The results from a societal perspective are given in Table 18. These results show that a considerable reduction of fuel, costs and CO_2 can be achieved with a switch to A-labelled tyres with respect to energy, in total 506Ml of fuel, 365M€ and 1.3Mton of CO_2. The energy savings potential for the various vehicle groups vary between 3.5 to 5.5%. Overall cost savings are the highest for passenger cars (170M€ for vehicles on petrol and 72M€ for vehicles on diesel). This is caused by the fact that nearly 90% of the vehicle population are passenger cars. Cost savings for distribution trucks are lowest due to their share in annual mileage. Heavy duty vehicles account for cost savings of roughly 70M€.

Table 18: Societal perspective: Annual fuel, cost and CO_2 reduction in case of changing to A-labelled tyres.

Tyre class	Vehicle group	Energy savings potential (average)	Annual fuel savings	Annual cost savings	Annual CO_2 reduction
	[]	[%]	[Ml]	[M€]	[$MtCO_2$]
C1	Passenger cars (petrol)	5.23%	249	170	0.59
	Passenger cars (diesel)	5.23%	95	72	0.25
	Service/delivery (diesel)	5.35%	61	46	0.16
C2	Distribution (diesel)	4.00%	1	1	0.00
C3	Heavy duty (diesel)	4.05%	92	70	0.24
	Bus (diesel)	3.84%	7	6	0.02
		TOTAL	506	365	1.26

Note
The above-shown results do not include additional investment costs of A-rated tyres. This has not been taken into account, since there is little evidence that tyre costs and performance are correlated [IN, 2013]. Furthermore, it is important to realize that the cost savings potential for the end-user is significant. This is illustrated with a short example.

Assuming the following for a passenger car :
- Annual mileage: 17000 km/year
- Fuel consumption: 7.5 l/100km
- Fuel savings potential: 5% (112€/year)
- Tyre lifetime: 4 years
- Discount rate: 4%
- Petrol price: 1.75€/l

Even at an additional investment cost of 400€ (100€ per tyre), the investment in A-rated energy tyres are advantageous for the end-user. At a fuel savings potential of 5% the same amount is earned back over 4 years. The net present value (NPV) of all fuel savings amount to 408€. These cost savings are far greater than the price differences of tyres for passenger cars.

4 Safety improvement potential

This chapter deals with the safety potential of a shift to A-rated tyres. The potential annual safety improvement is calculated as reduced (severe) injuries, fatalities and their societal monetary benefits.

In section 4.1 the method to determine the safety improvement potential is described, followed by the calculations in section 4.2. The results are given in section 4.3.

4.1 Method

The safety impact study is aimed to assess the safety potential of a shift to ‘A labelled’ tyres. The safety label for tyres is related to the wet grip performance of tyres. The wet grip performance and dry grip performance are determined by different tyre characteristics. The dry grip performance is therefore not related to the safety label for tyres and thus not assessed in this study. The wet grip performance is assessed by measuring the friction potential, which is highly correlated to the acceleration levels that can be achieved with the vehicle. From the acceleration levels the safety related quantities such as braking distance and safe cornering speed can be calculated.

In this study the braking distance and resulting impact speed for tyres with various labels is related to personal injury. This can in its turn be related to the mutual societal cost/benefit of the use of tyres with the regarded labelling. The distribution of tyres with each of the labels equipped on vehicles on Dutch roads, as presented in Chapter 2 is used to get an indication of the overall cost reduction.

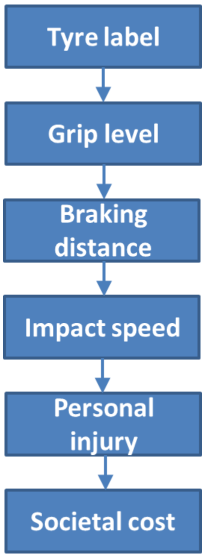


Figure 6: Method flow diagram

Figure 6 shows a flow diagram of this method. Each part of the method shown in this figure is discussed more elaborated in the calculations section.

4.2 Calculations

Several assumptions are made in the translation from impact speed reduction to societal cost. These assumptions are listed below:

- A division of accidents in car to pedestrian accidents and city roads, rural roads and motorway car to non-pedestrian accidents is used in the current study.
- Data from the German In-Depth Accident Study (GIDAS) database regarding impact speeds for the scenarios investigated in the European Assessment of vehicle Safety Systems (ASSESS) project [ASSE,2011] is also representative for the situation in the Netherlands and is applied to the generalized scenarios used in this study
- Data on impact speed for pedestrian related accidents in the European project on Assessment methodologies for forward looking Integrated Pedestrian and further extension to Cyclists Safety (AsPeCSS) project [ASPE,2013] is used for the generalized pedestrian scenario this study.
- The injury risk relation for pedestrians is taken from the database created in the UK On The Spot (OTS) project [TRL, 2010] and applied to the situation in the Netherlands.
- The injury risk relation for car occupants from the ASSESS project is applied to the generalized scenarios used in this study
- The Bestand geRegistreerde Ongevallen in Nederland (BRON) accident data from 2009 [BRON, 2009] is used to reflect the current situation in the Netherlands.
- The factor of decrease in chance of injury or fatality, found from the injury risk relations for the calculated reductions of impact speed, is used to calculate the reduction of injuries and fatalities.

The labelling of tyres related to safety concerns wet grip. The wet grip is defined relative to the wet grip of a reference tyre, which is tested under the same conditions as the labelled tyre. In the analyses the calculation is done for a wet grip level of the reference tyre of 0.6 (this is in the required range defined by the standard). The resulting grip levels for different tyre labels are listed in Table 19. As a reference a grip level for non-labelled tyres is set at the legal requirement for passenger car braking performance according to ECE R13H [ECER13H, 2014] (defined for dry roads). For the following statistics, passenger cars predominantly use C1 tyres, light trucks (vans and light-weight trucks) use C2 tyres and heavy trucks use C3 tyres.

Table 19: Wet grip levels for different tyre labels (categories D and G are not used in the labelling)

Tyre label	Wet grip level		
	C1	C2	C3
A	>0.92	>0.84	>0.75
B	0.84 – 0.92	0.75 – 0.83	0.66 – 0.74
C	0.75 – 0.83	0.66 – 0.74	0.57 – 0.65
D	None	None	0.48 – 0.56
E	0.66 – 0.74	0.57 – 0.65	0.39 – 0.47
F	0.6 – 0.65	0.53 – 0.56	0.35 – 0.38
G	None	None	None
Legal limit	>0.52	>0.5	>0.5

4.2.1 *Braking distance*

The wet grip levels are used for the calculation of the braking distance. Figure 7 shows a comparison of the theoretical braking distance for a speed range up to 130 km/h.

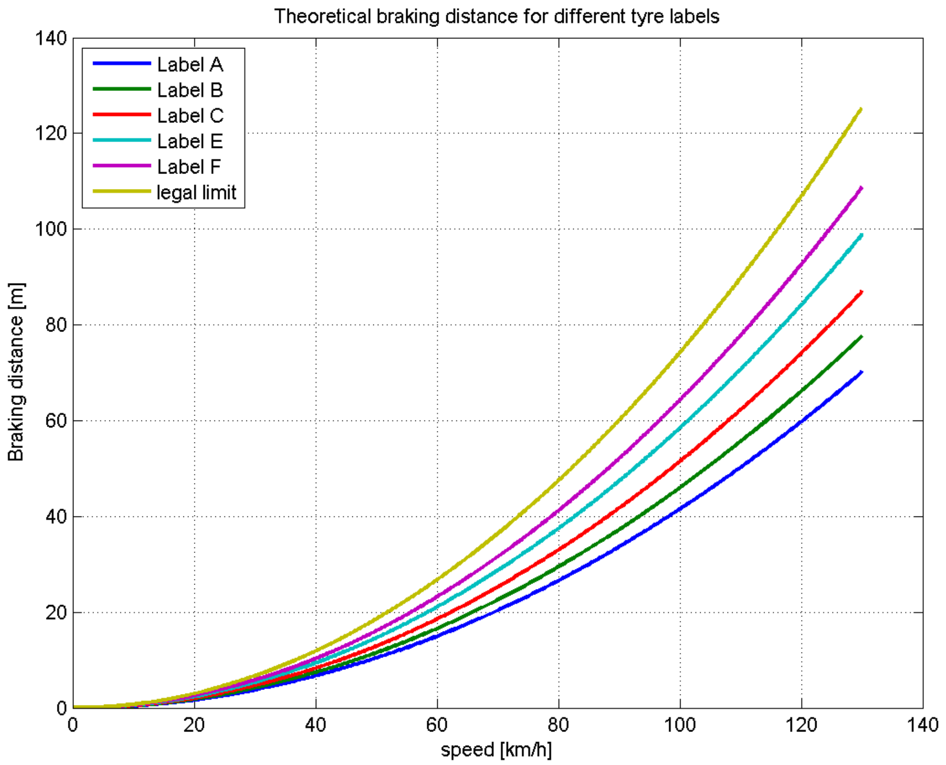


Figure 7: Brake distance calculated using grip levels of tyre labels and the legally required grip level according to regulation ECE R13H [ECER13H, 2014]

As can be seen the difference in braking distance is significant for the different tyre label classes. Table 20 provides a summary of the braking distance comparison for some commonly used legal maximum speed limits on Dutch roads.

Table 20: Calculated braking distance for different tyre labels and the legal limit at initial speeds 50, 80, 100 and 130 km/h

Tyre label	50 km/h	80 km/h	100 km/h	130 km/h
A	10.4	26.6	41.5	70.1
B	11.5	29.4	45.9	77.6
C	12.9	32.9	51.4	86.9
E	14.6	37.4	58.5	98.8
F	16.1	41.2	64.3	108.7
Legal limit	18.5	47.5	74.2	125.4

4.2.2 *Impact speed*

As can be seen in Table 20 the braking distance increases when tyres are used with less grip. As a result, a vehicle which has tyres with less grip may have a collision with a higher impact speed compared to using A-rated tyres.
A calculation is done for a scenario where the vehicle with A-rated tyres will reach standstill, just avoiding a collision. As an example Figure 8 shows the development

of speed in relation to distance for different tyre labels from an initial speed of 100 km/h.

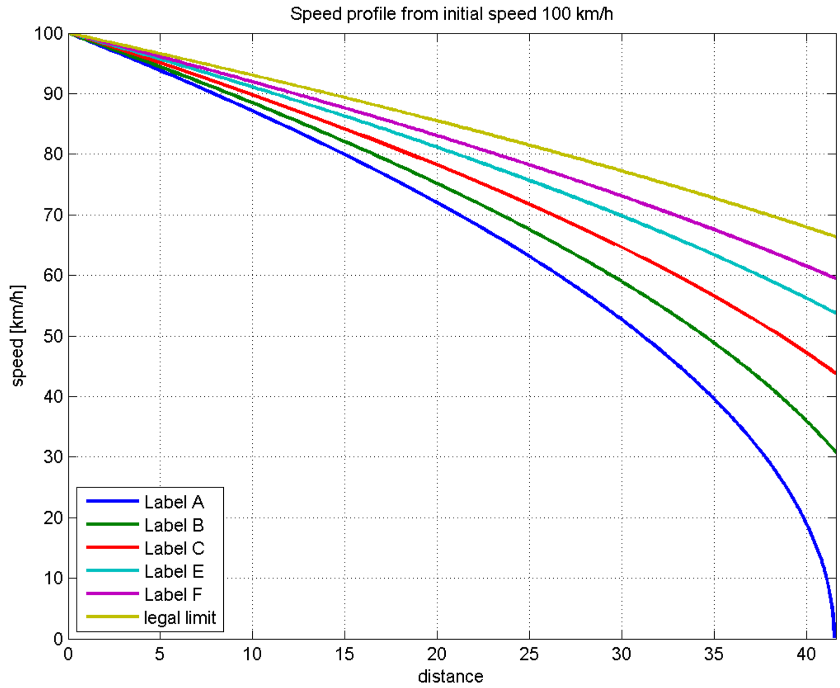


Figure 8: Example speed profile used for Impact speed assessment

In the ASSESS project data is gathered on the impact speed for typical car to car accident scenarios, based on information from the GIDAS database. This data is also categorized for three road types: urban, rural and motorway. Furthermore the AsPeCSS project provides data on the initial speed and impact speed of several car to pedestrian accidents. Based on this data Table 21 is constructed, showing the initial vehicle speed and average impact speed assumed in the current study.

Table 21: Average initial vehicle speed and impact speed of the accident scenarios used in this study

Accident scenario	Urban road car to car	Rural road car to car	Motorway car to car	Car to pedestrian
Initial speed (km/h)	50	80	120	48
Impact speed (km/h)	30	46	91	35

From the information in Table 21 the brake distance for every scenario can be calculated for each tyre label. For example, when a vehicle equipped with E label tyres would be involved in an average car to pedestrian accident, the braking distance used by that car to brake from 48 to 35 km/h can be calculated using the maximum deceleration that can be achieved with E label tyres. When this same distance would be available to decelerate a vehicle using A label tyres, the velocity of this vehicle at the moment of impact would be significantly reduced with respect to the vehicle which is using E label tyres. Using this method the benefit of A label tyres with respect to any other label, expressed in a reduction of impact speed, can be calculated for each scenario.

4.2.3 *Personal injury*

The change of impact speed when using a A-rated tyre with respect to any other tyres can be translated into a change of injury risk using a relation such as shown in Figure 9 for car occupants and in Figure 10 for pedestrians (based on the OTS database), [TRL, 2010].

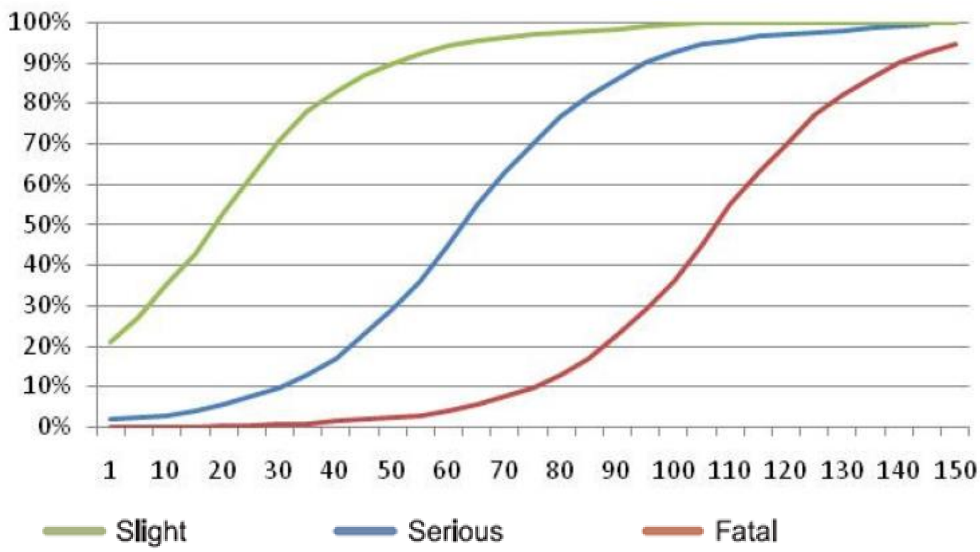


Figure 9: Injury risk of passenger car occupants depending on impact speed (in km/h)

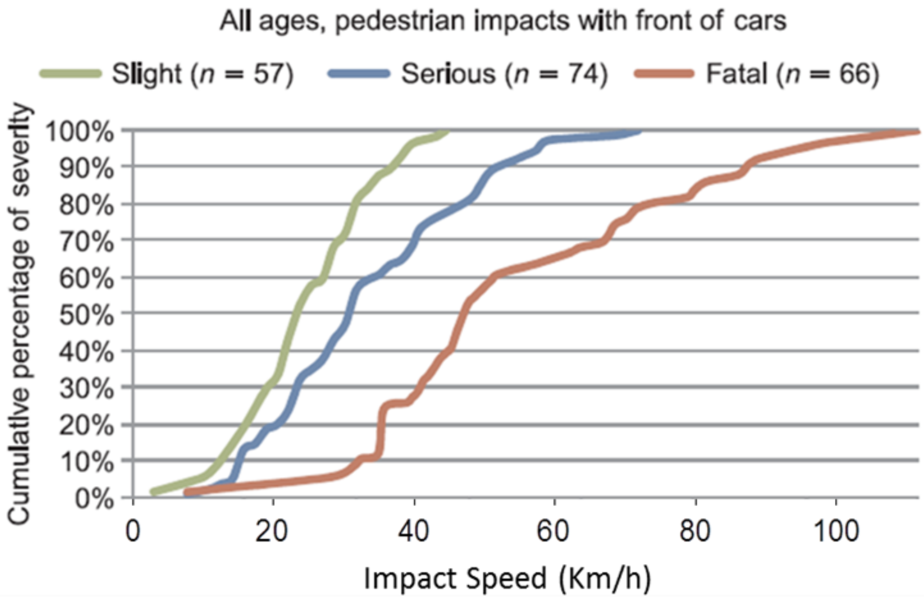


Figure 10: Injury risk of passenger pedestrians depending on impact speed (in km/h)

In these figures the chance is given for a person involved in an accident being at least slightly injured, at least seriously injured or being a fatality as a function of the accident impact speed. For example Figure 8 shows that approximately 50% of the people involved in an accident with an impact speed of 50 km/h is slightly injured or worse and approximately 5% is seriously injured or worse.

4.2.4 *Societal cost*

To calculate the total societal cost reduction each case of slight injury, serious injury or fatality which is reduced is multiplied with the societal cost assumed for each of these casualties. Based on [RWS, 2012] the following figures are used:

- € 2.5 million societal cost per fatality
- € 280000 societal cost per serious injury
- € 9000 societal cost per slight injury.

The BRON database [BRON, 2009] provides information on the number of slight injuries, serious injuries and fatalities regarding the accident scenarios investigated in the current study. The most recent data, from 2009, are shown in Table 22, Table 23 and Table 24 for wet surface conditions, respectively for passenger cars, vans and trucks.

Table 22: Passenger car accident statistics [BRON, 2009] - Slight injuries, serious injuries and fatalities for the regarded scenarios in accidents on Dutch roads on **wet road** surface conditions

	City road (car-to-car)	Rural road (car-to-car)	Motorway (car-to-car)	Pedestrian (car-to-pedestrian)
Fatality	19	52	18	8
Serious injury	327	226	74	56
Slight injury	1777	686	310	128

Table 23: Van accident statistics [BRON, 2009] - Slight injuries, serious injuries and fatalities for the regarded scenarios in accidents on Dutch roads on **wet road** surface conditions

	City road (van-to-car)	Rural road (van-to-car)	Motorway (van-to-car)	Pedestrian (van-to-pedestrian)
Fatality	6	1	0	3
Serious injury	33	36	10	8
Slight injury	113	92	34	15

Table 24: Truck accident statistics [BRON, 2009] - Slight injuries, serious injuries and fatalities for the regarded scenarios in accidents on Dutch roads on **wet road** surface conditions

	City road (truck-to-car)	Rural road (truck -to-car)	Motorway (truck -to-car)	Pedestrian (truck -to-pedestrian)
Fatality	0	2	2	0
Serious injury	3	15	7	1
Slight injury	21	21	16	2

4.3 Potential Benefits Safety

The reduced number of fatalities, serious injuries and slight injuries and their societal monetary benefits are shown in Table 25, respectively for C1, C2 and C3 tyres and in total. The results are separately discussed below.

Table 25: Reduced number of fatalities, serious injuries, slight injuries and societal benefits respectively for C1, C2 and C3 tyres

	C1	C2	C3	TOTAL	Societal monetary benefits [M€]
Reduced number of fatalities	37	4	2	43	107.5
Reduced number of serious injuries	218	29	13	260	72.8
Reduced number of slight injuries	323	10	30	364	3.3
Societal monetary benefits [M€]	156.5	18.2	8.9	183.6	183.6

The information in Figure 9 and Figure 10 is used to translate a calculated reduction of impact speed into a percentage decrease of slight injuries, serious injuries and fatalities. These percentage decreases for the transition from each individual tyre label to the A label are weighted using the tyre label distribution in the Netherlands. This leads to an overall percentage decrease in slight injuries, serious injuries and fatalities when using A label tyres only instead of the current distribution. The overall percentage decreases are applied to the numbers of slight injuries, serious injuries and fatalities as found in Table 22, Table 23 and Table 24, leading to a reduction of these casualties in absolute numbers.

4.3.1 C1 tyres

The number of reduced casualties per injury level is shown in Figure 11. Note that, for example, preventing a person from being fatally injured in an accident does not mean that this accident is prevented from happening altogether. The involved person will most likely be seriously injured instead. Nevertheless, the number of reduced serious injuries is larger than the number of people that will be seriously injured instead of fatally injured. Therefore there is still an absolute reduction of costs involved with serious injuries. The same applies for the reduction of serious injuries and slight injuries.

Using the assumptions for the societal costs presented in paragraph 4.2.4 the results of Figure 11 add up to a reduction in societal cost of 156M€ per year.

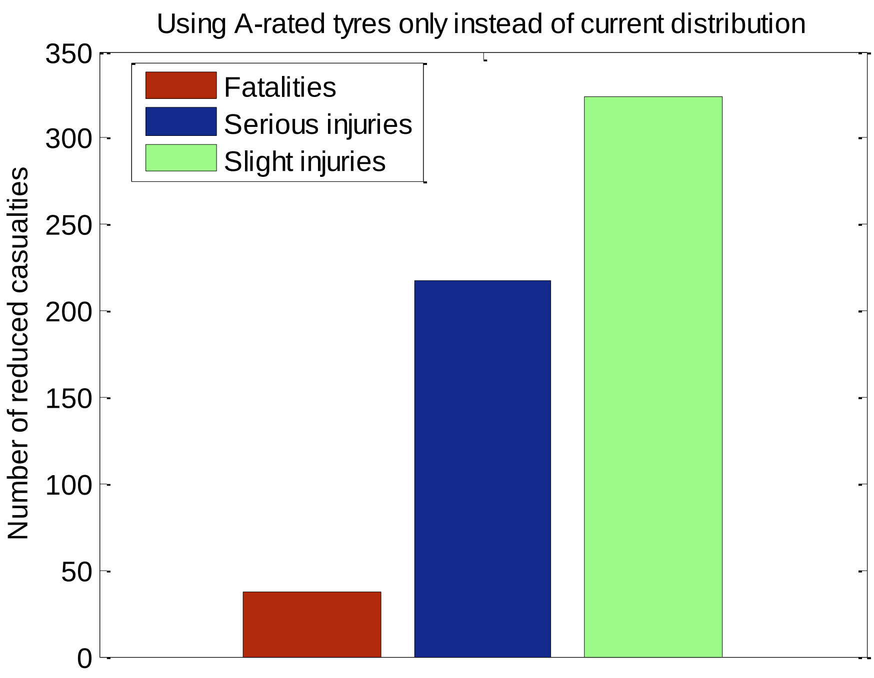


Figure 11: Reduction of casualties per year when using A-labelled tyres only instead of the current C1 tyre label distribution, regarding car-related accidents on Dutch roads on wet surface conditions in 2009

4.3.2 *C2 tyres*

Based on the above mentioned information on car and van accidents, the number of reduced casualties per injury level is shown in Figure 12. The reduction in societal costs amounts to 19M€ per year. Note that the reduction of fatalities and serious injuries are relatively high for van-related collisions; respectively 4 out of 10 and 30 out of 87 casualties. For slight injuries, the number of reduced casualties is considerable less (10 out of 254). Reasons for this phenomenon are among others a higher average mass of vans and lower wet grip properties of C2-tyres.

BRON does not provide separate split-up information for light trucks and heavy trucks. Instead, light and heavy trucks data are combined, and van data is reported separately. In order to estimate the potential safety benefit for light trucks (vans and light-weight trucks), the injury information of van-related accidents was used (see Table 23). Using only injuries of these van-related accidents provides a lower boundary for the reduction of societal costs. The actual societal cost reduction for C2 tyres is higher, but cannot be estimated with the available information.

It is important to note that not all accident-related information is available for light trucks versus car collisions. This data is required to calculate the reduction of societal costs. However accident studies using GIDAS accident data have indicated that the accident scenarios and conditions of light truck collisions on main roads are almost identical to passenger car collisions with respect to impact speed. Assuming equivalent accident behavior, the accident scenarios and injury risks of passenger car collisions have been applied to light trucks as well.

Because light-good vehicles have higher masses than passenger cars, and consequently a higher impact, the injury risk characteristic was corrected for masses. This correction was done by assuming equal kinetic energy ($E_{kin}=0.5mv^2$) at the impact.

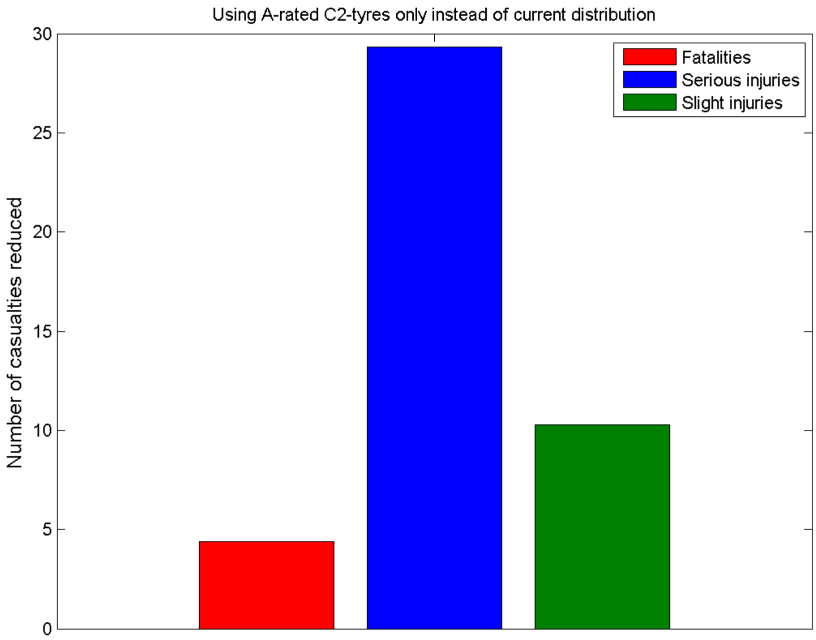


Figure 12: Reduction of casualties per year when using A-labelled tyres only instead of the current C2 tyre label distribution, regarding van-related accidents on Dutch roads on wet surface conditions in 2009

4.3.3 *C3 tyres*

As an initial estimate, it is assumed that wet grip A-label C3 tyres can reduce the casualties of each injury level by half (50%). Based on this assumption a reduction in societal costs of 9M€ per year can be achieved (see Figure 13).

It is important to note that due to lack of accident-related information for C3 tyres, it is not possible to use the same approach as used for C1 tyres to calculated the total reduction in societal costs. Information such as accident scenarios, impact speeds, injury risk characteristics, accident conditions etc. are not available from literature. In addition, the characteristics of cars cannot be adapted for trucks. Truck related accidents are more severe as on average there are more collision partners involved, more persons injured, higher injury levels, less wet grip, etc.

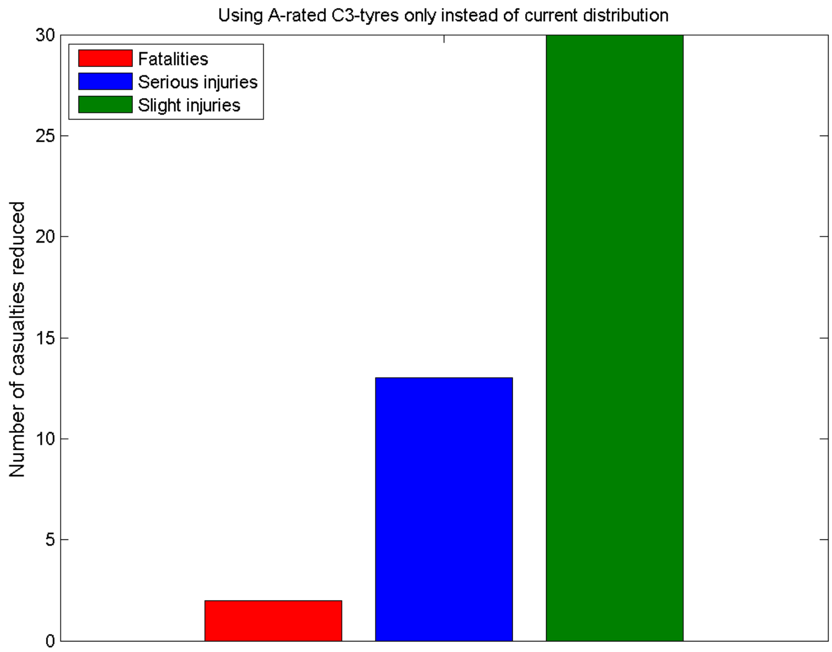


Figure 13: Reduction of casualties per year when using A-labelled tyres only instead of the current C3 tyre label distribution, regarding truck-related accidents on Dutch roads on wet surface conditions in 2009

5 Noise reduction potential

In this chapter, the noise reduction potential of the best performing tyres for noise is evaluated when compared to the 'average' tyre as currently used in the Netherlands. The noise reduction potential is calculated first as reduced noise levels in streets and highways. Based on the reduced noise levels reduced numbers of (highly) annoyed and (highly) sleep disturbed people are derived and their associated societal monetary benefits.

In the first section the computation method is described, followed by an overview of the calculations made in section 5.2. The results of the different computation steps are summarized and discussed in sections 5.3 and 5.4.

5.1 Method

The potential benefits in terms of environmental impact and health of a transition from the currently available tyre mix to tyres with the best performance for external rolling noise emission are computed according to the methods and assumptions that were developed in the VENOLIVA (VEhicle NOise LImit VAlues) study under assignment of the EC [VENO, 2011].

In this method the EC data base of type approval test results was used to assess the expected noise emission reduction during the acceleration and the constant speed tests caused by noise reducing measures, either to the power train or to the tyres or to both. From this emission reduction during the test the emission reduction in normal traffic was estimated, making a distinction between accelerating and free flowing traffic.

The five different vehicle types used in the VENOLIVA computation method, were regrouped into three different vehicle categories (Light, Medium and Heavy) to be consistent with the Dutch statutory noise impact calculation method [RMV, 2012]. The actual in-traffic noise reductions were differentiated for seven speed / traffic situations and five road surface types. After averaging of the relevant combinations noise reductions for eight different road types were derived. These values were used to carry out noise impact calculations for these eight road types, as well for the reference situation in 2013 as for a situation in which all vehicles would be equipped with the best performing low noise tyres according to the tyre label values.
The final step was to compute the total numbers of annoyed and sleep disturbed people in The Netherlands for the reference situation and for the situation with best performing low noise tyres. See also the flow diagram in Figure 14.

The monetised benefits are calculated for property valuation and avoided health costs due to reduced environmental noise levels. These figures are considered conservative estimates. Savings due to reduced costs for noise abatement by noise barriers, quiet road surfaces and dwelling sound insulation are not included as these are relatively much lower.

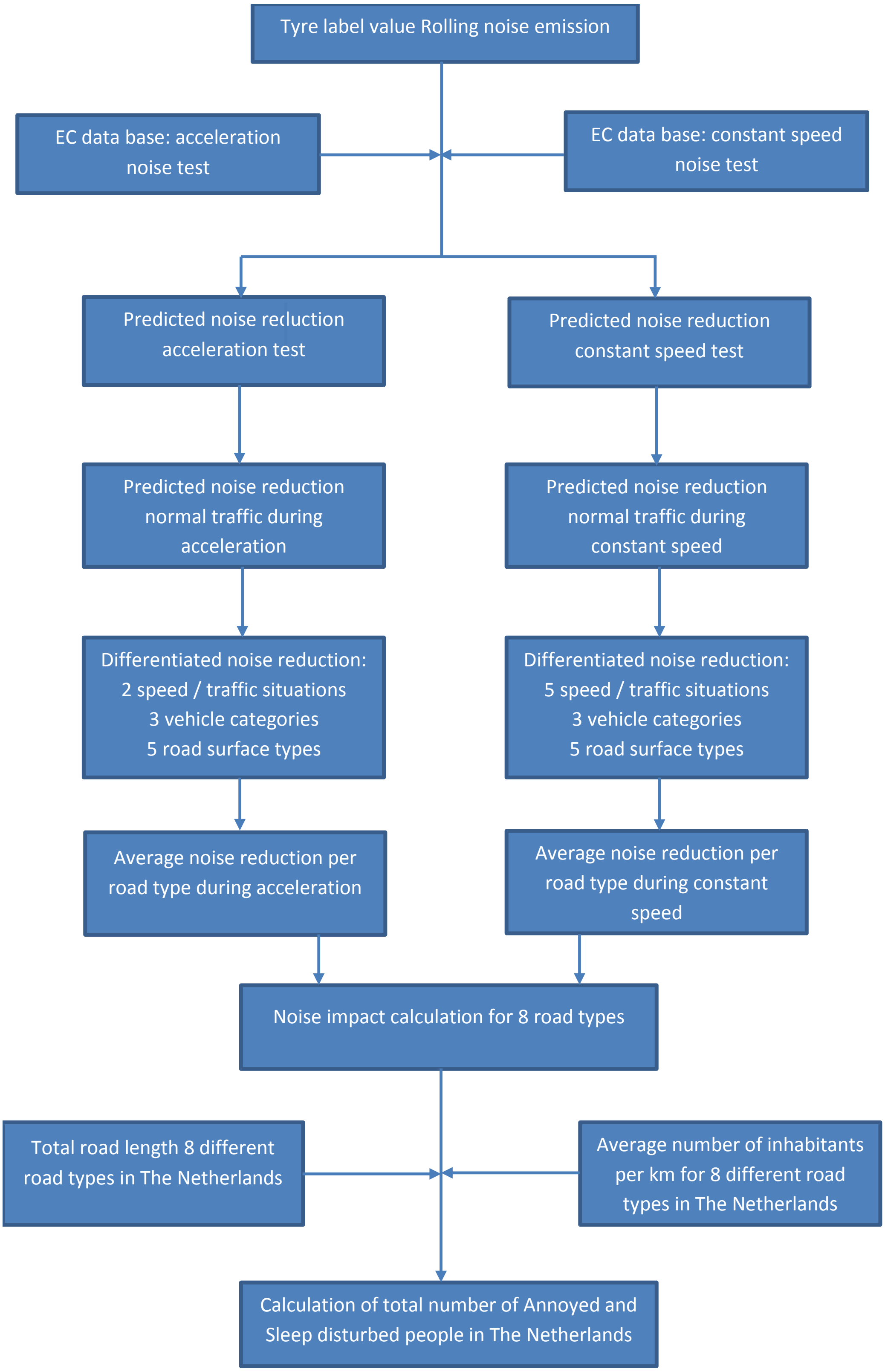


Figure 14: Flow diagram of the computation method for noise impact and numbers of annoyed and sleep disturbed people

5.2 Calculations

The characteristics of the currently available tyres were derived from the data in the VACO tyre label database (see Chapter 2). Hereby, a distinction was made between the tyre classes C1, C2 and C3. Within these classes the following sub-divisions are made, following the specification of the noise emission limit values:

C 1	Summer tyre	Winter tyre	
	Section width ≤ 185 mm	Section width 195 - 245 mm	
	With extra Load capacity	Without Extra Load capacity	
C 2	Summer tyre	Winter tyre	
C 3	Traction tyre	Steering tyre	Trailer tyre

The first computation step was to derive the average reductions of the tyre rolling noise for each of the tyre classes assuming a transition of the average noise emission of the current tyre mix in each sub-category of a tyre class to the best performing low noise tyre sample within this sub-category. The results of this derivation are given in Table 26. The average reductions for the three tyre classes were determined.

The second step was to compute the effective reductions of in-traffic vehicle noise emissions, resulting from a reduction of the average rolling noise emission as specified in Table 26. The reductions were computed as a function of the following road and traffic characteristics:

- Vehicle category: Light Vehicles (LV), Medium Vehicles (MV) and Heavy Vehicles (HV)
- Operating condition: Accelerating or Free flowing (= constant speed)
- Driving speed: 30, 40, 50, 80, 100 and 120
- Type of road surface:
  - Dense Asphalt Concrete (DAC),
  - Porous Asphalt Concrete (PAC),
  - 2-layer PAC,
  - 2-layer PAC with fine grading of the top layer (2/4 mm)
  - Thin noise reducing surface layer (porous or semi-porous)

The results of these computations are given in Appendix B.

The third step was to compute the reduction of the characteristic noise impact of a traffic flow for 8 different road / traffic combinations as specified in Table 27. The computations were based on the vehicle noise emission values from the Dutch statutory noise impact calculation method [RMV, 2012], diminished with the relevant noise reduction numbers derived from Appendix B. The results of this step are given in Table 28 and in Table 29.

The fourth step was to compute the reduction of the numbers of (highly) annoyed and (highly) sleep disturbed people from the changes of the traffic flow noise impact. These computations were carried out using the dose-effect relationships for road traffic noise as recommended in the position paper published by the EC [Annoy, 2002]. The results in terms of the changes of the numbers and in percentages are given in Table 30 and Table 31 and in Figure 15 and Figure 16.

Table 26: Weighted average reductions of tyre rolling noise per tyre class and sub-category – derived from label values in VACO database

Tyre class	Summer/ Winter	Section width	Extra Load	Number in data-base	Limit value cf. Reg (EC) 661/2009	Average rolling noise emission of sub-category	Best performing low noise sample of subcategory	Estimated reduction of rolling noise emission
C1	Summer	≤ 185	-	94	70	69,4	66	-3,4
C1	Summer	195-245	-	364	71	70,2	66	-4,2
C1	Summer	≤ 185	XL	20	71	69,8	68	-1,8
C1	Summer	195-245	XL	78	72	70,6	67	-3,6
C1	Winter	≤ 185	-	41	71	69,2	66	-3,2
C1	Winter	195-245	-	93	72	69,8	66	-3,8
C1	Winter	≤ 185	XL	30	71	69,2	67	-2,2
C1	Winter	195-245	XL	40	72	69,6	66	-3,6
Weighted average / sum				**760**	**71,2**	**69,9**	**66,2**	**-3,75**
C2	Summer			110	72	71,3	69	-2,3
C2	Winter			62	74	72,2	68	-4,2
Weighted average / sum				**172**	**72,7**	**71,6**	**68,6**	**-2,97**
C3	Traction			147	75	73,3	66	-7,3
C3	Steering			158	73	71,2	66	-5,2
C3	Trailer			50	73	70,2	67	-3,2
Weighted average / sum				**355**	**73,8**	**71,9**	**66,1**	**-5,79**

Table 27: Characteristics of 8 different road / traffic combinations used for computation of traffic flow noise impact

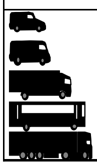
Road / traffic type	Residential street - Intermittent traffic	Residential street - Free flowing traffic	Main street - Intermittent traffic	Main street - Free flowing traffic	Arterial road	Urban motor way	Rural motor way	Rural main road	Total
Vehicle operating condition	accelerating	free flow	accelerating	free flow	free flow	free flow	free flow	free flow	
Speed range	V<50	V<50	V≈50	V≈50	60<V<80	V=100 / 80	V=120 / 80	60<V<80	
Total road length	15569	31610	7061	14336	3284	332	2185	32606	106982
Percentage of total road length	15%	30%	7%	13%	3%	0,3%	2%	30%	100%
Selected road length (km)	12455	25288	6355	12902	2627	265	1529	16303	77725
Percentage of selected road length	16%	33%	8%	17%	3%	0,3%	2%	21%	100%
Traffic intensity [vehicles / 24 h]	2000	2000	9470	9470	33700	48500	48500	16000	
Average number of exposed inhabitants/km	115	115	250	275	300	400	400	40	
Characteristic distance from road (m)	15	15	15	15	15	50	50	50	
Annoyance penalty, dB	0	0	3	0	0	0	0	0	
Noise sources									
	Powertrain + tyre/road	Tyre/road + powertrain	Powertrain + tyre/road	Tyre/road + powertrain	Tyre/road	Tyre/road	Tyre/road	Tyre/road	
	Powertrain	Powertrain + tyre/road	Powertrain	Powertrain + tyre/road	Powertrain + tyre/road	Powertrain + tyre/road	Powertrain + tyre/road	Powertrain + tyre/road	

Table 28: Representative noise impact values for traffic flows on 8 different road / traffic combinations, expressed in LDEN and Lnight

LDEN	Residential street - Intermittent traffic	Residential street - Free flowing traffic	Main street - Intermittent traffic	Main street - Free flowing traffic	Arterial road	Urban motor way	Rural motor way	Rural main road
Reference 2013	61,3	59,2	67,2	65,0	72,1	66,6	69,3	63,5
Best performing low noise tyres	60,2	57,1	66,2	62,8	69,7	64,1	66,7	61,4
LNIGHT								
Reference 2013	52,8	50,6	60,1	57,8	67,3	64,3	65,8	55,9
Best performing low noise tyres	51,7	48,4	59,1	55,6	64,9	61,8	63,2	53,7

Table 29: Reductions of LDEN and Lnight values due to a shift from an average tyre mix to the best performing low noise tyres for traffic flows on 8 different road / traffic combinations

ΔLDEN	Residential street - Intermittent traffic	Residential street - Free flowing traffic	Main street - Intermittent traffic	Main street - Free flowing traffic	Arterial road	Urban motor way	Rural motor way	Rural main road	**Average**
Reference 2013	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	**0,0**
Best performing low noise tyres	-1,1	-2,1	-1,0	-2,2	-2,3	-2,4	-2,7	-2,1	**-2,0**
ΔLNIGHT									
Reference 2013	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	**0,0**
Best performing low noise tyres	-1,0	-2,2	-1,0	-2,2	-2,4	-2,5	-2,7	-2,2	**-2,0**

Table 30: Reductions of numbers of (highly) annoyed and (highly) sleep disturbed people, resulting from to a shift from an average tyre mix to the best performing low noise tyres.

Annoyance	**Millions Highly Annoyed**	**Millions Annoyed**	**Differences MHA**	**Differences MA**	**Relative Differences MHA**	**Relative Differences MA**
Reference 2013	1,456	3,308	0,000	0,000	0%	0%
Best performing low noise tyres	1,240	2,947	-0,216	-0,361	-14,8%	-10,9%
Sleep disturbance	**Millions Highly Sleep Disturbed**	**Millions Sleep Disturbed**	**Differences MHSD**	**Differences MSD**	**Relative Differences MHSD**	**Relative Differences MSD**
Reference 2013	1,588	3,043	0,000	0,000	0%	0%
Best performing low noise tyres	1,384	2,734	-0,204	-0,310	-12,8%	-10,2%

Table 31: Reductions of numbers of (highly) annoyed and (highly) sleep disturbed people differentiated according to 8 different road / traffic combinations.

		Residential street - Intermittent traffic	Residential street - Free flowing traffic	Main street - Intermittent traffic	Main street - Free flowing traffic	Arterial road	Urban motor way	Rural motor way	Rural main road	Total
Millions Highly Annoyed	Reference 2013	0,168	0,216	0,299	0,427	0,166	0,013	0,096	0,069	1,456
	Best performing low noise tyres	0,153	0,176	0,275	0,353	0,138	0,011	0,077	0,057	1,240
Millions Highly Sleep Disturbed	Reference 2013	0,159	0,273	0,265	0,500	0,175	0,017	0,115	0,083	1,588
	Best performing low noise tyres	0,147	0,230	0,248	0,427	0,151	0,014	0,097	0,071	1,384

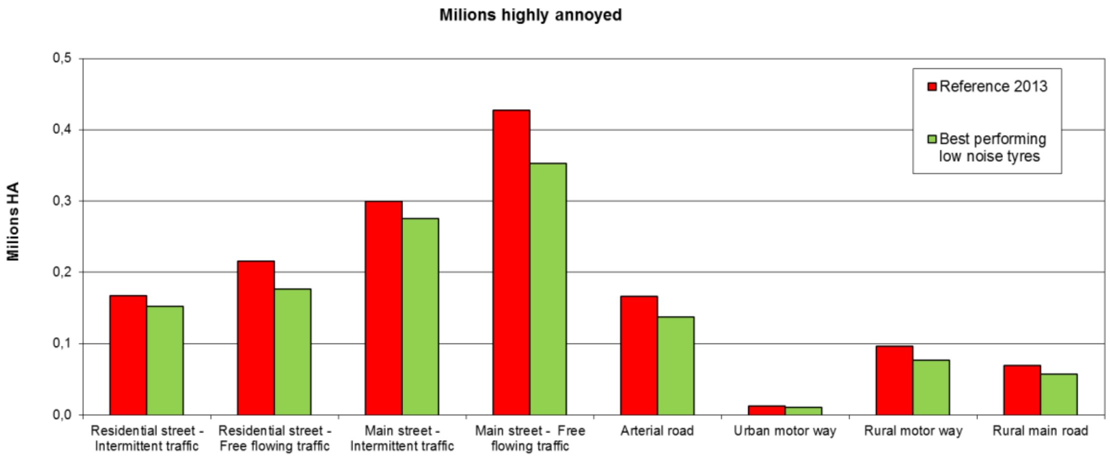


Figure 15: Graphic presentation of reduction of numbers of (highly) annoyed people differentiated according to 8 different road / traffic combinations.

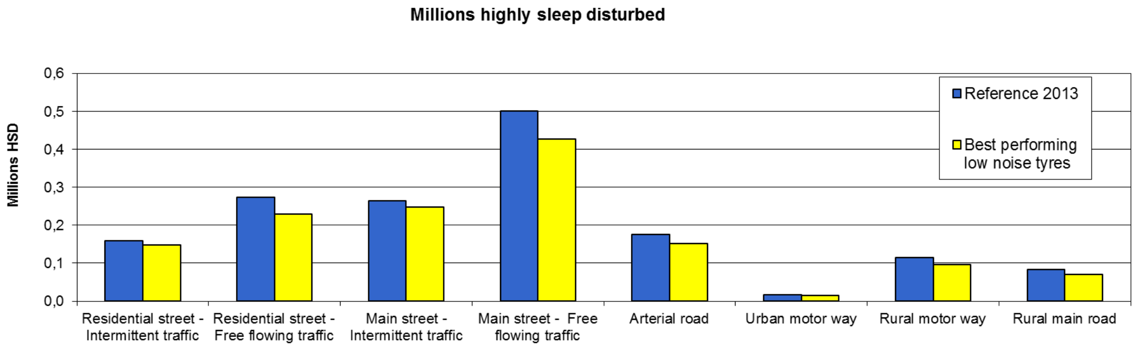


Figure 16: Graphic presentation of reduction of numbers of (highly) sleep disturbed people, differentiated according to 8 different road / traffic combinations.

5.3 Potential benefits noise

The results of the computations show that the average noise emission per vehicle will be reduced by:

- 1.2 -- 2.6 dB(A) for light vehicles;
- 0.6 – 2.6 dB(A) for medium vehicles;
- 0.6 -- 3.4 dB(A) for heavy vehicles,

depending on the type of road, type of road surface and traffic conditions.
The effects of these reductions per vehicle for the total noise impact of a the traffic flow will lead to an average reduction of L_{DEN} and L_{night} levels by 2.0 dB(A), ranging from 1.0 to 2.7 dB(A) for the various road types and traffic conditions.

The numbers of highly annoyed, annoyed, highly sleep disturbed and sleep disturbed people in the Netherlands will be reduced by 216000, 361000, 204000 and 310000 respectively, which implies reductions in terms of percentages of 15%, 11%, 13% and 10% (see Figure 17)

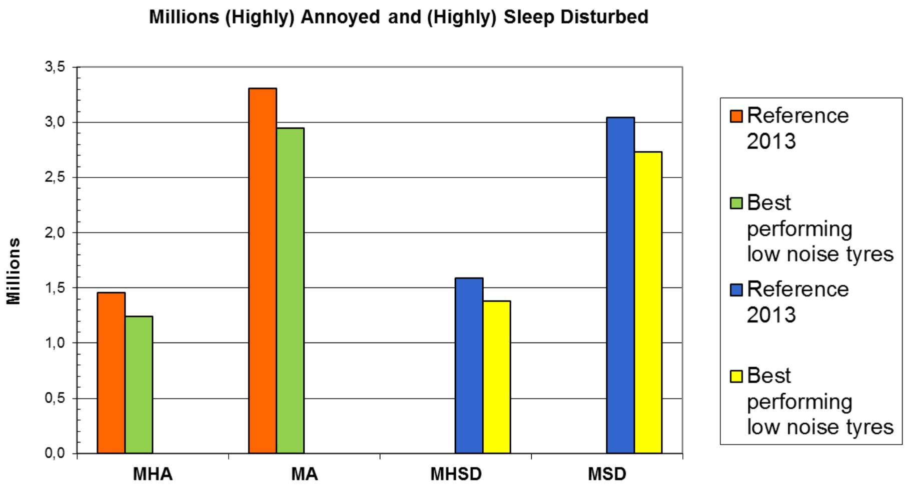


Figure 17: Reduction of Millions of (Highly) Annoyed and (Highly) Sleep Disturbed people resulting from a shift towards the best performing low noise tyres.

5.4 Monetary benefits of the use of low noise tyres

For the assessment of monetary benefits due to the widespread introduction of low noise tyres a methodology is used similar to that applied in the Venoliva study [VENO, 2011], but with an updated approach for health benefits.

An effective average noise reduction of 2 dB in roadside noise levels is assumed, growing from 0 dB in 2015 to 2 dB in 2019. The appraisal period considered is 2015-2025, assuming no changes in vehicle powertrain noise during this period. The effective replacement of all tyres is assumed to take place within 4 years, the approximate lifetime of car tyres. Calculated benefits take into account an average annual inflation rate of 1% and annual discount rate of 4%.

The monetary benefits of low noise tyres are calculated in terms of Hedonic pricing (HP) or property valuation of noise reduction, as specified in the EU position paper

[EUPOSPOP2003], and for health benefits using a methodology applied in the UK [IGCB, 2010]. HP and health benefits are the two largest savings, whereas others such as reduced noise abatement costs are comparatively lower (see Venoliva study [VENO, 2011]).

Hedonic pricing/property valuation
For the valuation of the effect of traffic noise reduction on property prices, a fixed valuation of noise reduction is applied in accordance with recommendations from the 2003 EU position paper on noise valuation [EUPOSPOP 2003] and adjusted for inflation.

The annual hedonic pricing benefit B_{HP} can be derived according to
$B_{HP} = V_{HP} * N_H * NR$
where
V_{HP} = value of hedonic pricing in Euros per household per dB per annum
N_H= number of households (calculated per road type and length)
NR= noise reduction in dB (LDEN) for the current year.

A V_{HP} value of € 25 per household per dB noise reduction for the year 2002 was used, which corrected for inflation to 2015 amounts to € 28.45. This is considered a very conservative estimate, as in some EU member states significantly higher values are reported.

Health benefits
Health effects of environmental noise are well known but not all simple to quantify, especially in terms of valuation. These effects include cardiovascular disease, hypertension (high blood pressure), stress, sleep disturbance, mental illness, cognitive effects on children, annoyance and their associated effects. To avoid potential overlap with Hedonic pricing which reflects perceived benefits, a conservative estimate is made based only on severe health effects such as acute heart disease as done the UK [IGCB, 2010]. This is based on statistical data on Acute Myocardial Infarction (AMI) in combination with the odds associated with a given environmental noise level, derived from a curve proposed by Babisch [BAB, 2006]. A variable valuation is given depending on the environmental noise level. No valuation is made for hypertension or other health effects due to lack of reliable data.

The annual health benefit valuation B_{health} per household and per dB noise reduction can be calculated from

$B_{health} = V_{AMI} * N_H * NR$

where
V_{AMI} = health benefit per household per dB noise reduction, related only to Acute Myocardial Infarction,
N_H = number of households
NR = dB noise reduction in L_{DEN} level

The average value over all road types for the health benefit V_{AMI} per household per annum is estimated at €16.75 in 2015.

Calculated benefits

The benefits for Hedonic Pricing (=property valuation) and health and the combined benefits are set out in Table 32 for annual average benefits and accumulated benefits over the whole appraisal period 2015-2025. The total benefits over the whole ten year appraisal period amount to 3.1 billion Euros, at an annual average of 307 million Euros. The evolution of benefits during the appraisal period is graphed in Figure 18. If all tyres were to be immediately replaced by AAA tyres, then the benefits would amount to 389 million Euros in total, of which 252 million Euros for HP benefits and 137 million Euros for health benefits. The annual average of 307 million Euros is calculated according to the same methodology used in earlier studies for the European Commission. The annual benefit of 389 million Euros is in line with the same methodology treated in this document, i.e. benefits for immediate implementation.

Table 32: Hedonic Pricing (= property valuation), health and total benefits in millions of Euros for the full introduction of low noise tyres, as an annual average and as accumulated benefits over the appraisal period 2015-2025.

	HP benefits (M€)	Health benefits (M€)	Total benefit (M€)
Annual benefit for immediate implementation	252	137	389
Annual average	202	106	307
Accumulated 2015-2025	2018	1056	3074

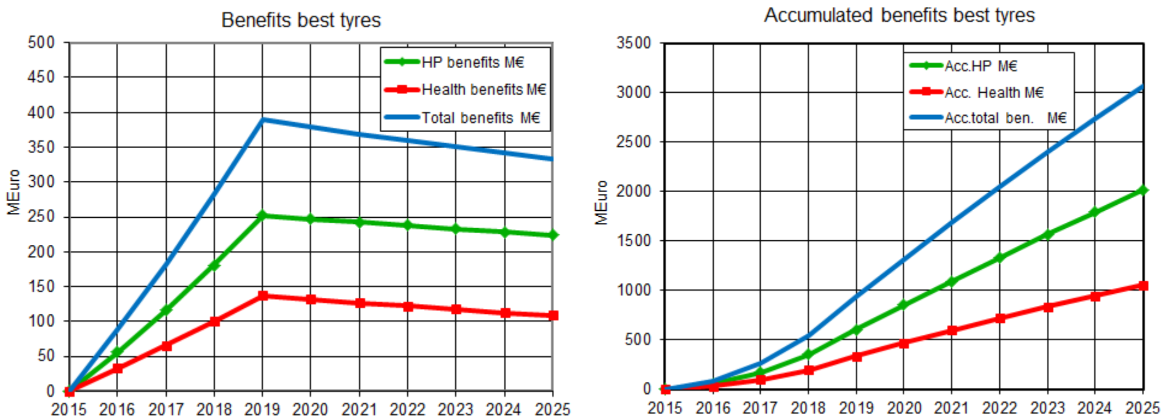


Figure 18: Hedonic pricing, health and total benefits in millions of Euros for the full introduction of low noise tyres, left per annum and right as accumulated benefits over the appraisal period 2015-2025.

6 Potential benefit of AAA-rated tyres

In this chapter, the potential benefit of AAA-rated tyres is determined. AAA-rated tyres are defined as high-performance tyres with A-rating in all three categories: energy, safety and noise performance.

Currently, it is unknown whether tyres exist that rate 'A' on energy and safety and noise. In other words: AAA-rated tyres might currently not be available on the Dutch market. This might not be the case for all vehicle types or tyre classes, since certain aspects in tyre performance are counter-acting, e.g. low rolling resistance can have a negative influence on the wet grip of a tyre. In those cases, the calculation should be treated as a theoretical potential that could be achieved for an innovative tyre with A-rating in all three aspects.

For the calculation of the potential benefit of AAA-rated tyres in terms of energy, safety and noise, the societal benefits as discussed in the previous chapters are summed up.

Based on the assumptions and calculations made in the previous chapters, this study concludes that AAA-tyres have a large potential benefits for the Netherlands. The sum of all annual savings from a societal perspective are shown in Table 33.

- *Fuel savings:* A sum of 506 Ml fuel could be saved annually due to the improved rolling resistance of AAA-rated tyres.
- *CO_2 reduction:* A sum of 1.3 MtCO_2 could be saved annually due to the improved rolling resistance of AAA-rated tyres.
- *Reduced amount of fatalities*: About 43 fatalities could be reduced due to the improved wet grip of AAA-rated tyres.
- *Reduced amount of serious injuries:* About 260 serious injuries could be reduced due to the improved wet grip of AAA-rated tyres.
- *Reduced amount of slight injuries*: About 364 slight injuries could be reduced due to the improved wet grip of AAA-rated tyres.
- *Reduced amount of (highly) annoyed people:* About 216.000 (-15%) highly annoyed people and 361.000 (-11%) annoyed people could be reduced due to the improved noise performance of AAA-rated tyres.
- *Reduced amount of (highly) sleep disturbed people:* About 204.000 (-13 %) highly sleep disturbed people and 310.000 (-10%) sleep disturbed people could be reduced due to the improved noise performance of AAA-rated tyres.
- *Cost savings:* In total, a sum of nearly 1 billion Euros (938M€) could be saved annually due the increased performance of AAA-rated tyres. Cost savings related to energy, safety and monetary benefits due to reduced noise impact amount to 365M€, 184M€ and 389M€ respectively. Cost savings related energy are derived from fuel costs. Safety cost savings are determined by indicative values for each number of reduced fatality, serious injury and slight injury. Monetary benefits related to noise are determined via the method of property valuation and the reduced amount of health costs for people who are highly annoyed and/or highly sleep disturbed due to noise.

Table 33: Potential annual improvement potential of AAA-rated tyres from a societal perspective

	Energy savings potential	Safety improvement potential	Noise reduction potential	TOTAL
Annual fuel savings [Ml]	506	-	-	506
Annual CO_2 reduction [$MtCO_2$]	1.3	-	-	1.3
Reduced number of fatalities	-	43	-	43
Reduced number of serious injuries	-	260	-	260
Reduced number of slight injuries	-	364	-	364
Reduced number of highly annoyed people	-	-	216000	216000
Reduced number of annoyed people	-	-	361000	361000
Reduced number of highly sleep disturbed people	-	-	204000	204000
Reduced number of sleep disturbed people	-	-	310000	310000
Annual cost savings [M€]	365	184	389	938

7 Discussion and recommendations

This chapter addresses choices and assumptions made, potential shortcomings and possible biases. It also gives some recommendations for further research.

Current distribution of tyre use

The method described above to estimate the currently used tyres looks at which tyres are currently sold and which tyres have a large market share. Tyres coming into the market via other channels (e.g. tyres mounted on new vehicles, tyres bought on internet) are assumed to have the same label distribution. It is expected that this method is accurate enough to represent 90% of the tyres actually used in practise. However, since the dataset is based on the 7 tyre brands and sizes with the highest market share, the resulting tyre distribution is probably a conservative estimate. It is assumed that the leading tyre brands with high market share are running ahead of competition in the introduction of innovative technologies. The 'real' tyre distribution would then be even worse. Potential benefits of switching to AAA-rated tyres would effectively be higher.

Tyre wear

The study uses the label performance of new tyres. Benefits have been calculated of moving from currently-used new tyres to A-labelled new tyres. This is a theoretical situation. In practise tyres are always more or less worn. Effectively, this leads to an alteration of the 'original' tyre performance as it was tested for the tyre label. Since this effect occurs for all tyre types, it was decided to neglect this effect in the switch and base required estimates of the savings potentials on the documented label performance of tyres. However, the effect of alteration might be different for different tyres labels.

Label performance of tyres

Label performance of tyres are assumed to represent the 'true' performance of tyres. Although this assumption seems self-understood, it is acknowledged that several sources indicate an incoherence between the labelled performance and the measured performance of a tyre ([CONS, 2014][IN2, 2013]). Depending on the level of incoherence and whether it is systematic or not, the here presented results should be more or less representative of the 'true' situation. The same study ([CONS, 2014]) also notes that there are large differences in the performance of tyres. The research question thus remains: 'What is the effective saving potential when collectively switching to the best-performing tyre?' Based on the available knowledge, this study provides an educated estimate to this question.

Safety and wet grip

Tyre labelling enables the end-user to choose for the safest tyre in terms of wet grip, i.e. the tyre with the shortest braking distance. However, vehicle safety is a complex measure which depends on several parameters, most importantly the tyre profile depth, the correct use of winter/summer tyres and the tyre pressure.

Road accident data 2009
The safety improvement potential is evaluated using Dutch road accident data from 2009, which is the most recent data available in the BRON database. It is recommended to assess similar data for the current situation on Dutch roads, in order to be able to scale the results of the safety improvement potential study to the current situation.

As a first estimate, the most recent statistics in traffic accidents in the Netherlands as well as the overall trend from 2009 to 2012 can be used [SWOV, 2013]. Accordingly, this would roughly result in a 10% reduction of casualties and effectively of societal costs. The overall reduction potential would then be 166M€ instead of 184M€ (see Table 34).

Table 34: Reduction in societal costs of wet grip A-labelled tyres (2009 vs. 2012)

Tyres	Reduction in societal costs using 2009 injury data [M€]	Reduction in societal costs using 2012 injury data [M€]
C1 tyres	157	141
C2 tyres	18	17
C3 tyres	9	8
TOTAL	184	166

From A, A and A to AAA
When determining the collective savings potential of AAA-rated tyres, it is assumed:
a) that AAA-rated tyres exist and are commercially available and
b) that the separate savings potentials of energy, safety and noise can be added to determine the overall savings potential.

When comparing tyres, it's important to know that some performance factors conflict with others. There lies a challenge for tyre manufacturers to develop tyres that are both, safe and energy efficient. While there exist some examples of AAA-rated tyres, it has not been studied in how far these types of tyres are commercially available for all vehicle categories. This requires further research.

In the case that AAA-rated tyres exist and are commercially available, the savings potentials of energy efficiency, safety and noise are strongly independent of each other. It is thus assumed that overall savings potential can be calculated as the summation of every single parameter.

Costs and benefits
Investment costs of AAA-rated tyres have not been taken into account in this study. There is little evidence that tyre costs and performance are correlated [IN, 2013]. Cost differences between tyres are therefore expected to be low. Since the cost savings potential for the end-user is significant, even additional investment costs of 400€ for a passenger car (100€ per tyre) could still be advantageous for the end-user. This should justify a switch to tyres which are more energy-efficient, safer and less noisy.

The here presented monetary benefits are regarded an underestimation for several reasons:
- reduced need for noise reduction policy measures: stimulation measures directed at the use of less noisy tyres targets the noise at the source where it is

being generated. Hereby noise reduction can be achieved more efficiently and presumably less expensive. Additional cost savings associated to the reduced need for other noise reduction policy measures, like noise barriers, have not been taken into account.
- Hedonic pricing and health benefits: For the calculation of hedonic pricing, a value of €28.45 per household per dB noise reduction has been used. This is considered a very conservative estimate, as in some EU member states significantly higher values are reported. In the UK a progressive valuation is used that increases with the noise level. Additionally, the average value over all road types for the health benefit V_{AMI} per household per annum is estimated at €16.75 in 2015. The real health benefits may be significantly higher if all other effects could be quantified.

It must be noted that the here discussed results do not cover the calculation of all long-term cost-benefits and the break-even period under consideration of other external costs. Other external costs could be for instance:
- costs associated with a reduced or increased amount of maintenance (e.g. due to the reduced or extended lifetime of tyres): Depending on the hardness of the tyre and its manufacturing material, tyre wear could be higher or lower for A-rated tyres than for standard tyres. As an effect, different tyre maintenance costs could emerge for end-users.
- costs (e.g. due to less or more particle emissions): Different emissions of particulate matter could have an effect on societal health costs. These and other related effects of tyre wear have not been included in the scope of this study and deserves further research.

Policy options
Considering the above mentioned shortcomings and recommendations for further research, an important point to address in a follow-up study is the rationale for policy options. This quick-scan study gives a clear indication of potentially large benefits of AAA-rated tyres for the Netherlands. Several policy options could therefore be considered to accelerate the market uptake of these tyres.

Depending on the estimated autonomous development of tyre distribution in the Netherlands, policy options and instruments to consider could range from non-intervention to incentives or regulation:
- No regret: allow the market to take the initiative
- Incentives e.g. information campaign and public awareness
- Incentives e.g. financial (subsidies, tax differentiation)
- Voluntary agreements with the sector (green deals)
- Regulation for mandatory fitment of AAA-rated tyres

8 Acknowledgements

The authors thank Johan Sliggers, Ministry of Infrastucture and Environment in The Netherlands, for initiating this study and his comments to drafts of this report.

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10 Signature

Delft, 12 June 2014

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A Current tyre distribution in the Netherlands – Split of summer and winter tyres

The tyre label applies to all tyres, C1 for passenger cars, C2 for vans and C3 tyres for heavy duty trucks and buses. Excluded from tyre labels are tyres for special uses:

- re-treaded tyres;
- off-road professional tyres;
- tyres designed to be fitted only to vehicles registered for the first time before 1 October 1990;
- T-type temporary-use spare tyres;
- tyres whose speed rating is less than 80 km/h;
- tyres whose nominal rim diameter does not exceed 254 mm or is 635 mm or more;
- tyres fitted with additional devices to improve traction properties (for example studded tyres);
- tyres designed only to be fitted on vehicles intended exclusively for racing.

The following tables (Table 36 to Table 40) show the current tyre distribution in the Netherlands as determined from the VACO database. As discussed in chapter 2, on average vehicles in the Netherlands drive with a D-label for energy, a C-label for wet grip and a B-label for noise (see Table 1).

Table 35: Average tyre label per tyre class and criterion, assuming A=1, B=2, C=3, etc.

	Fuel Efficiency	Wet Grip	Noise	Noise (dB)
C1	4.4 (‘D-label’)	2.6 (‘C-label’)	1.9 (‘B-label’)	69.9
C2	4.3 (‘D-label’)	2.7 (‘C-label’)	2.0 (‘B-label’)	71.6
C3	3.7 (‘D-label’)	2.5 (‘C-label’)	1.8 (‘B-label’)	72.2

Table 36: Tyre distribution of C1 summer tyres in the Netherlands

C1 Summer tyres

sub class	# tyres	label	FuelEfficiency Class	WetGripClass	ExternalRollingNoiseClass
TOTAL	556	A/1	1%	16%	16%
		B/2	12%	48%	70%
		C/3	34%	29%	14%
		D/4	0%	0%	
		E/5	31%	7%	
		F/6	20%	0%	
		G/7	2%	0%	
0-185	94	A/1	1%	11%	6%
		B/2	9%	44%	77%
		C/3	46%	31%	17%
		D/4	0%	0%	
		E/5	23%	15%	
		F/6	21%	0%	
		G/7	0%	0%	
195-245	364	A/1	1%	16%	16%
		B/2	12%	49%	69%
		C/3	29%	29%	15%
		D/4	0%	0%	
		E/5	32%	5%	
		F/6	22%	0%	
		G/7	4%	0%	
0-185 XL	20	A/1	0%	5%	25%
		B/2	10%	35%	65%
		C/3	55%	40%	10%
		D/4	0%	0%	
		E/5	25%	15%	
		F/6	10%	5%	
		G/7	0%	0%	
195-245 XL	78	A/1	0%	22%	28%
		B/2	19%	54%	67%
		C/3	37%	22%	5%
		D/4	0%	0%	
		E/5	35%	3%	
		F/6	9%	0%	
		G/7	0%	0%	

ExternalRollingNoiseDB

dB(A)	TOTAL	0-185	195-245	0-185 XL	195-245 XL
65	0%	0%	0%	0%	0%
66	1%	1%	1%	0%	0%
67	5%	6%	5%	0%	6%
68	13%	24%	11%	25%	6%
69	13%	14%	12%	25%	15%
70	22%	35%	21%	10%	15%
71	29%	16%	35%	30%	18%
72	13%	1%	12%	5%	33%
73	2%	2%	2%	5%	4%
74	1%	0%	1%	0%	0%
75	0%	0%	0%	0%	1%
76	0%	0%	0%	0%	0%
77	0%	0%	0%	0%	0%
78	0%	0%	0%	0%	0%
79	0%	0%	0%	0%	0%
80	0%	0%	0%	0%	0%

Table 37: Tyre distribution of C1 winter tyres in the Netherlands

C1 Winter tyres

sub class	# tyres	label	FuelEfficiency Class	WetGripClass	ExternalRollingNoise Class
TOTAL	204	A/1	0%	0%	47%
		B/2	0%	10%	52%
		C/3	18%	61%	1%
		D/4	0%	0%	
		E/5	59%	29%	
		F/6	22%	0%	
		G/7	1%	0%	
0-185	41	A/1	0%	0%	49%
		B/2	0%	20%	49%
		C/3	17%	54%	2%
		D/4	0%	0%	
		E/5	49%	24%	
		F/6	32%	2%	
		G/7	2%	0%	
195-245	93	A/1	0%	0%	45%
		B/2	0%	6%	55%
		C/3	16%	62%	0%
		D/4	0%	0%	
		E/5	60%	31%	
		F/6	23%	0%	
		G/7	1%	0%	
0-185 XL	30	A/1	0%	0%	47%
		B/2	0%	13%	53%
		C/3	23%	57%	0%
		D/4	0%	0%	
		E/5	60%	30%	
		F/6	17%	0%	
		G/7	0%	0%	
195-245 XL	40	A/1	0%	0%	48%
		B/2	0%	5%	50%
		C/3	20%	68%	3%
		D/4	0%	0%	
		E/5	65%	28%	
		F/6	15%	0%	
		G/7	0%	0%	

ExternalRollingNoiseDB

dB(A)	TOTAL	0-185	195-245	0-185 XL	195-245 XL
65	0%	0%	0%	0%	0%
66	3%	5%	2%	0%	5%
67	7%	7%	8%	13%	3%
68	28%	37%	24%	33%	25%
69	9%	2%	12%	3%	15%
70	16%	12%	14%	17%	25%
71	19%	34%	14%	33%	3%
72	18%	2%	27%	0%	25%
73	0%	0%	0%	0%	0%
74	0%	0%	0%	0%	0%
75	0%	0%	0%	0%	0%
76	0%	0%	0%	0%	0%
77	0%	0%	0%	0%	0%
78	0%	0%	0%	0%	0%
79	0%	0%	0%	0%	0%
80	0%	0%	0%	0%	0%

Table 38: Tyre distribution of C2 summer tyres in the Netherlands

C2 Summer tyres					
# tyres	110				
label		FuelEfficiency Class	WetGrip Class	ExternalRollingNoise Class	ExternalRollingNoiseDB
A/1		0%	7%	7%	
B/2		15%	46%	88%	
C/3		38%	39%	5%	
D/4		0%	0%		
E/5		33%	7%		
F/6		13%	0%		
G/7		1%	0%		
dB(A)					
65					0%
66					0%
67					0%
68					0%
69					7%
70					21%
71					19%
72					48%
73					3%
74					0%
75					2%
76					0%
77					0%
78					0%
79					0%
80					0%

Table 39: Tyre distribution of C2 winter tyres in the Netherlands

C2 Winter tyres					
# tyres	62				
label		FuelEfficiency Class	WetGrip Class	ExternalRollingNoise Class	ExternalRollingNoiseDB
A/1		0%	3%	8%	
B/2		0%	19%	81%	
C/3		16%	60%	11%	
D/4		0%	0%		
E/5		55%	16%		
F/6		27%	2%		
G/7		2%	0%		
dB(A)					
65					0%
66					0%
67					0%
68					2%
69					0%
70					10%
71					29%
72					16%
73					23%
74					8%
75					11%
76					2%
77					0%
78					0%
79					0%
80					0%

Table 40: Tyre distribution of C3 tyres in the Netherlands

C3 tyres

sub class	# tyres	label	FuelEfficiency Class	WetGrip Class	ExternalRollingNoise Class
TOTAL	327	A/1	0%	6%	37%
		B/2	6%	37%	50%
		C/3	34%	55%	13%
		D/4	42%	2%	
		E/5	15%	0%	
		F/6	3%	0%	
		G/7	0%	0%	
DRIVE AXLE	147	A/1	0%	1%	35%
		B/2	1%	29%	39%
		C/3	18%	66%	25%
		D/4	48%	4%	
		E/5	27%	1%	
		F/6	7%	0%	
		G/7	0%	0%	
STEERING AXLE	158	A/1	0%	9%	37%
		B/2	6%	43%	61%
		C/3	48%	48%	3%
		D/4	41%	0%	
		E/5	5%	0%	
		F/6	0%	0%	
		G/7	0%	0%	
TRUCK TRAILER	50	A/1	2%	4%	66%
		B/2	16%	46%	28%
		C/3	44%	50%	6%
		D/4	36%	0%	
		E/5	2%	0%	
		F/6	0%	0%	
		G/7	0%	0%	

ExternalRollingNoiseDB

dB(A)	TOTAL	DRIVE AX	STEERING	TRAILER
65	0%	0%	0%	0%
66	0%	1%	1%	0%
67	4%	5%	6%	4%
68	3%	5%	5%	14%
69	6%	2%	5%	24%
70	14%	3%	18%	22%
71	11%	4%	16%	16%
72	11%	7%	16%	4%
73	22%	20%	25%	12%
74	12%	21%	6%	2%
75	10%	19%	1%	0%
76	3%	4%	0%	2%
77	1%	3%	0%	0%
78	3%	7%	0%	0%
79	0%	0%	0%	0%
80	0%	0%	0%	0%

B Noise reduction of vehicles at different speeds and on different road surfaces

Table 41: Reductions of vehicle noise emissions resulting from an average reduction of tyre rolling noise as specified in as function of vehicle category, operating condition, driving speed and road surface type. The content of the green highlighted cells was used as input for the noise impact calculations for 8 road types (see Figure 14)

				Road surface type					Average reduction		Weighted	
		Speed	Traffic mix	DAC	PAC	2-layer PAC	2-layer PAC Fine top	Thin Surface Layer	Accelerating	Free Flow	Average reduction Accelerating	Free Flow
		km/h										
Light Veh	Accelerating	30	90%	-1,22	-0,95	-1,02	-1,35	-1,35	-1,18		-1,29	
	Free flow	30	90%	-1,77	-0,95	-1,18	-2,36	-2,36		-1,73		-2,07
Medium Vel	Accelerating	30	5%	-0,53	-0,42	-0,44	-0,59	-0,59	-0,52		-0,56	
	Free flow	30	5%	-1,75	-1,06	-1,50	-2,38	-2,38		-1,82		-2,07
Heavy Veh	Accelerating	30	5%	-0,64	-0,50	-0,53	-0,71	-0,71	-0,62		-0,68	
	Free flow	30	5%	-2,11	-1,46	-2,27	-2,92	-2,92		-2,34		-2,52
Vehicle Mix	Accelerating	30		-0,84	-0,65	-0,70	-0,93	-0,93	-0,81		-0,88	
	Free flow	30		-1,89	-1,15	-1,62	-2,57	-2,57		-1,96		-2,23
Light Veh	Accelerating	40	90%	-1,22	-0,95	-1,02	-1,35	-1,35	-1,18		-1,29	
	Free flow	40	90%	-1,77	-0,95	-1,18	-2,36	-2,36		-1,73		-2,07
Medium Vel	Accelerating	40	3%	-0,53	-0,42	-0,44	-0,59	-0,59	-0,52		-0,56	
	Free flow	40	3%	-1,75	-1,06	-1,50	-2,38	-2,38		-1,82		-2,07
Heavy Veh	Accelerating	40	7%	-0,64	-0,50	-0,53	-0,71	-0,71	-0,62		-0,68	
	Free flow	40	7%	-2,11	-1,46	-2,27	-2,92	-2,92		-2,34		-2,52
Vehicle Mix	Accelerating	40		-0,87	-0,68	-0,72	-0,96	-0,96	-0,84		-0,91	
	Free flow	40		-1,91	-1,17	-1,65	-2,60	-2,60		-1,98		-2,25
Light Veh	Accelerating	50	90%	-1,22	-0,95	-1,02	-1,35	-1,35	-1,18		-1,29	
	Free flow	50	90%	-1,77	-0,95	-1,18	-2,36	-2,36		-1,73		-2,07
Medium Vel	Accelerating	50	3%	-0,53	-0,42	-0,44	-0,59	-0,59	-0,52		-0,56	
	Free flow	50	3%	-1,75	-1,06	-1,50	-2,38	-2,38		-1,82		-2,07
Heavy Veh	Accelerating	50	7%	-0,64	-0,50	-0,53	-0,71	-0,71	-0,62		-0,68	
	Free flow	50	7%	-2,11	-1,46	-2,27	-2,92	-2,92		-2,34		-2,52
Vehicle Mix	Accelerating	50		-0,90	-0,70	-0,75	-1,00	-1,00	-0,87		-0,95	
	Free flow	50		-1,90	-1,15	-1,60	-2,57	-2,57		-1,96		-2,23
Light Veh	Accelerating	80	85%	-1,22	-0,95	-1,02	-1,35	-1,35	-1,18			
	Free flow	80	85%	-1,77	-0,83	-1,18	-2,36	-2,36		-1,70		-1,97
Medium Vel	Accelerating	80	5%	-0,53	-0,42	-0,44	-0,59	-0,59	-0,52			
	Free flow	80	5%	-2,28	-1,65	-1,88	-2,98	-2,98		-2,36		-2,62
Heavy Veh	Accelerating	80	10%	-0,64	-0,50	-0,53	-0,71	-0,71	-0,62			
	Free flow	80	10%	-2,87	-2,87	-2,87	-3,69	-3,69		-3,19		-3,41
Vehicle Mix	Accelerating	80		-0,90	-0,70	-0,75	-0,99	-0,99	-0,87			
	Free flow	80		-2,19	-1,55	-1,80	-2,87	-2,87		-2,26		
Light Veh	Accelerating	100	85%	-1,22	-0,95	-1,02	-1,35	-1,35	-1,18			
	Free flow	100	85%	-2,37	-1,07	-1,53	-3,06	-3,06		-2,22		-2,18
Medium Vel	Accelerating	100	5%	-0,53	-0,42	-0,44	-0,59	-0,59	-0,52			
	Free flow	100	5%	-2,32	-1,65	-1,88	-2,98	-2,98		-2,36		-2,38
Heavy Veh	Accelerating	85	10%	-0,64	-0,50	-0,53	-0,71	-0,71	-0,62			
	Free flow	85	10%	-2,87	-2,87	-2,87	-3,69	-3,69		-3,19		-3,28
Vehicle Mix	Accelerating	Mix		-0,96	-0,75	-0,80	-1,06	-1,06	-0,93			
	Free flow	Mix		-2,49	-1,53	-1,88	-3,21	-3,21		-2,46		
Light Veh	Accelerating	115	85%	-1,22	-0,95	-1,02	-1,35	-1,35	-1,18			
	Free flow	115	85%	-2,86	-1,25	-1,61	-3,58	-3,58		-2,57		
Medium Vel	Accelerating	100	5%	-0,53	-0,42	-0,44	-0,59	-0,59	-0,52			
	Free flow	100	5%	-2,36	-1,65	-1,81	-2,98	-2,98		-2,36		
Heavy Veh	Accelerating	85	10%	-0,64	-0,50	-0,53	-0,71	-0,71	-0,62			
	Free flow	85	10%	-2,87	-2,87	-2,87	-3,69	-3,69		-3,19		
Vehicle Mix	Accelerating	Mix		-1,01	-0,79	-0,84	-1,12	-1,12	-0,98			
	Free flow	Mix		-2,82	-1,56	-1,85	-3,55	-3,55		-2,67		