Improving air quality by increased use of friction tires
–
without compromising traffic safety
The final report of the STUD research programme 2011-2013

(Translation from Finnish by Virpi Kuukka-Ruotsalainen and Kalle Toiskallio, Lectus LP, revised by several steering group members)

1 Introduction

The air quality in the city of Helsinki is relatively good. From time to time, emissions of particles or nitrogen dioxide make the air quality poor, or even very poor, in some areas with heavy traffic. From a health perspective, particles are the most harmful air pollutant. Studies conducted in the Helsinki metropolitan area show a connection between increased concentrations of particles and health effects. Street dust is the biggest source of respirable particles (particulate matter, PM10)[1], especially at springtime. Cities' efforts to reduce street dust have lessened the amounts during the last few years, but the EU limit value for daily concentrations of PM10 are at risk of being exceeded in the busy street canyons of the the inner city. Concentrations above the acceptable limit have also been detected near the main arterial roads. Most of the detected fine particles (PM2,5)[2] originate from traffic, wood burning fireplaces and also from very distant sources. A small amount of particles originating from street dust belong to this category.

The aim of the STUD research programme has been to examine how a growth in the use of friction tires would affect the air quality, traffic safety and the need for winter maintenance. To support the study, other winter countries' (such as Norway and Sweden) winter tire policies and their impacts have been closely studied.

What is the part that studded tires play in generating street dust and spreading it? How do drivers using studded tires experience and feel about driving and how do these visions differ from those of drivers using friction tires? How would a change in the winter tire shares in the Helsinki metropolitan area affect the distribution in the rest of the country? What needs to be done to maintain traffic safety if the number of friction tires grows very rapidly? How do studded tires wear the road surface at different speeds?

The environment authorities of the cities are responsible for measures taken to improve air quality in the Helsinki metropolitan area. The Helsinki Region Environmental Services Authority (HSY) monitors air quality. The Finnish Transport

[1] Particles with a diameter under 10 micrometers, but over 2,5 micrometers.
[2] Particles with a diameter under 2,5 micrometers.

Agency (LIVI) is mainly responsible for maintaining the urban freeways and the ring roads. The City of Helsinki's Public Works Department (HKR) is liable for street maintenance.

Environment and maintenance find a common interest: road wear caused by studded tires not only deteriorates air quality but it also generates a need to resurface pavements more often.

According to the Centre for Economic Development, Transport and the Environment at Uusimaa, 12-15 million euros are spent yearly on resurfacing the pavements. The City of Helsinki spends approximately 5-6 million euros every year. Since the 1990's the funding has not been sufficient for all the resurfacing needs. Spreading sand has become the main anti-skid method. The yearly expense for spreading sand and salt is over a million euros.

This final report often refers to Abstracts (for example see Abstract 9). This is in reference to the individual project summaries that are attached to the final report written in Finnish. Summaries can be found at www.NASTA.fi. For further information the reader can contact the authors of summaries.

2 Core results

STUD research programme - core results

- In Finland winter tires have been researched more from friction perspective than from an air quality perspective
- If the share of friction tires grew rapidly, it would greatly improve air quality in the Helsinki metropolitan area
- Street dust can cause severe negative health effects
- Reduced cost of resurfacing pavements and an increase in the use of so called quiet asphalt, which could be used on more streets.
- Speed of the vehicle affects safety more than the choice of winter tires
- If the use of friction tires greatly increases, winter maintenance, driver education and enlightenment need to be improved to maintain current traffic safety levels. Change in attitudes might improve traffic safety.

What does the street dust in the Helsinki metropolitan area consist of?

Source of street dust	Share	Standard deviation
Pavement	48 %	± 8
Traction sanding	25 %	± 9
Salt	3 %	± 3
Salt/mineral	7 %	± 7
Other	5 %	± 3
Not classified	12 %	± 4
TOTAL:	**100 %**	

3. Winter tire share and winter road conditions

3.1 Winter tire share

The use of winter tires is mandatory in Finland during the months of December, January and February. Passenger cars, vans and some other vehicle types are to use either studded or friction tires.

The share of studded tires in passenger cars has come down since 1990's. However the use of studded tires in vans has continuously grown. Passenger cars still outnumber vans forming statistics so considering all vehicle groups in total, use of friction tires has grown.

Use of friction tires is more common in the Helsinki area than the rest of the country. At the same time, weather in Helsinki is more volatile than in the Northern Finland.

Share of winter tires in passenger cars in Finland 1992 – 2010

Share of winter tires	1992 –1994	2000 – 2001	2009 – 2010
Cars with studded tires, %	95,1	88,2	87,7
Cars with friction tires, %	4,5	11,8	12,3

Share of winter tires	Late winter 2011	Late winter 2013
Cars with studded tires, %	76	79
Cars with friction tires, %	24	21

During late winter/early spring 2011 data collected from parked passenger cars along the roadside or inside parking garages showed that studded winter tires were used in 76% and friction tires in 24% of the passenger cars. The study was repeated in 2013 showing the friction tire's share reduction to 21%. (Abstract 10)

According to interviews conducted around the Helsinki metropolitan area during winter 2011-2012, one third (1/3) of male drivers but only one fifth (1/5) of female drivers used friction tires. Often these drivers were older with more driving experience and drove more kilometres yearly than those using studded tires. Drivers using friction tires emphasized personal reasons for their tire selection, like suitability for their style of driving or road conditions. (Abstract 8)

Helsinki Metropolitan Area taxi owners preferred studs during winter 2011-2012. Studded tires were used in 60% and friction tires on one third of taxis. (Abstract 13)

In Finland the share of friction tires is not followed as systematically as in Norway or Sweden. In Finland the dominating tire is studded, in Norway friction. Sweden lands somewhere in between with the number of friction tires rapidly growing. In Helsinki the share of friction tires has clearly dropped during the last couple of years (2011: 24% -> 2013: 21%).

In all of these Nordic countries differences in tire preferences are clear. In their capital and larger cities friction tires are used more often than in the countryside. In the northern parts studded tires dominate.

Country	**2010, %**	**2013, %**	**Countries by regions, 2011 – 2013, %**
Finland	12	?	Helsinki inner city (2013) 21 Helsinki (2010) 18 Uusimaa province and Finland in general 12
Sweden	31	34 (2012)	Stockholm 34 East Sweden 27 South Sweden 51 North Sweden 7
Norway	62	63	Oslo, Bergen, Stavanger and Trondheim 65 – 86 Countryside 50 Tromsø (very northern city) 13

3.2 Weather conditions during winter times in the Helsinki Metropolitan Area

Winter road traffic safety greatly depends on existing weather and road conditions. During the last ten years the weather in Helsinki has varied greatly. Typical time for the first snow is in November. During the years 2002-2012 the number of "wintery days"[3] fluctuated between 48-130. This period of 10 winters does not greatly differ from the normal of the last 30 years.

During snowstorms the number of accidents clearly goes up at Uusimaa region. During heavy snow material damages increased more than personal injuries.

Some days accumulate more accidents than others. The day counts as an accumulation day[4], when at least double the amount of accidents compared to the winter's daily average are reported. The yearly number of these days during the 10 year period (1997-2007) was 3-11[5]. Often accidents pile up during snowfall and temperatures around 0 degrees celsius when the road surface's friction and visibility both suffer.

3.3 Road conditions and friction

Friction is the force resisting the relative motion of solid surfaces, fluid layers, and material elements sliding against each other.

Road surface's coefficient of friction (CF) describes the traction between tires and road surface. In principle it varies between 0-1. The smaller the number, the worse the traction. In practice, coefficient of friction varies between 0,1 (frozen road) – 0,8 (dry asphalt). The driving conditions are considered poor when CF is under 0,3[6] and very poor when CF is under 0,15. During poor conditions snowfall is moderate and can include icy rain while road surface can be icy at some places. Visibility is also reduced. Hazardous driving conditions exist when snowfall is dense, strong winds and whirling snow restrict visibility and disturb traffic and the road surfaces are polished and slippery. If the speed of the vehicle is 100 km/h and CF falls from 0,8 (dry asphalt) to 0,1-0,2 (icy road) the braking distance can quadruple from 50 meters to 200 meters (Haavasoja and Pilli-Sihvola, 2010).

When CF is under 0,3 the braking distance is 2,5 times longer than the braking distance on dry asphalt (CF 0,8). If it's under 0,15 the braking distance becomes 5 times longer[7].

Most winter tire tests published in automobile magazines are conducted while CF is less than 0,15. These kinds of road conditions are very rare in Finland. When CF reaches 0,32, the driver using friction tires doesn't have to adjust driving speed since there is no relevant difference in studies of the braking distances[8].

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3 The daily mean temperature in under 0C.
4 Accumulation day= at least double the amount of accidents compared to the winter's daily average are reported.
5 Sihvola N, Rämä P, Juga I. 2008. Determining the successfulness of the road weather information service 1997–2007. Helsinki 2008. Finnish Road Administration 15/2008. ISBN 978-952-221-067-8. http://www.liikennevirasto.fi/julkaisut
6 Driving conditions are considered normal when CF=0,3. The need for studded tires arises mainly during hazardous conditions.
7 Haavasoja T, Pilli-Sihvola Y. 2010. Friction as a measure of slippery road surfaces. SIRWEC 15th International Road Weather Conference, 5 – 7 February 2010, Quebec City, http://www.sirwec.org/Papers/quebec/11.pdf .
8 Malmivuo, Mikko. 2012. Safety effects of a decreased use of studded tyres. Publications of the Ministry of Transport and Communications 4/2012. p. 45-46

Current weather stations measuring CF are placed on highways that are well maintained in the winter.

Announcements of bad driving weather are given during winter season (October-April). Traffic weather service at the Province of Uusimaa (region around Helsinki Metropolitan Area) gave out warnings of hazardous driving conditions on the average of 16 times per year (2000-2007). This equals having hazardous driving conditions during 2,3 days per month. Poor conditions were reported yearly on 65 days which equals 9,3 days per month. On average, warnings of poor or hazardous driving conditions were in effect on 81 days and 38% of days during the winter season from October to April. While in effect, the warning covers the whole province.

Driving weather based on coefficient of friction

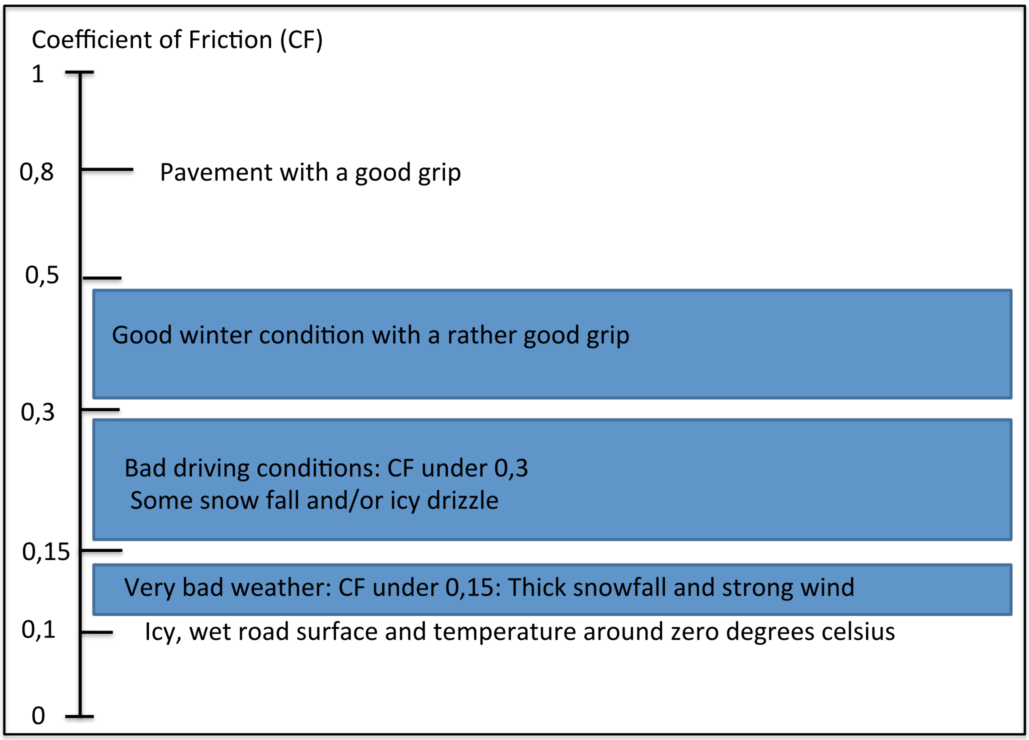

Table shows the number of days when according to The Road Weather Information Service (Liikennesää) driving conditions have been normal (N) or at least once during the day poor (P) or hazardous (H) at the Province of Uusimaa.

The last couple of decades have seen a rise in the mean temperatures and this trend will continue. Winter seasons will shorten in length but variations in weather become greater and strong winter storms should be paid attention to in the management of traffic and winter maintenance.

Normal, poor and hazardous road conditions at Province of Uusimaa during the winter season

MONTH	October			November			December			January			February			March			April		
Road weather	N	P	H	N	P	H	N	P	H	N	P	H	N	P	H	N	P	H	N	P	H
Number of days	25	5	**1**	17	11	**3**	17	11	**3**	12	14	**5**	14	12	**2**	20	9	**2**	27	3	**0**

4 Traffic safety and driving behaviour

The effects of studded and friction tires on traffic safety have been widely studied. However, the results vary greatly. Most evaluations support the fact that during winter weather using studded tires reduces the risk of accidents by a few percent, but on icy conditions by 10%. Increasing the winter maintenance is not usually considered. (Malmivuo 2012)

The VTT Technical Research Centre of Finland study[9] states that 17,6% of fraction tires in use are tire types manufactured to be used in the Central Europe. These account for 2,2% of all the winter tires. These tires do not have good traction on ice and snow. On wet or dry asphalt and faster driving speeds these tires can perform even better than their Nordic counterparts.

Drivers using friction tires feel they are not more accident prone or have more rear-end collisions than drivers using studs. For the moment drivers with friction tires are a minority, about 1/5 or 1/3 of Helsinki metropolitan drivers. (Abstract 8 and 10) but their driver profile is beneficial to traffic safety. Drivers are experienced, they drive numerous kilometres yearly and their vehicles are newer than average.

With a general shift towards friction tires inexperienced drivers and drivers with less anticipating driving styles and older vehicles would become friction tire users. These factors would, in fact, increase accident risk in winter. Therefore, several different measures supporting traffic safety should be implemented to keep the accident rate from growing. (Abstract 6)

Risk assessments are formed of many kinds of factors and often several perspectives. Even when things go smoothly or even extremely well in general, the risk springs up from an unexpected situation during poor weather conditions. A panel of experts evaluated effects on accident risks. They concluded that campaigning for more friction tires with the implementation of other safety measures would increase the probability of accidents by 0,7%, but setting restrictions by 2,4%. (Abstract 14)

Traffic safety experts emphasize reducing injuries far more than the driver population's ability to learn and adapt to driving conditions.

[9] Luoma, Juha. Frequency of tyres for mild winter conditions in Finland. Espoo 2011. VTT – Research Notes 2600.

In addition to national and other traffic safety evaluations it should be noted that when the share of friction tires in the four largest cities in Norway (Oslo, Bergen, Trondheim and Stavanger) rapidly grew in the 1990's from 20% to 70%, the total number of fatal accidents did not increase.

Nor did the number of accidents increase when so called stud fees were put to use halving the number of studded tires in 10 years. In Norway statistics only include accidents leading to personal injury[10].

Elvik and his research group evaluated traffic safety in the largest cities in Norway more meticulously from 1999 to 2009. Their result is a statistical model showing that a reduction of studded tires by 25% raised accident rates by 5%.

Interpreting these results from a different angle, the optimal share of studded tires should be at least 20% as a smaller share starts to accelerate the growth of accident rate[11].

In addition to restricting the use of studded winter tires, Norway has worked hard to improve air quality in many other ways. For example in Oslo, City Council has approved 2004-2010 an environmental speed limit of 60 km/h. Magnesium chloride is used for binding street dust and the main city streets are cleaned weekly. Furthermore, several mobility management strategies have been implemented.

Several different experiments were conducted on an icy test driving ring to find what would be the optimal share for friction and studded tires to maintain current traffic safety levels. (Abstract 7)

With both tire types the traction strongly depends on temperature. A change in air temperature from –3 C to –10 C caused traction to be halved. This change alone is significantly greater that differences between any tire types.

If vehicles travel the road without accelerating or braking and vehicles with studded tires account for 50% - 100% of all vehicles, braking traction stays the same. Reducing the share of studded winter tires to 25%, traction diminishes by 12%. Should all the vehicles have friction tires, traction diminishes by 25% at the most.

If traffic consists solely of friction tired vehicles and braking incident occurs, the traction will be reduced on the icy road surface by 20% at most.

On these test conditions it was shown that reducing the number of studded vehicles to account for 50% of total traffic will not lead to reduction in traction or the icy road surface becoming more polished than usual.

If the number of studded vehicles is reduced to less than 25%, surface traction can lessen by 25% compared to a situation where only studded tires are in use.

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[10] In Norway, tire type of all the involved parties in an accident is reported. In Finland, police states they do not have recourses for similar data collection.

[11] Elvik, Rune, Fridstrøm, Lasse, Kaminska, Frislid Meyer, Sunniva 2013. Effects on accidents of changes in the use of studded tyres in major cities in Norway: A long-term investigation. Accident Analysis & Prevention Volume 54, May 2013. Also, see Abstract 7.

Even a great increase in friction tires will not compromise traffic safety by polishing the icy road surface.

5 Air quality and health

5.1 Street dust – what it is, how it arises and escapes

Street dust consists mainly of particulate matter (PM) that accumulates in the streets from a wide variety of sources. Dust particles are released into the air by traffic and wind when the streets are dry.

A substantial portion of the respiratory particles (PM10) forms due to brake wear or grinding of road sanding materials and pavement under motor vehicle tires.

A small portion of street dust is fine particles (PM2.5). These mostly originate from motor vehicle exhaust fumes, wood burning in small fireplaces and other sources originating from very long range, as from abroad.

Tire's dust emission is

- wear of the tire's own material
- road surface abrasion products from the interaction processes between the road surface and tyre, brakes and engine.
- particles that are deposited on or in the vicinity of roads that may be re-suspended back into the air through vehicle-induced turbulence

Studded tires loosen particles whenever road surface is clear of snow. Traction sand adds to dust amounts specially while it's being distributed. Sand also contributes to street dust (by a few percent) when sanding materials caught between the road surface and tires cause road surface abrasion in the manner of sand paper (so called sand paper effect).

Dust does not always immediately rise to the breathable height but can accumulate on street surfaces and environment. Humid, snowy and icy winter conditions are suitable for collecting dust. The street dust that forms and accumulates over the winter is stirred up into the atmosphere by traffic flows and wind lift when streets dry. (Abstract 3)

During springtime a significant proportion of respiratory particles (PM10) originates from street dust.

Studies conducted during the winter season 2011-2012 show that street dust consists mostly of mineral particles which mostly (40-50%) originate from pavement wear caused by studded tires. ¼ of particle mass came from washed stone materials used for traction sanding. ¼ of particle mass came from other sources like construction sites, dust from tires and vehicle brakes, use of winter-salting (NaCl) on roads and plant materials that are ground up on roadways.

Differences in the materials used for sanding (coarseness, washed/unwashed etc), the amounts of sand used and the frecuency of sanding and weather conditions (snow coverage, humidity, rainfall, temperature etc) affect the distribution. (Abstract 4)

Compared to summer tires, not to mention friction tires, studded tires produce more dust when road surface is relatively clean and levels of re-suspension low. This is mainly caused by the studs wearing the surface pavement. The highest dust levels were measured for a new studded tire and the lowest for a summer tire. (Abstract 4)

Reducing the number of studs in a tire reduced the wear and thus the emissions of respiratory particles (PM10).

Studded tires made after 1 July 2013 have to comply with new requirements. These new requirements are aimed at limiting the number of studs and reducing their effect on road wear. When tested at low re-suspension levels, this new type of tire (simulated by removing 25% of studs of test tires) created 10-28% less dust compared to the 2011 tire types[12].

At high re-suspension levels there were no significant differences between winter tire types and emissions of studded tires were similar to the emissions of friction tires. During early spring dust re-suspension (dust amounts stocked up during winter) is so great that emission differences between tyre types disappear. Dust emissions were 15-20 times greater during early spring than during other times of the year.

In addition it was noted that dust emission levels reduce as (all types of) tires wear out and age. This causes changes both in pavement wear and re-suspension. The quantities of these factors were not evaluated in this study.

It was also observed that with all tire types the higher the driving speed, the higher the dust emission levels.

Studded winter tires increase PM10-dust compared to studless tires. New studded winter tire caused the highest emissions and summer tire the lowest. (Abstract 4)

Cities in central Europe are often said to suffer from street dust. Studded tires are not used there so other air quality problems come to focus. Vehicle exhaust, energy production and industrial emissions worsen the air quality especially in larger cities considerably more than in the Helsinki Metropolitan Area. The large share of diesel fueled vehicles amounts to higher levels of fine particles (PM2.5) and nitrogen dioxide (NO2). In addition to these, high levels of ozone (O3) especially in central and southern Europe worsen the air quality. Sand is used as an anti-skid method but the problems caused by this do not cumulate to the springtime like in Finland. Snowy periods are shorter thus sending the sand up in the air more often and in smaller quantities.

[12] Studded tire with 30% studs removed (meets new requirements as of 1.7.2013) was tested.

5.2. The health effects of street dust

Road surface wear by studded tires increases the formation and amounts of coars respirable particles (diameter 2,5-10 micrometers) in the air. Coarse particles containing abundant soil minerals and their negative effects on health have not been studied as extensively as smaller particles coming from vehicle exhaust fumes. For a long time, it was thought that exposure to coarse particles only caused irritation symptoms.

Even short periods of exposure to coarse particles is probably connected to the increase in hospital admissions due to respiratory and cardiac symptoms, or even premature deaths.

During days of high concentrations of coarse particles in the air, the reported number of deaths caused by respiratory problems increased. Greater numbers of hospital admissions due to cardiac diseases, asthma and chronic obstructive pulmonary disease were also reported.

Evaluating winter season, it came clear that amounts of rough particles was in conjunction to the number of hospital admissions due to cardiovascular diseases: 10 microgram increase (in cubic metre of air) in daily concentration added the number of hospital visits by 3%.

In addition, there were indications that coarse particles led to an increase in the deaths and hospital visits caused by lung diseases and also an increase in childrens' asthma. Analysis restricted to springtime indicated connections between particles and deaths caused by lung diseases.

Correlations between high particle concentrations and severe health problems were not very strong during the studded tire season, probably because of the small amount of data. However, observations support the perception that street dust is connected also to severe health effects. Personal risk of getting health problems because of street dust is very small. However, because of the commoness of the exposure we can talk about national health problem. In any case, severe health effects are just a top of iceberg since most of urban residents can feel the less severe health problems, such as irritation of eyes and airways. For example, increased use of medicines or work absenteeism has not been even evaluated.

6. Pavement wear

Asphalt pavement rutting can be caused by the following four mechanical reasons: Pavement wear due to studded tires, densification and shear deformation of the surface course, and deformation of non-binded road structure courses.

Of these rutting mechanisms pavement wear is clearly caused by studded tires, deformation and different forms of condensation are mostly caused by heavy traffic.

Spreading salt expedites the surface wear by turning snowy, icy or dry pavement wet.

If large cities like Helsinki limited the use of studded tires on the basis of reducing the need for resurfacing the roads, the greatest benefits would be seen on the roadways with speed limits of 60 km/h or more and on low-noise pavements .

If the profile or geometry of the road forces traffic to move on a narrow wheel track, great potential savings on surface maintenance could be seen by limiting the use of studded tires. (Abstract 9)

7. Studded tires and environmental noise

The STUD research programme did not research the noise effects of winter tires. However, some observations from previously conducted research programs and reports are mentioned in the following.

Road traffic is the main cause of noise ~~hazards~~ problems in Helsinki. According to the Noise study[13] (2012) about 40 percent of Helsinki residents live in areas where the average daytime noise level from road and street traffic exceeds the Governments's daytime guideline value (55 dB). About 10 percent of the residents are exposed to noise from trams, trains and the metro. Noise from other sources is local and not as relevant.

In the City of Helsinki Noise Abatement Action Plan, several measures have been presented to reduce noise ~~abatement~~ levels TAI exposure. On areas already developed and built, noise barriersand low-noise pavements could be used to reduce noise levels. The action plan for noise abatement currently under evaluation (2013) presents a plan for a network of low-noise pavements. Speed limits or traffic volumes do set limitations to the use but when used, the noise reduction is between 2-4 dB which equals to halving the traffic volume. Reaching the target does not considerable add to paving expenses. The added cost comes from resurfacing the streets more often.

By 2012 there were circa 64 kilometres of noise barriers in Helsinki. Using current expenses estimates this is a 120 million euro investment. Between 2008-2012, 11 kilometres of noise barriers were added and the total investment for these construction projects was 19 million euros.

The primary goal in noise abatement is to reduce noise emissions at their ~~origin~~ source. National noise abatement measures include reducing rolling noise by using low-noise pavements and tires. The rolling noise of a passenger car is louder than its motor noise when the driving speeds exceed 40 km/h. Despite this there have been no significant reductions of in the rolling noise caused by thecontact between tire and road surface.

[13] City of Helsinki, strategic noise mapping 2012 http://www.hel.fi/hel2/ymk/meluselvitys/

The rolling noise reduction project (VIEME, 2008) examined the noise levels and air quality effects of several different tire types. Friction tires were tested and observed to be the quietest even compared to the summer tires. When tested on regular asphalt the noise levels of studded tires exceeded those of summer tires by 1 dB, but on low-noise pavements they were 3 dB noisier.

7.1 Changes in studded and friction tires

The Ministry of Transport and Communications' ordinance 466/2009 effective on 1.2.2009 sets limits to the number of studs per rotation path metre. Tires manufactured on 1.7.2013 or after will be affected by this ordinance.

The permitted number of studs is reduced. The number of studs can only be increased if an independent (unbiased) study proves that the new tire will not wear our the pavement more than a tire manufactured according to the previous regulation.

A new type of stud, approved by the Finnish Transport Safety Agency Trafi, can be used in all studded tires as long as the number of studs does not exceed 50 per rolling circumference. In practise the total number of studs should be significantly reduced and reductions of 15% in surface wear should be achieved.

If manufacturers want to use more than 50 studs, tire and stud combination and three different tire sizes need to be tested and supervised by an approved research institution[14]. During this test method standardized sheet of granite is driven over 400 times with a high speed (100 km/h). Granite is weighted before and after the runs and tire type is approved for future use on the basis of the wear of the surface.

A tire that has passed this test is already on the market and in this case the number of studs is significantly greater compared to the current models. According to abrasion test pavement wear is slighter than seen with a tire with maximum of 50 studs.

Friction tires can be divided into two categories: Nordic and Central European. Nordic tire development has taken into consideration surviving the difficult and continuously changing winter conditions. Development in Central Europe focuses on driving performance on dry or wet asphalt that can be seen on main roads for most of the winter season.

On relatively few times during the winter season when friction coefficient is less than 0,15, the traction of the Nordic friction tire is significantly poorer than traction of studded tire. Friction tire's traction on snow and ice has been improved by adding lamella cut-outs to the tread surface of a tire.

The consumer cost of Nordic friction tire and studded tire are almost the same at the moment. International market share is relatively small for both types. One can assume that if the use of friction tires grows they will become less expensive than studded tires. Currently friction tires meant for the Central European market exceed the market volume of Nordic friction tires making them cheaper to purchase.

[14] At the moment the approved institutions are Nokia Tire's testing department and Test World Ltd.

8. How should we move forward?

8.1 Proposal for a measurement program

The STUD research programme presents an operations model for the Helsinki metropolitan area consisting of four phases:

1) Raising public discussion (campaign?) on winter tire policy
2) The concrete measures of public authorities causing changes in the winter tire shares
3) Evaluations of development options and costs of winter maintenance and management of information of the weather condition
4) Studies of effects of previous measures

1. A campaign to create discussion in thecommunity
Campaigning should be professionally planned and implemented using communications and discussions by specialists at different medias
The big picture of the effects: information on collective effects of winter tire choices delivered to public via several medias
Health: the effects of tires on air quality and noise levels
Way of driving: tire choices in relation to driving style
Real experiences: utilizing the experiences of drivers and companies using friction tires
”Pit stop”: campaign aimed at customers of ”a tire hotel” for the use of several different types of tires during winter season. This enables the use of proper tires in different driving conditions. Vehicle owners can purchase or rent tires from the tire hotel.
Staff training: City employees are introduced and trained to use friction tires. Education on the anticipating way of driving is provided.
Driver education: friction tires on slippery roads – subsidized driving education

2. Reducing street dust – methods for the Metropolitan area
Limit the time of use: the use of studded tires is allowed for example between December 15th and February 15th. Allowed time period may be adjusted yearly according to the weather conditions. This encourages yearly information distribution of winter tire related issues.
Prohibition of stud use on selected areas/streets: police enforcement with the help of parking enforcement officials. Transition time of few years needed.
An environmental protection fee of a certain area: The maximum range of the area could include all urban freeways inside of the Helsinki borders and the area inside of the Ring road III. Minimum area might be a downtown neighborhood. The fee can be cancelled when the needed share of friction tires has been achieved.
STUD tax: a tax to be added into the consumer price of new studded winter tires. The aim of this tax would be to raise the consumer price of the studded tires above that of friction tires (for example, 100 euros per a tire set of four tires). This tax needs to be endorsed by the Government.

Friction tires and Electronic Stability Control (ESC). The City of Helsinki would pay money (100 euros per a tire set of four tires, for example) for a car owner who is willing to change his or her studded tires to friction tires - and has an ESC in the car.
Friction-less-parking. Cars equipped with friction tires would get a discount (30-50%) on on-street parking payments in Helsinki (comparable with the low-emission cars at the moment). Furthermore, a right-of-way to pre-bookings of the park&ride systems (in the future). This might also be a possibility for parking operators to market themselves in the city center. The campaign or measurement can be cancelled when the needed share of friction tires has been achieved.
Public procurements of transport services and tires. The procurements of cities of the Helsinki Metropolitan Area and the State dealing with passenger cars and taxi rides, not to mention longer-term public acquisitions, could favor friction tires. Furthermore, the city employees right to charge km costs could be made conditional on the use of friction tires.

3. Development of winter maintenance and management of weather condition information
Improved timing of traction sanding and salting. Better focus on the most problematic spots and street classes. Selecting proper sand types and sufficient washing of the sanding material. Improving timing and methods of sand removal. Environmental quidelines.
Roughening of the hard ridge of snow on the road. Investigating equipment needs and updating work methods.
Pavement heating systems. Street surface kept unfrozen, heating cables placed on the most challenging locations such as bus stops, intersections and steep hills.
Improving real-time and regional road weather information management. Winter maintenance zeroes in on the problem spots and times, regional road weather information delivered to drivers.

4. Monitoring and evaluating the effects of actions
-Effects on air quality and health
-Changes in tire shares and relation to traffic safety
-Effects on winter maintenance and its costs
-Continuous calculations of tire shares
-Impact on public opinions on winter tire selections

8.2. Evaluating the action plan

Enlightenment and campaigning are an essential basis for public knowledge and help generate discussion among the public and peer groups. The direct effects of enlightenment and campaigning on drivers tire selection, air quality, traffic safety, road maintenance or traffic noise are hard to indicate or measure. However, results can be measured by the quantity of public awareness.

Changing winter tires (owned or rented) more frequently depending on weather conditions (like drivers using a tire hotel) may be more broadly adapted by the general public.

Stud taxation may raise interest in the current pricing of winter tires. Today studded tires are priced similarly to friction tires when at the end of 1990's friction tires were less expensive[15].

The effect of limiting stud use in certain areas or street sections depends on the extent of these limits. Limiting use on a single street would have minimal effects, but it would bring the topic into public consciousness. Areal stud tax or fee, collected for example in whole downtown, would improve the air quality significantly as has happened in Oslo. Street section based fees could be efficient when put to use in busy street canyons where air quality is poor. Focusing solely on these few problem streets could raise public awareness among the general audience, as it has done in Oslo.

The safety related issues of winter tires are associated with driver behaviour (like anticipating changes in traffic situations and appropriate driving speeds) and driving under extreme conditions (very poor driving conditions and lack of winter maintenance, wet ice on a steep hill) when coefficient of friction (CF) is less than 0,15.

Leaving out the extremities (of age, driving experience, driver behavior, obedience to the law) enlightenment can to some extent really affect traffic safety.

Prohibiting studded tires entirely in the whole Helsinki metropolitan area could cause problems both in traffic safety and traffic flow especially at intersections and pedestrian crossings. To lessen the negative impact the street surface should be roughened (by machinery) or winter maintenance otherwise significantly improved. At first, specially drivers used to driving in a ”sporty” way (i.e., at the ultimate borderline between grip and loss-of-grip) or very inexperienced or uncertain drivers, could cause accident rates to go up.

The effect of a stud tax on traffic safety would be nearly marginal as it still leaves the individual driver with the choice of a tire type. Prohibiting studs on a single street section can simply lead to drivers choosing another route. Prohibiting use on several streets comes close to a regional ban, which would generate greater impact. Effects on the environment or maintenance can be seen with all the proposed actions. Effects are in relation to the strength or size of a measure taken.

Information on friction and its changes are currently available mostly from highways (operated by the Finnish Transport Agency). If similar information was available from the City's street network, the effects and credibility of road weather information and intelligent transportation in general would grow among drivers.

Improving winter maintenance to support the use of friction tires does not necessarily increase total costs. The yearly million euros budget used for sanding and salting the streets would increase by a few hundred thousand euros. Mostly it is all about shaping and modifying current work methods and choosing the right tools (for example the model of the snow plough's blade). Currently unused methods of roughening the hard ridge of snow or ice on the road during regular winter maintenance could be

[15] The use of studded tires. Case: Helsinki. (In Finnish) City of Helsinki. Public works Department. Publications 2001:4.

considered. This practice of roughening could be focused on intersections, steep hills and bus stops.

Systematic research focusing on shifts in tire share and their effects would be beneficial. Today statistics are based on individual studies with variable observation periods conducted by organisations with different interests. Additional research would serve as a basis for continuous compilation of statistics carried out in the future.

8.3 Social impacts

Finnish tire industry manufactures both studded and friction tires. Change in tire shares would not greatly affect the operating revenue of these companies. Studs are a traditional Finnish branch of business and the general demand can be affected by the reduction in the use at Helsinki metropolitan area. The change in quantity would be more symbolic, since from the international perspective the Helsinki metropolitan area is not considered a large market. However, the metropolitan area might lead by example and other regions could follow. This is unlikely to happen as it has not happened in the northern parts of Norway or Sweden either. In any case, the demand for studs from abroad (specially from Russian Federation) would make up for the financial loss caused to the industry.

Drivers' choice of winter tires is a part of the Finnish traffic culture. The yearly winter tire tests published in automobile magazines are widely published and greatly effective among motorists. At the moment, these tests emphasize other qualities of tires (like traction on dry or wet asphalt, rolling noise, rolling resistance etc.) so heavily that stud and friction tires are placed in separate categories. The reader easily gets an impression that stud and friction tires are not even comparable.

All the actions mentioned would lead the Finnish winter tire policies towards Nordic, that is, more environmentally-friendly direction. This in part would make the reduction measures (of the share of studded winter tires in the metropolitan area) more acceptable to the general public.

8.4 Further research requirements

Due to limited resources it was decided that STUD research programme would only focus on the topics and methods previously discussed.

In the future it would be important to conduct experimential studies on correlation between driver behaviour and choice of tire type. Further noise related research would be important from the perspective of community planning and attractiveness of the living environment. Studying the pass-by noise caused ~~by~~ tires of different types or the methods to prevent or reduce this noise pollution is in need of further research.

It was agreed not to include heavy road traffic in this research programme. If the share of friction tires was to greatly increase, the issues related to the hard ridge of snow or ice on the road would affect the smoothness of traffic flow and traffic safety of heavy vehicles. This would reflect to other (passenger) vehicles. These issues should be further investigated and evaluated.

Legislative issues are not discussed here but will be addressed during the decisions of further measurements. They will be central when the authorities make decisions on possible actions affecting the current tire share distribution.

9 Summaries of STUD research program's research projects

(Ordinance number = reference number in text)
For further information, contact the coordinator (kalle.toiskallio@lectus.fi) or the individual researchers

1. Juga, Ilkka (Ilmatieteen laitos): Pääkaupunkiseudun talvikauden sää ja keliolot
2. Lanki, Timo (THL): Katupölyn vaikutukset terveyteen. Epidemiologinen tutkimus pääkaupunkiseudulla
3. Kupiainen, Kaarle ja Ritola, Roosa (Nordic Envicon Oy): Nastarengas ja hengitettävä pöly
4. Kupiainen, Kaarle, Ritola, Roosa, Stojiljkovic ja Ana (Nordic Envicon Oy), Pirjola, Liisa ja Malinen, Aleksi (Metropolia ammattikorkeakoulu): Talvirenkaiden pölypäästöt ja eri katupölylähteiden osuudet kadun varrella kerätyissä hiukkasnäytteissä
5. Malmivuo, Mikko (Innomikko Oy): Nastarenkaiden vähentämisen liikenneturvallisuusvaikutukset
6. Mikkonen, Valde (Valmixa Oy): Kolaririskin vähentäminen siirryttäessä nastattomiin talvirenkaisiin
7. Tuononen, Ari ja Sainio, Panu (Aalto-yliopisto, insinööritieteiden korkeakoulu): Nastavirta – eri talvirengasvirtojen vaikutus jäisen tienpinnan kiillottumiseen ja liukkauteen
8. Katila, Ari, Laapotti, Sirkku, Peräaho, Martti ja Hernetkoski, Kati (Turun yliopisto): Kitkarenkaiden talvenaikaisen käytön lisääntymisen vaikutukset kolaririskiin. Kolaririskin vähentämisen mahdollisuudet
9. Heikkinen, Harri M. (Aalto-yliopisto, insinööritieteiden korkeakoulu): Nastarenkaiden vaikutus päällysteiden kulumiseen taajamanopeuksissa
10. Prittinen, Paula ja Rekilä, Katja (Aalto-yliopisto, insinööritieteiden korkeakoulu): Talvirengasjakaumat Helsingin kantakaupungissa 2011 ja 2013
11. Aarnikko, Heljä (SITO Oy): Yksityisautoilijoiden kokemukset kitkarenkaiden käytöstä
12. Brax, Joel (Finnmap Infra Oy): Kokemuksia Oslon nastarengasmaksuista
13. Toiskallio, Kalle (Lectus Ky): Helsingin seudun taksiautoilijoiden talvirengasvalinnat
14. Vehmas, Anne (Ramboll Oy): Talvirengasskenaarioiden vaikutustarkastelu