Potential policy instruments and measures against microplastics from tyre and road wear

Mapping and prioritisation

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Kort sammanfattning

I denna rapport kartläggs, identifieras och prioriteras potentiella styrmedel och åtgärder mot mikroplast från däck- och vägslitage. Rapporten har tagits fram inom ramen för det regeringsuppdrag som Statens väg- och transportforskningsinstitut (VTI) fick i december 2017 för att ta fram och sprida kunskap om mikroplast från vägtrafiken. I uppdraget står det bland annat att VTI ska ”identifiera och utvärdera potentiellt effektiva styrmedel och åtgärder med syfte att begränsa utsläppen”.

Syftet med rapporten är att identifiera potentiella styrmedel och åtgärder som kan minska belastningen av mikroplast från däck- och vägslitage på miljön, samt att bedöma vilka som bör prioriteras för fördjupad utredning eller kunskapsuppbyggnad. Rapporten omfattar styrmedel och åtgärder som minskar utsläppen, spridningen och effekterna av mikroplastpartiklar från däck och vägmarkeringar i miljön samt de som bidrar till att öka kunskapen inom området. Den innehåller 35 styrmedels- och åtgärdsrubriker under vilka det finns preciseringar som anger vad det är för potentiellt styrmedel eller åtgärd som avses. Totalt har 58 preciseringar beskrivits och rangordnats utifrån prioritering. Fokus ligger på styrmedel och åtgärder som bidrar till att minska uppkomst och utsläpp av däckpartiklar. Detta motiveras av att däckslitage utgör den allra största källan till mikroplast från vägtrafiken och att det generellt är effektivast att vidta en åtgärd vid källan.

Eftersom det inte finns tillräckligt med kunskap om påverkan av mikroplast från däck- och vägslitage kan inte risken och därmed inte heller åtgärdsbehovet bedömas. Kunskapsbristen om effektiviteten hos identifierade styrmedel och åtgärder gör det inte heller möjligt att på sakliga grunder göra väl underbyggda prioriteringar mellan olika styrmedel och åtgärder. De prioriteringar som ändå görs (på grund av bedömt behov av kunskap och förebyggande åtgärder) bygger därför på mer eller mindre grova bedömningar.

Prioriteringen av styrmedlen och åtgärderna har skett i nivåerna: högt prioriterad, prioriterad och inte prioriterad. I flertalet fall behövs mer kunskap innan de kan utvärderas, implementeras eller genomföras, varför förslag som leder till direkta åtgärder inte kan ges. Drygt 40 procent av dem handlar om att främja forskning eller utveckling inom specifika områden eller generellt.

Sammanfattningsvis finns det många potentiella styrmedel och åtgärder för att minska belastningen av mikroplast från däck- och vägslitage som bedömts mer eller mindre relevanta av olika anledningar. Bland de 20 som vi har prioriterat högt anser vi några vara särskilt intressanta. De är de som handlar om 1) minskat trafikarbete, 2) körbeteende, 3) däckens slitagebenägenhet 4) lufttryck och hjulinställningar, 5) reglering av farliga ämnen, 6) uppsamling av däckpartiklar under färd, 7) hållbar hantering av vägdagvatten, och 8) kunskapsuppbyggnad för bedömning av risker och behov av åtgärder.

Nyckelord

styrmedel, åtgärder, mikroplast, däckslitage, vägslitage, däck- och vägslitage, däckslitagepartiklar, gummipartiklar, däck, vägmarkeringar, polymermodifierad bitumen, vägtrafik, minska utsläpp, minska spridning, minska effekter.

Abstract

In this report potential policy instruments and measures against microplastics from tyre and road wear have been mapped, identified, and prioritised. The report has been produced within the framework of a commission from the Swedish Government, received by the Swedish National Road and Transport Research Institute (VTI) in December 2017 to develop and disseminate knowledge about microplastics from road traffic. The assignment states, among other things, that VTI should identify and evaluate potentially effective policy instruments and measures aimed at limiting emissions.

The aim of the report is to identify potential policy instruments and measures that can reduce microplastic pollution of the environment caused by tyre and road wear, and to assess which of these should be prioritised for in-depth investigation or knowledge building. The report covers policy instruments and measures that reduce emissions, spread, and effects of microplastic particles from tyres and road markings in the environment, as well as those that contribute to increasing knowledge within this field. It contains 35 policy instrument and measure headings, under which the potential policy instruments or measures concerned are specified. A total of 58 policy instruments and measures have been described and ranked based on assessed priority. The focus is on policy instruments and measures that help reduce the generation and emissions of tyre particles. This is motivated by the fact that tyre wear is by far the largest source of microplastics from road traffic and that it is generally most effective to take action at the source.

Since there is insufficient knowledge on the impacts of microplastics from tyre and road wear, the risks, and thereby the need for action, cannot be assessed. Further, due to lack of knowledge regarding effectivity of the identified policy instruments and measures it has not been possible to make well-informed and objective prioritisations between them. The assessments nevertheless made regarding which instruments and measures to prioritise (due to assessed needs for knowledge and preventive measures) are therefore more or less uncertain.

Policy instruments and measures have been given one of the following priority levels: Highly Prioritised, Prioritised and Not Prioritised. In most cases, more knowledge is needed before they can be evaluated or implemented, which is why proposals leading to direct measures cannot be given. More than 40 percent of the policy instruments and measures concern promoting research or development, in specific areas or in general.

In summary, a large number of potential policy instruments and measures to reduce microplastic pollution caused by tyre and road wear have been identified and assessed to be more or less relevant for various reasons. Among the 20 that we have given high priority to, some are particularly interesting. These relate to 1) reduced road traffic (vehicle-kilometres), 2) driving behaviour, 3) tyre wear propensity 4) air pressure and wheel alignment, 5) regulation of hazardous substances, 6) collection of tyre particles while driving, 7) sustainable management of stormwater from roads, and 8) knowledge building to enable assessment of risks and the need for action.

Keywords

policy instruments, measures, microplastics, tyre wear, road wear, tyre and road wear, tyre wear particles, rubber particles, tyre, road markings, polymer-modified bitumen, road traffic, reducing emissions, reducing spread, mitigating effects.

Summary

In this report, potential policy instruments and measures against microplastics from tyre and road wear have been mapped, identified, and prioritised. The report has been produced within the framework of a commission from the Swedish Government, received by the Swedish National Road and Transport Research Institute (VTI) in December 2017 to develop and disseminate knowledge about microplastics from road traffic. The assignment states, among other things, that VTI should identify and evaluate potentially effective policy instruments and measures aimed at limiting emissions.

The purpose of this report is to identify potential policy instruments and measures that can reduce microplastic pollution of the environment caused by tyre and road wear. Another aim is to assess which of these should be prioritised for in-depth investigation, and which research and knowledge building activities to prioritise in order to assess the need for action, or design effective policy instruments and measures. The report covers policy instruments and measures categorised into the sub-objectives to 1) reduce emissions, 2) reduce spread, 3) reduce effects and 4) increase knowledge generally within this area.

The report takes a Swedish perspective when concerning national policy instruments, but also covers policy instruments that require implementation at EU level, or other international level. Tyres and road markings have been included in the mapping because they contain polymers which contribute to microplastic emissions, however polymer-modified bitumen, which can also contribute to microplastic emissions, is only included indirectly in measures related to road wear.

The main focus has been on policy instruments and measures that help limit the generation and emissions of tyre particles. Reasons include the fact that tyre wear is the main source of microplastics from road traffic, and that it is generally more effective to take action at an early stage, i.e. preferably before particles are generated or released into the environment.

The mapping and prioritisation of potential policy instruments and measures covers many different types of policy instruments and measures. These relate to

- the tyres (e.g. hazardous substances, degradability, type of tyre, wear propensity, tyre pressure)
- the vehicle (e.g. weight, engine power, acceleration, wheel alignment)
- the road markings (e.g. hazardous substances, type of paint, height above the road surface)
- the road (e.g. surfacing material, bendiness, hilliness)
- operation and maintenance (e.g. snow clearing, road cleaning, road surfacing)
- traffic behaviour (e.g. driving style, driver behaviour, speed)
- spread (e.g. collection of tyre particles during travel, sustainable management of stormwater)
- limiting traffic volumes (e.g. physical planning, public transport, taxes)
- knowledge building (general and specific).

The report contains 35 policy instrument and measure headings, which briefly show what they relate to. Under these one to three policy instruments or measures are specified. In total 58 policy instruments or measures have been described and ranked according to priority. Most of them are policy instruments; only a few are measures not preceded by policy instruments. The report includes a broad selection of more or less comprehensive policy instruments and measures, which have been divided into different categories. Just over 40 percent concern the promotion of research or research & development (including development of products, methods, and systems). Another few relate to other ways of building knowledge, e.g. through guidance, information and education that may result in behavioural changes (e.g. in driving style, travel and transportation habits, or consumption). In

addition to these policy instruments resulting in knowledge building, there are several administrative instruments (e.g. restrictions or bans on hazardous substances, labelling requirements regarding the wear propensity of tyres, limit values for tyre wear, and ecodesign requirements); economic instruments (e.g. to reduce road traffic (vehicle-kilometres) and to influence the development of the vehicle fleet); and those concerning physical planning (e.g. to reduce road traffic (vehicle-kilometres)). Policy instruments and measures with more focus on physical solutions have also been included (e.g. collection of tyre particles, tyre pressure monitoring, wheel alignment, and road design).

The policy instruments and measures have been prioritised from a microplastic perspective, and categorised as either Highly Prioritised, Prioritised, or Not Prioritised. In most cases, further knowledge is required before they can be evaluated, implemented or enforced. It may e.g. be the case that an in-depth assessment of the policy instrument or measure must be carried out first, or that it cannot be implemented or enforced, or assessed for relevance, until certain data is available. Policy instruments and measures involving the promotion of research or development are, however, generally considered candidates for immediate implementation.

As the knowledge on tyre and road wear and the identified policy instruments and measures is very limited, it has not been possible to make well-informed and objective prioritisations between them. Therefore, this report does not suggest policy instruments or measures for immediate implementation, apart from those that promote knowledge building and development. For several important aspects, such as effectiveness, cost-effectiveness and feasibility, there is often no or very limited knowledge. The assessments nevertheless made regarding which policy instruments or measures to prioritise are, therefore, more or less uncertain, and often based on only a single or few aspects. Mostly, supposed or potential effectiveness has been considered. The discussion about each policy instrument or measure also details positive and negative side effects not related to microplastics, however these effects have not been taken into account during prioritisation.

There is not enough available knowledge on the environmental concentrations, exposure and effects to assess the risks for the environment and human health, which means that it has also not been possible to assess the need for action. However, as emissions of microplastics from tyre and road wear are significant and increasing with the increasing road traffic; as the particles are probably persistent in the environment; and as the particles and any hazardous substances they contain may have negative impacts on organisms, we still feel that there is justification for implementation of preventative measures aimed at reducing microplastic pollution caused by tyre and road wear. The need to take action against microplastics has been highlighted for example by the European Commission’s group of Chief Scientific Advisors and is also in line with the precautionary principle included in the Swedish Environmental Code.

Before any decision is made to implement a policy instrument, or combination of instruments, all relevant aspects need to be considered and an impact assessment should be carried out. This should include evaluation of effectiveness, cost-effectiveness, feasibility, implementation time, any interactions with other policy instruments, all positive and negative side effects, and any other significant factors that may influence the assessment, and thereby the decision.

In summary, a large number of potential policy instruments and measures to reduce microplastic pollution of the environment caused by tyre and road wear have been identified and assessed to be more or less relevant for different reasons. Of the 20 policy instruments and measures given a high priority in this report there are some we consider particularly interesting. These are the ones related to 1) reduced road traffic (vehicle-kilometres), 2) changed driver-behaviour (through information to new drivers, more drivers trained in eco-driving, and development of systems to support eco-driving), 3) decreased tyre wear (by developing tyres with lower wear propensity and a method for measuring wear propensity), 4) optimisation of tyre pressure and wheel alignment, 5) regulations regarding hazardous substances, 6) collection of tyre particles during travel, 7) sustainable management of stormwater from roads, and 8) knowledge generation to enable evaluation of risks and need for action.

Preface

This report maps, identifies and prioritises a large number of potential policy instruments and measures targeting microplastics from tyre and road wear. It takes a mainly Swedish perspective, but also covers policy instruments required at EU level, or other international level.

The report has been prepared within the framework of a government commission given to the National Road and Transport Research Institute (VTI) on December 21, 2017, with a final reporting date of June 1, 2021. The commission involves collection and dissemination of knowledge regarding microplastics from road traffic, as well as identification and evaluation of potentially effective policy instruments and measures aimed at limiting emissions.

Since there is very limited knowledge both regarding tyre and road wear and regarding the identified policy instruments and measures, it is currently not possible to make factually based and well-informed prioritisations between different policy instruments and measures. There is often a complete lack of knowledge, or insufficient knowledge, on important aspects such as effectiveness and cost-effectiveness. The assessments provided in this report of which policy instruments or measures to prioritise are therefore more or less uncertain, and often based on only a single or few aspects. The prioritisations made highlight the policy instruments or measures that should be prioritised for further investigation and which research or other knowledge building that should be prioritised to enable effective policy instruments and measures to be designed, and to assess the need for action.

There is also not enough available knowledge to assess the environmental and human health risks caused by the exposure to microplastics from tyre and road wear, which means that it has not been possible to assess the extent of the need for action. However, as emissions of microplastics from tyre and road wear are significant and increasing as road traffic increases, as the particles are probably persistent in the environment, and as the particles and any hazardous substances they contain may have negative impacts on organisms, we still feel that there is justification for taking preventive action aimed at reducing microplastic pollution.

This report should be seen as a first step towards the development of effective policy instruments and measures targeted at reducing microplastic pollution caused by tyre and road wear from road traffic and assessing the need for action.

Stockholm, September 2021[1]

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Granskare/Examiner

Björn Sundqvist, Swedish Transport Administration.
Julia Taylor, Swedish Environmental Protection Agency

During the review valuable feedback was also provided by Helen Lindblom, Swedish Transport Administration; Kerstin Bly Joyce and Eric Sjöberg, Swedish Environmental Protection Agency; Mats Gustafsson VTI and Arne Sköldén, Michelin Nordic AB. The conclusions and recommendations in the report are those of the authors and do not necessarily reflect the views of VTI as a government agency.

[1] This report is a translated version of an original report in Swedish published in 2021. The translation has been carried out by an external translator.

Table of contents

1. Introduction

Tyre and road wear has been identified as one of the main sources of microplastics in the environment. For this reason, the Swedish Government in December 2017 gave the National Road and Transport Research Institute (VTI) a commission to compile and disseminate knowledge regarding microplastics from road traffic. The task included the identification and evaluation of potential effective policy instruments and measures that could be used to limit emissions (Swedish Government, 2017b).

Tyre and road wear particles are generated as a result of the wear (i.e. abrasion) that occurs when a moving tyre comes into contact with the road surface. The particles then spread to different parts of the environment. The majority of these emissions are made up of rubber particles from tyres, which are assumed to make up at least half of all microplastic emissions in Sweden (Andersson-Sköld et al., 2020). A much smaller portion consists of microplastic particles from road markings (e.g. paint) and from polymer-modified bitumen, in locations where this is used as a binding agent in asphalt. However, the exact magnitude of these emissions is yet to be confirmed. The amount of tyre particles emitted in Sweden has been estimated to just over 11,000 tonnes annually by Polukarova et al., (2021). Based on very rough and uncertain estimates regarding the total amount of polymers present in the tyre and road wear particles emitted in Norway each year (Vogelsang et al., 2018), the following distribution applies: tyres: 4,300–5,700 tonnes of polymers per year; road markings: 90–180 tonnes of polymers per year; and polymer-modified bitumen: 28 tonnes of polymers per year.

Tyres, road markings, and polymer-modified bitumen contain either thermoplastic polymers, thermosetting polymers, or both. The generated particles are smaller (usually much smaller) than 5 mm and are generally covered by the term microplastics[2]. There are different types of tyres, with different characteristics, designed for different types of vehicles and different conditions. The latter include:

- summer tyres
- winter tyres with studs (also known as studded tyres)
- winter tyres without studs (also known as friction tyres)
- all season tyres (also known as all-round tyres).

There are also different types of road markings: thermoplastic road markings, waterborne paints, solvent-based paints, two-component paints, and road marking tape. In Sweden, most road markings are thermoplastic road markings. These usually contain approximately 3 percent of the thermoplastic polymer Ethylene Vinyl Acetate (EVA), which alongside 10–15 percent resin[3] makes up the binding agent (Scandinavian Road Marking Association, personal contact, summer 2021). Whether the resin is polymerised to any extent when the road marking product is heated to approximately 200 °C before application is unknown. As a rough estimate, around 15,000 tonnes of road marking products are applied to state-owned Swedish roads each year, i.e. excluding municipal and private roads (the Scandinavian Road Marking Association, personal contact, autumn 2019), however these figures cannot be used as an estimate of the amount of wear (see further 3.3.12).

Occasionally, a small amount (3–10% by weight) of plastic polymers is added to bitumen (Porto, et.al, 2019) to increase the durability of the asphalt (Honarmand et.al, 2019). In Sweden, polymer-modified bitumen is used mainly on heavily trafficked roads with a large proportion of heavy vehicles.

[2] Rubber particles from tyres are classed as microplastics by e.g. the EU and OECD, however there is no consensus about whether rubber should be covered by this term.

[3] The resin in Swedish thermoplastic road markings usually consist of pentaerythritol resin or C5 hydrocarbon resin, or a combination of these (the Scandinavian Road Marking Association), personal contact, autumn 2019).

The usage data below has been supplied by the Swedish Transport Administration (Sundqvist, Swedish Transport Administration, April 1, 2021, personal contact). According to the Swedish Transport Administration, the use of polymer-modified bitumen varies from year to year, mainly depending on which roads are built, but also on which roads are repaired (subjected to maintenance). In 2020, polymer-modified bitumen was used in approximately 15 percent of the asphalt used for surface maintenance on state-owned roads, which corresponds to around 12,000 tonnes of polymer-modified bitumen. This does not include the volumes used during the construction of new roads. A rough estimate by the Swedish Transport Administration shows that approximately 2–3 percent of all state-owned roads have surfacing containing polymer-modified bitumen, however they also point out that not all polymer-modified bitumen is found in the wearing course. In newly built roads, some polymer-modified bitumen may also be present in the binding and base layer immediately below the wearing course, from where it cannot be spread as a result of road wear.

A number of factors influence the magnitude of the tyre and road wear. These, for instance, include:

- the tyre or road marking (e.g. type, brand, design, tread, chemical composition, age)
- the road (e.g. curves, hills, type and texture of the road surface, speed limit)
- the vehicle (e.g. weight, tyre pressure, wheel alignment)
- driver behaviour (e.g. acceleration, breaking, speed)
- climate and weather (e.g. temperature, road condition (dry, wet, snow-covered, icy), use of studded tyres, snow clearing).

Where in the environment the particles end up depends on e.g. the road surfacing; soil conditions by the road; runoff conditions from the road; the distance to waterways, lakes and oceans; stormwater management; wind conditions; precipitation; removal of snow; and use of sewage sludge. Their potential impact on the environment and human health depends on for example where the particles are deposited, who is exposed, the amounts and sizes of particles to which organisms are exposed, which hazardous chemicals are leached, and how persistent the particles are.

Knowledge regarding tyre and road wear is very limited in many areas, why the risks cannot be assessed with any certainty. Despite this, the introduction of measures aimed at reducing microplastic pollution caused by tyre and road wear is deemed to be justified. The reasons for this, for instance, are that:

- emissions of microplastics from tyre and road wear are very large and increasing, partly due to increasing traffic and a trend towards heavier vehicles;
- particles are likely to be persistent and accumulate in the environment;
- both the particles themselves and the hazardous substances they contain may have a detrimental effect on the environment and living organisms.

The need to take action against microplastics has been highlighted by many different stakeholders, and even advocated by the Chief Scientific Advisors to the EU Commission in their Scientific Opinion on Environmental and Health Risks of Microplastic Pollution[4] (European Commission, 2019). This is also in line with the so called Precautionary Principle in the Swedish Environmental Code (2 chap. 3 §), which says that anyone undertaking or planning to undertake a business or carry out an action must put in place the protective measures, take into account the limitations, and take all other precautions

[4] Environmental and Health Risks of Microplastic Pollution. European Commission´s Group of Chief Scientific Advisors, Scientific Opinion 6/2019 (Supported by SAPEA Evidence Review Report No. 4). Scientific Advice Mechanism. Directorate-General for Research and Innovation.

required to prevent, avert, or counteract that the business or action causes harm to, or have a negative impact, on human health or the environment.

1.1. Purpose

The purpose of this report is to identify policy instruments and measures with the potential to reduce microplastic pollution of the environment caused by tyre and road wear. Another aim is to evaluate, based on current knowledge, which of these policies and measures should be prioritised for further study, and which types of research and other knowledge building activities are needed to assess the need for action or to design effective policy instruments and measures.

1.2. Scope and limitations

The report maps and identifies policy instruments and measures which have the potential to reduce microplastic pollution of the environment from source to recipient caused by tyre and road wear. It covers policy instruments and measures aimed at reducing emissions, limiting dispersion, and decreasing the effects of particles that have spread to the environment, as well as those aimed at increasing our knowledge in this area. The underlying assumption is that road vehicles will, for the foreseeable future, use rubber tyres and drive on roads with road markings. The report considers national policy instruments from a Swedish perspective, but also covers instruments that must be developed at EU level or other international level. Tyres and road markings are included in the evaluation, however polymer-modified bitumen has not been studied specifically, despite the fact that reduced road wear would also decrease the amounts of microplastics generated from this type of bitumen. Some policy instruments and measures apply specifically to car tyres, while others also apply to tyres from other types of vehicles (e.g. trucks, buses, motorbikes, and machinery). The main focus has been on policy instruments and measures that help limit the generation and emission of tyre particles. The reasons for this are both that tyre wear is the largest source of microplastics from road traffic and that it is generally more effective to put measures in place in the early part of the chain (from generation to effects in the environment), i.e. preferably before the particles are generated or emitted into the environment. In the report, the term ‘emission’ is used for both the generation of particles and for the release of particles from tyres or road markings.

Since there are big gaps in our knowledge regarding most aspects of tyre and road wear, it is currently not possible to make well-grounded prioritisations between different policy instruments and measures, nor to propose extensive actions, motivated solely by microplastics from tyre and road wear. There are also no grounds for carrying out a complete evaluation of different policy instruments or measures based on various important aspects, such as effectiveness (i.e. to what degree the measures resulting from the policy instruments can contribute to reaching set goals, without also consideration to costs or other factors), cost-effectiveness, and feasibility. For this reason, the report has been limited to a more quantitative study with the scope to describe and discuss a large number of potential policy instruments. This means that the assessments of which policy instruments or measures to prioritise are fairly uncertain, and often based on only a single or a few of the abovementioned aspects. Recommendations focus mainly on policy instruments or measures to be prioritised for further investigation, or the types of research or knowledge-gathering that is needed to enable effective actions to be designed.

Several of the potential policy instruments and measures may also have positive impacts on other aspects, in addition to decreasing microplastic pollution. These positive impacts, here called ‘positive side effects’, have been included in the descriptions of the different policy instruments and measures. Examples include noise-reduction, improved road safety, reduced land-use for road traffic, lower emissions of greenhouse gases and other air pollutants, and reduced costs. These can either be sufficient to motivate the introduction of a policy instrument or measure in themselves or be enough when combined with the goal to reduce microplastic pollution, despite the aforementioned knowledge gaps concerning both the risks posed by microplastic particles from tyre and road wear, and the effectiveness and cost-effectiveness of the policy instrument or measure in question. These positive side effects can be achieved either by using policy instruments and measures directly targeted at them, or as indirect effects of other policy instruments and measures. In some instances, other policy instruments and measures may provide a more cost-effective way to achieve a particular positive side effect, however no such assessments have been carried out as part of this report. Several potential policy instruments and measures can bring negative side effects, and these have also been included in the description of each instrument or measure. The priority of each policy instrument or measure has, however, been made from a microplastic perspective (without consideration to positive side effects). In one case, negative side effects have influenced the prioritisation.

The policy instruments and measures discussed in this report can either be specific or relate to a group of instruments or measures. Under each policy instrument or measure heading between one and three policy instruments or measures are described.

Some policy instruments and measures overlap, and others are variations on the same theme, but with a different approach, control mechanism, or stakeholder. Additionally, some policy instruments and measures may interact with each other, or be suspected to interact. Within the framework of this report, it has not been possible to analyse such interactions, nor to perform more in-depth analysis of negative side effects, effectiveness, cost-effectiveness, feasibility, and implementation time (see also 1.3 below), which must be carried out before a policy instrument or measure is introduced.

1.3. Method

The identification of potential policy instruments and measures is partly based on the measures described in the knowledge compilation on tyre and road wear prepared by VTI 2020 (see Andersson-Sköld et al., 2020) as part of this government commission, and partly on a small number of other publications (see section 3.1). More potential policy instruments and measures have also been developed during the preparation of this report, for example based on other existing knowledge within this area (e.g. on factors impacting tyre and road wear), by modification and supplementation of existing policy instruments with other goals, and after contacts with experts in certain issues. All policy documents and measures are described individually in sections 3.2 to 3.6. To provide a harmonised summary and overview, they have also been compiled in Table 2, section 3.7, and in an extended version of the same table in Appendix A. Extended summary table – potential policy instruments and measures. As there is often a lack of information regarding several aspects of the described policy instruments and measures, they are difficult evaluate and compare with each other.

A few important aspects considered in the discussion and prioritisation of each policy instrument or measure, where possible, are:

- *Effectiveness (ability to achieve intended goals):* the degree to which the measures can reduce the burden, without consideration to other aspects, such as cost
- *Cost-effectiveness*: the cost of the policy instrument or measure in relation to the reduction in burden
- *Feasibility*: how difficult it would be to implement the policy instrument or measure (e.g. whether it can be implemented at the national level or must be implemented at EU level, and whether there are any technical or legal barriers)
- *Implementation time*: the time it would take to implement the policy instrument or measure

- *Positive and negative side effects:* any impact, effect or consequence[5] that results from a policy instrument or measure, and which is unrelated to microplastics from tyre and road wear (e.g. an increase or decrease in other environmental impacts, road safety, or costs).

As there is no baseline data on factors such as the magnitude of existing emissions of tyre and road wear particles, the effect on emissions of a particular policy instrument or measure, nor the cost of implementing it, only rough estimates can be made based on existing knowledge. In many cases it has not even be possible to make rough estimates regarding effectiveness and/or cost-effectiveness. In relation to effectiveness, no assessment has been made regarding the extent to which measures are put in place as a result of a policy instrument.

For each policy instrument or measure, a judgement has been made regarding whether it should be highly prioritised, prioritised, or not prioritised, from a microplastics perspective. Often the decision is either highly prioritised or prioritised for further investigation. Highly prioritised and prioritised measures, for instance, include those deemed to result in large reductions in emissions (high effectiveness) and those for which a lower effectiveness is acceptable, as the investment (cost) is low.

Current knowledge gaps also mean that there is a real need for policy instruments and measures that promote further research in this area. The increasing knowledge this would bring can then provide the basis for developing policy instruments and measures able to reduce microplastic pollution of the environment caused by tyre and road wear. Research as a policy instrument has also been categorised as highly prioritised, prioritised, or not prioritised. This judgement is based on whether the proposed research in the long run has the potential to result in an effective policy instrument or measure that could reduce microplastic pollution caused by tyre and road wear.

For several of the described policy instruments and measures, the initial focus is to enable research or other knowledge building activities, to potentially in the next step proceed to evaluation and assessment of policy instruments or measures connected to the research findings.

It may also be the case that some policy instruments or measures can be fully justified by other aspects (positive side effects) and lead to reduced microplastic pollution as a bonus. In this scenario, it would not be necessary to investigate the effectiveness in relation to reducing microplastic pollution. In other scenarios, both reduced microplastic levels and other positive side effects may be required to justify the implementation of a policy instrument or measure. These types of discussions are included in this report, however the prioritisations provided at the end of each chapter, in Table 2 and Appendix A. Extended summary table – potential policy instruments and measures, focus on microplastics.

[5] Impact: the physical action itself. Effect: the change it causes in the environment. Consequence: the importance of this change.

2. On policy instruments and measures

Policy instruments are tools used by the government and authorities. They take the shape of mandatory rules and regulations or non-mandatory incentives and are used to force different entities (e.g. private individuals and companies) into changing their behaviour, put in place measures, or act in a way that helps fulfil one or several political aims.

Policy instruments relating to the environment may, for instance, include incentives to limit the use of a product. A measure is the action that entities (e.g. private individuals, companies or authorities) take as a result of the policy instrument (Swedish Environmental Protection Agency, 2012). The action causes effects which may contribute to the goal being achieved (Transport Analysis, 2018).

2.1. Categories of policy instruments

There are many different types of policy instruments, and a number of different ways to categorise them. This means that there is no standardised way of doing this. They can for instance be classified into the overall categories market-based and non-market-based instruments. Market-based policy instruments use market prices to create financial incentives for individuals and businesses (Swedish Environmental Protection Agency, 2020a). Market-based policy instruments are characterised by the transfer of responsibility from the public to the private sector, and the utilisation of market forces to stimulate desired societal change (Transport Analysis 2018). The remaining policy instruments, which do not utilise market mechanisms, are non-market-based instruments (Swedish Environmental Protection Agency, 2020a).

A more detailed classification method can for instance use the categories administrative policy instruments (also known as legal policy instruments), economic policy instruments, information-based policy instruments, research & development (Swedish Environmental Protection Agency, 2012; Transport Analysis, 2018) and physical planning (Transport Analysis, 2018), see Table 1. These categories partly overlap (Swedish Environmental Protection Agency, 2020a). The summary table in Appendix A states whether individual policy instruments belong to any of these categories.

Table 1.Categories of policy instruments, their purpose, and examples of environmental policy instruments.

Category	Purpose	Example
Administrative (legal and regulatory) policy instruments	To use mandatory rules and regulations, as well as control mechanisms to force actors in society to act in a more sustainable and environmentally friendly way[6]	Legislation, norms, limit values, long-term agreements, environmental classification, regulations, technical requirements, examinations, supervisions, management by objectives[7], permits, public procurement[6].
Economic policy instruments	To use financial incentives to influence stakeholders in society to act in a more sustainable and environmentally friendly way[6]	Taxes, tax deductions, fees, benefits (incl. investment aid), subsidies, deposits, trading in emission allowances, trading in certificates, environmental compensation[7].
Information-based policy instruments	To use information and communication to convey knowledge that generates awareness, willingness to participate, and changed attitudes, resulting in understanding and acceptance of both existing policy instruments and the introduction of new instruments[7] [6]	Information, environmental labelling[8], advice, education and opinion formation[7] [6] public procurement[6]
Research & development	To increase knowledge and further development of technical solutions and facilitate market introduction of new technical solutions or products within prioritised areas, which can help achieve set goals[7] [6]	Research, development, demonstrations, technology and system evaluation[7], innovation procurement[6]
Physical planning	To use physical planning to reduce the impacts of travel and transportation patterns[6]	Planning for denser and more mixed-use development, extended use of bus lanes, walkways and cycling lanes, fewer car park spaces[6] environmental zones

Other categories of policy instruments e.g. include authoritarian (mandatory), stimulating, capacity-building, symbolic, encouraging, and awareness-raising instruments (Transport Analysis, 2018).

Alternatively, classification methods can be based on what the instruments are targeted at, which could be:

- tyres (e.g. hazardous substances, degradability, tyre type, wear propensity, tyre pressure)
- vehicles (e.g. weight, engine power, acceleration, wheel-balancing)
- road markings (e.g. hazardous substances, degradability, type of paint, height above the road surface)
- roads (e.g. road surface material, bendiness, hilliness)
- operation and maintenance (e.g. snow clearing, road sweeping, road surface material)

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[6] Transport Analysis, 2018.

[7] Swedish Environmental Protection Agency, 2012.

[8] Environmental labelling is a policy instrument used by the government and authorities, but can also be promoted by businesses or organisations. The Swedish Government has given Miljömärkning Sverige AB the overall responsibility for the Nordic Swan Ecolabel and the EU Ecolabel in Sweden (Nordic Swan, 2021). This report also covers ecolabelling for which neither the government nor an authority holds direct responsibility.

- traffic behaviour (e.g. driving style, driver behaviour, speed)
- spread (e.g. collecting tyre particles during travel, sustainable management of stormwater on roads)
- reduced road traffic (vehicle-kilometres) (e.g. physical planning, combined planning of infrastructure and buildings, traffic limitation measures, speed limits, availability of public transport, carpools, loan-bikes, cycleways, raised vehicle or fuel taxes, congestion charges)
- knowledge building.

In this report, policy instruments and measures have been divided into four sub-objectives: 1) to reduce emissions, 2) to reduce spread 3) to reduce impacts and persistence, and 4) to increase knowledge generally.

3. Potential policy instruments and measures targeting microplastics from tyre and road wear

This chapter describes and assesses policy instruments and measures that could be used to target microplastics from tyre and road wear, as identified during the preparation of this report. These are also provided in Table 2, and in an extended version of the same table in Appendix A. Under current conditions (i.e. vehicles with rubber tyres driving on roads) it is not possible to stop emissions completely at the source. For this reason, a combination of different policy instruments and measures targeting different segments are required to reduce emissions, reduce spread, and reduce the burden, together reducing the environmental burden.

3.1. Other studies on policy instruments and measures targeting microplastics from tyre and road wear

Individual policy instruments and measures are occasionally mentioned in the available literature on microplastics from tyre and road wear, however only a small number of studies have described multiple potential policy instruments targeting microplastics from tyre and road wear. Verschoor & de Valk (2017) at the Dutch Environment and Health Agency, RIVM[9] have investigated policy instruments and measures targeting microplastic emissions to water and suggested ten instruments or measures aimed at reducing emissions and dispersion of tyre wear particles. These include:

- introducing a legal threshold value for tyre abrasion;
- supplementing the EU tyre label with an indicator for abrasion;
- replacing non-porous asphalt top layers of motorways with porous asphalt;
- using information campaigns to encourage the use of a sustainability tool by road construction companies;
- increasing road sweeping frequency;
- banning use of winter tyres in the summer;
- promoting a tyre pressure monitoring system for passenger cars and vans;
- including uneven tyre abrasion in the periodic safety inspection of passenger cars and vans;
- reducing speed limits on motorways to 100 km/h;
- introducing a kilometre tax (Verschoor & de Valk, 2017).

They have also attempted to estimate the reduction potential, calculated as emissions (tonnes/year) for each policy instrument and measure. Due to the lack of baseline data on emissions of tyre wear particles, both in general and in relation to the proposed policy instruments and measures listed above, our view is that the estimated reduction potentials in tonnes per year are very uncertain.

There is also a Norwegian report, by Sundt et al. (2016) which was commissioned by the Norwegian Environmental Protection Agency (Miljødirektoratet) to describe and assess 50 measures for reducing microplastic emissions. Five of these relate specifically to microplastics from tyre wear and involve:

- reducing road traffic;
- supporting initiatives that promote tyres with lower wear propensity;

[9] RIVM, Rijksinstituut voor Volksgezondheid en Milieu (the Dutch National Institute for Public Health and the Environment).

- supporting initiatives that promote eco-driving;
- improving the management of stormwater on roads and wastewater;
- more frequent cleaning of roads and streets.

The Swedish Environmental Protection Agency has in its reports on two government commissions concerning microplastics (2017; 2019b) described and discussed a number of different policy instruments and measures aimed at reducing the emissions of microplastics from tyres and roads. However, due to the identified knowledge gap, only a few measures were proposed. These were to:

- give VTI a government commission to gather knowledge about microplastics from road traffic (Swedish Environmental Protection Agency, 2017);
- give the Swedish Transport Administration the overall responsibility for knowledge generation and assessment of the measures most appropriate for reducing the spread of microplastics from the national transport system[10] (Swedish Environmental Protection Agency, 2017);
- task the Swedish Transport Administration with evaluating how well the current treatment technology for stormwater on roads works in relation to microplastics (Swedish Environmental Protection Agency, 2017);
- give the Swedish Energy Agency responsibility for investigating the possibilities and appropriateness of extending the energy labelling of tyres to also consider tyre wear (Swedish Environmental Protection Agency, 2017);
- put in place notification requirements for artificial football pitches[11] and other outdoor facilities for sports and play (> 200 m^2) using rubber or plastic as their base (Swedish Environmental Protection Agency, 2019a).
- extend existing guidance on prevention and limitation of negative environmental impacts caused by artificial football pitches to also include outdoor facilities for sports and play with a base containing products of rubber or plastics (Swedish Environmental Protection Agency, 2019a).

Within the framework of this (i.e. VTI's) commission from the Government, we have also produced a knowledge compilation regarding microplastics from tyre and road wear (Andersson-Sköld et al, 2020), in which we assessed and discussed a number of policy instruments and measures targeting microplastics from tyre and road wear. Additionally, the City of Stockholm (2019a) has adopted an action plan which includes 50 concrete measures, some of which relate to tyres and roads.

In parallel with the preparation of this report, a working group within the OECD[12] (2020a) has also prepared a draft report (November 2, 2020) on microplastics in marine and freshwater, with focus on textiles and tyres. The draft includes descriptions and assessments on the best currently available technologies and methods for limiting microplastic emissions from textiles and tyres and describes both existing and potential new policy instruments targeting microplastic pollution. The draft report also comprises a chapter designed to offer some guidance to authorities and other stakeholders on potential preventative measures and ways to manage microplastics from tyres and textiles while awaiting the

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[10] The Swedish Transport Administration were willing to take on this task, but were never assigned it (Björn Sundqvist, Swedish Transport Administration, March 3, 2021, personal contact).

[11] Rubber granules from shredded car and machine tyres is the most commonly used infill material in artificial turf pitches, and currently used in over half of all such pitches in Sweden (Swedish Environmental Protection Agency, 2021a).

[12] OECD Working Party on Resource Productivity and Waste.

knowledge building that is required to enable implementation of more comprehensive policy instruments and measures. Many of the policy instruments and measures mentioned in the OECD's draft report are basically more or less the as those described in this report and were already present in an earlier draft of this report when we gained access to the draft from the OECD.

The OECD report classifies policy instruments and measures along the lifecycle chain as follows: design and manufacturing, use phase, end-of life, and end-of-pipe (which includes emissions from e.g. wastewater treatment plants). This classification is slightly different from that chosen for this report (see section 3.2).

In December 2020, the Nordic Council of Ministers published a report on reducing emissions of microplastics from tyre wear (Skumlien Furuseth & Støhle Rødland, 2020), which focuses on measures aimed at reducing emissions of microplastics and on capturing already emitted microplastics. The report mentions some of the policy instruments and measures described in this report.

In addition to the abovementioned reports, there are also a few Swedish Government Official Reports and other inquiries, which looked at policy instruments targeted at other goals that may also help to reduce microplastic pollution caused by tyre and road wear. Examples include policy instruments related to road tax (Hennlock et al., 2020) and the use of studded tyres (Swedish Environmental Protection Agency, 2016; SOU 2015:27). There is also a report titled 'Policy instruments for the reduction of climate impact from plastics', which suggests various taxes and fees relating to plastics, however this report does not cover rubber polymers or rubber products (Bjerkesjö et.al., 2020). There are also some currently used policy instruments and measures that already help reduce microplastic pollution caused by tyre and road wear, even though microplastics were not considered when the instruments or measures were developed. This applies to e.g. speed limits, congestion charges, investments in public transport (which lead to switching from car travel to public transport) and systems for stormwater management.

3.2. Overall objectives and sub-objectives

The overall objective for all policy instruments and measures targeting tyre and road wear included in this review is to reduce microplastic pollution of the environmental caused by tyre and road wear. This objective has been divided into the following sub-objectives, which have also been used to classify the described policy instruments and measures:

- sub-objective 1 – to reduce emissions
- sub-objective 2 – to reduce spread
- sub-objective 3 – to reduce the impact of the particles that spread
- sub-objective 4 – to increase knowledge generally.

Some of the policy instruments and measures relate to more than one sub-objective but are still only described under one of them. Instruments and measures that lead to reduced emissions can be referred to as source-limiting, as they already at the source either prevent particles from forming or reduce the number of particles generated.

Those that reduce the spread of already emitted particles include different types of separation systems, and those that reduce the effects of the particles may involve substitution of hazardous chemical substances or the development of tyres that break down more easily. To minimise the impact as effectively as possible, policy instruments and measures should primarily be introduced as early in the chain as possible, i.e. preferably before the particles are generated. This covers instruments and measures that reduce emissions (sub-objective 1) or reduce their harmfulness and persistence (sub-objective 3). It is often also easier, more cost-effective, and better for the environment to use policy instruments and measures early in the chain rather than attempting to reduce the spread of already emitted particles, using e.g. separation systems, treatment, or decontamination. This also avoids simply moving the problem to another location, which is what happens with e.g. microplastic-contaminated masses. Policy instruments aimed at increasing knowledge generally fall under sub-objective 4 if they concern general knowledge building regarding e.g. emissions, dispersion and impact. If the policy instrument is instead aimed at promoting research into a specific aspect of a potential policy instrument or measure, it falls under one of the other three sub-objectives.

3.3. Potential policy instruments and measures for sub-objective 1 – Reduce emissions

Policy instruments and measures that reduce emissions can either prevent the generation of particles, e.g. by reducing number of vehicle-kilometres travelled on roads, or limit the amounts of particles being generated, e.g. by reducing the wear propensity of tyres, decreasing the weights of vehicles, or using road surfacing materials which are less likely to cause tyre wear. This section describes policy instruments and measures designed to reduce emissions or to generate knowledge, thereby enabling development of appropriate policy instruments and measures for reducing emissions.

3.3.1. Reduced road traffic (vehicle-kilometres)

Policy instruments and measures: All policy instruments and measures that reduce road traffic (i.e. vehicle-kilometres). This includes those that make it more difficult for private and goods vehicles to use the roads, as well as those that promote alternative means of transportation or the avoidance of travel, i.e. both carrots and sticks.

There is a strong correlation between the number of kilometres travelled by road vehicles and the amount of tyre and road wear particles being generated. A reduction in the number of vehicle-kilometres travelled can be achieved by reducing the demand for transportation, more effective use of vehicles used for road transport, and by switching from travelling by car to walking, cycling and public transport, and from transport by trucks to transport on railroad and or water. A reduction in the number of vehicle-kilometres travelled, in particular in urban areas, has been highlighted by the OECD (2020b) as a way to reduce particle volumes in general, and by Sundt et al. (2016), as a way to reduce microplastic particles in particular.

Policy instruments and measures that lead to a reduction in the number of vehicle-kilometres travelled can reduce the generation of tyre and road wear particles significantly. There are a number of policy instruments with the potential to reduce the number of vehicle-kilometres travelled. Spatial planning, i.e. planning of buildings, services, infrastructure and traffic, can be used as a stimulating policy instrument, creating the conditions needed to establish desirable travel and transport patterns (Transport Analysis, 2018).

This can include planning for:

- improved infrastructure for pedestrians and cyclists;
- provision of bicycle-sharing systems, municipal carpools, as well as well-functioning and extensive public transport systems;
- increased capacity and more maintenance of railways;
- denser and more mixed-use developments (Transport Analysis, 2018).

Physical planning can also be used to make less desirable travel and transportation patterns more inconvenient, e.g. by limiting car access and providing fewer carpark spaces (Transport Analysis, 2018).

To make people leave the car behind and instead travel by e.g. bicycle or public transport, simply improving the public transport offering and providing better facilities for cycling and walking is rarely enough. These measures generally only result in switches between walking, cycling, and public transport. To encourage a move away from cars also requires making driving more expensive or less convenient, i.e. both carrots and sticks are needed.

Another option is to limit the available space and access to some parts of the road traffic through political decisions relating to infrastructure and planning measures. Examples include the introduction of environmental zones, banning cars on certain roads or during certain times, taking space from cars and increasing the space for walking, cycling and public transport, and reducing the number of parking spaces. For means of transport with high capacity, such as public transport, walking, cycling and heavy goods vehicles, accessibility should instead be prioritised (Swedish Transport Administration, 2018).

Other traffic reducing measures include taxes and charges. Financial traffic reducing measures currently used in Sweden include congestion charges (governed by Act [SFS 2004:629] on congestion charges) and taxes on road vehicles (e.g. vehicle tax; carbon dioxide tax on diesel and petrol; energy tax on diesel, petrol and electricity; tax on traffic insurance premiums; infrastructure charges, such as charges to use certain bridges) (Hennlock et al., 2020). Another example is the reduction obligation (governed by Act [SFS 2017:1201] to reduce greenhouse gas emissions from certain fossil fuels), which requires petrol and diesel to contain a higher proportion of biofuels, with the aim to reduce greenhouse gas emissions, which is an indirect traffic-reducing policy instrument, as this addition of biofuels increases the cost of petrol and diesel.

There are three main reasons for taxing road traffic: 1) to finance infrastructure, 2) to internalise negative external effects, such as emissions of greenhouse gases and other air pollutions, and 3) for purely fiscal reasons. As the emissions of greenhouse gases and air pollutants decrease because of the increased share of biofuels and the transition towards electric powered vehicles, the negative external effects of these emissions also decrease, and at the same time the government income from energy and carbon dioxide taxes also decreases. One way to manage this change may be to introduce a kilometre tax. Hennlock et al. (2020) have investigated a road tax for cars in the shape of a kilometre tax, which could be geographically differentiated. Hennlocket al. (2020) have estimated the implementation period for such a tax to between seven and twelve years, including time for a government inquiry, consultation procedures, preparation, consideration by the Legislation Council, notification to the EU, proposition and implementation. A proposal by Verschooor & de Valks (2017) regarding policy instruments targeting microplastics also includes a kilometre tax, which is proposed to cover motorbikes, cars, and vans being driven on motorways.

In 2016, the Swedish Road Tax inquiry (SOU 2017:11) prepared a proposal for a distance-based road tax on heavy goods vehicles and goods vehicle combinations with a total weight of at least 12 tonnes. After this, the Swedish Ministry of Finance (2018) prepared a proposal for a distance-based road wear tax for heavy goods vehicles (above 3.5 tonnes). Neither of these proposals became reality. Instead, an inquiry is currently underway to analyse the design of a new system for environmental governance for road freight, which will investigate different options such as a distance-based system or a system that is neither time-based nor distance-based (Swedish Ministry of Finance, 2020).

There are also currently enforced policy instruments that have the opposite effect and instead lead to increased road use. Examples include tax deductions for travel and measures aimed at, so called, regional expansion and increased commuting between larger towns, and benefit taxation of public transportation tickets. If the tax deduction for travel became distance-dependent and travel method-neutral (instead of mainly promoting car travel) this would, according to an analysis by Sandberg et al. (2012) result in an 11 percent reduction in the vehicle-kilometres travelled in the Mälardalen region (a densely populated part of Sweden), and in a 10 percent reduction in Norrland (a sparsely populated part of Sweden). It would also lead to an increase in the use of public transport of 40 percent in Mälardalen and 75 percent in Norrland, respectively. The Travel Deduction Committee suggested in their report Tax Relief for Work Journeys (SOU 2019:36) that the travel deduction should be discontinued in its current form and replaced with a distance-based and travel method-neutral tax deduction for work-related travel further than 30 km and up to 80 km, one way. This proposal is expected to reduce the number of work-related car journeys by 2 percent and the number of kilometres travelled (per person) by 11 percent. The use of public transport is expected to increase by 3 percent, and vehicle-kilometres travelled by 12 percent.

Transport demand can decrease for other reasons than as a result of policy instruments or measures specially designed to reduce it. One example is increased remote working, which decreases the need to travel to and from a workplace and external meetings, as well as the need for office space. This change would bring benefits for both the employee (shorter travel times) and the employer (lower costs). A significant increase in remote working and in the use of online meetings and seminars have taken place since the spring of 2020 due to Covid-19, and the advice and guidelines published by the Swedish Public Health Authority to reduce the spread of the virus. It is possible that we will continue to work more from home and meet online even after the effects of the pandemic have subsided.

Positive side effects

Reducing the number of vehicle-kilometres would lead to a number of positive side effects concerning the many environmental and health aspects of traffic, including emissions of climate-impacting greenhouse gases and air pollutants which are hazardous to human health, acidifying, eutrophying, or ozone producing; noise; other types of pollution (e.g. light), intrusion into or fragmentation of the natural environment; effects on biodiversity and ecosystem services; land-use (Swedish Environmental Protection Agency, 2020b); impacts on the natural landscape; impacts on water quality; and the risk of accidents. The climate-political framework (Swedish Government, 2017a) adopted by the Swedish Parliament (the Riksdag) on the 15 June 2017 states that emissions of greenhouse gases from domestic transport, excluding domestic air travel, should be reduced by at least 70 percent by the year 2030 from 2010 levels. According to forecasts by the Swedish Transport Administration (2020b), the number of vehicle-kilometres travelled by cars in Sweden will increase by approximately 1.0 percent per year, over the period from 2017 to 2040, which corresponds to 27 percent over the entire period. The rate of increase for vehicle-kilometres travelled by goods vehicles is expected to be approximately 1.6 percent per year over the same time period, which corresponds to around 44 percent (Swedish Transport Administration, 2020d).

Negative side effects

Some policy instruments and measures that lead to reduced road traffic may have negative side effects, as they may limit accessibility and may increase the time it takes to travel from one place to another. Longer times spent transporting people or goods mean higher costs.

Discussion and assessment

There is no doubt that policy instruments and measures that reduce the number of vehicle-kilometres on roads in turn reduce the impact of microplastics from tyre and road wear, as road traffic is the prime reason for these particles being generated.

For this reason, the effectiveness is deemed to be high for policy instruments and measures that have a significant effect on road traffic (vehicle-kilometres). It is important to note that the policy instruments mentioned above have different abilities to affect road traffic, and that some would have to be introduced in combination with other measures to produce a significant reduction. This may require amendments to currently used policy instruments and measures, as well as the introduction of new ones. As mentioned above, there are also other reasons for prioritising policy instruments and measures that reduce traffic flows on roads than to decrease microplastic emissions.

How and where road traffic is limited influences the magnitude of both the positive and negative side effects. Improved logistics, resulting in better fill rates for goods vehicles, has probably only positive effects at the societal level. More car sharing and opportunities to work from home, and increased use of video conferencing rather than physical meetings, would probably also have mainly positive effects for society. When it comes to measures that restrict accessibility, trade-offs must be made between the so-called functional goal, which relates to accessibility, and the so-called consideration goal, which relates to health, road safety, and the environment (both these goals are included in the Swedish transport policy[13]). The environment covers both quality goals and climate goals. When trade-offs are made between accessibility and consideration goals, it must be born in mind that the Swedish Government and the Riksdag (i.e. Parliament) have decided that to meet the overarching traffic policy goal, accessibility must be increased over the longer term, with the provision that no-one should suffer death or serious injury as a result of a road accident, and that this must be achieved in a way that contributes towards reaching the environmental quality objectives and to better health (Swedish Government, 2021). This, in combination with the many positive side effects resulting from reduced road traffic (vehicle kilometres) may be sufficient to justify the introduction of traffic control measures, despite the fact that these may sometimes lead to reduced accessibility.

Convincing reasons for reducing road traffic (vehicle-kilometres) may include reaching the goal for reducing greenhouse gas emissions, reduced exposure to air pollutants that impact human health, and reduced exposure to noise. These factors will probably provide stronger motivation for reducing road traffic than microplastic particles would, although reduced road traffic is expected to result in significantly lower microplastic emissions. It can be assumed that the emissions of tyre and road wear particles are in direct proportion to the number of vehicle-kilometres on roads. For this reason, thorough investigations into the impacts or cost-effectiveness of policy instruments on microplastics tyre and road wear are not always deemed necessary. Location-specific assessments of negative side effects from reduced access and increased travel time should, however, be carried out.

Implementation of these policy instruments and measures take place at the national level, by different authorities or through political decisions, but could also take place at the local level, for example through urban planning or local regulations. Implementation times vary between different instruments and can range from a few months for smaller, localised measures to more than a decade for more comprehensive policy instruments, such as a kilometre tax.

As described above, there are a number of policy instruments and measures that can impact road traffic, in turn influencing the amount of microplastics generated from tyre and road wear. Detailed evaluations of these measures have not been carried out, and we are therefore unable to rank them after priority. Despite this, our view is that any policy instruments and measures resulting in a more transport-effective society and a reduction in road traffic (vehicle kilometres) should be highly prioritised for further investigation.

3.3.2. Influencing the composition and development of the vehicle fleet

Policy instruments: a) Promote research on the importance of the weight, motor power and acceleration of cars for tyre and road wear, and b) reduce the percentage of heavier cars with more powerful engines and better acceleration (e.g. SUVs) for instance by taxes or a modified bonus-malus system.

The composition and development of the vehicle fleet are very important to the amounts of tyre particles being generated, where for example heavier and more powerful vehicles and vehicles with faster acceleration generate more tyre wear particles. A lighter electric car with less engine power and slower acceleration is better from a microplastic, energy and resource perspective than a heavier electric car

[13] Sweden's Transport Policy Goals were presented in the government bill "Goals for future travel and transport" (Government bill 2008/09:93) and adopted by the Riksdag in 2009. The goals consist of one overarching goal, one accessibility goal and one consideration goal.

with a more powerful engine and faster acceleration. The same applies when comparing lighter and less powerful petrol or diesel cars with heavier and more powerful petrol and diesel cars, respectively. In general, smaller and lighter cars are more environmentally friendly than larger and heavier cars, see Figure 1.

The trend both in Sweden and internationally is towards a greater number of heavier cars, as the proportion of SUVs (Sport Utility Vehicles) (also known as city jeeps) and electric cars increases. According to IEA[14] (2019) the number of SUVs has increased globally, from 35 million vehicles in 2010 to more than 200 million in 2019. SUVs now (2018) make up 40 percent of all new vehicles sold globally, almost half of all cars sold in the United States, and a third of new cars sold in Europe (IEA, 2019). On average, SUVs use 25 percent more fuel than mid-sized cars (IEA, 2019). According to Continental (2021b), the weight, engine power and torque significantly impact how far a tyre can travel before it is worn out; as assessed on a three-point scale, from low to high. The wear increases with higher weight, engine power, and torque (Continental, 2021b), which are characteristics of both SUVs and electric cars.

SUVs are available even in the electric car segment, mostly as plug-in hybrid electric vehicles, but lately more compact versions of battery electric vehicle SUVs have also been launched. Sales of electric cars have increased mainly in the European market. Figures for 2020 show that globally, battery electric cars and plug-in hybrid electric cars make up approximately 4.2 percent of new cars sold, which is an increase from 2019, when the proportion was 2.5 percent (EVvolumes.com, 2020).

Of the 3.24 million electric cars (hybrid and fully electric) sold in 2020, China contributed the highest portion (41.3%), followed by Germany (12.3%). Sweden was in 7th place with a 3 percent share (EVvolumes.com, 2020).

Figure 1.There is a risk that the trend towards heavier cars with more powerful engines may lead to increased emissions of microplastics. Photo: Mikael Johannesson, VTI.

According to Nokian Tyres (2019), electric cars do not generate more tyre wear, despite being heavier and having more power and torque than cars with combustion engines. They claim that the opposite is true, and that this can be explained by the fact that the driver assist system reduce slipping by utilizing the electric motor's rapid power adjustment. . This system act much faster than the corresponding systems in cars with combustion engines (Nokian Tyres, 2019). On the other hand, Continental (2021c) claim that the higher weight, longer breaking distance, and immediate torque of electric vehicles lead to

[14] International Energy Agency.

higher tyre loads, but that this is solved using tyres especially designed for electric cars, with more robust rubber, optimised grip, and minimal rolling resistance.

Policy instruments can be used to reduce the proportion of heavy vehicles, e.g. SUVs, and increase the proportion of normal-sized electric cars. Sweden uses a bonus-malus system for new class I and II passenger cars, light buses, and light trucks, which means that anyone buying a more environmentally friendly vehicle, with relatively low carbon dioxide emissions, is rewarded with a bonus, while those purchasing vehicles with relatively high carbon dioxide emissions are punished with higher vehicle taxes (Swedish Transport Administration, 2020b).

To increase the environmental impact, simplify the bonus-malus system, and ensure that the system is self-financed, some changes have been introduced. Since April 1, 2021, the Act on Road Traffic Taxes (SFS 2006:227) contains new rules, including year-on-year tax increases for the first three years for new petrol or diesel-driven cars, light buses, and light trucks. Additionally, the climate bonus has been increased from max 60,000 SEK to max 70,000 SEK for vehicles with zero emissions (SFS 2017:1334).

Positive side effects

Any policy instrument that reduces the number of heavy, powerful and high-torque petrol, diesel, or hybrid cars will have positive side effects, including lower fuel consumption (less air pollution and lower environmental impact), lower resource use, increased road safety for mid-sized and smaller cars involved in road accidents, and decreased land use. Instruments that lead to an increase in the number of fully electric cars have positive side effects, despite the fact that fully electric cars are heavier than ’normal’ cars, as they have a lower impact on the environment and lead to lower emissions of air pollutants, given the electricity mix available in Sweden. The magnitude of the decreased emissions from a lifecycle perspective also depends on the manufacturing processes for cars and batteries.

Negative side effects

When policy instruments promoting lighter vehicles with lower accelerating power are implemented, there is a risk that these will be detrimental to electric cars, which may in turn lead to an increase in greenhouse gas emissions. This must be considered in the development of such instruments. They will also lead to higher costs for individuals wishing to purchase the type of vehicle targeted by the policy instrument. Another negative side effect is that it will become more difficult for manufactures and dealerships to sell some car models.

Discussion and assessment

Policy instruments that lead to changes in the vehicle fleet, e.g. a move towards lighter and less powerful vehicles with lower acceleration, may be motivated for several reasons, apart from the resulting lower microplastic emissions from tyre and road wear. For petrol and diesel cars, this would mean lower fuel consumption (less impact on the climate and air pollution), reduced resource consumption, improved road safety for mid-sized and smaller cars, and decreased land use. There are a number of environmental reasons why it would be good to break the trend towards bigger and heavier cars, such as SUVs, e.g. by using the existing bonus-malus system, which discourages purchases of petrol and diesel-driven SUVs, which generally emit more carbon dioxide than ‘normal’ petrol and diesel cars. According to Transport & Environment (2020), plug-in hybrid electric cars may emit as much, or even more, than an energy-efficient petrol or diesel car, depending on the way in which they are used and how much fuel they consume when not run on electricity. Sales figures for new cars show that the proportion of SUVs is increasing fast, despite the bonus-malus system, why changes must either be made to the bonus-malus system, so that the weight of the vehicle is taken into account, or another effective policy instrument is introduced to reduce the number of SUVs. Even in relation to electric vehicles, a trend towards lighter and less powerful cars is desirable, for energy, resource, and road safety reasons. However, it is likely that other aspects will be more influential when it comes to potentially moving towards vehicles with lower weight, engine power, and acceleration than a reduction in microplastic emissions.

Our view is that research into the importance of the weight, engine power, and torque of cars to tyre and road wear should be highly prioritised. Additionally, ways to reduce the proportion of heavier and more powerful cars (e.g. SUVs), for example through taxes or modification of the bonus-malus system, should be prioritised for further investigation.

3.3.3. Labelling of tyre wear propensity

Policy instruments: a) Promote and drive the development of a standardised method for measuring tyre wear, and b) introduce labelling of the wear propensity of tyres in the EU Regulation on tyre labelling.

Different types of tyres (i.e. summer tyres, winter tyres with or without studs, and all-purpose tyres), as well as tyres from different brands and of different models, wear to different extents. According to preliminary findings from wear studies carried out in VTI's road simulator (2020), both on summer tyres and on winter tyres with and without studs, the difference in wear was greatest between the four different summer tyres included in the tests (Gustafsson, VTI, personal contact, December15, 2020). The wear was more than twice as high for the tyre with the highest wear than for the tyre with the least wear (Gustafsson, VTI, personal contact, December 15, 2020, see Figure 2). According to Verschoor and de Valk (2017), experts within the tyre industry have estimated that the wear propensity varies by 10–20 percent. Labelling of the wear propensity of tyres may encourage more people to choose tyres that last longer, thereby reducing the generation of tyre wear particles.

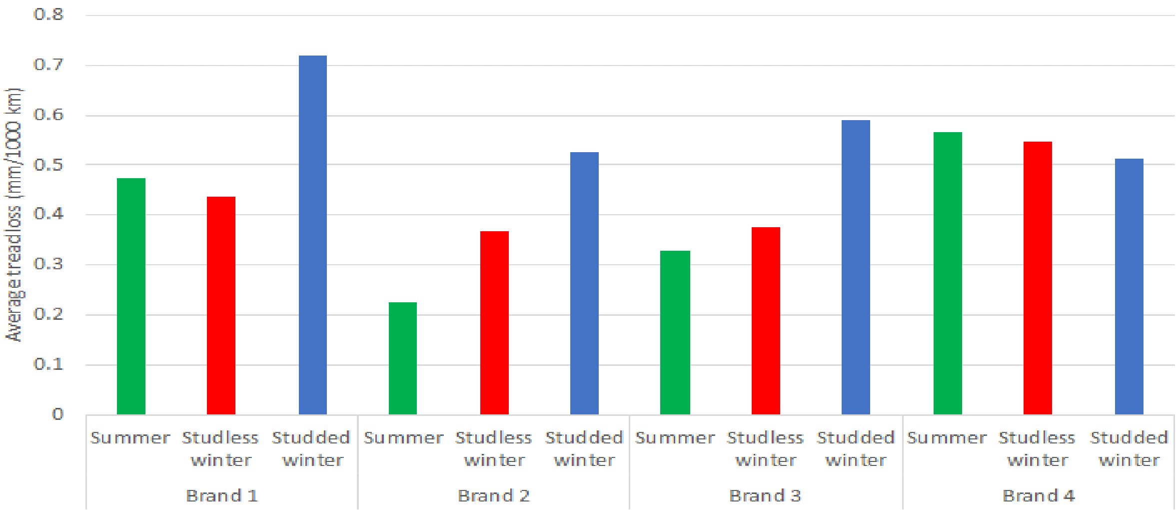

Figure 2. Differences in wear between different types of summer and winter tyres from a variety of manufacturers, according to tests in VTI's road simulator, measured as reduction in tread depth (mm/1000 km). The tests show that tyre wear varies significantly. Source: Mats Gustafsson, personal contact, December 15, 2020, VTI.

Labelling requirements

The EU requires tyres to be labelled. The requirements are set out in the Regulation of the European Parliament and Council (EU) 2020/740 on the labelling of tyres, which came into force on May 1, 2021, replacing the previous regulation on the labelling of tyres (EU no 1222/2009). The regulation covers labelling with respect to fuel efficiency (based on rolling resistance), wet grip performance, and external rolling noise. Tyre wear is currently not included in this regulation.

The new regulation means that labelling is now also required for trucks and buses (European Commission, 2021c). Other changes include the requirement that labelling must be more visible and clearer for consumers, and the addition of labelling for grip performance on snow and ice (European Council, 2020a), see Figure 3. The symbol for ice grip makes it possible to identify tyres adapted to icy road conditions, which are common in the Scandinavian climate. This may lead to better road safety when non-studded winter tyres are chosen and used in Sweden, as winter tyres of the type used in Central Europe are not designed for icy roads, but for a milder climate with wet and snow-covered roads (Industry Europe, 2019).

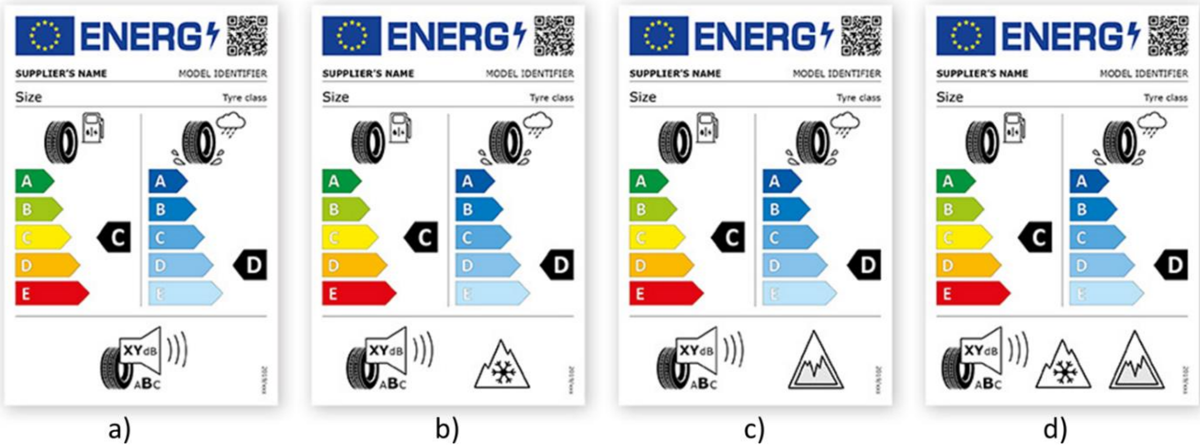

Figure 3. The EU's new labelling system for tyres. Image d) depicts all available labels. The bottom sections show labels for external rolling noise (i.e. tyre with sound symbol), the ability to grip in heavy snow conditions (i.e. peaks with snowflake symbol) and the ability to grip in icy conditions (triangle with icicles symbol). The symbols for snowy and icy conditions can be used separately (see image b and c) or together (see image d). The boxes above show the symbol and class (A-E) for fuel-efficiency (on the left) and wet grip (on the right). Source: © European Union, 1995–2021 (European Commission, 2021c).

The regulation also includes provisions for adding parameters son tyre abrasion and mileage (i.e. the number of kilometres for which a tyre can be used before having to be replaced due to wear), as soon as appropriate methods for testing this have been developed (European Council, 2020a). The reason for providing the ability to add these parameters is the wish to use consumer awareness to reduce microplastic emissions from tyre wear. The Regulation refers to the EU Commission's strategy for plastics in a circular economy, which mentions the need to address the unintentional release of microplastics from tyres, e.g. through information measures such as labelling and through minimum requirements for tyres (European Council, 2020b). The regulation also states that the EU Commission ought to mandate the development of a testing method for tyre abrasion (European Council, 2020b).

Efforts to identify the most appropriate testing method have been initiated by the tyre industry, led by a working group within the European Tyre and Rim Technical Organisation (ETRTO). In a conference presentation (Tyre and Road Wear Particles Platform, November 19, 2020) they introduced a proposal for the design of a testing method (what should be measured and under what conditions). They also announced a long-term plan for when such a method could be prepared and standardised: in 2025 for a standardised test using vehicles, and 2029 for a standardised laboratory test using a drum. The EU Commission also announced funds for the development of a measuring method for tyre wear, which will commence in early 2021 and take 15 months.

The United States requires all tyres to be labelled with a so called treadwear grade of between 100 and 700, where a lower grade indicates a higher wear propensity (Grigoratos et al., 2018). The labelling has been designed for the American market, and the manufacturers are themselves responsible for managing the system, although the National Highway Traffic Safety Administration can perform checks (Ashley, 2015). In laboratory wear tests carried out by Grigoratos et al. (2018), the labelling did not however correlate to the wear measured on the tyres being tested.

Positive side effects

The labelling may lead to greater longevity, i.e. lower tyre consumption, which would reduce the lifecycle impact of tyres (including manufacture, tyre waste, and tyre waste), as well as lower costs for consumers.

Negative side effects

A negative side effect is the cost of developing a robust test system, and the cost of carrying out the tests and checking that the wear matches the labelling.

Discussion and assessment

A compulsory labelling system for the wear propensity of tyres which applies across the European market has the potential to become an effective policy instrument. This is partly because it would be a compulsory regulation on labelling across the entire European tyre market, which would enable consumers to choose tyres that wear less, and partly because wear propensity varies greatly. How effective it would be would also depend on the proportion of consumers who choose tyres with a lower wear propensity.

The implementation of such a system may be associated with a few challenges. It is expected to be difficult to develop a standardised method sufficiently able to reflect actual wear correctly enough to be accepted, as different tyres may perform more or less well in different conditions, e.g. in different climates and on different road surfacing materials. The implementation time depends on the time it takes to produce a standardised and harmonised testing method for measuring tyre wear. It also depends on how long it would take to produce and commission the equipment required for large-scale testing. Although this work has commenced, it will probably take several years (potentially 5–7 years) before labelling of the wear propensity of tyres can be introduced. However, the fact that the regulation is already prepared for this will reduce the time. The decision to include tyre wear in the labelling regulation will be made by the European Council and Parliament.

Funding for the development of a standardised method can be partly provided by the EU and partly by the tyre industry. The cost of testing the tyres could be borne by the tyre industry; this would probably also apply to the cost of having a tyre labelled, which ought to be managed by the EU. It has not been possible to estimate the associated costs, however as the operational costs are mainly associated with manufacturing and consumption, they are expected to be added to the price of tyres once the labelling has been introduced. As this will increase the use of tyres that wear more slowly, the costs may decrease for tyre consumers. The responsibility for supervision and control will probably rest with the EU Commission. Our view is that promoting and driving the development of a standardised method for measuring tyre wear should be highly prioritised. As a subsequent step, once a measuring method has been developed, the introduction of a labelling system should be a high priority, however this measure cannot be prioritised at the present time.

3.3.4. Tyres with low wear propensity

Policy instrument: Promote research & development of tyres with low wear propensity.

There is currently great variation in the time it takes for different tyres to wear out (see section 3.3.3). While we wait for a standardised method for measuring tyre wear to be developed, research into factors resulting in low wear propensity can aid the development of tyres which have a low wear propensity in the conditions for which they are intended. The tyre industry is constantly developing tyres optimised for different usage types and conditions and are well aware of the different factors (e.g. chemical composition, tread, dimensions) that impact the wear propensity of a tyre. Nokian Tyres (2020) has developed and launched a summer tyre on the Scandinavian market, which they claim reduce emissions of tyre particles by 35 percent compared to the previous tyre of the same model. Depending on driving style, this may enable the tyre to be used for approximately 10,000 additional kilometres. For the tyre industry to develop these types of tyres voluntarily there must be a demand. Without demand from consumers, research funding from external financing bodies will be required, e.g. EU grants.

Whether the development and possible use of future airless tyres for passenger cars will result in higher or lower tire wear is at present not known. According to Bridgestone (2020), one of a number of manufacturers currently in the process of developing airless tyres, the energy loss caused by rolling resistance will be just as low as it is for those of their tyre models designed for fuel efficiency, the tyres cannot suffer punctures, and the materials in the tyres will be recyclable. According to Michelin's FAQ document, (Michelin, 2020a) their airless tyre prototype consists mainly of rubber, aluminium, and a composite material they call resin-embedded fibreglass. The expected travel distance before the tyre will need replacing will, according to Michelin (2020a) be the same for the prototype as for their standard tyres.

Positive side effects

Tyres with low wear propensity result in lower tyre consumption. This reduces the lifecycle impact of tyres (including manufacture, disposal, and waste products from tyres) and leads to lower costs for consumers.

Negative side effects

According to Continental (2021b), there is a conflict between wet grip, tyre wear, and rolling resistance when developing a tyre, which means that improving one characteristic may have a negative effect on another. This means that there is a risk that lower wear propensity leads to less road traction, and therefore reduced road safety. However, Continental (2021a) also claims that modern premium tyres contain a special silica compound that reduces the conflict between tyre wear and wet grip. There is also a risk that a tyre with a lower wear propensity needs other chemical substances. Whether these are more or less harmful than those used in standard tyres must be considered. It is also not known whether tyres with lower wear propensity generate a smaller or greater number of very small particles, however this must be investigated.

Discussion and assessment

By promoting and offering incentives for research into, and development of, tyres with low wear propensity, emissions of tyre wear particles can be reduced. This could probably occur faster than if we wait until a labelling system for wear propensity is in place. Promotion of research & development is deemed to be an effective policy instrument, as we know that the wear varies greatly between different tyres. However, it would have to be complemented with e.g. information campaigns aimed at private consumers or requirements in public procurement processes in order to increase demand for low wearing tyres and thereby produce an impact and a real reduction in tyre wear. It is considered possible to develop tyres with low wear propensity, however difficulties may arise if it turns out that lower wear propensity leads to reductions in e.g. road safety, or if it requires chemicals that are more hazardous to the environment or human health than those currently used. At the present time, there is also a great range of tyres developed to offer particular characteristics, e.g. adapted to different types of vehicles and climatic conditions, or to reduce noise. For this reason, it seems likely that many different types of tyres with low wear propensity will have to be developed. The cost-effectiveness is expected to be high, as it is known that wear propensity varies significantly between different tyres, and the cost of introducing this policy instrument is deemed to be affordable. The costs will probably be mostly borne by the tyre industry and larger research funding bodies. The implementation time may be a few years. As Sweden does not have a tyre manufacturing industry, this would involve advocating for support for this type of development within the EU or in other international contexts.

Our view is that promoting research & development of tyres with a low wear propensity should be highly prioritised. Based on wear propensity data and information regarding achievable levels, it will then be possible to introduce limit values or labelling, both of which are policy instruments with a high potential for reducing the emissions of tyre wear particles.

3.3.5. Tyre wear limit values

Policy instrument: Develop EU limit values for tyre wear.

If, or when, an appropriate and standardised method for measuring tyre wear has been developed, this would also enable the introduction of EU-wide tyre wear limit values for different types of tyres. This could result in an enforceable policy instrument aimed at tyre manufactures to make them produce tyres that generate less wear particles. As already mentioned, there is significant variation in how much different tyres wear. There are, however, limitations regarding what could be the lowest possible limit value since the same characteristics that cause tyre wear are also required to achieve a good grip.

Positive side effects

The introduction of tyre wear limit values would result in longer-lasting tyres, thereby decreasing the tyre consumption. This would reduce the lifecycle impact of tyres (including manufacture, disposal, and tyre waste products) and lead to lower costs to consumers.

Negative side effects

If tyre characteristics are modified to reduce wear, a conflict may arise with characteristics that are important from a road safety point of view, such as traction. Changes to the tyre formula means that the proportions of different chemicals and components change, or that other chemical additives must be added. Whether these are more or less harmful than the ones currently used in standard tyres would have to be investigated. Lower tyre wear will result in a lower demand for tyres, which will affect for example those manufacturing and selling tyres.

Discussion and assessment

Limit values for tyre wear are fairly difficult to design. They must vary for different types of tyres, and it may be difficult to find a testing method that reflects actual wear, as this is impacted by a large number of factors. It must also be confirmed that road safety can be maintained. This requires studies to investigate appropriate limit values with account taken to the road safety of different types of tyres. For this reason, implementation would involve a number of challenges and require the existence of a harmonised, standardised testing method for tyre wear. It is likely that implementation will occur far (perhaps 10 years) into the future, i.e. once harmonised testing methods for tyre wear have been developed and studies have been carried out into what limit values would be possible when considering road safety for different types of tyres. The development of limit values should be led and funded by the EU and involve experts from the tyre industry and academia. It has not been possible to estimate the likely cost of developing such limit values. This policy instrument is deemed to have a high effectiveness, providing a standardised method for measuring tyre wear is available.

Our view is that there is currently not sufficient knowledge to set limit values for tyres, why this policy instrument should not be prioritised at the present time. However, as soon as sufficient data on the wear propensity of different types of tyres and a standardised way to measure this become available, it should be highly prioritised for further investigation.

3.3.6. Ecodesign requirements concerning tyre wear and hazardous substances

Policy instrument: Introduce an EU regulation on ecodesign requirements for tyres, including a) limit values for tyre wear and b) restrictions and bans on hazardous substances.

The design (e.g. tread and hardness) and chemical composition (e.g. proportions of natural rubber and additives) of tyres are important factors that affect tyre wear. Ecodesign requirements for tyres, which include e.g. limits on tyre wear and a ban on hazardous substances may result in lower emissions of tyre wear particles, and reduced leakage of hazardous substances from tyres.

The EU Ecodesign Directive (Directive 2009/125/EU of the European Parliament and the Council) establishes a framework for the setting of ecodesign requirements on energy efficiency for energy-related products, such as lighting in homes and offices, electric appliances, domestic appliances, and heating and air-conditioning systems (EU, 2020). It also covers products that do not themselves use energy but still affect the overall energy use (Swedish Energy Agency, 2018). The Directive contains two types of requirements: specific requirements setting exact limit values for e.g. highest permitted energy consumption or lowest proportion of recyclable materials, and generic requirements which may mean that products must be energy-efficient or recyclable, that information must be provided on how to use and maintain the product to minimise its environmental impact, and that a lifecycle analysis must be carried out to investigate any potential for improvement (EU, 2020).

From previously mainly focusing on a products energy use during the usage phase, it has become increasingly common to consider the entire lifecycle of a product, and to set requirements for e.g. the technical lifespan, recycling, reparability, water use, environmental emissions, and data on hazardous substances (Swedish Energy Agency, 2018). Requirements on noise and functionality may also be included (Swedish Energy Agency, 2018).

The ecodesign requirements for a product become product-specific EU regulations that apply directly in the member countries (Swedish Energy Agency, 2018) and are revised every 5th year (RISE, 2019). There are currently no ecodesign requirements for tyres, however Regulation (EU) No 661/2009 of the European Parliament and of the Council (concerning requirements for the general safety of motor vehicles, their trailers and systems, components and separate technical units intended therefor) contain similar minimum requirements on efficiency as those set out in ecodesign regulations (European Commission, 2020a). It also includes certain requirements regarding health and safety (European Commission, 2020a). Energy labelling regulations (such as the EU regulation on labelling of tyres) (see section 3.3.3) can complement ecodesign requirements with e.g. compulsory labelling requirements (European Commission, 2021b).

Positive side effects

Limit values for tyres would result in a longer lifespan, thereby decreasing the tyre consumption. This would reduce the lifecycle impact of tyres (including manufacture, disposal, and tyre waste products) as well as lower the costs to consumers.

Negative side effects

When tyre characteristics and content are modified to reduce wear and emissions of hazardous substances, conflicts may arise with characteristics that are important from a road safety perspective, such as traction. This must be taken into account. Lower tyre wear will lead to a lower demand for tyres, which will affect for example manufacturers and sellers of tyres.

Discussion and assessment

Ecodesign requirements for tyres would to some extent overlap any future wear propensity labelling (see section 3.3.3) but could be more enforceable as they include requirements, e.g. in the shape of limit values, that must be met to permit the sale of the product in question in the EU. This would result in the worst products disappearing from the market. Lists of banned substances, such as hazardous chemicals, could also be included in any ecodesign requirements. There may be some challenges when it comes to determining the limit values for tyre wear (see section 3.3.5). Limit values and lists of banned substances would, however, be less difficult to prepare than limit values for tyre wear. Before this can be achieved, current knowledge regarding hazardous substances in tyres must be compiled and complementing studies carried out to identify substances that should be candidates for limitation or banning. Thereafter the possibilities for substitution of these substances needs to be investigated.

The effectiveness of this policy instrument is deemed to be high, as it would constitute an enforceable requirement and as there is variation between different tyres both concerning wear propensity and toxicity (see e.g. Wik & Dave (2005; 2006)[15]. This would obviously require the limit value for tyre wear to be set at a level which is much higher than the wear performance of the worst tyres on the market. The process to produce an ecodesign regulation requires a number of steps: a preparatory study, a proposal from the Commission, consultation, implementation proposal, impact assessment, comments from the WTO, voting by the Committee, evaluation by the European Council and Parliament, adoption by the EU Commission, and finally entry into force, which usually takes place approximately a year after the decision (Swedish Energy Agency, 2020). This process is financed by the EU. The implementation time would vary depending on whether limit values for tyre wear were to be included, as the expectation is that these will take a long time to prepare. If only lists of forbidden substances were to be included, the implementation time could be much shorter (perhaps a couple of years).

Our view is that there is currently insufficient knowledge to be able to set limit values for tyre wear, why this part of the policy instrument cannot be prioritised at present. However, as soon as sufficient data on the wear propensity of different tyre types becomes available, this policy instrument should be highly prioritised for further investigation. Regarding ecodesign requirements that cover bans or limits on hazardous substances, action could be taken sooner. Our view is that further investigation into potential candidates for limitations or bans should be highly prioritised (see also section 3.5.1).

3.3.7. Global technical regulations on tyres regarding wear and hazardous chemicals

Policy instrument: Include a) demands for lower tyre wear and b) restrictions and bans on hazardous chemicals in global technical regulations relating to tyres.

There are UN regulations with provisions for vehicles, their systems, parts and equipment, established by the World Forum for Harmonization of Vehicle Regulations (WP.29[16]) which is a part of the UN's Economic Commission for Europe (UNECE, 2019). These regulations, for instance, relate to safety and environmental aspects and performance-oriented test requirements (European Commission, 2020b). Among them is a global technical regulation for tyres (Global Technical Regulation no. 16) (UNECE, 2014), which aims to establish harmonised technical provisions for pneumatic tyres equipping passenger cars and light trucks (≤ 4,536 kg, equivalent to 10,000 pounds). The regulation does not include the generation of tyre wear particles, although e.g. tyre wear indicators are covered. These types of global technical regulations could be used as policy instruments to reduce the impact of microplastics from tyre wear if parameters such as tyre wear and hazardous chemicals were added.

The harmonisation of vehicles is governed by two international agreements, one from 1958 and one from 1998, which are both in force (European Commission, 2020b). The agreement from 1998 has 38 contracting parties (European Commission, 2020b), for instance the EU, United States, Japan, Kina, India, Korea, and Russia (European Commission, 2020c). So far, 20 global technical regulations have

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[15] As part of these two studies, toxicity tests were carried out on leachates of tyre particles from different tyres, using the crustacean *Daphina magna*. The study from 2005 tested 12 different tyres, and the study from 2006 tested 25 different tyres. Both studies showed that the toxicity varied between different tyres.

[16] World Forum for Harmonization of Vehicle Regulations (WP.29).

been established as a result of this agreement (European Commission, 2020b). The World Forum contains six permanent working parties with experts, which e.g. include ‘Noise and Tyres’ and ‘Pollution and Energy’, and also forms informal working groups to deal with specific tasks (UNECE, 2019).

Positive side effects

Regulations that limit tyre wear mean that tyres do not wear out as fast, which in turn reduces tyre consumption. This reduces the lifecycle impact of tyres (including manufacture, disposal, and waste products from tyres) and results in lower costs for consumers.

Negative side effects

When the characteristics of tyres are modified to reduce wear, conflicts may arise with characteristics that are important from a road safety perspective, such as traction, and perhaps also the desire to reduce the content of hazardous substances. This must be taken into account. Lower tyre wear will lead to a lower demand for tyres, which will affect for example manufacturers and sellers of tyres.

Discussion and assessment

If tyre wear and hazardous chemicals were to be included in the global technical regulations, this would create the conditions required to reduce both tyre wear and the use of hazardous chemicals on the global tyre market. These types of regulations are, however, not globally enforceable; instead the contracting parties decide individually whether or not to adopt a regulation, and whether or not to make it compulsory (UNECE,2019).

As the World Forum, which is made up of more than 120 representatives, meet three times per annum in addition to the work carried out by the working parties (UNECE, 2020), and has in place a well-developed expert organisation and well-structured working process, it has the power to aid implementation. This also means that the implementation time will be shorter once proposals for limit values and control of hazardous chemicals in tyres have been prepared. For an amendment (or addition) to come into force across the EU, a decision must be made by the EU, with involvement of the European Council, the EU Commission, and the European Parliament. The effectiveness of this policy instrument is deemed to be high, as there is significant variation in the wear of different tyres.

Naturally, this requires any limit value for tyre wear to be set significantly higher than the wear level of the worst performing tyres currently available on the market, and also requires the EU to be a contracting party. The cost-effectiveness is expected to be high, as the effectiveness is expected to be high, and the implementation cost low. Longer lasting tyres should also benefit consumers, due to lower spend on tyres.

Our view is that there is currently insufficient knowledge to be able to set limit values for tyre wear, why this part of the policy instrument cannot be prioritised at present. However, as soon as sufficient data on the wear propensity of different tyre types becomes available, this policy instrument should be highly prioritised for further investigation. In relation to bans or limits on hazardous substances, action could be taken sooner. Our view is that further investigation into potential candidates for limitations or bans should be highly prioritised (see also section 3.5.1)

3.3.8. Restrictions or ban on the use of studded tyres

Policy instrument: Promote research into reducing the use of studded tyres and its impact on a) emissions of tyre wear particles and b) road safety (friction and traction).

The studs on studded tyres cause abrasion on the road surface and road markings, and roughen up the asphalt surface, which may lead to increased microplastic emissions from road markings and road surfacing in cases where these contain polymer-modified bitumen. There is no published data on whether studded tyres generate greater or smaller numbers of tyre particles than non-studded tyres. However, it is reasonable to assume that the roughening of the asphalt surface caused by studded tyres would result in more tyre particles being released from non-studded winter tyres, and also from summer tyres for a period of time after the end of the season for studded tyres, than would have been the case if the surface was smoother. A ban on studded tyres, and reducing the use of such tyres, have been discussed and investigated several times at the national scale in Sweden (e.g. SOU 2015:27; Swedish Environment Protection Agency, 2016), as well as implemented and evaluated locally (e.g. Johansson et al, 2011; Norman, 2016). The policy instrument discussed in this section is, however, limited to the promotion of research into how restrictions or bans on the use of studded tyres would affect emissions of tyre wear particles and road safety.

Use of studded tyres in Sweden

The use of studded tyres on Swedish passenger cars varies between different parts of the country, with the highest usage in the region North (95%) and the lowest usage in regions South and Stockholm (42%), according to surveys carried out between January and March of 2018 (Swedish Transport Administration, 2019). The average percentage of Swedish passenger cars using studded tyres was 61.7 percent, non-studded winter tyres 37.6 percent, and summer tyres 0.7 percent during the winter season of 2018 (Swedish Transport Administration, 2019). Since 2010, the portion of passenger vehicles using studded tyres has decreased by 6.6 percent (from 68.3%) (Swedish Transport Administration, 2019).

Rules regarding the use of studded tyres in Sweden

The use of studded tyres is permitted in Sweden during the period from 1 October–15 April, however in winter conditions, or if winter conditions are expected, studded tyres may be used outside this period according to the regulations from the Swedish Transport Agency (TSFS 2009:19). The Transport Agency can then make decisions regarding exemptions from the rules and may e.g. extend the period during which studded tyres are permitted if required.

In addition to restrictions on the use of studded tyres, the Traffic Ordinance (SFS 1998:1276) contains legislation requiring light and heavy passenger cars, light and heavy trucks and buses, and trailers used in Sweden to be equipped with winter tyres or similar equipment (e.g. snow chains or sand spreaders) from 1 December–31 March if winter conditions are present.

Local traffic regulations banning studded tyres

Changes in the Traffic Ordinance (SFS 1998:1276) have since 2009 enabled municipalities to adopt local traffic regulations containing bans of studded tyres for specific roads or road sections, which in 2011 was extended to enable inclusion of all roads within a specified area. Such local bans on studded tyres are in place for the following roads:

1. Hornsgatan (since 2010), Flemminggatan and parts of Kungsgatan (since 2016) in Stockholm (City of Stockholm, 2019b), see Figure 4.
2. Friggagatan and Odinsgatan in Gothenburg (City of Gothenburg, 2020) (since 2010)
3. Parts of Kungsgatan and Vaksalagatan in Uppsala (Uppsala Municipality, 2019).

Figure 4. Road sign showing that studded tyres are prohibited on Kungsgatan in Stockholm. Photo: USER_70782/Mostphotos.

International bans and other policy instruments

According to data from 2015 and 2016, studded tyres were permitted in 23 European countries, of which 19 had in place restrictions regarding e.g. time periods and speed (Swedish Environmental Protection Agency, 2016). Studded tyres were banned in 20 European countries, 10 of which are located within the Alpine Region (Swedish Environmental Protection Agency, 2016). Bans on studded tyres were at that time in force in several places outside Europe, for example in six American states, one Canadian state and the whole of Japan (Swedish Environmental Protection Agency, 2016).

Other ways to regulate the use of studded tyres e.g. include taxes. The Norwegian cities of Oslo, Trondheim, Stavanger, and Bergen impose a charge on all cars driving with studded tyres (Riksförbundet M Sverige, 2020). Variations to the periods when studded tyres are permitted in different parts of Norway are also used.

Alternatives to studded tyres

There are a few different alternatives to using studded tyres in winter conditions, including non-studded winter tyres (also called friction tyres) adapted to Scandinavian or Central European conditions, and snow chains. In Sweden, the most commonly used alternative is non-studded winter tyres adapted to Scandinavian conditions. The Traffic Ordinance contains a requirement to use winter tyres or equivalent equipment, however, does not specify what counts as equivalent equipment. According to the Swedish Transport Agency (2020a), equivalent equipment is snow chains and sand spreaders.

The rules for using snow chains varies between the countries in Europe. Some countries have banned them, others allow them in some places, under certain conditions, and some countries even require them in certain circumstances or road conditions. An alternative to snow chains is snow socks, which is a cover made of polyester fabric or a composite material, fitted over the tyres (Snökedjor.se, 2020). In May 2020, CEN published a standard on supplementary grip devices for tyres of passenger cars and light duty vehicles (EN 16662-1:2020), which covers snow chains, snow socks, and hybrid solutions (CEN CENELEC, 2020).

Policy instruments for limiting the use of studded tyres

Different policy instruments aimed at reducing the use of studded tyres have been evaluated by the Swedish Environmental Protection Agency (2016). The policy instruments suggested for further investigation include:

- trade-in incentives and sales tax;
- policy instruments targeting company cars;
- requirements during public procurement processes;
- information (e.g. information campaigns).

Another potential measure involves taxing the use of studded tyres in built-up areas. This policy instrument was evaluated as part of a Swedish government inquiry called the Particulate Level Inquiry (Partikelhaltsutredningen, SOU 2015:27). The conclusion was that introduction of a tax on the use of studded tyres to meet the environmental quality standards for air could not be justified. The reasons given included e.g. that the instances when levels are exceeded have decreased over the last few years as a result of different policy instruments being introduced (e.g. local bans on studded tyres), and the fact that the situation is expected to improve even further due to a congestion charge that has been introduced and due to changes to the rules on maximum number of studs permitted on studded tyres (SOU 2015:27). Although the environmental quality standards for air were only exceeded in a small number of municipalities, and a few places, and not every year, air pollution still causes 7,600 premature deaths per annum according to calculations by Gustafsson et al. (2018), why it may be desirable to reduce levels even below current limit values. They also estimate that approximately 215 premature deaths per year are caused by road dust, a significant portion of which is generated by studded tyres. The use of studded tyres is highlighted as an important source of locally generated particles (Gustafsson et al. 2018).

Another policy instrument with the potential to limit the use of studded tyres is to introduce different rules in the northern and southern parts of Sweden regarding the time periods when studded tyres are permitted. By differentiating or adjusting the period of the year when studded tyres may be used, the amount of tyre and road wear particles being generated can be influenced. To what extent and in what way must be investigated before this type of change is introduced.

Positive side effects

A ban on studded tyres, or limits on their use, would have positive side effects, including lower generation of other small harmful particles (PM10 and PM2,5) than microplastic particles, as well as reduced noise, lower fuel consumption, less contamination (which accelerates corrosion) and less road wear (Swedish Environmental Protection Agency, 2016). The cost of the road surface wear caused by studded tyres is estimated to approximately 700 million SEK per annum (Swedish Environmental Protection Agency, 2016). A health-related lifecycle assessment of studded tyres has been carried out by Furberg et.al. (2018) and concludes that from a lifecycle perspective, the use of studded tyres generally causes more years of life lost due to premature death than they save by improving road safety. The main contribution to negative health impacts during the lifecycle relates to particle emissions (67–77%), while the health impacts associated with manufacturing the studs made up the rest, of which workplace accidents during small-scale cobalt mining accounted for 8–18%. According to this study, restricting the use of studded tyres would lead to more lives being saved overall.

Negative side effects

A total ban on studded tyres could have a negative effect on road safety. On a smooth and wet road, studded winter tyres perform better than non-studded winter tyres, although in all other conditions, non-studded winter tyres adapted to Scandinavian conditions generally have comparable characteristics (VTI, 2019).

There are other reasons why a total ban on studded tyres may cause problems, as the surfacing materials used on Swedish roads today have been adapted to the wear of studded tyres and have a high stone content, including hard-wearing and coarse stone aggregates (in particular in the national road network). Studded tyres cause more wear on surfaces but are also needed to roughen up the hard rock materials, to avoid polishing and reduced friction (Hjort, VTI, personal contact, June 4,2020). If no vehicles used studded tyres, this would cause problems as the Swedish road surfaces would be too smooth, which would increase the risk that they become slippery (Hjort, VTI, personal contact, June 4 2020), both in snowy and icy conditions. Should the use of studded tyres decrease significantly, it may not be sufficient to replace hard-wearing surfacing materials with less hard-wearing ones to avoid the risk of reduced friction and increased skidding. Another potential negative side effect of using less hard-wearing surfacing materials may be increased generation of particles from the stone materials (Gustafsson, VTI, personal contact, May 20, 2021).

Many European countries where studded tyres are not used and the road surfaces are softer, have significant problems with polishing and regular monitoring of road friction is therefore required, complemented by action where needed, e.g. by milling the asphalt (Hjort, VTI, personal contact, June 4, 2020). A few attempts have been made (by e.g. Nordström & Samuelsson, 1990; Vaa & Giaever, 2003; Tuononen, 2014) to estimate how the roughening caused by studded tyres affects the available friction on roads covered in snow and ice. There is, however, insufficient data to determine the proportion of studded tyres that would be required to ensure that the surface is roughened up enough and avoid excessive polishing. This is an area that requires further study. This matter is further complicated by the fact that the percentage required to be roughened up would vary over time and from one place to another, and depends on multiple factors, including e.g. temperature, the characteristics of the snow or ice, the mineral composition of the asphalt, the traffic volumes on the road, and the proportion of heavy traffic.

Discussion and assessment

It is a known fact that the use of studded tyres results in small harmful particles being generated due to wear of studs, tyres, road surfaces, and road markings, and that reducing the use of studded tyres in built-up areas leads to lower particle levels and positive health effects. Decreasing the use of studded tyres also reduces noise levels. This means that policy instruments targeting studded tyres can be justified for health reasons. However, there is still some uncertainty regarding friction, traction, and accident risks related to decreased use of studded tyres, which must be investigated before extensive policy instruments targeting the use of studded tyres can be introduced. Examples include the need for research into what proportion of studded tyres is ‘needed’ to ensure that the polishing effect does not lead to insufficient friction and poor grip, and which types of asphalt would be suitable if studded tyres are used less. To motivate a ban on studded tyres from a microplastics perspective, it must first be investigated whether a reduction in the use of studded tyres leads to a net reduction in the amounts of tyre wear particles being generated. Regarding road markings and surfacing materials containing polymer-modified bitumen, it is already known that studded tyres cause more wear on these, which means that reducing the use of studded tyres can lead to a reduction in the amount of particles being generated.

Initially, the policy instrument relating to banning or reducing the use of studded tyres concerns increasing our knowledge. We currently do not have sufficient knowledge in this area to be able to evaluate the effectiveness or cost-effectiveness of this type of policy instruments from a microplastics perspective. However, regulating the use of studded tyres may, at least in some circumstances, be motivated for other reasons, mostly health reasons. There are several side effects and complex relationships that need to be considered before any limitations or bans on studded tyres are introduced.

How any limitations or bans are designed, and for instance are delimited in time or space, may influence their impact, and must therefore also be considered.

Our view is that promoting research into reducing the use of studded tyres and the impact this would have on emissions of tyre wear particles and road safety is a measure that should be prioritised.

3.3.9. Restricting the usage period for non-studded winter tyres

Policy instruments: a) Introduce restrictions regarding the time of year when non-studded winter tyres may be used, e.g. through amendment of the Swedish Transport Agency Regulation TSFS 2009:19 and b) complementing this with information campaigns.

Winter and summer tyres have different characteristics, and wear less, perform better, and provide the best road safety when used during the season for which they are designed. A policy instrument aimed at reducing the increased amount of wear particles generated by non-studded winter tyres used in summer compared to summer tyres could involve restricting the time period when the use of non-studded winter tyres is permitted.

According to Continental (2020a), winter tyres are made of flexible rubber compounds designed to remain soft and pliable in temperatures below 7 °C. They also have treads designed to give a good grip on roads covered in ice and snow. If winter tyres are used when driving at higher temperatures or on warm asphalt, the tread of a winter tyre wears much faster than the tread on a summer tyre, as it is softer (Continental, 2020a). Driving on winter tyres all year round reduces the lifespan of the tyres by approximately 60 percent, according to Continental (2020a), and may result in the winter tyre offering poor road safety in the following winter season. The rolling resistance of a winter tyre on a warm surface is also much higher than that of a summer tyre, as the softer rubber compound in the winter tyre changes its shape more, resulting in both higher fuel consumption and more noise (Continental, 2020a).

From a safety perspective, winter tyres are also inferior in warmer weather, as the tyres are too soft and the grip performance is less good, which may cause problems if the car has to turn or break suddenly (Continental, 2020a. In tests carried out by the VTI (Hjort et al., 2015), the breaking distance for winter tyres used in summer was approximately 15 percent longer on dry asphalt (air temperature 14–18 °C, sunny) and 20 percent longer on wet asphalt (air temperature 10–14 °C, cloudy) than when the same test was carried out for summer tyres.

Tyre razzias[17] carried out in 2018 showed that 11.9 percent of cars in the southern half of Sweden used non-studded winter tyres in the summer (Däckrazzia, 2019). The southern half of the country also has the highest usage of non-studded winter tyres.

Just as winter tyres are not appropriate for summer use, summer tyres are not appropriate for use in the winter or if the temperature falls below 0 °C, whatever the road conditions. The rubber compounds used in summer tyres are designed for warmer weather. In lower temperatures they become rigid, the rubber loses its elasticity, and may crack (Continental, 2020b). The tread block also becomes more rigid, which may result in cracks forming or splinters coming off, reducing the grip (Continental, 2020b).

Positive side effects

Positive side effects of restricting the time period during which non-studded winter tyres can be used may include improved road safety, reduced fuel consumption, and less noise (Continental, 2020a).

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[17] Tyre razzias (Däckrazzior) have been carried out since 2004 in a partnership between the Swedish Energy Agency, VTI, the Swedish Tyre Industry Information Counsel. The National Society for Road Safety (NTF) and Bilprovningen (a vehicle inspection company), to increase awareness of the importance of tread depth and air pressure for road safety and the environment, and about energy labelling of tyres. Tyre checks and information are offered during these regular traffic checks (Däckrazzia, 2020).

Reduced fuel consumption would in turn lead to lower emissions of greenhouse gases and air pollutants, as well as a lower cost per kilometre. Additionally, fewer tyres would be consumed, reducing the overall environmental impact of tyres, from cradle to grave, as well as costs for car owners.

Negative side effects

There is a risk that the proportion of studded winter tyres would increase slightly if the possibility to avoid changing tyres is taken away, since there are drivers who use non-studded winter tyres solely to avoid tyre changes. This would bring all the negative characteristics of studded tyres, as well as the inconvenience of having to change tyres.

Discussion and assessment

This policy instrument would by mandatory provisions cause lower emissions of microplastics, improved road safety, and lower tyre consumption. This is unlikely to be controversial, as it benefits those targeted by the measure, as they would be safer on the roads and their tyres would last longer. The policy instrument would neither require a lot of effort nor high costs and could probably be introduced via amendment of the regulations and general advice from the Swedish Transport Agency regarding the use of tyres etc. designed for cars and car-drawn trailers (TSFS 2009:19). If so, the implementation period would be short. To amend a regulation takes approximately one year (Norén, Swedish Transport Agency, personal contact, September 10, 2020). In addition to this measure, providing information regarding the risks of using winter tyres in the summer and how much faster these tyres wear out may improve the effectiveness of such an amendment to the regulation. As the number of vehicles using non-studded winter tyres all year round is fairly small from a national perspective, the total reduction in emissions is not expected to be particularly high. However, this instrument can also be justified by improved road safety. A potential challenge is how to determine which tyres should be categorised as winter tyres. As an example, some Central European winter tyres are designed for higher temperatures than Scandinavian winter tyres.

The effectiveness of this policy instrument is deemed to be limited from a microplastics perspective (as a fairly small number of people use this type of tyres all year round). However, due to the relatively small effort required to introduce this measure, it is expected to be cost-effective and thereby relevant. It could also be introduced in the near future. There is, however, some uncertainty regarding the extent to which those currently using non-studded winter tyres all year round would instead use studded tyres in the winter, when the incentive of avoiding tyre changes no longer applies.

Our view is that the policy instrument to restrict the period of the year when non-studded winter tyres can be used should be prioritised for further investigation. In a potential next step, the implementation of this policy instrument should be complemented by information regarding the restrictions.

3.3.10. Tyre pressure monitoring or more frequent air pressure checks

Policy instrument: To fund an investigation regarding which policy instruments or measures would be most appropriate for increasing the proportion of tyres used at the correct pressure (e.g. tyre pressure monitoring systems or more frequent air pressure checks).

The air pressure of tyres affects their wear and the lifespan of the tyre in a number of different ways. This and many other aspects mean that correct air pressure should be maintained, and the pressure checked regularly. Which policy instruments or measures would be most appropriate for increasing the percentage of tyres with the correct air pressure ought to be investigated.

Tests by Paige (2012) have shown that when the air pressure is too low, tyres change in several ways. The contact area between the tyre and road (footprint) becomes longer, the load on the tyre shoulders (i.e. the edges of the contact area) increases, and due to the cycle of tension and relaxation within the tyre carcass and belt cords, stress and strain reactions arise in the rubber matrix surrounding the cords, raising the temperature in the rubber material (Paige, 2012). Together, these changes increase the risk of tyre failure (Paige, 2012). According to Michelin (2018), a tyre pressure that is too low can lead to:

- tyres being less durable and degrading faster;
- increased risk of sudden punctures;
- reduced ability to take corners with precision;
- longer breaking distances;
- increased rolling resistance, and thereby fuel consumption;
- reduced driving comfort;
- increased risk of aquaplaning.

It also means that tyres have to be changed more frequently, as they wear unevenly and that the vehicle becomes more difficult to manoeuvre in an emergency situation, such as during evasive action or breaking (Däckrazzia, 2019).

Modelling studies by Li et al. (2011) have shown that if the tyre pressure is slightly too high, the wear is slightly less than with optimal pressure. This is because the deformation is lower, resulting in less loss of energy and lower heat generation (Li et al. 2011). Despite this, elevated air pressures are not to be recommended, as the tyres, just as when the pressure is too low, wear unevenly and therefore have to be replaced sooner. No actual measurements showing the effect of tyre pressure on the total number of tyre particles being generated have been found in the literature (Andersson-Sköld et al., 2020).

A tyre pressure that is too high has, according to Continental (2021b), a low to medium effect on how far a tyre can be driven before it is worn out, whereas a tyre pressure that is too low has a high impact, on a three-point scale from low to high.

Tyre pressure monitoring systems are systems that warn the driver via a signal when the pressure in one or more tyres decreases by 20% or falls below 1.5 bar. It also emits a warning signal if the system malfunctions (Swedish Transport Agency, 2014). There are two types of tyre monitoring systems. Direct tyre monitoring systems have a pressure sensor inside each tyre, measuring the actual pressure directly (Transport & Environment, 2016). Indirect tyre monitoring systems are software-based solutions that estimate the difference in pressure between the tyres by comparing their rotational speeds (Transport & Environment, 2016) to determine whether one of the tyres has a smaller diameter (Swedish Transport Agency, 2015).

Tyre pressure monitoring systems were introduced with Regulation (EC) no 661/2009 of the European Parliament and of the Council, which required all new passenger vehicles in the EU to be fitted with these types of systems from November 1, 2014. In Sweden, this requirement was not included in the national regulations that take over once the vehicle is in use, as the Swedish Transport Agency felt that the main objective of this system is already achieved in Sweden, as tyre pressure is checked routinely when changing between summer and winter tyres (Swedish Transport Agency, 2014). The Agency also did not think that the cost of this safety measure with certainty could be economically justified (Swedish Transport Agency, 2015). However, a Swedish study by Däckrazzia (2019) showed that 19 percent of all cars had at least one tyre with a tyre pressure that was 30 percent too low or more. Apart from the EU, some other countries have also made tyre pressure monitoring systems mandatory, including the United States (van Zyl, et al., 2013), China, Taiwan, and South Korea (Research and Markets, 2020).

Positive side effects

Policy instruments and measures that lead to correct tyre pressures improve road safety (see above), reduce fuel consumption, and make tyres last longer (i.e. less uneven wear and fewer punctures) which reduces the lifecycle impact of tyres (including manufacture, disposal, and tyre waste products), thereby reducing the costs to consumers. Correct air pressure also gives a slight noise reduction, except on particularly coarse road surfaces, where the noise instead increases (Sandberg & Eijsmont, 2002). The savings made due to decreased fuel consumption and longer lifespans for tyres can be compared with the increased cost of adding tyre pressure monitoring systems or extra tyre pressure checks.

Negative side effects

These systems cost money and require a certain amount of maintenance. The cost of active tyre pressure monitoring systems is higher, as they require a pressure sensor to be mounted on each tyre (on both summer and winter tyres). According to data from VIANOR (2020), the cost of such a sensor can vary from 400 SEK to 2,000 SEK (≈ 40 to 200 euros). An impact assessment by the Swedish Transport Agency (2015) estimates that in addition to the cost of the sensors, costs for installation, diagnostics, and reprogramming may also apply. Reprogramming may be required each time the tyres are changed for systems unable to manage two sets of tyres with sensors. A cost for changing the battery may also apply on models without integrated batteries. In systems with integrated batteries, the entire sensor must be replaced. According to the Swedish Transport Agency (2015), the manufacturers have stated that the lifespan for a sensor is 5–10 years.

Indirect tyre pressures monitoring systems are cheaper but may also involve additional costs on top of the cost of the software-based system. If tyres not approved for the vehicle type are to be used, the system must be modified to function correctly (Swedish Transport Agency, 2015). The system must also be calibrated if the tyre dimension or air pressure changes. According to the instruction manual, calibration can be carried out by the vehicle owner. There is also a risk that the vehicle owner trusts the monitoring system completely, and therefore only checks the tyre pressure if the warning lamp is on, which means that the driver may drive around with an air pressure that is too low for extended periods of time.

Discussion and assessment

There is no measurement data in the scientific literature on the total number of wear particles being generated when the tyre pressure is too low, versus when the pressure is optimal, although modelling has indicated that the wear increases when the tyre pressure is too low (Salminen, 2014). This means that it is difficult to evaluate the effectiveness of tyre pressure monitoring systems in relation to wear particles. Irrespective of whether or not more tyre wear particles are generated, incorrect tyre pressure significantly reduces the lifespan of tyres, as they wear unevenly and are more likely to break or suffer a puncture. This means that a greater number of tyres is consumed, resulting in a higher lifecycle impact from tyres. In addition, the other positive side effects, such as lower fuel consumption (and consequently less air pollution and reduced environmental impact), less noise, and improved road safety, make it even more interesting to strive for an optimal tyre pressure. We feel that the information on the impact on tyre pressure of different ambient temperatures and after different driving times provided in the car handbooks could be improved, as they often only specify the correct pressure for cold tyres. This should also be complemented by instructions on how checking and increasing tyre pressures should be managed at other temperatures.

Our view is that an investigation into the most appropriate policy instruments or measures for increasing the number of tyres with correct air pressure should be prioritised.

3.3.11. Wheel alignment and tyre balance

Policy instruments: a) Promote research into the extent to which incorrect wheel alignment and tyre balance affect the amount of tyre wear particles being generated, and (b) investigate how more frequent checks of wheel alignment and tyre balance could be introduced.

Wheel alignment and tyre balance influence the tyre wear. Tyres wear unevenly and more if they are not aligned with the direction of travel, so-called toe-in or toe-out, i.e. pointing inwards or outwards, (Mats Gustafsson, VTI, personal contact, April 2021), see Figure 5. If the tyre´s vertical angle (i.e. camber angle) is incorrect, so that the upper part of the tyre leans too much inwards, towards the chassis, or outwards, away from the chassis, the tyre will wear unevenly (Wang, 2017). We have not been able to find any study looking at whether an incorrect camber leads to higher tyre wear (i.e. more microplastic particles) or only results in uneven wear, reducing the lifespan of the tyre. According to Continental (2021b), incorrect wheel alignment has a high impact on how far the tyre can travel before being worn out, when rated on a three-point scale from low to high.

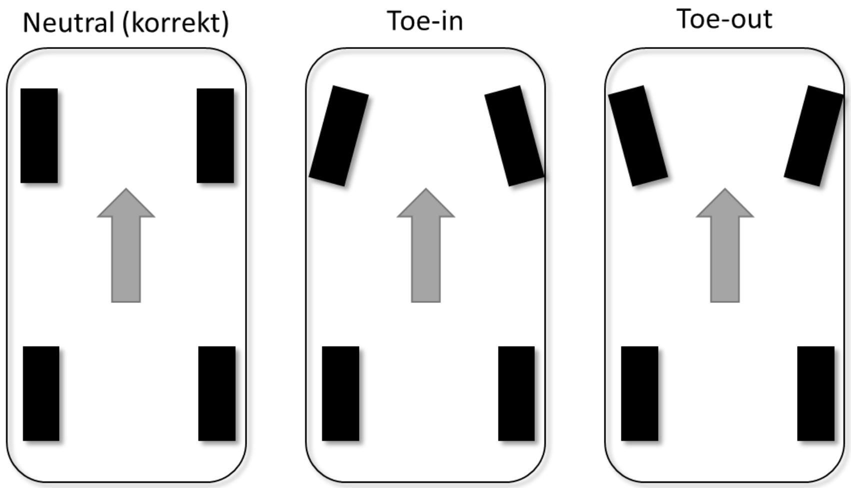

Figure 5. Illustration showing one example of correct, and two examples of incorrect wheel alignment, where the wheels are not aligned to the direction of travel, so-called toe-in or toe-out. Figure by Mats Gustafsson, VTI.

Potential policy instruments targeted at increasing the number of checks may include requirements that wheel alignment and tyre balance are checked after a certain number of kilometres, or information regarding how regular checks increase the longevity of tyres, while also reducing the emissions of tyre particles.

According to measurements by Däckrazzia (2018) in Gothenburg in 2017, half of the surveyed 161 cars had unevenly worn tyres and would benefit from checking or adjusting their wheel alignment.

Changes in the wheel alignment or tyre balance may occur after a collision with another vehicle, or when driving into hollows, across kerbs, or over bumps, or even due to normal wear (Verschoor & de Valk, 2017). This means that the wheel alignment may need to be checked for instance after driving into something. Signs of incorrect wheel alignment can include abnormal or uneven tyre wear, or problems with steering or handling (e.g. that the vehicle pulls or drifts to one side, that the steering wheel remains at an angle when driving in a straight line, or does not return to its original position after a turn) (Michelin, 2020b).

Wheel alignment checks may reduce the incidence of uneven tyre wear. Some repairers offer a simpler wheel angle check, after which they suggest a wheel alignment check and adjustment if required. Others only offer the complete check including adjustment, which takes approximately 45 minutes to an hour, of which the actual adjustment only takes up a small portion.

A less effective alternative to checking the wheel alignment more frequently may be to check the wear pattern of the tyres more frequently (although the wheel alignment may need to be adjusted before there are any visible signs on the tyres). This could for example be made mandatory during tyre changes, service, repairs, and MOT inspections, followed by notification of the need for wheel alignment.

An Australian company has developed a new technology able to electronically monitor and adjust the wheel alignment on a moving vehicle (Dofttek, 2020). This technology is not yet available on the market but could replace the need for more frequent checks and reduce the incidence of unevenly worn tyres.

Tyre imbalance can also cause uneven wear, as it means that one section of the tyre is lighter or heavier than the others, making the tyre bounce or wobble (Michelin, 2020b). According to Continental (2021a), tyre balancing is recommended after purchasing new tyres, rims or wheels; if tyres have been rotated or repaired; and if the vehicle has been driven into a large hole, a certain distance (5,000–10 000 km) or for a certain period of time (1–2 years).

Positive side effects

Correct wheel alignment and tyre balance make the tyres last longer (due to less uneven wear and fewer punctures), which lowers the lifecycle impact of tyres (including manufacture, disposal, and tyre waste products) and reduces the cost to consumers. It may also reduce the wear on the suspension, improve road safety, raise driving comfort, and decrease fuel consumption, thereby reducing the climate impact and emissions of air pollutants.

Negative side effects

More frequent checks of wheel alignment and tyre balance will lead to increased costs for the car owner. Data collected from some Swedish repairers shows that the cost of wheel alignment is around 1,000–1,600 SEK (≈ 100–160 euros), and tyre balancing costs around 700 SEK (≈ 70 euros) if the tyres are fitted to the car, and 300 SEK (≈ 30 euros) if they are not.

Discussion and assessment

More frequent checks of wheel alignment and tyre balance could reduce the amount of tyre wear and increase the lifespan of tyres. It would also have other positive side effects, such as less wear on the suspension, lower fuel consumption and improved road safety.

The cost of the greater number of checks would have to be borne by the vehicle owner but would be partly cancelled out by reduced wear on the vehicle and tyres, and the lower fuel consumption. If only further checks to identify unusual wear were made mandatory, the costs would be negligible. To determine whether a policy instrument resulting in improved wheel alignment is justified based on decreased emissions of microplastics would require investigation into the extent to which the total tyre wear is affected by incorrect wheel alignment. Irrespective of how incorrect wheel alignment and tyre balance affects the overall tyre wear, correcting these will reduce the amount of uneven wear. This would reduce tyre consumption, which in turn would reduce the emissions of microplastics over the lifetime of a tyre, as there will be fewer worn out tyres able to emit microplastics. If and how further checks could be introduced should be investigated and evaluated.

There is currently no reliable data on the effect of incorrect wheel alignment and tyre balance on emissions of tyre wear particles, however tyres that are not aligned to the direction of travel (i.e. toe-in or toe-out) ought to result in more tyre wear, for purely physical reasons. Our view is that producing knowledge regarding the extent to which wheel alignment and tyre balance affect the generation of tyre particles should be prioritised. Once this is known, the next step may be to evaluate which type of policy instrument or measure to implement.

3.3.12. Road markings with low wear propensity

Policy instrument: Promote research &development of road markings with lower wear propensity.

Different types of road markings have different abilities to withstand wear. The wear increases in cold temperatures, when studded tyres are used, and due to winter maintenance measures, such as ploughing and sanding. Increased research & development of road markings with lower wear propensity may lead to decreased wear.

The lifespan of road markings is, according to Babić et al. (2015), generally the longest for road marking tape (permanent) and two-component systems with epoxy or acrylate. However, according to the Scandinavian Road Marking Association (personal contact, autumn 2019), two-component systems are not suitable for the Swedish climate. They are too hard, which means that they crack easily in colder climates and when subjected to studded tyres and ploughing activities. The most appropriate types of road markings for Swedish conditions, according to the Scandinavian Road Marking Association (personal contact, autumn 2019) are thermoplastic road markings with added ethylene vinyl acetate copolymer (EVA), which makes the material more flexible and less likely to crack. This is also the dominating road marking type on Swedish roads. The lifespan of thermoplastic road markings is approximately 2–4 years (Babić et al., 2015). In the last five years, since the Scandinavian certification system for road markings was introduced, the performance of certified road markings has improved and they now meet the performance requirements regarding retroreflection for a significantly greater number of wheel passages than they did previously (Söderberg, Swedish Transport Administration, personal contact, June 30, 2020; Fors, VTI, personal contact, August 17, 2020).

Thermoplastic road markings are both viscous and elastic, which brings several benefits but can also have drawbacks in certain conditions (Mirabedini, et al., 2020). On warm summer days there is for instance a risk that the road marking will flow and collect debris, while it can become brittle and break in cold weather (Mirabedini, et al., 2020). Different types of additives and formulas can mitigate this problem (as mentioned above, EVA is used as an additive in Sweden). It would probably be possible to optimise the composition even further. The findings from a research study by Mirabedini, et al. (2020) demonstrated for example that the thermal stability of road markings increased, and the need for plasticisers decreased, when a resin treated with epoxidized soybean oil was added. Figure 6 shows thermoplastic road markings with different amounts of wear.

In some cases, some road markings can be replaced with other materials, thereby reducing emissions. As an example, the City of Gothenburg, stopped using road markings of two-component type to colour cycleways red a few years ago, and now use red asphalt instead (NCC, personal contact, 19-09-2019).

Positive side effects

Road marking materials that wear less will lower the costs of maintenance (i.e. removal, repainting, and purchasing road marking products).

Negative side effects

There is a risk that new road marking materials with lower wear propensity contain more hazardous substances, which must be considered. They may also include less hazardous chemicals, which would then be a positive side effect.

Figure 6. Thermoplastic road markings with varying degrees of wear. Photo: Delilah Lithner.

Discussion and assessment

The promotion of research & development of new road marking formulas, or new types of road markings that have a lower wear propensity may be an effective measure to reduce the wear of road markings. It is well known, and extensively studied, that road markings wear down relatively quickly and have to be repainted at varying intervals. However, there is no data on the amount of road marking products being worn off our roads. It is not possible to estimate the amount being worn off simply based on figures on consumption of road marking products, both because these figures do not include data on road markings that are actively removed for repainting, and because the repainting efforts are governed by a set budget, and therefore do not reflect the actual need for repainting (Söderberg, Swedish Transport Administration, personal contact, March 18, 2020).

Repainting can also be performed by painting over existing road markings. Data on the amount of road markings being worn away is required, both to estimate the magnitude of this problem from a microplastics perspective (see policy instruments in section 3.6.1) and to assess the potential for reducing the wear, and the amount of microplastic particles, by development of more hard-wearing road marking products.

Our view is that research & development of new, improved road marking formulas or new types of more hard-wearing road marking products should be prioritised.

3.3.13. Use of certified road markings

Policy instrument: a) Promote research into whether certified road markings are better from a microplastics perspective and b) introduce guidelines on using certified road markings on municipal roads.

Since 2015, a Nordic certification system is in place for road markings used in Sweden, Norway and Denmark (Johansen & Fors, 2018). Road marking products for use on the national road networks in these countries must be approved by the certification system. There are currently no requirements to use certified road markings on municipal roads, but according to Söderberg (Swedish Transport Administration, personal contact, June 302020) the aim is for municipalities to also introduce certification requirements. The roads managed by the national authorities have a length of 98,500 km and municipal roads make up 42,800 km according to figures from 2019 (Swedish Transport Administration, 2020c).

The certifications are based on performance measurements, mainly relating to the visibility of the markings for instance including retroreflection, luminance coefficient, colour in daylight and vehicle headlights, and friction (Johansen & Fors, 2018). The road markings are certified in relation to the number of wheel passages they can withstand with preserved functionality, which is shown using classes (P0-P6) of between ≤ 50,000 and 2,000,000 wheel passages (Johansen & Fors, 2018). Measurements are made over a period of 1 to 2 years. The certification system covers several categories of road marking products, including white and yellow markings, different thicknesses, and required functionality. Functionality requirements can vary between different roads. Roads with street lightning, which are more common in built-up areas, do not have the same need for retroreflection, which means that products without or with a lower glass bead content, which have greater durability, can be used. For this reason, the certification system has introduced an extra category without the retroflection requirement, to enable certification of road markings without glass beads, or with a lower glass bead content.

In addition to certification, road markings could also be environmentally labelled (see section 3.5.3).

Positive side effects

Increased use of more durable road marking products will decrease the cost of maintenance (i.e. removal, repainting, and purchasing of road marking products).

Negative side effects

It costs to have road markings certified. The current price is e.g. 50,000 SEK (≈ 5000 euros) for two years' monitoring, which gives a classification of up to Class P5, and 35,000 SEK (≈ 3,500 euros) for one year's monitoring and classification up to Class P4 (Fors, VTI, personal contact, December 222020). As the testing period for certification is relatively short (1–2 years) it cannot confirm the total lifespan of a product. This means that it is possible that a certified road marking product may wear down faster than one that has not been tested.

Discussion and assessment

Since the certification system does not measure the total wear of a road marking over its lifetime, it is not possible to make a direct connection between a certified product and a reduced amount of road marking particles. The tests are mainly based on performance, not on wear, although some of the included measures, such as coverage rate, provide an indication of wear. It would be useful if the amount of wear could be included in the certification, however this has turned out to be difficult to measure and it has not been deemed economically viable to extend the monitoring period to cover the entire lifespan of a product, as this can be longer than 5 years. Despite some uncertainty regarding total wear, it is still considered likely that certified road markings on average wear less. Guidelines to municipalities on using certified road markings on public roads for which they are responsible is justified based on the positive side effects. However, making this a mandatory requirement cannot be justified due to the aforementioned uncertainties regarding wear amounts. According to Söderberg (Swedish Transport Administration, personal contact, June 30, 2020), adding a requirement to the

Swedish General Material and Work Description (AMA)[18] would be effective, as this would make it a technical requirement. It may take a long time (> 6 years) before all municipalities have implemented a new certification requirement. The AMA is revised every 3–4 years and the municipalities' procurement processes for road markings take between 1 and 7 years (Söderberg, Swedish Transport Administration, personal contact, June 30, 2020).

Our view is that research into whether certified road marking products are better from a microplastics perspective should be prioritised. There is currently insufficient data to introduce guidelines regarding the use of certified road markings on municipal roads solely to reduce the emissions of microplastics, and for this reason, this should not be prioritised at the present time.

3.3.14. Inlaid road markings

Policy instruments: a) Extend research of inlaid road markings and its impact on road marking wear, and b) investigate under what conditions inlaid road markings may be appropriate in the Swedish road network.

An important factor, which may affect the wear of road markings is the way in which they are applied. At present, road markings in Sweden are applied on top of the asphalt surface, which for thermoplastic road markings means that they protrude approximately 2–4 mm above the surrounding surface (Linjemarkering Väst AB, 2020). To reduce the wear of road markings, they can be applied in grooves cut into the asphalt, ensuring that the road markings are level with the surrounding road surface. In Norway, inlaid road markings have been evaluated by the national road authority (Norwegian Public Roads Administration, 2010). The findings show both reduced wear and good performance regarding dry and wet retroreflection (Norwegian Public Roads Administration, 2010). Inlaid road markings have been used for a long time in for example the United States. The state of South Dakota started testing inlaid (also called recessed) road markings on concrete roads as early as in 1995, and this method has been used in several states since then (Construction equipment, 2012).

In Sweden, the asphalt materials mainly used on the national road network (ABS 16[19]) have a higher stone-content and a lower percentage of fine materials are compared to the asphalt materials used in Norway (Söderberg, Swedish Transport Administration, personal contact, 30-06-2020). This stone-rich asphalt becomes more damaged by cutting (grooving). Therefore, measures carried out to cut grooves in the surface, between opposing traffic lanes, to reduce the risk of collision, cause more damage and holes in the asphalt surface in Sweden than in Norway (Söderberg, Swedish Transport Administration, personal contact, June 30, 2020). They also lead to more potholes and reduce the lifespan of the surface by 1–2 years (Söderberg, Swedish Transport Administration, personal contact, June 302020). Inlaid road markings have not been introduced in Sweden because the damage would be too great and surfacing costs too high (Söderberg, Swedish Transport Administration, personal contact, June 302020). This could, however, be an option on some stretches and sections of the road and for some types of surfacing materials.

Tests are currently underway in Sweden looking at deepening the sinus grooves used in the centre of dual carriageways by a few millimetres, then applying the road marking within them to reduce wear (Söderberg, Swedish Transport Administration, personal contact, June 30,2020). Currently, the highest point of the groove is level with the asphalt (which means that the road marking is higher than the asphalt), and the lowest point is 10 mm below the asphalt surface. According to Söderberg (personal contact, June 30, 2020) cutting a few millimetres deeper has the potential to reduce wear without

[18] The AMA is a Swedish General Material and Work Description which is used as terms of reference when technical method instructions are prepared.

[19] ABS16: Asphalt concrete with a high stone content, stone sizes up to 16 mm.

affecting the surfacing material much more than what already happens when the sinus groove is cut. Application of road markings in grooves cut into the asphalt is more appropriate and causes less damage on roads with finer stone materials. Coarser stone materials are often used on highly trafficked roads, whereas finer materials are often used in built-up areas, to minimise noise.

Positive side effects

It is possible that deepening the sinus grooves may also lead to cost savings, however the final results of the tests are not available at this point in time (Söderberg, Swedish Transport Administration, personal contact, June 30, 2020).

Negative side effects

Cutting into asphalt materials with high stone content causes major damage to the surfacing. This would lead to high repair costs.

Discussion and assessment

Inlaid road markings are deemed to have the potential to reduce the wear of road markings, and thereby the amount of microplastic particles. As the stone-rich asphalt mostly used in the national road network would suffer severe damage if cut, it has been deemed (by the Swedish Transport Administration) that using in-laid road markings everywhere is not an option. These could, however, be used on certain roads, e.g. roads with the denser (lower stone content) asphalt surfacing material (ABT[20]) which is used on low and medium trafficked roads, on roads with smaller-sized stones in the surfacing material, and on some sections of the road, such as the central reservation. If the results of the Swedish tests are positive, inlaid road markings could be tested in more locations. If these subsequent tests also show positive results, a decision to use inlaid road markings at a greater scale on selected sections of the road could be made by the Swedish Transport Administration relatively soon. A formal change in the requirements from the Swedish Transport Administration (2020a, Requirements – VGU, Design of roads and streets) would be required. This would be fairly quick to implement, however as the road marking contracts are 4–5 years long, and have to end first, the implementation time may still be quite long (Söderberg, personal contact, June 302020). Another policy instrument could be to avoid specification of a particular product or technique in procurement requirements and instead state that the choice of technology and product should comply with the recommendations in place at the point in time when the road marking is applied. Neither cost-effectiveness nor effectiveness can be assessed until the tests mentioned above have been evaluated.

Our view is that in-depth investigation of the conditions in which inlaid road markings may be appropriate in the Swedish road network should be prioritised. In parallel with this, continued research i.e. testing of inlaid road markings should also be prioritised.

3.3.15. Road surfacing materials that reduce tyre wear

Policy instruments: a) Promote research on road texture and develop road surfacing materials optimised for reducing tyre wear, and b) increase road maintenance.

The micro and macro texture of the road surface is expected to have a significant impact on tyre wear (Lundberg et al.,2019; Pohrt, 2019). Research into how road texture can be optimised for low tyre wear could result in road surfacing materials causing less tyre wear being developed.

The microtexture relates to the wavelength range (1 µm–500 µm) corresponding to the surface of the stone materials included in the asphalt, while the macrotexture relates to the wavelength range (0.5–

[20] ABT: Dense asphalt concrete.

50 mm) corresponding to the surface of the asphalt (Lundberg et al., 2019). A high microtexture (i.e. a coarser surface) increases friction, thereby increasing the tyre wear (Lundberg et al, 2015) compared to a lower microtexture (i.e. a smoother surface).

At low speeds, friction is mainly impacted by the microtexture, while the macrotexture is more influential at higher speeds (Lundberg et al, 2015). The texture of the road surface depends on the grain size and mineral composition of the material, and on studded tyre usage. Some minerals are harder, while others split or crack when exposed to pressure or abrasion, and this can affect the tyre wear (Andersson-Sköld et al., 2020). As friction is desirable and increases with the texture (Lundberg et al., 2015) this may conflict with the efforts to reduce tyre wear.

Large holes and uneven patches can also lead to increased tyre wear, which may be mitigated by more frequent road maintenance. According to Continental (2021b), coarse surfacing materials have a medium impact on tyre wear on a three-point scale from low to high.

Positive side effects

Road surfaces optimised to reduce tyre wear may also generate less noise and provide lower rolling resistance, thereby reducing the fuel consumption, which in turn decreases the environmental impact and reduces emissions of air pollutants. Less tyre wear also makes the tyre last longer. More frequent maintenance may improve road safety and travelling comfort, and reduce vehicle damage.

Negative side effects

Road surfacing materials optimised to reduce tyre wear may offer less friction. More frequent maintenance involves direct costs, although long-term cost-effectiveness should also be considered.

Discussion and assessment

To develop a road surfacing material optimised for reduced tyre wear may be complicated, as many important safety and performance requirements must be considered, and these may be in conflict with the wish to reduce tyre wear. Further knowledge is needed regarding how road surface materials can be optimised to reduce tyre wear, noise and rolling resistance, whilst maintaining road safety. There is also insufficient knowledge regarding the extent to which more frequent road maintenance could reduce tyre wear.

Our view is that research into road surfacing materials that lead to decreased tyre wear is a policy instrument that ought to be prioritised. We expect microplastics to be a less important aspect than some other factors when it comes to the issue of more frequent road maintenance. We therefore do not feel more frequent road maintenance should be prioritised from a microplastics perspective at present.

3.3.16. Road design that decreases tyre wear

Policy instruments: a) Promote research into the extent to which the layout of roads and streets affect tyre and road wear, and b) design roads and streets with fewer sharp bends and steep hills.

The road layout influences tyre and road wear. By designing roads with fewer sharp turns and steep hills, we could reduce tyre wear. A road layout involving bends, in particular sharp bends, or inclines, is expected to generate more wear than a straighter, flatter road (Andersson-Sköld et al., 2020; Pohrt, 2019).

Positive side effects

Roads without sharp bends and hills are favourable both from a road safety and fuel consumption perspective. Lower fuel consumption leads to lower emissions of greenhouse gases and air pollutants. These types of roads also generate less noise.

Negative side effects

If roads are required to be straight and flat, the opportunity to adapt them to their surroundings decreases, and their impact on the surroundings (i.e. natural landscape, buildings, cultural heritage, etc.) increases. The cost of building and maintaining a road may also increase if it has to be made flat, which e.g. may require both tunnels and extensive demolition.

Discussion and assessment

To reduce the number of sharp bends and steep hills in the construction of new roads and renovation of existing ones would have a positive impact on wear, road safety, and fuel consumption. The requirements from the Swedish Transport Administration (2020a, Requirements – VGU road and street design) already contain limit values and guideline values regarding e.g. how sharp bends can be and the maximum incline of hills. These requirements are mandatory when the Swedish Transport Administration builds new roads or carry out major restructuring. They should normally be applied to all restructuring work, however, can be disregarded where not socioeconomically viable. For other road owners, the requirements are not mandatory, but can be regarded as guidance (Swedish Transport Administration, 2020a). However, they too could consider the possibility of reducing the number of sharp bends and steep hills when designing new roads.

Thus, there are already policy instruments in place for national roads and to make these requirements stricter is not deemed to be justified solely based on microplastic emissions. In assessments on whether deviations from the guidelines are motivated, it may be good to not only consider socioeconomic aspects but also microplastics, once data on how much emissions could be reduced becomes available. Additionally, both negative and positive side effects of straighter and flatter roads must be considered.

Our view is that, based on current knowledge regarding tyre and road wear, stricter requirements on road design should not be prioritised. The reason is partly that this is expected to be costly, and partly that there is a lack of knowledge regarding the extent to which the layout of roads affects emissions of tyre and road wear particles. Despite the lack of knowledge, our view is that further knowledge gathering should not be prioritised at present. It is likely that other aspects than emissions of tyre and road wear particles, such as impact on landscape and cost, are more important when a road layout is chosen.

3.3.17. Speed limits and speed adaptations

Policy instruments: a) Promote research into the extent to which speed limits and speed adaptation can impact the generation of wear particles, and b) introduce speed limits and speed adaptations.

The generation of tyre particles increases with speed, according to Wang (2017) and Pohrt (2019). Measurements by Kwak et al. (2013) have also shown that higher speeds increase the generation of small tyre wear particles (PM2.5 and PM10) than lower speeds. This is because of the higher temperature of tyres driven at higher speeds (Li et al., 2011). This means that the introduction of speed limits could reduce both tyre wear and the generation of small tyre particles. Driving at high speeds through bends has also been shown to generate higher emissions of ultrafine particles, by Foitzik et al. (2018). Pohrt (2019) estimates that reducing the speed through a bend from 50 km/h to 30 km/h may reduce tyre wear by up to 13 percent.

Breaking and acceleration increase the emissions of tyre and road wear particles. Breaking measurements by Kwak et al. (2013) showed a significant increase in the number of small tyre wear particles (PM2.5 and PM10), and acceleration increases tyre wear according to modelling studies by e.g. Salminen (2014). Traffic planning solutions resulting in lower and more even speeds can help reduce tyre wear. Roads designed to include traffic lights, duty to give way, speed bumps and congestion measures produce more breaking and acceleration, which may increase wear (Andersson-Sköld et al., 2020).

Who is responsible for setting speed limits depends on the size and location of the road. Municipalities set speed limits on all roads they own, both within and outside built-up areas. The County administrative boards set speed limits on private roads and some national roads outside built-up areas, and the Swedish Transport Administration determines the speed limits in the national network of bigger roads.

There is also technology (advanced driver assistance systems) that can reduce speeds. Systems that help the driver to stay within the speed limit are known as intelligent speed adaptation, or assistance systems (ISA). There are different versions: an open system with warnings (using lights or audio signals), a half-open system which changes the pressure on the accelerator, and a closed system that reduces the speed automatically when the speed limit is exceeded (European Commission, 2021a).

Positive side effects

Lower speeds can lead to fewer road accidents, fewer serious accidents, lower risks of polluting land and water in case of an accident, lower fuel consumption, and thereby lower climate impact and air pollutant emissions. Noise is also reduced. Both the positive side effects and the reduction in tyre wear are greater when the highest speeds are reduced (Pohrt, 2019). Traffic planning that reduces the need for rapid deceleration or acceleration can also improve road safety.

Negative side effects

Speed limits can lead to longer travelling times and decreased accessibility. Removal of traffic lights and give way signs may have a negative effect on road safety.

Discussion and assessment

A number of positive side effects provide justification for the introduction of speed limits and traffic planning solutions that give a smoother traffic tempo. However, there is insufficient data to justify these measures purely from a microplastics perspective. There is also insufficient data to evaluate the effectiveness of such a policy instrument with respect to reducing the microplastic emissions from tyre and road wear. The impact on travel times and lower accessibility must be taken into account when decisions are made regarding whether to introduce speed limits. If the impact on travel times and accessibility are minor, the implementation would only require limited, or relatively limited, resources. The implementation period can be very short. Speed limits can be introduced within a few months and traffic planning solutions within a year or two. Intelligent speed adaption systems can also reduce the overall speeds and thereby the emissions of microplastics, but this has not been studied in detail in the preparation of this report and can therefore not be assessed.

Our view is that the generation of further knowledge regarding the extent to which speed limits impact the emissions of tyre wear particles should be prioritised. The next step may be to introduce speed limits or speed adaptations.

3.3.18. Investment in eco-driving

Policy instruments: a) Provide information regarding the importance of driving style, b) increase the proportion of drivers trained in eco-driving, and c) promote development and use of effective systems to support eco-driving.

Driver behaviour influences tyre wear. According to Continental (2021b), the driving style has a significant effect on how far a tyre can travel before it must be replaced. This is rated on a three-point scale from low to high. Sundt et al. (2016) estimate that a smoother driving style could reduce the generation of tyre wear particles in Norway by 10 percent. During fast acceleration, rapid deceleration and high-speed turns, tyre wear increases significantly according to Continental (2021b), and thereby also the emissions of microplastics. Information, education and guidance on the importance of driving style and its connection to tyre wear and microplastic emissions can be used to increase awareness.

This information could be provided as part of the general training for new drivers and other training, such as courses in eco-driving. The importance of a smoother driving style is already emphasised in these types of training initiatives for a range of reasons, although reducing emissions of microplastics from tyre and road wear is not mentioned as a reason (Gudmundsen, Yrkesförarcentrum, personal contact, November 6, 2021).

As part of the eco-driving training, drivers are taught to plan their driving better and to drive less aggressively, with less acceleration and breaking, and at a slower, more even speed. They are also taught how to reduce fuel consumption and tyre wear, and the importance of correct tyre pressure. Eco-driving is already included as both a theoretical and practical element in the training for a driving licence, and in theoretical form in the training required to obtain a professional driver certificate. A certificate of professional driver competence is required to transport passengers or goods by bus or truck within the EU and to operate vehicles requiring special driving licence qualifications, and this is regulated in the Swedish Act (SFS 2007:1157) on professional driver competence (Swedish Transport Agency, 2021). The licence is valid for five years, after which the driver has to undergo further training to renew it (Swedish Transport Agency, 2021). If the proportion of drivers having participated in eco-driving courses could be increased within other driver categories as well, this may lead to lower emissions of tyre wear particles.

In addition to eco-driving training, there are several more or less advanced eco-driving support systems that give feedback to the driver while driving. A number of EU-funded research projects connected to eco-driving, and spanning multiple years, have been carried out in the last ten years, and some projects are still ongoing. A review carried out as part of ecoDriver research project showed that eco-driving support systems are important tools to reduce emissions (Carsten, 2016). It also showed that systems that are integrated into the vehicle are more effective than non-integrated systems, e.g. those based on apps, which mainly rely on GPS data.

The 1st of May 2020 was the start date for the EU Horizon 2020-funded projects ‘uCARe’ and ‘MODALES’, which will take three years and aim to reduce the impact of transportation on air quality. One of the steps towards achieving this involves providing vehicle-users with simple and effective instructions on how to reduce their own emissions (uCARe, 2020; Modales, 2019). The findings from these projects could be used to identify new ways to influence driver behaviour, with the aim to reduce microplastic emissions.

There are also telematics services[21] providing real-time data from individual vehicles, which are used by companies and professional drivers to monitor and optimise driving based on a number of aspects, including fuel consumption, vehicle location, and journey logs.

Positive side effects

A smoother driving style helps improve road safety and provide a better traffic climate. It also reduces fuel consumption, resulting in less air pollution, lower climate impact, and lower transportation costs. A smoother driving style also generates less noise. It would also reduce the wear on both roads and vehicles.

Negative side effects

We have not found any negative side effects other than the cost and time required for implementation.

[21] Telematics is a technology area comprising telecommunication, vehicle technology, electrotechnology, and computer science.

Discussion and assessment

Since information, training and guidance regarding the importance of driving style for road safety, greenhouse gas emissions, air pollution and tyre wear is already included in e.g. training for driving licenses, professional driver certificates, and eco-driving courses, it should be very easy and cheap to include information regarding microplastics in these trainings. This has been confirmed by Gudmundsen (Yrkesförarcentrum [Professional Driver Center], personal contact, November 6, 2021). Despite this, our view is that yet another argument for adopting a smoother driving style is unlikely to motivate many more people to change their driving style. For this reason, the effectiveness is deemed to be low, although there would still be a value in increasing public awareness of the connection between driving style and emissions of tyre and road wear particles.

To increase the proportion of drivers receiving eco-driving training is, however, deemed to be an effective way to convince drivers to drive more smoothly, thereby reducing emissions of tyre wear particles. An important aspect of eco-driving is the reduction in fuel consumption, which in turn decreases greenhouse gas emissions and air pollution, as well as transportation costs. Other positive side effects of a smoother driving style include less noise, improved road safety, better traffic climate and less wear on both vehicles and roads.

Eco-driving courses cost money and are not generally attended by private individuals (except when included in the training to obtain a driving licence). Mainly it is companies that either require their employees to attend this training (e.g. haulage companies) or offer their employees the opportunity to attend a course. The compulsory training for professional drivers only covers the theory of eco-driving. Neither the effectiveness nor the cost-effectiveness regarding emissions of tyre and road wear particles have been investigated in this report. Despite this, the addition of information regarding microplastics from tyre wear in the various eco-driving courses and offering free web-based t training to anyone who has not yet received it, is expected to be worthwhile from a socio-economic perspective. Training in eco-driving is already available as online courses. The cost to the government would involve developing a new training course or purchasing an existing one, as well as costs for information efforts required to make drivers aware that the training is available.

Our view is that adding information about the importance of driving style for emissions of tyre wear particles from a microplastic perspective should be highly prioritised. To increase the number of drivers trained in eco-driving by offering for example a free online course should be highly prioritised for further investigation. These priorities are based mainly on the fact that driving style has a significant impact on tyre wear and that the investment required is relatively low. Our view is that continued promotion of research & development relating to effective eco-driving support systems, and the promotion of their use, should also be highly prioritised.

3.3.19. Snow clearance optimised for reducing the wear of road markings

Policy instruments: a) Promote research or investigation into how snow clearance can be optimised to reduce the wear of road markings, b) develop a guidance, and c) include requirements in procurement processes.

Clearing snow from roads in winter can cause significant wear of road markings. The snow is cleared either using plough trucks, road graders (equipped with dozer blades during winter), or tractors fitted with plough blades. Plough blades can have different edges. Edges in steel or hard metal wear road markings more than plastic or rubber edges (Ljungberg, 2000). However, the wear from plastic and rubber edges can also contribute to microplastic emissions. Spring-loaded blades cause less wear on the road surface than fixed blades, and also reduce the risk of the driver being injured or the machine being damaged (Halmstad Municipality, 2020), which may occur if the blade gets stuck in the asphalt. The drawback with springs, however, is that they prevent the plough from pushing through hard-packed snow. The prevailing conditions determine the type edges being most suitable to use. Plastic and rubber edges are for example not used in icy conditions. Graders fitted with dozer blades, on the other hand, are able to tear away packed ice and snow (Halmstad Municipality, 2020).

The plough settings can also affect the wear (Söderberg, Swedish Transport Administration, personal contact, March 5, 2020). The wear of road markings could be reduced by choosing for example the right type of blades and optimising the plough settings. Figure 7 shows snow clearing of a walking and cycling path.

Figure 7. Snow clearing of a walking and cycling path. Photo: Göran Blomqvist, VTI.

Positive side effects

Snow clearing could be performed more gently by switching from hard metal and steel edges to plastic or rubber wherever possible. If these were also spring-loaded, savings could be achieved as a result of lower maintenance requirements, accident risk, and damage to equipment.

Negative side effects

A potential negative side effect of switching to rubber and plastic is that they themselves emit plastic particles. Another negative side effect is that gentler ploughing may result in more snow and ice remaining on the road, which may increase the risk of accidents, as well as the fuel consumption, with follow-on effects.

Discussion and assessment

A potential policy instrument could be to promote investigation or research into how different blades and blade settings can be optimised to reduce the wear of road markings, taking into account the risk of increased emissions of microplastics from the blade itself if switching to plastic or rubber materials. This could provide the basis for providing guidance to snow plough operators and the entities that hire them on e.g. how to choose blades and settings to reduce the wear of road markings and road surfaces. Once sufficient data is available, one possibility would be for the client to include requirements in the procurement process e.g. that a particular type of blade is used under certain circumstances. As the Swedish Transport Administration and municipalities hire a very large number of contractors across the country, who use different blades and settings, a short guidance for example in the shape of an instruction video may be a way to reach out to the snow clearers. It is important to find a level where the ploughing is not too gentle, as this could lead to not enough snow being removed and increase the risk of accidents. The implementation time for this measure is expected to be short (< 3 years). It has not been possible to assess neither the effectiveness nor the cost-effectiveness, but as this measure may lead to reduced costs for maintenance, machinery damage and blades, the total cost is expected to be low.

Our view is that the promotion of research or investigations into how snow clearance operations can be optimised should be prioritised, including studies on how different blades and settings can be optimised to reduce the wear of road markings. Depending on the outcome, the next step could be to produce guidance or place demands on contractors regarding procedures, choice of blades etc., however this is not currently a priority.

3.3.20. Green procurement

Policy instrument and measure: a) Identify products and services that contribute to decreasing microplastic pollution caused by tyre and road wear, and b) include requirements in public procurement.

Green procurement relates to public procurement processes that consider various environmental aspects when products and services are selected. Lower microplastic emissions from tyre and road wear could be one such aspect. In 2018, public procurement in Sweden amounted to approximately 706 billion SEK (net of VAT) (≈ 70.6 billion euros), which corresponds to 17 percent of the GDP at basic prices (Töyrä et al., 2019), i.e. net of taxes and subsidies. This means that any requirements included in public procurement can be very impactful. For emissions of microplastics, public procurement can lead to direct reductions, but also affect the market, indirectly resulting in less microplastic pollution. At present, mainly requirements that lead to decreased road traffic (vehicle-kilometres) can be seen as related to microplastic emissions. Once labelling systems for tyres and road markings have been introduced, demands related to these can also be made during procurement of tyres and road markings. The same is true for operation and maintenance, once more data on this have been produced (e.g. concerning microplastic emissions connected to snow clearing or street sweeping).

Positive side effects

Different positive side effects apply depending on the product or service being procured. Procurement agreements for business travel, can for example result in lower climate impact, lower emissions of air pollutants, less crowding, lower resource consumption, and improved road safety.

Negative side effects

A requirement for green procurement may result in higher costs if the products and services that meet the requirement are more expensive. It is also possible that a requirement leading to lower emissions of tyre and road wear particles may have other negative impacts, for example on another environmental aspect or from a road safety aspect. Examples include if tyres with a lower wear propensity would require chemicals that are hazardous to the environment or human health, and that reduced tyre wear may result in less friction and decreased road safety.

Discussion and assessment

As public procurement contributes a sizeable portion of our consumption and environmental impact, the inclusion of requirements regarding tyre types, vehicles, means of transportation, operation and maintenance, etc. in procurement processes may be a very effective way to promote the introduction of better alternatives on the market. It may also result in more sustainable travel, which will reduce the overall amounts of microplastics from tyre and road wear. This can involve both a reduction in emissions (sub-objective 1) and effects (sub-objective 3). As an example, the Swedish Transport Administration and municipalities purchase the main part of all road markings. For this reason, any requirements made by them during procurement have a significant impact on the types of road markings used in the country, which in turn affects wear (see also section 3.3.13). Public procurement of tyres also covers comparatively high volumes, as it relates to buses used in public transport and all other vehicles used within the public sector. This process offers plenty of opportunity to influence the environmental harmfulness and wear propensity of tyres used within the public sector, thereby indirectly influencing the market to become more environmentally friendly.

Our view is that public procurement offers a lot of potential for reducing the impact of tyre and road wear particles on both the environment and human health, in relation to three of the sub-objectives, i.e. to 1) reduce emissions, 2) reduce spread, and 3) reduce effects and persistence. However, due to a lack of knowledge within some of these areas, it is currently not possible to fully utilise the power of public procurement to reduce microplastic emissions. The overall effectiveness of public procurement of goods and services is deemed to be significant, although this is expected to vary significantly depending on the products and services being procured and must therefore be evaluated separately for each category (e.g. travel, tyres, vehicles, road markings, snow clearing).

Our view is that the design and inclusion of requirements resulting in lower volumes of tyre and road wear particles in public procurement processes for goods and services should be prioritised. In some cases, further data or development is needed before requirements can be included in procurement processes. One of these is that a labelling system for tyres and road markings needs to be introduced first. In other cases, it is possible to move forward right away and make suggestions, evaluate proposals, and set requirements, e.g. requirements which result in reduced road traffic.

3.4. Potential policy instruments and measures for sub-objective 2 – Reduce spread

This section describes the policy instruments and measures mainly targeted at reducing the spread of microplastics from tyre and road wear, or at increasing our knowledge regarding dispersion to enable appropriate instruments to be developed. Examples include collection of tyre particles during travel; management of stormwater from roads, water from road cleaning, sweep-sand and snow; and increased street sweeping.

3.4.1. Collection of tyre particles during travel

Policy instrument: Promote research, development and evaluation of devices that can capture tyre particles from a vehicle in motion.

A group of students at Imperial College in London have invented a device that captures tyre particles from vehicles in motion (Wilson, 2020). This means that generated particles are collected before entering the environment. Their prototype is a simple device that is mounted on the wheel and uses electrostatic forces to capture particles (Wilson, 2020), see Figure 8.

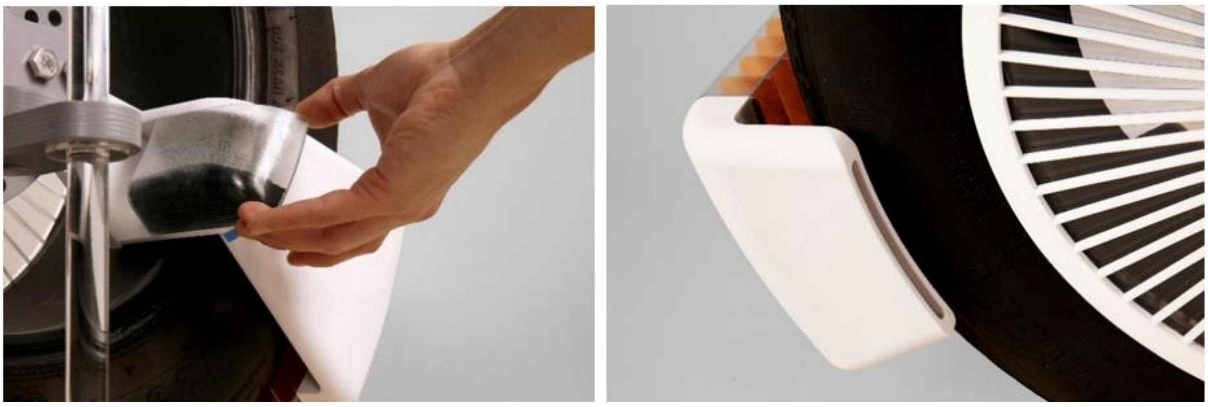

Figure 8. Collection device (prototype) from The Tyre Collective, which uses electrostatic forces to capture tyre wear particles from a vehicle in motion. Photos: The Tyre Collective. (Published with permission from The Tyre Collective, 2021.)

They claim that their prototype can collect up to 60 percent of all airborne particles from tyres under controlled conditions (Wilson, 2020). How the efficacy of this method is affected by e.g. speed or different road surfaces has not yet been evaluated. The promotion of research & development in this area may result in devices of this type being developed, evaluated and brought to market faster.

Positive side effects

Collection of airborne particles improves air quality and reduce health impacts from small particles (PM2.5 and PM10) generated by vehicles, leading to health benefits, particularly in built-up and heavily trafficked areas. The particles are collected in concentrated form before being spread into the environment, which both reduces the environmental impact and makes them much easier to manage.

Negative side effects

To mount a collection device on each tyre will entail the financial cost of purchasing the device. This cost will probably not be particularly high, as the particles are collected only using electrostatic forces, however each tyre would require a device. Devices would also have to be emptied once they are full of particles, then handled correctly (perhaps recycled) which would require time and money.

Discussion and assessment

Collection of tyre wear particles during travel is a physical measure expected to provide a good complement to other policy instruments and measures aimed at preventing emissions as close to the source as possible. As this prototype collects airborne particles, there is also significant potential to reduce negative health impacts in built-up and heavily trafficked areas, which is a positive side effect. If the collection efficiency is as high in reality as claimed for the prototype (i.e. 60 percent of airborne particles) this would be an effective device for the airborne fraction, and probably also cost-effective. This equipment is currently only a prototype and its effectiveness in real-life driving conditions has not yet been evaluated.

It may be difficult to convince drivers to purchase this type of collection device, as it involves both a financial cost and time for emptying. Mandatory legislation or subsidies would probably be required to persuade private individuals to purchase such collection devices. It would be easier to introduce mandatory use of such a device on heavier vehicles and those used for professional purposes. It may also be possible to amend the Traffic Ordinance (SFS 1998:1276) to include a requirement that this type of device is used on any vehicle being driven in a Class 3 environmental zone (the highest class). It would also be necessary to develop systems for collection (for example at petrol stations and charging stations) and management of particles. The final cost is difficult to estimate, as this device is not yet available as a commercial product, but only as a prototype. Our view is that the promotion of research, development and evaluation of particle collector devices such as this should be highly prioritised.

3.4.2. Sustainable management of stormwater and masses contaminated with tyre and road wear

Policy instrument: Promote research and development of sustainable solutions for managing stormwater and masses containing tyre and road wear particles.

By sustainable management of stormwater on roads, we can limit the spread of tyre and road wear particles to waterways, lakes and oceans. All generated masses must also be managed correctly to avoid simply moving particles from one location to another. There are a number of existing methods and solutions for managing stormwater from roads, however these have not been designed specifically for the management of tyre and road wear particles. Research & development can be used to produce sustainable systems.

Ditches run alongside the majority of the national road network. These are primarily intended for draining the roads, but depending on design, are also capable of storing pollutants (Swedish Road Administration, 2003). The ditches must be cleared regularly, resulting in masses containing tyre and road wear particles that must be managed. Some locations also have stormwater facilities, used for detention and cleaning of stormwater from roads. The most common type of stormwater facility in Sweden is stormwater dams (CEDR, 2016). According to Blecken (2016), these stormwater dams are designed to settle particles within the size range of 10 µm to 5 mm and may therefore provide an effective way to separate microplastic particles. A study by Jönsson (2016) reported a retention level of 90–100 percent in two stormwater dams, for microplastic particles larger than 20 µm. However, sediments must be removed from the facilities once the volumes are large enough to risk particles being transported away from the facility or disrupting it in some other way (Wadsten & Arm, 2008). This is a drawback, as it involves moving the particles to other locations, where the masses are deposited. Dams also require large areas and can therefore rarely be used in more densely populated areas. In those areas, different filtering techniques are used instead, such as drain filters and detention storage.

Some of the stormwater on roads in densely populated areas is led through combined sewers to wastewater treatment plants, where the majority of the microplastic particles are separated and end up in the sewage sludge. Depending on what happens to the sludge afterwards, the particles may spread further in the environment, e.g. to fields if used as fertilizer. Combined systems for stormwater and wastewater were constructed in densely populated areas in Sweden until the 1950s and currently make up approximately 13 percent of the sewage system (Swedish Water, 2016). Stormwater from hard surfaces in urban environments in Sweden is currently mainly led into ditches and gully pots, from where it follows the pipe network to a nearby recipient (Swedish Environmental Protection Agency, 2019a).

The infrastructure regulations from the Swedish Transport Administration (TRVINFRA-00231) set out requirements for dimensions and design of drainage systems for roads and railroads (Swedish Transport Administration, 2020e). The overall requirement for dimensions state that a drainage system must be capable of receiving and handling the flows and water volumes for which it has been dimensioned throughout its intended technical lifetime, in such a way that traffic is not affected and so that unacceptable consequences for structures, surrounding land, water and buildings are avoided. Drainage is regulated in different environmental laws, including the Swedish Environmental Code (SFS 1998:808) and the Act containing Special Provisions concerning Water Operations (SFS 1998:812).

Positive side effects

Management solutions for stormwater on roads, designed to separate microplastics, can also filter other pollutants, including chemicals. They can also reduce the risk of flooding, contribute to nutrient reduction, and add aesthetic and ecological value.

Negative side effects

Management solutions for stormwater on roads can be expensive to construct, operate and maintain. Examples of maintenance include emptying or exchanging filters. Some stormwater facilities, such as dams, require a lot of space and produce large volumes of semi polluted masses or sediments.

Discussion and assessment

Measures that result in stormwater on roads being managed in terms of tyre and road wear particles are deemed to be important to reduce the spread of microplastics to waterways. Positive side effects include the capture of different pollutants and the reduced risk of flooding. However, it is vital to demand that the masses they produce are managed in a sustainable way, to avoid simply moving the problem from one location to another. The smaller the polluted volumes to be managed, the better. For this reason, further research is required into how to produce treatment systems for stormwater from roads that are effective and practically applicable, and that do not produce large volumes of polluted masses. Research is currently underway into abatement techniques for stormwater from roads, for example by CEDR (Conference of European Directors of Roads), and at several universities in Sweden and other parts of the world.

Although there are many existing techniques for treatment of stormwater, stormwater from roads, and wastewater, there is little knowledge on how to achieve sustainable management of tyre and road wear particles, both in terms of handling masses produced by water separation and how to capture the smallest particles. There are also knowledge gaps regarding the dispersion of particles in roadside ditches and different stormwater systems. This means that research on dispersion is also required to ensure that the correct measures are implemented in the right place (see section 3.6.1).

One of the Swedish Environmental Protection Agency conclusions in their reporting a government commission was that there is a need to reduce the dispersion of microplastics via stormwater and develop cost-effective treatment techniques, with particular focus on those used close to the source (i.e. stormwater on roads and in built-up areas with a lack of space) (Swedish Environmental Protection Agency, 2019b). They were later asked by the government to allocate funding for measures that improve the aquatic environment (175 million SEK in total (≈ 17.5 million euros), until 2023), including funding to invest in reducing the emissions of microplastics and other pollutants via stormwater (Swedish Environmental Protection Agency, 2021b).

Our view is that research & development of sustainable solutions for managing stormwater from roads and masses containing tyre and road wear particles should be given a high priority.

3.4.3. Cleaning of roads and streets, and optimisation opportunities

Policy instrument: a) Promote research into how street sweeping affects the dispersion of microplastics, and b) evaluate available optimisation opportunities.

Some of the tyre and road wear particles end up on roads or streets. Improved cleaning of roads and streets could be used to limit the spread of microplastics from tyre and road wear. Sundt et al. (2016) estimate that this measure, and measures to reduce traffic volumes and encourage smoother driving, has great potential to reduce the amounts of microplastic particles generated by road traffic in Norway.

Different types of cleaning machines and techniques have different abilities to collect road dust and individual fractions of road dust. Cleaning can involve sweeping, rinsing, vacuuming, dry suction, wet suction, high pressure washing, etc. The cleaning-effectiveness depends on the techniques, or combinations of techniques, being used, but can also be positively influenced by lower driving speeds during cleaning. The cleaning strategy can also affect the result, e.g. the time of year when cleaning is carried out, or when it is carried out in relation to precipitation events. The results of the cleaning are also affected by the amount of dust on the road surface, the characteristics of the dust, and the structure, condition and dampness of the road surface (Järlskog et al. 2017).

According to studies by Järlskog et al. (2017) and Polukarova et al. (2020), some cleaning machines were able to capture micro- and nanoparticles. Nanoparticles of 1–300 nm were identified in the water from road sweeping, alongside very high levels of organic pollutants, such as aliphatic hydrocarbons, volatile aromatics, phthalates, and polycyclic aromatic hydrocarbons (PAH), which means that the water from street sweeping needs to be cleaned (Polukarova et al., 2020). The sweep sand can also contain microplastics and pollutants. Another study, by Aronsson et al. (2018), demonstrated the presence of microplastic, rubber and bitumen particles in the street sweeping water, in sizes from 100 µm (which was the smallest fraction measured). There is, however, a lack of data on the effectiveness of different types of road cleaning when it comes to reducing the spread of microplastics from tyre and road wear. Road sweeping can also generate microplastics, if sweepers with plastic brushes are used, as these wear down. Figure 9 depicts brushes and spraying equipment on a road cleaning machine.

Figure 9. Brushes and spraying equipment on a cleaning machine. Photo: Mats Gustafsson, VTI

The way in which sweep sand, sweep water and water from washing the sand are handled determines whether the tyre and road wear particles and other pollutants are simply moved from one location to another, or if their spread is limited. Some of the sweep sand is put in landfill, while the rest is reused in different ways. As an example, sand is used in the construction of roads, noise barriers, and during pipe works (Stockholm City Council, 2019a).

The action plan regarding microplastics for the city of Stockholm (2019a) includes two measures related to sand from street sweeping. These involve analysing the collected sand for microplastics, monitoring for any technological developments, and investigating the possibility to clean collected sand.

Positive side effects

Extended and more efficient sweeping of streets and roads may result in other pollutants and small particles being removed, and provided these are managed appropriately, their impacts would be decreased. Efficient street sweeping can also help reduce the amounts of breathable particles being resuspended, thereby improving the air quality in areas near roads and streets, although several studies have shown that many of the standard methods used to clean roads are not effective for particles as small as this (Amato et al., 2010 and Mats Gustafsson, VTI, personal contact, May 2021).

Negative side effects

When plastic brushes are used for sweeping, they wear down, resulting in plastic particles being generated. More frequent sweeping and appropriate management of sweep sand, sweep water, as well as water and the waste fraction from washing the sand, would lead to increased operating costs. More frequent street sweeping at night in built-up areas may also generate noise and require parking restrictions on the streets. Sweeping carried out using brushes made of steel rather than plastic would increase the road wear, and the number of particles generated from e.g. road markings.

Discussion and assessment

Sweeping of roads and streets may provide a way to reduce the spread of microplastics, particularly if plastic brushes are not used, and provided that sweep sand and water from sweeping are managed appropriately. There are however a few issues related to street and road sweeping that must be investigated first. These concern the effectiveness of sweeping for reducing the dispersion of microplastics, how sand and water from the sweeping are currently managed, and ought to be managed, and the amounts of microplastic particles generated when plastic brushes are used.

As road sweeping is an ongoing measure used for other purposes than specifically to reduce emissions of microplastics, it is important to investigate in what way and how often street sweeping should be carried out to be optimised from a number of perspectives, of which microplastics should be one.

The knowledge-raising measures regarding sweep sand introduced by the City of Stockholm are deemed to be important in this context. As street sweeping already takes place, a small adjustment in sweeping strategy that also take into account the issue of microplastic dispersion should not be particularly costly to make.

Our view is that research into the way in which sweeping of roads and streets affect the spread of microplastics should be highly prioritised. After this, it may be relevant to investigate any opportunities for optimisation, although this cannot be prioritised at present.

3.4.4. Dust binding measures

Policy instrument: Promote research into how dust binding affects the dispersion of microplastics.

The use of dust binding on roads may reduce the resuspension of road dust, thereby limiting the dispersion of microplastic particles, particularly to air. There is, however, limited data on the overall effect on dispersion, why this should be studied.

Dust binding involves spraying a dust binding agent, in the form of a salt solution, on the road surface to keep it damp (SOU 2015:27). Tests carried out by Gustafsson et al. (2010) using four different dust binding agents (i.e. calcium chloride ($CaCl_2$), magnesium chloride ($MgCl_2$), calcium-magnesium acetate (CMA), and sugar solution) showed that the agents were more or less equal regarding the amount of dust they bind, but that their effect on the friction between the tyres and the road surface varied. Calcium chloride had the best friction characteristics, but the disadvantage of being corrosive to e.g. concrete and metal (Gustafsson et.al, 2010).

Since 2011, the City of Stockholm have tried to reduce the particulate levels in air, using cleaning with vacuum suction and dust binding with calcium-magnesium acetate, intended to reduce the resuspension of particles (Gustafsson et al., 2018). The results have been monitored by VTI and SLB-analys at the Environment and Health Administration of the City of Stockholm (Gustafsson et al., 2018). The results show that these measures reduce PM10 concentrations, but that it is difficult to optimise dust binding, as it takes place according to a fixed schedule (Monday, Wednesday, and Friday) rather than when needed. This means that dust binding measures are sometimes not carried out when they are required, and sometimes are carried out when there is no need. For this reason, the environmental quality standards are sometimes breached when this could have been avoided, and unnecessary costs are sometimes incurred (Gustafsson et al., 2018).

Positive side effects

Dust binding can reduce the concentrations of PM2.5 and PM10 and avoid breaches of the environmental quality standards for air, which is positive for human health (Gustafsson et al, 2019a, Gustafsson et al., 2019b, Gjerstad et al., 2019).

Negative side effects

Dust binding does not remove the dust from the road. Instead of becoming resuspended, it may end up in the stormwater during active flushing or precipitation. Additionally, it is probably more difficult for cleaning machines to collect the dust if dust binding agents have been applied (in particular the very fine dust) (Andersson-Sköld et al., 2020).

The effectiveness of dust binding varies depending on humidity. The effect lasts longer in humid conditions in the autumn than in the spring when the humidity decreases and the sun dries the road faster (Gustafsson et al., 2010). Dust binding is also expensive. In the City of Stockholm, the annual cost of dust binding on approximately 30 streets between 2013 and 2015 amounted to 40 million SEK (≈ 4 million euros) (SOU 2015:27).

Of the dust binding chemicals most commonly used in Sweden, both magnesium chloride and calcium chloride are corrosive and have negative impacts on vegetation, groundwater, and surface water. Calcium-magnesium acetate (CMA), on the other hand, is less corrosive and more environmentally friendly, although the degradation of CMA in higher concentrations may cause oxygen deficiency in aquatic environments (Gustafsson et al., 2010).

Discussion and assessment

Dust binding is not considered a particularly effective way to reduce the dispersion of microplastics. It could even lead to increased dispersion to aquatic environments via stormwater during active flushing or precipitation. Dust binding can, however, be used to reduce high particle concentrations in air temporarily, and it is actually already used for this purpose. To meet the air quality standards is very important, and something dust binding can contribute to. The measures of dust binding and street sweeping should be evaluated in combination to enable evaluation of if, and how, the use of these two measures could be optimised to both reduce the dispersion of microplastics from tyre and road wear, and to achieve other positive effects. Although dust binding is not considered an effective measure to reduce the dispersion of microplastics, it is possible that the cost of adapting existing dust binding measures to also take into account microplastic dispersion would not be particularly high. If this is the case, it might justify introducing this measure despite its low effectiveness. As this measure is deemed to have a low potential for reducing the spread of microplastics, our overall feeling is that it should not be prioritised at the present time.

3.4.5. Sustainable management of microplastics in snow from roads

Policy instruments: a) Promote research into whether microplastics in cleared snow from roads is a potential problem and b)investigate appropriate ways to manage cleared snow.

During the winter, particles and pollutants from road traffic accumulate in snow on streets and roads. Current recommendations are to either place cleared snow on nearby land, where it is left to melt, or in a dedicated snow deposit area. Where there are not enough deposit areas, there is a possibility to be granted an exemption from the general Swedish ban on dumping in water bodies When such dumping exemptions are considered, dispersion of microplastics should also be taken into account.

There is currently a lack of data on the amounts of microplastics from tyre and road wear present in cleared snow from roads and the risks they may pose when large volumes of snow are deposited on land, or when exemptions are made to allow snow to be dumped in water. The action plan for reduced spread of microplastics, 2020–2024, from the City of Stockholm, includes three measures related to microplastics in snow (City of Stockholm, 2019a).

These are to:

1. identify locations that can be used for long-term storage of snow, and adapt these to avoid dispersion of microplastics
2. analyse microplastic contents of deposited snow and sand collected from streets
3. monitor technological developments and investigate opportunities for cleaning of deposited snow and collected sand.

Positive side effects

The positive side effects cannot be assessed, as the results of surveys and management requirements are not yet known.

Negative side effects

We cannot see any other negative side effects than cost and time required to conduct the research.

Discussion and assessment

Our view is that a survey looking at the amounts of microplastics from tyre and road wear found in snow masses, how these masses are managed, and in which environmental compartments they end up, is needed to enable assessment of the risks of current management procedures, and to determine whether these masses should be managed differently. As some areas are more sensitive than others, management procedures should be adapted to the environment in which the masses will be deposited. Figure 10 shows an example of a less appropriate place to deposit snow, right next to a pond built for amphibians. It is also important, particularly in larger towns, to earmark and adapt places where snow can be deposited, both to reduce the spread of microplastics and the need for dumping in water bodies.

The findings from such a survey could also show whether the masses need cleaning or not. The measures included in the action plan against microplastics for the City of Stockholm are considered very relevant in this context.

Our view is that the promotion of research into whether microplastics in snow can potentially cause problems should be highly prioritised. Based on the results, the next step may be to investigate appropriate ways to manage the snow, however this cannot be prioritised at present.

Figure 10. Polluted snow deposited next to a pond built for amphibians, Vinterviken, Stockholm. Photo: Mikael Johannesson, VTI.

3.4.6. Regulating the use of end-of-life tyres

Policy instruments: Introduce a) requirements relating to dispersion of microplastics in the producers' responsibility for end-of-life tyres, and b) notification requirements for facilities containing artificial turf or moulded granules, and riding arenas containing rubber or plastic.

Policy instruments related to the use of end-of-life tyres are not directly connected to policy instruments for tyre and road wear. However, they have still been included in this report, because tyre waste is generated as a consequence of tyres reaching their end of life and may be used to create new products from which microplastics can be emitted.

End-of-life tyres are covered by an ordinance (SFS 1994:1236) on producers' responsibility for tyres, which means that anyone producing, importing, or selling tyres must accept end-of-life tyres and ensure that they are reused, recycled, or managed in some other environmentally acceptable way (Swedish Environmental Protection Agency, 2020c). Some usage areas and management methods can result in microplastic dispersion. The ordinance of producers' responsibility for tyres does not include any requirement that the reuse or recycling should be environmentally acceptable; it requires only reuse or recycling.

For tyre fractions used in such a way that they re-enter the environment there are at present only general requirements, such as those included in the general rules of consideration in the Swedish Environmental Code (2 chap.). This could be extended by adding a requirement to the producers' responsibilities ordinance that the use of end-of-life tyres must be carried out in a way that minimises the dispersion of microplastics and chemicals to the environment.

According to Svensk Däckåtervinning (2020) (a Swedish tyre recycling company), the collection rate for tyres is higher than 100 percent when the number of collected tyres (92,574 tonnes in 2019) is compared to the number of imported tyres for the same year. Recycling statistics do not include tyre casings (destined e.g. for retreading) as these are removed before tyres are sent for recycling. Approximately 45% of all truck and bus tyres sold in Sweden are retreaded, while the percentage of retreaded car tyres is negligible (Svensk Däckåtervinning, 2020). Factory-mounted tyres on vehicles under 3.5 tonnes are also not included in the producers' responsibility, or the recycling statistics, as they are the producers' responsibility of the vehicle manufacturers (Svensk Däckåtervinning, 2020).

Collected tyres are sorted and prepared for different usage areas, including whole tyres, segments, granulates, or powder (Svensk Däckåtervinning, 2020). During the granulation process, rubber, textile, and steel are sorted into separate fractions, which are recycled separately (Svensk Däckåtervinning, 2020). According to Svensk Däckåtervinning, the tyre recycling categories were divided as follows in 2019:

- energy recovery 69.7% (of which the cement industry 30.1%)
- other material recovery (e.g. steel from the tyre and tyres sent for pyrolysis) 15.6%
- material recycling, blasting mats 5.9%
- material recycling, granulate 4.5%
- material replacement (e.g. gravel in drainage courses) 3.2%
- export of whole tyres 1.1%.

The percentages of each category have varied over the last few years. The biggest change is that the portion used for blasting mats and granulates has halved, which according to Svensk Däckåtervinning (2020) is a consequence of reports regarding microplastics and artificial turf pitches. The main portion, almost 70 percent, is currently used for energy recovery, where the cement industry is the main receiver.

The Swedish Environmental Protection Agency (2019b) has, in their reporting of a government commission on microplastics, proposed that all facilities larger than 200 m^2 using artificial turf or moulded granules, as well as riding arenas containing rubber or plastic, should be subject to notification requirements to enable municipalities to put in place appropriate requirements regarding construction and maintenance (e.g. facilities for stormwater collection and particle filtration). They also propose that current guidance on artificial turf is expanded to also cover outdoor sport and recreation facilities with surfaces of rubber or plastic. Figure 11 shows an example of a measure by an artificial turf pitch, where rubber granules on shoes and clothes are brushed off at a brushing station to reduce the spread of rubber granules from the pitch.

The ECHA[22] has been tasked by the EU Commission to prepare a proposal for restricting purposely added microplastics[23] which has been out for consultation, but not yet been adopted. The proposal contains two options; rubber granules will either be subjected to or not subjected to the restrictions being proposed (ECHA, 2020).

Positive side effects

Collection systems for artificial turf pitches may reduce operating costs, as smaller amounts of rubber granules will be needed to top up the pitch. Rubber granules collected locally can be reused on the pitch, which also saves resources.

Negative side effects

If the use of end-of-life tyres is regulated, the result may be reduced demand for tyre materials, increasing the proportion of end-of-life tyres used for energy recovery. Energy recovery generates emissions of carbon dioxide and air pollutants. If notification requirements are introduced, operators will incur higher costs for supervision and measures to reduce the spread (e.g. collection facilities or systems).

Figure 11. Artificial turf pitch with rubber granules and brushing station with information board stating the following: 'We have to think of the environment. Brush off clothes and shoes here. We will return the granules to the artificial turf pitch.' (Translated from Swedish). Photo: Delilah Lithner.

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[22] ECHA: European Chemicals Agency.

[23] Annex XV restriction dossier proposal: https://echa.europa.eu/sv/registry-of-restriction-intentions/-/dislist/details/0b0236e18244cd73

Discussion and assessment

Our view is that it would be useful if a rule stating that 'the use of end-of-life tyres must take place in a way that minimises the spread of microplastics and chemicals from the tyres' was added to the Ordinance on producers' responsibility, as this would become a general rule limiting the spread.

The introduction of notification requirements for the above-described outdoor facilities containing rubber and plastics would require a new regulation in the Swedish environmental Examination Regulation (SFS 2013:251) concerning permits and notification requirements for business and activities, which is adopted by the Government. The effectiveness of introducing such a requirement is deemed to be very high, as the spread of rubber granules can vary significantly between well-managed facilities and facilities that have not put in place any measures to reduce the spread. The costs resulting from the notification requirements would include fees for registration, evaluation and supervisory visits (inspections), which would be paid by the operator. The introduction of this measure is not expected to cause any difficulties.

The cost of changing the ordinance on producers' responsibility concerns mainly the number of working hours required to change it. The process is standardised and expected to be fairly uncomplicated. The implementation time is expected to be short (< 3 years). The time from memorandum to government decision, to entering into force is at least 3–4 months, but would likely be longer in this case, as the matter is not urgent.

The advantage of adding a clause to the ordinance on producers' responsibilities is that this would cover all potential areas of usage, while the advantage of notification requirements is that this would improve the control and monitoring of the types of facilities currently considered to be sources of microplastic dispersion. However, both of these could be implemented.

Our view is that the inclusion of rules regarding end-of-life tyres in the responsibilities of producers should be prioritised, and that further investigation into the introduction of notification requirements for facilities using artificial turf and moulded granulates, as well as riding arenas containing rubber or plastics, should be highly prioritised.

3.5. Potential policy instruments for sub-objective 3 – To reduce effects and persistence

This section describes policy instruments mainly aimed at reducing the effects and persistence in the environment or at increasing our knowledge regarding effects and persistence, to enable appropriate measures to be prepared. These could include different ways to reduce the amounts of hazardous chemicals in tyres and road markings, via bans, environmental labelling, requirements on procurement processes, and development of new types of tyres that degrade more easily.

3.5.1. Ban on hazardous chemicals in tyres and road markings

Policy instruments: a) Promote investigations to identify hazardous chemicals that are candidates for restrictions or bans, and b) introduce general or targeted bans or restrictions on hazardous chemicals within the EU.

A policy instrument that could reduce the risk of toxic effects from chemicals in tyres and road markings is to introduce different bans or restrictions on the use of hazardous chemicals in tyres and road markings within the EU. It is well known that tyres can contain several different chemicals that are hazardous to the environment and human health, and that their breakdown products can leak into aquatic environments or be emitted into the air.

At present, the only restriction relating specifically to the chemical content of tyres within the EU is a limit of the concentration of PAHs. Through an earlier EU directive (2005/69/EC) and the Commission

Regulation ((EU) no 1272/2013) currently in force, concentrations are, since January 1, restricted to 1 mg/kg for benso[e]pyrene (BaP) and 10 mg/kg for the sum eight listed PAHs. Other hazardous chemicals in tyres could also be banned or restricted to reduce the risk of negative effects when they are released into the environment. In addition to general bans on the use of certain chemicals in certain areas, lists of banned products could also be included in any future ecodesign requirements for tyres (see section 3.3.6).General requirements for vehicles are set out in Directive (2000/53/EC) of the European Parliament and of the Council on end-of-life vehicles, prohibiting e.g. the use of the hazardous metals lead, mercury, cadmium and hexavalent chromium.

Road markings can also contain chemicals that are hazardous to the environment or human health. As an example, some countries use lead chromate as a pigment in yellow road markings. Some types of road markings also contain hazardous solvents, epoxy resins, and plasticisers. No studies have looked at leaching of chemicals from road markings and how these affect organisms, apart from those carried out as a sub-project within this government commission (Österblad, 2021; Lithner, 2021), see section 3.5.3.

Positive side effects

General bans or restrictions on the use of a chemical that is hazardous to human health, or the environment would reduce the impact of the chemical in question, not only from tyres, but also from other products containing the same substance.

Negative side effects

Banned hazardous chemicals have to be replaced by other chemicals, which may not meet the same functional requirements or are substandard in some other way. It is important to ensure that the replacement chemical really is better from an environmental and health perspective.

Discussion and assessment

An EU-wide ban on the most hazardous chemicals in tyres and road markings is deemed to be an effective policy instrument. How effective it actually turns out to be will depend on the extent to which replacement chemicals with acceptable functionality are available, and their level of harmfulness to the environment or human health. Prohibiting or restricting the use of certain chemicals within the EU may also have a positive effect on the global market. These types of bans take several years to implement, as the introduction of a ban within the EU involves an extensive process. To proceed with this policy instrument, we must first gather the existing knowledge regarding content, leaching, and effects of hazardous chemical substances from tyres, then complement this with new knowledge. Thereafter, possibilities for substitution must be investigated. The implementation of bans and restrictions of hazardous substances is part of a continuous process, which is updated as we gain new knowledge regarding hazardous substances being released and their effects. Before decisions on substitution are made, it must be considered whether the substitution would have a negative impact on some other important aspect, such as wear propensity, noise, rolling resistance, or grip.

Our view is that the initial step of promoting investigation into hazardous substances that would be candidates for restricted or prohibited use in tyres and road markings should be highly prioritised. If, and when, such candidates have been identified, the subsequent step of introducing bans or restrictions should be given a high priority. As tyre wear particles are generated in much greater amounts than road markings, tyres should be prioritised initially.

3.5.2. Ecolabelling of tyres based on chemical content

Policy instruments: a) Develop criteria for labelling of tyres based on their chemical content, and b) ecolabel tyres based on approved content of chemicals.

An alternative, or complement, to prohibition of hazardous chemicals in tyres may be ecolabelling of tyres based on approved chemical content. Criteria can be used to define which substances can be included, or not included, in a product to achieve ecolabelling. There used to be criteria in place for tyres in the Nordic Swan ecolabel[24]. The first criteria document was adopted in 1999, however there was little interest in the Nordic Swan Ecolabel on tyres from the tyre industry; only a couple of retreading firms and tyre manufacturers chose to ecolabel their tyres with the Nordic Swan (Sterner, Nordic Swan, personal contact, July 1, 2020). The lack of interest from the tyre industry was the main reason why the Nordic Swan Ecolabel of tyres was discontinued, with the final active licence expiring some time in 2011 or 2012 (Sterner, Nordic Swan personal contact, July 1, 2020). The labelling considered e.g. PAH and metal content, rolling resistance, wet grip, noise, waste, and sustainability.

Instead of a voluntary labelling scheme, chemical content in tyres could be included in the existing EU tyre labelling system (see section 3.3.3.) or in any future ecodesign requirements for tyres (see section 3.3.6.).

Positive side effects

The impacts of chemicals from tyres on humans and the environment can be reduced throughout the lifecycle of tyres, i.e. not only from the microplastics that are generated.

Negative side effects

The price of tyres may increase slightly to pay for the ecolabelling. If the labelling was to consider solely chemical content, information regarding whether the tyre performs less well on some other aspect, e.g. wear propensity, will be missed. Such other aspects must be taken into account when this instrument is designed.

Discussion and assessment

Attempting to include ecolabelling for chemical content in existing EU labelling or future ecodesign requirements for tyres is felt to be more appropriate than e.g. the Nordic Swan Ecolabel of tyres, for a number of reasons:

- Previous experiences of the Nordic Swan Ecolabel shows that there is limited interest from the tyre industry in non-mandatory labelling.
- There is already a mandatory labelling scheme for tyres within the EU, which could potentially be extended to also include chemical content.
- If this aspect was to be included in any future ecodesign requirements, they will become mandatory and therefore have much greater impact than voluntary labelling.
- Having a single system for the EU would be easier for both tyre manufacturers and consumers.
- The tyre market is global, which means that any adaptations in single countries or on small markets are difficult to implement.

The implementation time is expected to be a few years, as it must first be investigated which substances to include or not include, and to ensure that suitable alternatives are available. After this, the labelling regulation would have to be amended, which may take another few years. If requirements on chemical content was instead to be included in an ecodesign directive, this directive would first have to be designed. As part of such a process, it is also important to consider whether changing the chemical content would affect other important tyre characteristics.

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[24] The Nordic Swan is an independent voluntary ecolabelling system where the applicant agrees to follow the criteria determined by the Nordic Swan.

Our view is that preparation of criteria for labelling of tyres based on chemical content within a voluntary environmental labelling system should not be prioritised. Instead, this should be included in any future ecodesign requirements for tyres (see section 3.3.6) or be added to the tyre labelling regulation (see section 3.3.3) which should be prioritised for further investigation. Alternatively, lists of banned substances may be included in the global technical regulations for tyres (see section 3.3.7).

3.5.3. Ecolabelling of road markings based on chemical content

Policy instruments: a) Promote research into content, leaching, and effects of chemicals from road markings, and b) prepare criteria for ecolabelling of road markings.

An alternative, or complement, to prohibition of hazardous chemicals in road markings may be ecolabelling of road markings based on approved chemical content.

When road markings containing hazardous substances are exposed to water and wear, hazardous substances or degradation products may be emitted. There is already a Nordic Swan Ecolabel in place for different types of indoor and outdoor paints, although not for road markings.

As part of this government commission, VTI and the University of Stockholm have carried out a study looking at leaching of different road marking products, followed by toxicity testing and chemical analysis of the leachates. The findings from this study show that there is variation both in the effects on test organisms and in the emitted substances and concentrations between different road marking products (Österblad, 2021; Lithner, 2021). As this is an initial, and limited study, no general conclusions can be made. Instead, further studies are required, covering more products, repeated tests, and additional types of tests.

Negative side effects

The price of ecolabelled road markings may be slightly higher, to fund the labelling process. If labelling considers only chemical content, there is a risk that some other characteristic of the road markings such as wear propensity is not as good, and this must be considered when the labelling system is designed.

Discussion and assessment

Voluntary ecolabelling systems (e.g. the Nordic Swan Ecolabel) are deemed to be effective measures for elimination of hazardous substances potentially present in road markings. The implementation time is difficult to estimate, as further data on the negative environmental impacts of road markings must first be generated. At best, the implementation time may be short (< 3 years). The first step would be an application to Nordic Ecolabelling, followed by a feasibility study, after which criteria would be prepared, sent out for consultation, and finally considered for adoption by the Nordic Ecolabelling Board (Nordic Swan, 2020). As this labelling is voluntary, its success will depend on whether road marking manufacturers are interested in implementing it. As there is such limited data on the hazardous chemical substances included in road markings and the extent to which they are leached, it is difficult to estimate the effectiveness of this measure until such data becomes available.

Our view is that promotion of research into content, leaching, and impact of hazardous substances from road markings should be prioritised. Based on the findings from this research, the next step may be to prioritise the design of ecolabelling criteria, however this cannot be prioritised at present.

3.5.4. Tyres that are more easily degradable

Policy instrument: Promote research into the possibility of developing tyres that are more easily degradable.

The persistence of tyres in the environment affects how long the particles are able to impact the environment, and to what extent the particles accumulate in the environment. If tyres that degraded faster were to be developed, the environmental accumulation would decrease. There are some natural microorganisms able to break down rubber, however the degradation rate depends on both the organisms present and the composition of the rubber material. According to Stevenson et.al. (2008), one way to boost the microbial degradation of tyres would be to alter the chemical composition of tyres. A number of antimicrobial additives and stabilisers with a negative impact on microorganisms, and thereby degradation, are added to tyres. Stevenson et.al. (2008) state that it may not be possible to replace these additives without affecting functionality and safety. They do, however, highlight the possibility of changing the tyre composition by increasing the percentage of natural rubber, as this is usually more biodegradable than synthetic rubber types.

Negative side effects

Degradability may be in conflict with the durability of tyres and the number of particles generated. It could also be possible that faster degradation of tyres might lead to faster emissions of hazardous substances and degradation products, causing concentrations to be temporarily higher, as the dilution time is shorter. However, this is not known. There is also a risk that functionality and safety are impacted, which must be considered.

Discussion and assessment

Our view is that research into the possibility of producing tyres that break down faster in the environment but maintain the same functionality and durability during use and do not generate more wear particles should be prioritised. Such a tyre would have to combine a number of different characteristics, which makes this complicated to achieve. If it succeeds, it will probably be many years before more easily degradable tyres are available on the market.

3.6. Potential policy instruments and measures for sub-objective 4 – Increase knowledge generally

This section describes policy instruments and measures aimed at increasing knowledge generally regarding emissions, dispersion, impacts and degradation, to help determine the risks posed by microplastics from tyre and road wear. It also discusses the development of methods for studying these aspects, as well as knowledge sharing, dissemination of knowledge, and guidance.

3.6.1. Research into emissions, dispersion, effects and degradation

Policy instrument: Promote research into emissions, dispersion, effects, and degradation of microplastics from tyre and road wear.

There are huge knowledge gaps regarding many aspects of emissions, dispersion, impacts and degradation of microplastics from tyre and road wear (Andersson-Sköld et al., 2020; Baench-Baltrschat et.al. 2020). There is, however, some knowledge, mainly regarding tyres, tyre wear, and tyre wear particles, which has led to these being identified as a potential problem. There is hardly any data on microplastics from road markings and polymer-modified bitumen, but these also generate a much smaller portion of the microplastics emitted from road traffic (see chapter 1) (Andersson-Sköld et.al., 2020). As an overall prerequisite for many of the policy instruments described in this report additional knowledge on emissions, dispersion and effects of microplastic particles from tyre and road wear is needed. As an example, more data is required on the size of the emissions and the factors that influence their magnitude, where in the environment the particles end up and accumulate, how they impact the environment, how long it takes for particles to break down in different environments, and which degradation products are formed. This is a huge area, and we have chosen not to describe the existing knowledge gaps in detail here (see further e.g Andersson-Sköld et.al., 2020; Baench-Baltrschat et.al. 2020). Policy instruments promoting research within these areas can indirectly decrease microplastic pollution caused by tyre and road wear via the knowledge they produce and the ways in which this new knowledge can provide a foundation for producing effective policy instruments and measures.

Discussion and assessment

Our view is that research into emissions, dispersion, effects and degradation of microplastics from tyre and road wear should be highly prioritised, as this knowledge is needed to determine the risks to the environment and human health, as well as the need for policy instruments and measures.

3.6.2. Standardised and automated methods for sampling, sample preparation, and analysis

Policy instruments: Promote development of a) standardised methods for sampling, sample preparation, and analysis, and b) automated methods for analysis of tyre and road wear particles.

To generate more knowledge regarding tyre and road wear particles, we must be able to analyse particles and to compare different studies to each other. To enable and simplify this work, we need standardised methods for collection and preparation of samples, analysis of tyre and road wear particles, as well as automated analysis methods. There are currently no standardised methods for collection and preparation of samples, nor for analysis of tyre and road wear particles (Andersson-Sköld et al., 2020). At present, analysis of tyre and road wear particles can be very complicated, expensive and time-consuming to perform, depending on the medium in which the sample is collected and the aspects to be analysed. This is, however, a fairly new area and both methods for sample preparation and automated analysis methods are currently being developed using e.g. machine learning. Like the section above, this is also a very large area and relates more to indirect policy instruments to reduce the impact of tyre and road wear than the other instruments discussed in this report.

Development of standardised methods for collection and preparation of samples, as well as standardised and automated analysis methods, is considered very important to enable us to generate the knowledge we need. Our view is that promoting this type of research and method-development should be highly prioritised.

3.6.3. Networks of excellence and initiatives for knowledge-exchange and generation of new knowledge

Policy instrument: Support and encourage participation in networks of excellence on tyre and road wear, to exchange knowledge and generate new knowledge.

Networks of excellence and initiatives regarding tyre and road wear involving experts from different areas and organisations (research, authorities, and industry) can aid effective exchange of knowledge and generation of new knowledge.

There are already some industry-led initiatives aimed at increasing our knowledge regarding microplastics from tyre and road wear. One example is the European Tyre Wear Platform, led by the European Tyre & Rubber Manufacturers' Association, ETRMA[25]. Its members are experts from the tyre industry, authorities, and academia, as well as representatives from NGOs. Its aim is to generate and share scientific knowledge, and to investigate potential measures to limit the generation and spread of tyre and road wear particles in the environment (ETRMA, 2019).

[25] ETRMA European Tyre & Rubber Manufacturers´ Association.

Another example is the Tire Industry Project, which started in 2005 and includes 11 leading tyre producers, which together hold approximately 65 percent of the global tyre manufacturing capacity. Its aim is to proactively identify and address the potential human health and environmental impacts associated with the lifecycle impacts of tyres (World Business Council for Sustainable Development, 2020). This association has funded a large number of scientific studies on tyre and road wear.

Since 2020, Sweden has a National Plastics Collaboration (Nationella plastsamordningen), which falls under the Swedish Environmental Protection Agency (2020d). It is intended to be a driving and collective force to achieve sustainable use of plastic in Sweden. Knowledge gathering regarding microplastics (including tyre and road wear) is a prioritised area. The Swedish Environmental Protection Agency is responsible for gathering and sharing knowledge, and for promoting dialogue and collaboration between all relevant stakeholders.

Discussion and assessment

It is important for research and development concerning tyres to be performed by the industry, as they are experts on tyres. It is also important for research to be carried out by researchers who are completely independent of all interests, and who have competencies in different areas. In addition, reviews and investigations must be carried out by researchers and authorities. It can be very valuable for different stakeholders to meet and exchange knowledge. Industry-led platforms can lead to increased exchange of knowledge between different research groups and authorities. By including both experts and stakeholders with different competencies and experiences, the results become very credible, provided the different stakeholders can reach consensus.

Our view is that it is important for authorities and academia to encourage, create, maintain, and take part in networks of excellence for tyre and road wear. The reason is that this can help us increase our knowledge regarding microplastics from tyre and road wear more effectively and raise the quality of any results. This increases the chances that appropriate measures are put in place to reduce any problems that arise or to prevent them from occurring in the first place.

Our view is that maintaining and encouraging participation in networks of excellence for tyre and road wear and to promote knowledge exchange and generation of new knowledge should be highly prioritised.

3.6.4. Targeted guidance on measures for reducing microplastic pollution caused by tyre and road wear

Policy instrument: Produce targeted guidance on voluntary measures to reduce microplastic pollution caused by tyre and road wear.

To aid the work to reduce microplastics pollution caused by tyre and road wear, guidance on voluntary measures could be produced. The City of Stockholm has prepared an action plan against microplastics, which was adopted in January 2020. Guidance can be useful both for this type of comprehensive action plan and for smaller initiatives.

Discussion and assessment

A guidance could be used by authorities and other stakeholders, such as taxi and haulage companies wishing to reduce emissions, spread, and effects of microplastics from tyre and road wear. Such guidance could for example be based on factors we currently know can reduce emissions, spread, and effects. As the effectiveness of some of the measures that may be included in this type of guidance is difficult to determine, and as the measures would be voluntary in this case, it is difficult to estimate its potential effectiveness. In addition, there is uncertainty regarding how difficult it would be to make relevant stakeholders aware of the existence of such guidance. On the other hand, the cost of producing the guidance would be limited. It would also be possible to put together more comprehensive guidance aimed at municipalities, and more specific ones aimed at e.g. haulage companies, taxi firms, and public transport operators. This guidance should ideally be updated as new knowledge becomes available, e.g. as different measures are evaluated.

Our view is that the preparation of guidance on voluntary measures to reduce microplastic pollution caused by tyre and road wear should be highly prioritised.

3.6.5. Information campaigns concerning issues with microplastics from tyre and road wear

Policy instrument: Investigate whether it would be useful to inform target audiences about the issues with microplastics from tyre and road wear and what can be done to reduce microplastic pollution.

To gain acceptance for policy instruments and measures, and to achieve behavioural changes, information campaigns are needed regarding the issues of microplastics from tyre and road wear and ways to mitigate this pollution. Additionally, all policy instruments and measures must be viewed as being reasonable and fair. Information can be targeted at different segments of society or to the general public. Ways to achieve this include information via media, short information videos, and leaflets.

Discussion and assessment

Targeted information and awareness-raising campaigns are considered important to increase the effectiveness of any policy instruments and measures introduced, as they can improve understanding and acceptance of the measures. Without understanding and acceptance it is difficult to achieve the desired behavioural changes. Each policy instrument and measure must be combined with some form of information initiative. How this should be carried out and designed must be assessed on a case-by-case basis. For this reason, this policy instrument cannot be considered separately, nor is it possible to determine its effectiveness separately. It is particularly important that information intended to motivate and justify is aimed at the general public if a measure is not mandatory. The cost of such information initiatives is expected to vary greatly depending on the policy instrument or measure and target audience.

Our view is that investigating whether it can be justified to inform different target groups regarding the issues around microplastics from tyre and road wear and what can be done reduce microplastic pollution should be prioritised.

3.7. Summary table – Potential policy instruments and measures, and prioritisations

Table 2 below is divided into four sub-tables (one for each sub-objective) and includes all policy instruments and measures described in sections 3.3 to 3.6 of this report. The table mimics the structure of the report, and shows columns with section number, policy instrument or measure heading, and the policy instruments and measures specified. The final column also shows how the respective policy instruments and measures have been prioritised, and the main reasons for the prioritisation. Prioritisations are usually based on very rough assumptions regarding a single, or small number, of aspects, such as effectiveness. Prioritisations can have three main levels: Highly Prioritised, Prioritised, and Not Prioritised. These levels and sub-levels can further be described as follows:

- *Highly Prioritised* and *Prioritised* means that immediate implementation is considered to be possible (e.g. the policy instrument to ‘promote research’).
- *Highly Prioritised for Further Investigation* and *Prioritised for Further Investigation* means that there is data showing the policy instrument or measure in question could reduce microplastic pollution, but that further investigation is required to determine if and how any implementation should be carried out.

- *Not Currently Prioritised*, must await xx, but will then be Highly Prioritised… means that the policy instrument or measure cannot be prioritised at present, because another policy instrument or measure must be completed first, however once this has been completed, the policy instrument or measure should be highly prioritised. Also in this case, there is data that shows that microplastic pollution can be reduced using the policy instrument or measure in question.
- *Not Currently Prioritised*, depends on results of a) means that the policy instrument or measure cannot be prioritised, as another policy instrument or measure must be completed first. However in this case, there is uncertainty as to whether the policy instrument or measure in question can reduce the burden, or reduce it to any significant extent.
- *Not Prioritised* means that the policy instrument or measure is considered less relevant for one or several reasons.

Table 2. Summary tables (2a-d) of potential policy instruments and measures for each of the sub-objectives, and prioritisation from a microplastic perspective. Prioritisation is colour-coded as follows: red for Highly Prioritised, yellow for Prioritised, and no colour for Not Prioritised policy instrument or measure. In addition, pink is used for instruments and measures that are Not Currently Prioritised, as they require another policy instrument to be completed first but will thereafter be Highly Prioritised.

Table 2a. Potential policy instruments and measures for sub-objective 1 – Reduce emissions

Section	**Policy instrument or measure heading**	**Description of policy instrument or measure**	**Priority**
3.3.1.	Reduced road traffic (vehicle-kilometres).	All policy instruments and measures that reduce road traffic (i.e. vehicle-kilometres). This includes those that make it more difficult for private and goods vehicles to use the roads, as well as those that promote alternative means of transportation or the avoidance of travel, i.e. both carrots and sticks.	Highly prioritised for further investigation or research (due to effectiveness).
3.3.2.	Influencing the composition and development of the vehicle fleet.	a) Promote research on the importance of the weight, motor power and acceleration of cars for tyre and road wear, and b) reduce the percentage of heavier cars with more powerful engines and better acceleration (e.g. SUVs) for instance by taxes or a modified bonus-malus system.	a) Highly prioritised (because it may lead to an effective policy instrument in the next step). b) Prioritised for further investigation (due to effectiveness).
3.3.3.	Labelling of tyre wear propensity.	a) Promote and drive the development of a standardised method for measuring tyre wear, and b) introduce labelling of the wear propensity of tyres in the EU Regulation on tyre labelling.	a) Highly prioritised (because it may lead to an effective policy instrument in the next step). b) Not currently prioritised, must await a), but will then be highly prioritised (due to effectiveness).
3.3.4.	Tyres with low wear propensity	Promote research & development of tyres with low wear propensity.	Highly prioritised (due to effectiveness).
3.3.5.	Tyre wear limits.	Develop EU limit values for tyre wear.	Not currently prioritised, must await 3.3.3a, but will then be highly prioritised for further investigation (due to effectiveness).

Section	Policy instrument or measure heading	Description of policy instrument or measure	Priority
3.3.6.	Ecodesign regulations concerning tyre wear and hazardous substances.	Introduce an EU regulation on ecodesign requirements for tyres, including a) limit values for tyre wear and b) restrictions and bans on hazardous substances.	a) Not currently prioritised, must await 3.3.3.a and 3.3.5, but will then be highly prioritised for further investigation (due to effectiveness). b) Not currently prioritised, must await 3,5,1a, but will then be highly prioritised for further investigation (due to potential effectiveness)
3.3.7.	Global technical regulations regarding tyre wear and hazardous chemicals	Include a) demands for lower tyre wear and b) restrictions and bans on hazardous chemicals in global technical regulations relating to tyres.	a) Not currently prioritised, must await 3.3.3a and 3.3.5, but will then be highly prioritised for further investigation (due to effectiveness), b) Not currently prioritised, must await 3.5.1a, but will then be highly prioritised (due to potential effectiveness).
3.3.8.	Restrictions or bans on the use of studded tyres.	Promote research into reducing the use of studded tyres its impact on a) emissions of tyre wear particles and b) road safety (friction and traction).	a) Prioritised (because it may lead to an effective policy instrument in the next step). b) Prioritised (due to the need for knowledge).
3.3.9.	Restricting the usage period for non-studded winter tyres.	a) Introduce restrictions regarding the time of year when non-studded winter tyres may be used, e.g. through amendment of the Swedish Transport Agency Regulation (TSFS 2009:19) and b) complementing this with information campaigns.	a) Prioritised for further investigation (due to potential cost-effectiveness). b) Not currently prioritised (depends on the outcome of a).
3.3.10.	Tyre pressure monitoring or more frequent air pressure checks.	To fund an investigation regarding which policy instruments or measures would be most appropriate for increasing the proportion of tyres used at the correct pressure (e.g. tyre pressure monitoring systems or more frequent air pressure checks).	Highly prioritised (due to potential effectiveness in the next step).
3.3.11.	Wheel alignment and tyre balance.	a) Promote research into the extent to which incorrect wheel alignment and tyre balance affect the amount of tyre wear particles being generated, and (b) investigate how more frequent checks of wheel alignment and tyre balance could be introduced.	a) Highly prioritised (because it may potentially lead to an effective policy instrument in the next step). b) Not currently prioritised (depends on the outcome of a).
3.3.12.	Road markings with low wear propensity.	Promote research & development of road markings with lower wear propensity.	Prioritised (due to potential effectiveness).
3.3.13.	Use of certified road markings.	Promote research into whether certified road markings are better from a microplastics perspective and b) introduce guidelines on using certified road markings on municipal roads.	a) Prioritised (because it may potentially lead to an effective policy instrument in the next step). b) Not currently prioritised (depends on the outcome of a).

Section	Policy instrument or measure heading	Description of policy instrument or measure	Priority
3.3.14.	Inlaid road markings.	a) Extend research of inlaid road markings and its impact on road marking wear, and b) investigate under what conditions inlaid road markings may be appropriate in the Swedish road network.	a) & b) Prioritised (because they may potentially to lead to an effective policy instrument in the next step, b) also because of potential cost-effectiveness.
3.3.15.	Road surfacing materials that reduce tyre wear.	a) Promote research on road texture and develop road surfacing materials optimised for reducing tyre wear, and b) increase road maintenance.	a) Prioritised (due to potential effectiveness). b) Not currently prioritised (because other aspects are more important when road surfacing materials are chosen).
3.3.16.	Road design that decreases tyre wear.	a) Promote research into the extent to which the layout of roads and streets affect tyre and road wear, and b) design roads and streets with fewer sharp bends and steep hills.	a) Not prioritised (see reasoning for b). b) Not prioritised (because other aspects are expected to be more influential, and that cost-effectiveness is expected to be low).
3.3.17.	Speed limits and speed adaptations.	a) Promote research into the extent to which speed limits and speed adaptation can impact the generation of wear particles, and b) introduce speed limits and speed adaptations.	a) Highly prioritised (because it may potentially lead to an effective policy instrument in the next step). b) Not currently prioritised (depends on the outcome of a).
3.3.18.	Investment in eco-driving.	a) Provide information regarding the importance of driving style, b) increase the proportion of drivers trained in eco-driving, and c) promote development and use of effective systems to support eco-driving.	a) Highly prioritised (because of the value in raising awareness). b) Highly prioritised for further investigation (due to effectiveness and small investment). c) Highly prioritised (due to effectiveness).
3.3.19.	Snow clearance optimised for reducing the wear of road markings.	a) Promote research or investigation into how snow clearance can be optimised to reduce the wear of road markings, b) develop a guidance, and c) include requirements in procurement processes.	a) Prioritised (because of low cost and that it may potentially lead to an effective policy instrument in the next step). b) & c) Not prioritised at present (depend on outcome of a).
3.3.20.	Green procurement.	a) Identify products and services that contribute to decreasing microplastic pollution caused by tyre and road wear, and b) include requirements in public procurement.	a) & b) Prioritised for further investigation (due to potential effectiveness and cost-effectiveness).

Table 2b. Potential policy instruments and measures for sub-objective 2 – Reduce spread

Section	Policy instrument or measure heading	Description of policy instrument or measure	Priority
3.4.1.	Collection of tyre particles during travel.	Promote research, development and evaluation of devices that can capture tyre particles from a vehicle in motion.	Highly prioritised (due to potential effectiveness and cost-effectiveness).

Section	Policy instrument or measure heading	Description of policy instrument or measure	Priority
3.4.2.	Sustainable management of stormwater and masses contaminated with tyre and road wear.	Promote research & development of sustainable solutions for managing stormwater and masses containing tyre and road wear particles.	Highly prioritised (due to effectiveness).
3.4.3.	Cleaning of roads and streets, and optimisation opportunities.	a) Promote research into how street sweeping affects the dispersion of microplastics, and b) evaluate available optimisation opportunities.	a) Highly prioritised (because of need for more knowledge and that this may potentially lead to an effective policy instrument in the next step. b) Not prioritised at present (depends on outcome of a).
3.4.4.	Dust binding measures.	Promote research into how dust binding affects the dispersion of microplastics.	Not prioritised (due to expected low effectiveness).
3.4.5.	Sustainable management of microplastics in snow from roads.	a) Promote research into whether microplastics in cleared snow is a potential problem and b) investigate appropriate ways to manage cleared snow.	a) Highly prioritised (due to the need for knowledge to assess the need for action). b) Not currently prioritised (depends on outcome of a).
3.4.6.	Regulating the use of end-of-life tyres.	Introduce a) requirements relating to spread of microplastics in the producers' responsibility for end-of-life tyres, and b) notification requirements for facilities containing artificial turf or moulded granules, and riding arenas containing rubber or plastic.	a) Prioritised for further investigation (due to cost-effectiveness (low cost and potential effectiveness). b) Highly prioritised for further investigation (due to effectiveness).

Table 2c. Potential policy instruments and measures for sub-objective 3 – Reduce impact and persistence

Section	Title of policy instrument or measure	Description of policy instrument or measure	Priority
3.5.1.	Ban on hazardous chemicals in tyres and road markings.	a) Promote investigations to identify hazardous chemicals that are candidates for restrictions or bans, and b) introduce general or targeted bans or restrictions on hazardous chemicals within the EU.	a) Highly prioritised (because it may to lead to an effective policy instrument in the next step). b) Not currently prioritised, must await outcome of a), but is thereafter likely to be highly prioritised (due to effectiveness).
3.5.2.	Ecolabelling of tyres based on chemical content.	a) Develop criteria for labelling of tyres based on their chemical content, and b) ecolabel tyres based on approved content of chemicals.	*Voluntary labelling*: a) & b) Not prioritised (due to previous low level of interest from tyre industry). **Mandatory labelling:* a) Prioritised for further investigation (due to effectiveness). b) Not currently prioritised (must await out a), but is thereafter likely to be prioritised due to effectiveness). **This prioritisation was missing in the Swedish version of the report.*

Section	Title of policy instrument or measure	Description of policy instrument or measure	Priority
3.5.3.	Ecolabelling of road markings based on chemical content.	a) Promote research into content, leaching, and effects of chemicals from road markings, and b) prepare criteria for ecolabelling of road markings.	a) Prioritised (due to need for knowledge required to assess risks and the need for action). b) Not currently prioritised (depends on outcome of a).
3.5.4.	Tyres that are more easily degradable.	Promote research into the possibility of developing tyres that are more easily degradable.	Prioritised (because of need for knowledge and that this may potentially lead to an effective policy instrument in the next step).

Table 2d. Potential policy instruments and measures for sub-objective 4 – Increase knowledge generally.

Section	Policy instrument or measure	Description of policy instrument or measure	Priority
3.6.1.	Research into emissions, dispersion, effects and degradation.	Promote research into emissions, dispersion, effects, and degradation of microplastics from tyre and road wear.	Highly prioritised (due to the need for knowledge to enable assessment of risks and the need for action).
3.6.2.	Standardised and automated methods for sampling, sample preparation and analysis.	Promote development of a) standardised methods for sampling, sample preparation, and analysis, and b) automated methods for analysis of tyre and road wear particles.	a) & b) Highly prioritised (due to need for knowledge regarding the extent of the problem).
3.6.3.	Networks of excellence and initiatives for knowledge-exchange and generation of new knowledge.	Support and encourage participation in networks of excellence on tyre and road wear, to exchange knowledge and generate new knowledge.	Highly prioritised (due to effectiveness and the need for knowledge).
3.6.4.	Targeted guidance on measures for reducing microplastic pollution from tyre and road wear.	Produce guidance on voluntary measures to reduce the burden of microplastics from tyre and road wear.	Highly prioritised (due to potential cost-effectiveness).
3.6.5.	Information campaigns concerning issues with microplastics from tyre and road wear.	Investigate whether it would be useful to inform target audiences about the issues with microplastics from tyre and road wear and what can be done to reduce microplastic pollution.	Prioritised (because it may lead to potential cost-effectiveness and potential effectiveness in the next step.

Table 3 contains excerpts from Table 2a-d and includes only highly prioritised potential policy instruments and measures. In total, 20 of 58 policy instruments and measures have been given a high priority.

Table 3. Excerpt from Table 2a-d showing all highly prioritised potential policy instruments and measures. Bold text is used to highlight those related to research and/or development.

Section	Policy instrument or measure heading	Description of policy instrument or measure	Highly prioritised…
3.3.1.	Reduced road traffic (vehicle-kilometres).	All policy instruments and measures that reduce road traffic (i.e. vehicle-kilometres). This includes those that make it more difficult for private and goods vehicles to use the roads, as well as those that promote alternative means of transportation or the avoidance of travel, i.e. both carrots and sticks.	for further investigation or research (due to effectiveness).
3.3.2.	Influencing the composition and development of the vehicle fleet.	a) Promote **research** on the importance of the weight, motor power and acceleration of cars for tyre and road wear.	a) (because it may lead to an effective policy instrument in the next step).
3.3.3.	Labelling of tyre wear propensity.	a) Promote and drive the development of a standardised method for measuring tyre wear.	a) (because it may lead to an effective policy instrument in the next step).
3.3.4.	Tyres with low wear propensity.	Promote **research & development** of tyres with low wear propensity.	(due to effectiveness).
3.3.10.	Tyre pressure monitoring or more frequent air pressure checks.	To fund an investigation regarding which policy instruments or measures would be most appropriate for increasing the proportion of tyres used at the correct pressure (tyre pressure monitoring systems or more frequent air pressure checks).	(due to potential effectiveness in the next step).
3.3.11.	Wheel alignment and tyre balance.	a) Promote **research** into the extent to which incorrect wheel alignment and tyre balance affect the amount of tyre wear particles being generated.	a) (because it may potentially lead to an effective policy instrument in the next step).
3.3.17.	Speed limits and speed adaptations.	a) Promote **research** into the extent to which speed limits and speed adaptation can impact the generation of wear particles.	a) (because it may potentially lead to an effective policy instrument in the next step).
3.3.18.	Investment in eco-driving.	a) Provide information regarding the importance of driving style, b) increase the proportion of drivers trained in eco-driving, and c) promote **development** and use of effective systems to support eco-driving.	a) (because of the value in raising awareness). b) for further investigation (due to small investment and effectiveness). c) (due to effectiveness).
3.4.1.	Collection of tyre particles during travel.	Promote **research, development** and evaluation of devices that can capture tyre particles from a vehicle in motion.	(due to potential effectiveness and cost-effectiveness).

Section	Policy instrument or measure heading	Description of policy instrument or measure	Highly prioritised…
3.4.2.	Sustainable management of stormwater and masses contaminated with tyre and road wear.	Promote **research & development** of sustainable solutions for managing stormwater and masses containing tyre and road wear particles.	(due to effectiveness).
3.4.3.	Cleaning of roads and streets, and optimisation opportunities.	a) Promote **research** into how street sweeping affects the dispersion of microplastics.	a) (because of need for more knowledge and that this may potentially lead to an effective policy instrument in the next step.
3.4.5.	Sustainable management of microplastics in snow from roads.	a) Promote **research** into whether microplastics in cleared snow is a potential problem.	a) (due to the need for knowledge to assess the need for action).
3.4.6.	Regulating the use of end-of-life tyres.	Introduce b) notification requirements for facilities containing artificial turf or moulded granules, and riding arenas containing rubber or plastic.	b) for further investigation (due to effectiveness.
3.5.1.	Ban on hazardous chemicals in tyres and road markings.	a) Promote **investigations** to identify hazardous chemicals that are candidates for restrictions or bans.	a) (because of likelihood to lead to an effective policy instrument in the next step).
3.6.1.	Research into emissions, dispersion, effects and degradation.	Promote **research** into emissions, dispersion, effects, and degradation of microplastics from tyre and road wear.	(due to the need for knowledge to enable assessment of risks and the need for action).
3.6.2.	Standardised and automated methods for sampling, sample preparation and analysis.	Promote **development** of a) standardised methods for sampling, sample preparation, and analysis, and b) automated methods for analysis of tyre and road wear particles.	a) & b) (due to need for knowledge regarding the extent of the problem).
3.6.3.	Networks of excellence and initiatives for knowledge-exchange and generation of new knowledge.	Support and encourage participation in networks of excellence on tyre and road wear, to exchange knowledge and generate new knowledge.	(due to effectiveness and the need for knowledge).
3.6.4.	Targeted guidance on measures for reducing microplastic pollution from tyre and road wear.	Produce guidance on voluntary measures to reduce the burden of microplastics from tyre and road wear.	(due to potential cost-effectiveness).

4. Discussion and conclusions

As the overall purpose of this report is to identify potential policy instruments and measures to reduce microplastic pollution of the environment caused by tyre and road wear, any prioritising between different policy instruments and measures should focus on those that reduce the risks of microplastics from road traffic in the most cost-effective way. The cost of reducing the risk should not exceed the benefit of doing so. There is, however, only limited knowledge regarding the magnitude of the environmental and human health impacts and how the impacts vary depending on when, where and how the emissions occur, and what sizes and types of particles are involved. If this data was available, a natural strategy for reducing the risk would be to focus on policy instruments and measures that reduce the negative environmental and human health impacts the most per cost. As we do not have access to such detailed knowledge, we have decided to map all potential policy instruments and measures we have been able to find. Based on the new knowledge acquired when efforts to increase knowledge have been completed a risk mitigation strategy for selecting policy instruments and measures can be chosen. Where sufficient knowledge is available, the strategy should be to reduce the environmental and human health impacts as cost-effectively as possible. However, where sufficient knowledge is not available, the strategy may instead be to focus on reducing the pollution in general, as cost-effectively as possible, irrespective of where the emissions occur, where the impacts are greatest, and the type of microplastic particles from road traffic concerned. This is unlikely to be the most effective way to reduce the risk, but a reasonable strategy when the aforementioned knowledge is not available.

Focus – to reduce emissions of tyre wear particles

All the four sub-objectives into which the surveyed policy instruments and measures have been divided, i.e. 1) to reduce emissions, 2) to reduce spread 3) to reduce effects and persistence, and 4) to increase knowledge generally, can help reduce microplastic pollution of the environment caused by road traffic. However, in this report, the main focus has been on policy instruments that restrict the generation and emission of tyre particles. Reasons include the fact that tyre particles are the biggest source of microplastics from road traffic and that it is generally more effective to take action earlier in the chain (from generation to effects on the environment), i.e. ideally before the particles are generated or released into the environment. The sub-objective to ’reduce emissions’ covers approximately 60 percent of the included policy instruments and measures.

Broad survey – many different policy instruments and measures

This review of potential policy instruments and measures targeting microplastics from tyre and road wear includes a total of 35 policy instrument and measure headings under which one to three policy instruments or measures are specified. This gives 58 more or less specific policy instruments or measures in total (see Table 2a-d). Several of the policy instruments and measures are connected and constitute different steps. The first step may be to promote research e.g. into the importance of the speed of road vehicles to the generation of microplastic particles, and the second step depends on the outcome of the first. This could e.g. be to implement speed limits. Most of the policy instruments and measures are fairly specific, although some target wider areas for which a number of different policy instruments and measures could be appropriate. An example of the latter is ‘reduced road traffic (vehicle-kilometres)’, which covers many different policy instruments and measures aimed at reducing the number of vehicle-kilometres on road, but which we have chosen not to specify individually. The same applies to ‘green procurement’ and ‘research into emissions, dispersion, impacts, and degradation’. For this reason, it is not possible to state the exact number of policy instruments or measures that can be designed under each heading.

Additionally, some of the policy instruments are not unique, but overlap each other or are variants on a theme, where the approach, control or actor differs. Examples include policy instruments related to the wear propensity of tyres. In this area, ‘limit values for tyre wear’ could be included both in the policy instrument ‘ecodesign regulations for tyres’ and in ‘global technical regulations for tyres’. In these examples, the main difference between the policy instruments is the actor (EU and international organisation, respectively).

The way in which the various policy instruments and measures interact with each other has not been evaluated, as this survey is not intended to provide suggestions for appropriate combinations of policy instruments and measures for immediate implementation, but instead to review all possible policy instruments and measures, independently of each other. A combination of policy instruments and measures would, however, definitely be required, since no individual policy instrument covers all aspects (e.g. reducing the number of particles, as well as their spread and harmfulness), and since no individual policy is as effective as is assumed to be desired. As there is uncertainty regarding the seriousness of this issue, we are, however, unable to estimate the need for action.

This review mainly covers policy instruments; only a few measures not preceded by policy instruments have been included. The report covers a wide variety of more or less comprehensive policy instruments and measures, which can be divided into different categories. Just over 40 percent (24 of 58) relate to the promotion of research, or research & development (including development of products, methods, and systems). A few more concern other ways to increase knowledge, i.e. by providing guidance, information, and education that may result in behavioural changes (e.g. regarding driving style, travel and transportation habits, or consumption). In addition to these policy instruments resulting in knowledge building, there are several administrative instruments (e.g. restrictions or bans on hazardous substances, labelling requirements for the wear propensity of tyres, limit values for tyre wear and ecodesign requirements); economic instruments (e.g. reducing road traffic (vehicle-kilometres) and governance of trends regarding the vehicle fleet); and those concerning physical planning (e.g. to reduce road traffic (vehicle-kilometres)). Some policy instruments and measures focusing on more physical solutions have also been included (e.g. collection of tyre particles, monitoring of tyre pressure, wheel alignment, and road design).

Knowledge gaps – no sharp proposals

Because of the lack of general knowledge, as well as the specific knowledge gaps regarding important parameters such as effectiveness, cost-effectiveness, and feasibility, it has not been possible to perform adequate evaluations of the reviewed policy instruments and measures. It has also not been possible to make well-grounded prioritisations between different policy instruments and measures. For this reason, it is also not possible to provide a list of policy instruments or measures proposed for immediate implementation that immediately reduce microplastic pollution caused by tyre and road wear. It has, however, been possible to suggest policy instruments related to the promotion of research & development, or just research. The research, and research & development activities that we have given a high priority and should be relevant to start with immediately are shown in Table 3 on highly prioritised policy instruments and measures. In a second step, these can, or may have the potential to, reduce microplastic pollution. They include both more general research, e.g. on emissions, dispersion, impacts and risk, and more specific research tasks related to individual potential policy instruments, such as the promotion of research & development of tyres with low wear propensity. Further knowledge is needed both to assess the extent of the problems caused by microplastics from tyre and road wear and the need for policy instruments and measures targeting these, and to enable the design of effective policy instruments and measures.

As we do not know the environmental concentrations of microplastics from tyre and road wear, nor the effects at different levels of exposure, we cannot assess the risks for the environment and human health, and therefore cannot scientifically determine how far-reaching any policy instruments or measures ought to be. How to act against the backdrop of current knowledge gaps becomes a matter for valuation rather than science, where the way we act now may lead to unnecessary costs but waiting may lead to environmental and health impacts that in turn result in costs to society. That emissions of microplastics from tyre and road wear are very high and increasing as road traffic increases, that these particles are probably persistent in the environment, and that the particles and substances they contain can have a negative effect on organisms, are combined felt to be enough to justify the introduction of preventative measures to reduce microplastic pollution caused by tyre and road wear. The need to take action against microplastics has been highlighted for example by the European Commission's Group of Chief Scientific Advisors and is also in line with the precautionary principle.

The identified knowledge gaps are based on the data and uncertainties we have found in the available literature, on websites, and in conversations with experts. It is, however, likely that the tyre industry already has a fair amount of not publicly available data, in particular regarding tyre development and technical aspects. For this reason, networks of excellence and initiatives for generating new knowledge, involving both the tyre industry, academia, and other stakeholders are important to accelerate and streamline the knowledge generation.

Highly Prioritised, Prioritised and Not Prioritised policy instruments and measures

The prioritisations of policy instruments and measures included in this report are uncertain, as they usually rely on broad estimations, considering only one or a few aspects. The three main levels of prioritisation used here, i.e. Highly Prioritised, Prioritised, and Not Prioritised, have been complemented with further information, as the bases for the prioritisations vary. For this reason, Table 2a-d also states whether each instrument or measure is considered possible to implement immediately, first requires further investigation, or whether some information must become available before a decision can be made as to whether or not the policy instrument or measure should be implemented (see also bullet points in section 3.7).

In many cases, prioritisations are based on either 'effectiveness' or 'potential effectiveness'. For the former, we expect the policy instrument or measure to be effective. For the latter, we think there is a possibility that the policy instrument or measure could be effective, but whether that is the case would have to be demonstrated e.g. through the research which is often included as a first step.

Most of the highly prioritised policy instruments and measures relate to promotion of research, or research & development, with focus on tyres or tyre particles. Of the 20 highly prioritised policy instruments and measures eight relate to the promotion of research, and a further five to the promotion of research & development (see Table 3). These high proportions were expected, partly because of the knowledge gaps and partly because of the need to develop tyres and road markings with lower impacts on the environment, better methods for measurements and analysis, and devices or systems (e.g. stormwater systems) able to collect microplastic particles. The rest of the highly prioritised policy instruments and measures are more direct and aimed at e.g. reducing road traffic (vehicle-kilometres), introducing reporting requirements for facilities using tyre granules such as artificial turf, raising awareness regarding the importance of driving style, increasing the percentage of drivers trained in eco-driving, investigating the best way to increase the proportion of tyres using correct air pressure, and producing guidance for target audiences. However, further investigation must be undertaken before any of these can be implemented.

There are also some policy instruments that are not prioritised at present, but will be highly prioritised, or possibly highly prioritised, in a subsequent step, i.e. once the first step has been completed. These include the introduction of tyre labelling regarding wear propensity, general or targeted restrictions or bans on hazardous substances at EU level, limit values for tyre wear within the EU, and an EU directive on ecodesign requirements for tyres, or the inclusion of these requirements in the global technical regulations for tyres.

Among the policy instruments and measures not considered a priority are both those expected to have low effectiveness (e.g. dust-binding measures) and those for which the prioritisation depends on the outcome of another policy instrument (e.g. instruments relating to research) and which therefore cannot be prioritised at present. They also include policy instruments for which the cost-effectiveness is expected to be low, or where other aspects are considered more important than microplastics (e.g. road layout).

As all evaluations are uncertain, there are no sharp or clear lines between the policy instruments or measures given a high priority and those considered to be 'prioritised' and 'not prioritised', respectively. Due to the knowledge gaps and uncertainties in the evaluations, and the fact that we do not want to leave out a policy instrument or measure that may have been more highly prioritised if we had more knowledge, we have been relatively generous in our decisions regarding instruments and measures to be highly prioritised for research and/or development. Priorities may change as new knowledge becomes available.

Policy instruments justified by positive side effects

In the assessment of which policy instruments and measures to potentially implement, it is necessary to weigh up the positive and negative side effects of the instruments and measures in question. However, the prioritisations in this report have been done without consideration to the positive side effects; instead, they have been done from a microplastics perspective. Side effects have, however, been discussed in each section. Negative side effects may be reason enough to not prioritise a certain policy instrument or measure. In one case, our view is that the negative side effect of high cost in combination with other reasons mean that the measure to 'design roads with fewer sharp turns and steep hills' should not be prioritised (see 3.3.16).

In some cases, the positive side effects can probably be enough justification for implementation of a policy instrument or measure; in this situation, the reduced microplastic emissions is an added bonus. Examples include reduced road traffic (vehicle-kilometres) and influencing the composition and development of the vehicle fleet. In other cases, the positive side effects in combination with a decreased microplastic pollution may justify implementation of a policy instrument. Examples include tyre pressure monitoring, street cleaning and restricting the time period when non-studded winter tyres are permitted.

Policy instruments with significant positive side effects may be easier to justify than those that solely reduce the microplastic pollution. This could alter the prioritisation levels given in this report, where the focus is on microplastics. These can, however, be just as important from a microplastics perspective, since there is no need to first evaluate their effectivity from a microplastics perspective, and thereby may reduce the time to implementation.

Impact assessments and information

Before any decision is made to implement a policy instrument, or combination of instruments, an assessment considering all relevant aspects and an impact assessment should be carried out. This should e.g. include evaluation of effectiveness, cost-effectiveness, feasibility, any interactions with other policy instruments, all positive and negative side effects, and any other significant factors that may influence the assessment, and thereby the decision.

For a policy instrument to be as impactful as possible, it is important to explain to all relevant target groups why the policy instrument or measure in question is needed. If this raises the general level of awareness, it is more likely to be accepted, which means that any measures needing to be introduced are actually implemented and have an impact. General information campaigns are also important, as they may contribute to voluntary behavioural changes that are beneficial from a microplastics perspective, such as changes in driving style, transportation habits, and purchase decisions. Voluntary actions are, however, not sufficient in themselves; policy instruments are also required to achieve any goals set.

In summary, a large number of potential policy instruments and measures to reduce microplastic pollution caused by tyre and road wear have been identified. These can be more or less relevant for different reasons. Among the policy instruments and measures given a high priority in this report there are some we consider particularly interesting. These are the ones related to 1) reduced road traffic (vehicle-kilometres), 2) changed driver-behaviour (through information in the drivers' education, more drivers trained in eco-driving, and development of systems to support eco-driving), 3) decreased tyre wear (by development of tyres with lower wear propensity and a method for measuring wear propensity), 4) optimisation of tyre pressure and wheel alignment, 5) regulations regarding hazardous substances, 6) collection of tyre particles while travelling, 7) sustainable management of stormwater from roads, and 8) knowledge generation to enable evaluation of risks and need for action.

References

Amato, F., Querol, X., Johansson, C., Nagl, C., Alastuey, A., (2010). A review on the effectiveness of street sweeping, washing and dust suppressants as urban PM control methods. *Science of The Total Environment 408*, 3070–3084. https://doi.org/10.1016/j.scitotenv.2010.04.025

Andersson-Sköld, Y., Johannesson, M., Gustafsson, M., Järlskog, I., Lithner, D., Polukarova, M., & Strömvall, A.-M. (2020). Microplastics from tyre and road wear: a literature review. VTI report 1028A. http://www.diva-portal.org/smash/record.jsf?pid=diva2%3A1430623&dswid=-6520

Aronsson, M., Galfi, H., Magnusson, K., Polukarova, M., Strömwall, A.-M. & Gustafsson, K. (2018). *Förekomst och spridning av mikroplast, gummi och asfaltspartiklar från vägtrafik* [Occurrence and spread microplastics, rubber and asphalt particles from road traffic]. The Traffic Office of the City of Gothenburg. https://www.ivl.se/download/18.694ca0617a1de98f4730d8/1625758703370/FULLTEXT01.pdf

Ashley, R. (2015, December 1). UTQG Ratings Unfurled. *TireReview, November 2015*. Retrieved 2020-09-11 from https://www.tirereview.com/utqg-ratings-unfurled/

Babić, D., Burghardt, T. E. & Babić, D. (2015). Application and Characteristics of Waterborne Road Marking Paint. *International Journal for Traffic and Transport Engineering 5*(2): 150–169. http://dx.doi.org/10.7708/ijtte.2015.5(2).06

Baench-Baltrschat, B., Kocher, B., Stock, F. & Reifferscheid, G. (2020). Tyre and road wear particles (TRWP) – A review of generation, properties, emissions, human health risk, ecotoxicity, and fate in the environment. *Science of the Total Environment,* 733, 137823. https://www.sciencedirect.com/science/article/pii/S0048969720313358

Bjerkesjö, P., Boberg, N., Hwargård, L., Nielsen, T., Romson, Å. & Stenmarck, Å. (2020). *Styrmedel för minskad klimatpåverkan från plast* [Policy instruments for reduced climate impact from plastics]. Swedish Environmental Protection Agency, report 6928. http://www.diva-portal.org/smash/record.jsf?pid=diva2%3A1454122&dswid=9757

Blecken, G.W. (2016). *Kunskapssammanställning – Dagvattenrening* [Knowledge compilation: Stormwater treatment]. Report no 2016-05., Swedish Water Development. https://www.svensktvatten.se/contentassets/979b8e35d47147ff87ef80a1a3c0b999/svu-rapport_2016-05.pdf

Bridgestone (2020). *Airless tires.* Retrieved 2020-11-01 from https://www.bridgestonetire.com/tread-and-trend/tire-talk/airless-concept-tires

Carsten, O., Jamson, S., Brouwer, R. Kooijman, D., Mejuto, P., Olstam, J, Saint Pierre, G., Winder, A. (2016) *D1.6: Final publishable summary report.* Version 1; 12/06/16, ecoDriver. https://cordis.europa.eu/docs/projects/cnect/1/288611/080/deliverables/001-Part1Finalpublishablesummaryreport160612.pdf

CEDR (2016). *Management of contaminated runoff water: current practice and future research needs.* Report 2016/01. https://www.cedr.eu/download/Publications/2016/CEDR2016-1-Management-of-contaminated-runoff-water.pdf

CEN (2020) EN 16662-1:2020 Road vehicles – Supplementary grip devices (SGD) for tyres of passenger cars and light duty vehicles – Part 1: General safety and performance requirements.

https://www.en-standard.eu/bs-en-16662-1-2020-road-vehicles-supplementary-grip-devices-for-tyres- of-passenger-cars-and-light-duty-vehicles-general-safety-and-performance-requirements/

CEN CENELEC (2020). EN 16662-1:2020 a new step for road vehicles safety when driving on snow and ice. Retrieved 2020-12-19 from https://www.cencenelec.eu/News/brief_News/Pages/TN-2020-040.aspx

City of Gothenburg (2020, n.d.). *Dubbdäcksförbud* [Ban on studded tyres]. Retrieved 2020-03-16 from https://goteborg.se/wps/portal/start/gator-vagar-och-torg/gator-och-vagar/trafikregler/dubbdack

City of Stockholm (2019a). *Stockholms stads handlingsplan för minskad spridning av mikroplast 2020–2040* [City of Stockholm´s Action Plan for reducing the spread of microplastics]. https://start.stockholm/globalassets/start/om-stockholms-stad/sa-arbetar-staden/klimat-och-miljo/handlingsplan-for-minskad-spridning-av-mikroplaster.pdf

City of Stockholm (2019b, October 10). *Dubbdäck* [Studded tyres]. Retrieved 2020-02-30 from https://trafik.stockholm/trafiksakerhet-trafikregler/dubbdack/

Commission Regulation (EU) No 1272/2013 of 6 December 2013 amending Annex XVII to Regulation (EC) No 1907/2006 of the European Parliament and of the Council on the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) as regards polycyclic aromatic hydrocarbons. OJ L 328, 7.12.2013, p. 69–71. http://data.europa.eu/eli/reg/2013/1272/oj

Construction equipment (2012, February 13). *Recessed striping increases safety*. Retrieved 2020-06-09 from https://www.constructionequipment.com/recessed-striping-increases-safety

Continental (2020a, n.d.). *Winter tyres in summer*. Retrieved 2020-06-08 from https://www.continental-tyres.co.uk/car/all-about-tyres/tyre-change-fitting/changing-tyres/winter-tyres-in-summer

Continental (2020b, n.d.). *Summer tyres in winter*. Retrieved 2020-06-08 from https://www.continental-tyres.co.uk/car/all-about-tyres/tyre-change-fitting/changing-tyres/summer-tyres-in-winter

Continental (2021a, n.d.). *Balancing tyres*. Retrieved 2021-02-20 from https://www.continental-tyres.co.uk/car/all-about-tyres/tyre-care-maintenance/balancing-tyres

Continental (2021b, n.d.). *Mileage and tyre wear*. Retrieved 2021-05-10 from https://www.continental-tyres.co.uk/car/all-about-tyres/tyre-care-maintenance/mileage-and-tyre-wear

Continental (2021c, n.d.). *Best tyres for electric cars and hybrids*. Retrieved 2021-05-12 fromhttps://www.continental-tyres.ie/car/all-about-tyres/tyre-essentials/electric-vehicle-tyres

Directive 2000/53/EC of the European Parliament and of the Council of 18 September 2000 on end-of life vehicles. http://data.europa.eu/eli/dir/2000/53/2020-03-06

Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for the setting of ecodesign requirements for energy-related products (recast). https://eur-lex.europa.eu/eli/dir/2009/125/2012-12-04

Doftek (2020, n.d.). *Wheel alignment monitoring for a sustainable future*. Doftek Active Wheel Alignment. Retrieved 2020-12-12 from: https://www.doftek.com.au/#technolog

Däckrazzia (2018*). Resultat från däckundersökning genomförd i samband med däckrazzior 2017* [Results from tire inspection carried out in connection with tire “raids” 2017]. A collaboration between the Swedish Energy Agency, the Police, VTI, the Swedish Tyre Association's information Board, the National Society for Road Safety (NTF) & Bilprovningen. https://www.dackinfo.se/wp-content/uploads/2011/09/Rapport_unders_17.pdf

Däckrazzia (2019). *Resultat från däckundersökning genomförd i samband med däckrazzior 2018* [Results from tire inspection carried out in connection with tire "raids" 2017]. A collaboration between the Swedish Energy Agency, the Police, VTI, the Swedish Tyre Association's information Board, the National Society for Road Safety (NTF) & Bilprovningen. https://www.dackinfo.se/wp-content/uploads/2019/09/Rapport_unders_18.pdf

Däckrazzia (2020). *Däckrazzia 2021.* A collaboration between the Swedish Energy Agency, the Police, VTI, the Swedish Tyre Association's Information Board, the National Society for Road Safety (NTF) & Bilprovningen. Retrieved 2021-01-01 from https://dackrazzia.se/

ECHA (2020). *Background Document to the Opinion on the Annex XV report proposing restrictionson intentionally added microplastics. Committee for Risk Assessment (RAC) Committee for Socio-economic Analysis (SEAC).* ECHA/RAC/RES-O-0000006790-71-01/F. ECHA/SEAC/RES-O-0000006901-74-01/F. https://echa.europa.eu/documents/10162/b56c6c7e-02fb-68a4-da69-0bcbd504212b

ETRMA (2019). *European TRWP Platform: Way Forward Report.* https://www.etrma.org/wp-content/uploads/2019/10/20200330-FINAL-Way-Forward-Report.pdf

European Commission (2019). *Environmental and Health Risks of Microplastic Pollution.* Directorate-General for Research and Innovation. Unit RTD.DDG1.02 – Scientific Advice Mechanism. https://ec.europa.eu/info/sites/default/files/research_and_innovation/groups/sam/ec_rtd_sam-mnp-opinion_042019.pdf

European Commission (2020a, n.d.). *Tyres: Energy labelling requirements apply to this product*. Retrieved 2020-10-01 from https://ec.europa.eu/info/energy-climate-change-environment/standards-tools-and-labels/products-labelling-rules-and-requirements/energy-label-and-ecodesign/energy-efficient-products/tyres_en

European Commission (2020b, n.d.). *International technical harmonisation.* Retrieved 2020-12-23 from https://ec.europa.eu/growth/sectors/automotive/technical-harmonisation/international_en

European Commission (2020c, July 13). *European Commission Automotive Industry – Global Technical Regulations.* Retrieved 2020-10-13 from https://ec.europa.eu/docsroom/documents/42306

European Commission (2021a). *Intelligent Speed Adaptation (ISA).* Retrieved 2021-02-28 from https://ec.europa.eu/transport/road_safety/specialist/knowledge/speed/new_technologies_new_opportunities/intelligent_speed_adaptation_isa_en

European Commission (2021b, n.d.). *Sustainable product policy & ecodesign*. Retrieved 2021-05-06 from https://ec.europa.eu/growth/industry/sustainability/product-policy-and-ecodesign_en

European Commission (2021c, n.d.). *Tyre label.* Retrieved 2021-05-06 from https://ec.europa.eu/info/energy-climate-change-environment/standards-tools-and-labels/products-labelling-rules-and-requirements/energy-label-and-ecodesign/energy-efficient-products/tyres_en

European Council (2020a, February 25*). Labelling of tyres: Council adopts new rules.* [Press release]. Retrieved 2020-09-10 from https://www.consilium.europa.eu/en/press/press-releases/2020/02/25/labelling-of-tyres-council-adopts-new-rules/

European Council (2020b). *Position of the Council at first reading in a view to adoption of a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the labelling of tyres with respect to fuel efficiency and other parameters, amending Regulation (EU) 2017/1369 and repealing Regulation (EC) No 1222/2009*. https://data.consilium.europa.eu/doc/document/ST-14649-2019-INIT/en/pdf

European union (2020). *Ecodesign requirements.*. Retrieved 2020-07-08 from https://europa.eu/youreurope/business/product-requirements/compliance/ecodesign/index_en.htm

EVvolumes.com (2020, n.d.). *Global Plug-in Vehicle Sales Reached over 3,2 Million in 2020.* Retrieved 2021-06-18 from https://www.ev-volumes.com/country/total-world-plug-in-vehicle-volumes/

Foitzik, M.-J., Unrau, H.-J., Gauterin, F., Dörnhöfer, J. & Koch, T. (2018). Investigation of ultra fine particulate matter emission of rubber tires. *Wear 394–395:* 87–95. https://doi.org/10.1016/j.wear.2017.09.023

Furberg, A., Arvidsson, R., & Molander, S. (2018). Live and Let Die? Life Cycle Human Health Impacts from the Use of Tire Studs. *International Journal of Environmental Research and Public Health*, *15*(8): 1774. https://doi.org/10.3390/ijerph15081774

Gjerstad, K.-I., Gustafsson, M., Blomqvist, G., Denby, B., Elmgren, M., Grythe, H., Janhäll, S., Järlskog, I., Johansson, C., Kulovuori, S., Kupiainen, K., Lundberg, J., Malinen, A., Norman, M., Ritola, R., Silvergren, S., Stojiljkovic, A., Sundvor, I., Þorsteinsson, Þ., Stefani, M., Vogt, M. (2019). *NORDUST: Nordic Road Dust Project.* http://urn.kb.se/resolve?urn=urn:nbn:se:vti:diva-14950

Government bill 2008/09:93. *Mål för framtidens resor och transporter* [Goals for future travel and transport]. https://www.regeringen.se/49bbc2/contentassets/80dd7d80fc64401ca08b176a475393c5/mal-for- framtidens-resor-och-transporter-prop.-20080993

Grigoratos, T., Gustafsson, M., Eriksson, O., & Martini, G. (2018). Experimental investigation of tread wear and particle emission from tyres with different treadwear marking. *Atmospheric Environment*, *182*, 200–212. https://doi.org/10.1016/j.atmosenv.2018.03.049

Gustafsson, M., Blomqvist, G., Jonsson, P., Ferm, M. (2010). *Effekter av dammbindning av belagda vägar* [Effects of dust binding of paved roads]. VTI Report 666. Swedish National Road and Research Institute (VTI). http://www.diva-portal.org/smash/get/diva2:675408/FULLTEXT01.pdf

Gustafsson, M., Lindén, J., Tang, L., Forsberg, B., Orru, H., Åström, S., & Sjöberg, K. (2018). *Quantification of population exposure to NO2, PM2.5 and PM10 and estimated health impacts*. Report C 317. Swedish Environmental Protection Agency. http://urn.kb.se/resolve?urn=urn:nbn:se:naturvardsverket:diva-7870

Gustafsson, M., Blomqvist, G., Elmgren, M., Johansson, C., Järlskog, I., Lundberg, J., Norman, M., Silvergren, S. (2019a*). Driftåtgärder mot PM10 i Stockholm: utvärdering av vintersäsongen 2017–2018* [Operational measures against PM10 pollution in Stockholm: evaluation of winter season 2017–2018]. VTI report 1000. Swedish National Road and Transport Research Institute (VTI). http://urn.kb.se/resolve?urn=urn:nbn:se:vti:diva-13579

Gustafsson, M., Blomqvist, G., Järlskog, I., Lundberg, J., Niska, A., Janhäll, S., Norman, M., Eneroth, K., Johansson, C. (2019b). *Optidrift: optimerad vinter- och barmarksdrift för bättre luftkvalitet* [Optidrift: optimized urban street operation for better air quality]. VTI report 1004. Swedish National Road and Transport Research Institute (VTI). http://urn.kb.se/resolve?urn=urn:nbn:se:vti:diva-13669

Halmstad Municipality (2020). *Vanliga frågor om snöröjning* [Frequent questions on snow clearing]. Retrieved 2020-06-08 from https://www.halmstad.se/trafikinfrastruktur/gatorochvagar/snorojning/vanligafragoromsnorojning.4960.html

Hennlock, M., Hult, C., Roth, A., Nilsson, L., Nilsson, M., Sprei, F., & Kåberger, T. (2020). *Vägskatt för personbilar* [Road tax for passenger cars]. Nr C 469. Swedish Environmental Research Institute (IVL). https://www.ivl.se/download/18.4447c37f16fa0999d1916a7/1580126098529/C469.pdf

Hjort, M., Bruzelius, F., Andersson, H., Krafft, M., Ydenius, A., & Rizzi, M. (2015). *Jämförelse av vinter och sommardäck på barmark sommartid: tester, riskanalys och djupstudier* [Comparison of winter and summer tyres on bare roads summer time: test, risk analysis and in-depth studies]. VTI-report 849. Swedish National Road and Transport Research Institute (VTI). http://urn.kb.se/resolve?urn=urn:nbn:se:vti:diva-7816

Honarmand, M., Tanzadeh, J., Beiranvand, M. (2019). *Bitumen and its modifier for use in pavement engineering.* In S. Heneda (ed.), *Sustainable construction and building materials,* IntechOpen. https://www.intechopen.com/books/sustainable-construction-and-buildingmaterials/bitumen-and-its-modifier-for-use-in-pavement-engineering

IEA, International Energy Agency (Cozzi, L., Petropolous, A) (2019, October 15). *Growing preference for SUVs challenges emissions reductions in passenger car market. EIA.* Retrieved 2020-06-22 from https://www.iea.org/commentaries/growing-preference-for-suvs-challenges-emissions- reductions-in-passenger-car-market

Industry Europe (2019, December 3*). EU Tyre Label Renewed With Focus On Winter Safety & Eco-Friendliness.* [News]. Retrieved 2020-07-02 from https://industryeurope.com/eu-tyre-label-renewed-with-focus-on-winter-safety-eco-friendliness/

Johansen, T. C., & Fors, C. (2018). *Nordic certification of road marking materials in Norway and Sweden 2016–2018*. VTI report 995A. Swedish National Road and Transport Research Institute (VTI). http://urn.kb.se/resolve?urn=urn:nbn:se:vti:diva-13440

Johansson, C., Norman, M. & Burman, L. (2011). *Vad dubbdäcksförbudet på Hornsgatan har betytt för luftkvaliteten* [What the ban on studded tyres on Hornsgatan has meant for air quality]. Environment and health andministration of the city of Stockholm. SLB analys 2:2011. https://www.slb.nu/slb/rapporter/pdf8/slb2011_002.pdf

Järlskog, I., Blomqvist, G., Gustafsson, M. & Janhäll, S. (2017). *Utvärdering av städmaskiners förmåga att reducera vägdammsförrådet i gatu- och tunnelmiljöer: En fältstudie i Trondheim 2016* [Evaluation of road sweepers' ability to reduce the road dust depot in street and tunnel environments: A field study in Trondheim, Norway]. VTI report 953. Swedish National Road and Transport Research Institute (VTI). http://urn.kb.se/resolve?urn=urn:nbn:se:vti:diva-12559

Jönsson, R. (2016). *Mikroplast i dagvatten och spillvatten: Avskiljning i dagvattendammar och anlagda våtmarker* [Microplastics in Stormwater and Sewage: Removal in Stormwater Ponds and Constructed Wetlands]. [Masters thesis, Department of Earth Sciences, Uppsala University]. http://www.diva-portal.org/smash/record.jsf?pid=diva2%3A1049924&dswid=7680

Kwak, J-H., Kim, H., Lee, J., Lee, S. (2013). Characterization of non-exhaust coarse and fine particles from on-road driving and laboratory measurements. *Science of the Total Environment 458–460,* 273–282. https://doi.org/10.1016/j.scitotenv.2013.04.040

Li, Y., Zuo, S., Lei, L., Yang, X. & Wu, X. (2011). Analysis of impact factors of tire wear. *Journal of Vibration and Control 18*(6): 833–840. https://doi.org/10.1177/1077546311411756

Linjemarkering Väst AB (2020). *Vägmarkering* [Road marking]. Retrieved 2020-06-08 from https://linjemarkering.se/vagmarkeringar/

Lithner, D. (2021). *Toxicitetstest och kemiska analyser på lakvatten från olika typer av vägmarkeringar* [Toxicity tests and chemical analysis on leachates from different road marking products]. [Unpublished manuscript]. Swedish National Road and Transport Research Institute (VTI).

Ljungberg, M. (2000). *Vinterväghållning och expertsystem – en kunskapsöversikt* [Winter Road Maintenance and Expert Systems – a Knowledge Overview]. VTI-meddelande 902. Swedish National Road and Transport Research Institute (VTI). http://www.diva-portal.org/smash/get/diva2:673365/FULLTEXT01.pdf

Lundberg, T., Ekblad, J., Göransson, N.-G., Sjögren, L., & Arvidsson, A. K. (2015). *Makrotexturens möjlighet att identifiera låg friktion: tillståndsmätning av vägytan* [The potential to identify low friction from macrotexture: condition assessment of road surface]. VTI report 877. Swedish National Road and Transport Research Institute (VTI). http://urn.kb.se/resolve?urn=urn:nbn:se:vti:diva-8279

Lundberg, T., Eriksson, O., & Glantz, C. (2019). *Kontroll och uppföljning av entreprenader – del 2, tillståndsutveckling, mätfel och risker: Vägytemätning med mätbil* [Control and follow-up of contracts – part 2, condition development, measurement errors and risks: Road surface measurement]. VTI report 1018. Swedish National Road and Transport Research Institute (VTI). http://urn.kb.se/resolve?urn=urn:nbn:se:vti:diva-13994

Michelin (2018, April 25). *Low tire pressure a major concern.* [News, April 25, 2018]. Retrieved 2020-11-01 from https://www.michelin.com/en/news/low-tire-pressure-a-major-concern/

Michelin (2020a). *Michelin® Uptis – The first airless mobility solution for passenger vehicles*. [FAQ]. Retrieved 2020-12-01 from https://michelinmedia.com/michelin-uptis/

Michelin (2020b). Wheel alignment and balancing*?*. Retrieved 2020-11-01 from https://www.michelin.co.uk/auto/tips-and-advice/advice-auto/wheel-alignment-and-balancing

Mirabedini, S.M., Zareanshahrakia, F. & Mannaria, V. (2020). Enhancing thermoplastic road-marking paints performance using sustainable rosin ester. *Progress in Organic Coatings*, Volume *139*, 105454. https://doi.org/10.1016/j.porgcoat.2019.105454

Modales (2019). *Modales. About.* Retrieved 2021-06-17 from https://modales-project.eu/about/

Nokian Tyres (2019, November 21). *There is a common misconception relates to electric cars – in reality, tyres will last for a long time.* [Company news]. Retrieved 2021-01-15 from https://www.nokiantyres.com/company/news-article/there-is-a-common-misconception-related-to-electric-cars-in-reality-tires-will-last-for-a-long-time/

Nokian Tyres (2020, September 15). *Greener driving for northern summer roads: the new Nokian Hakka Green 3 summer tire rolls lightly and sustainably.* [Company news]. Retrieved 2021-02-02 from https://www.nokiantyres.com/company/news-article/greener-driving-for-northern-summer-roads-the-new-nokian-hakka-green-3-summer-tire-rolls-lightly-and/

Nordic Swan (2020). *Hur tas kraven fram av Nordisk Miljömärkning?* [How are the requirements developed by Nordic Ecolabelling?]. Retrieved 2020-11-15 from https://www.svanen.se/svanens-arbete/hur-funkar-det/hur-tas-kraven-fram-av-nordisk-miljomarkning/

Nordic Swan (2021). *Om oss* [About us]. Retrieved 2021-03-04 from https://www.svanen.se/Om-oss/

Nordström, O. & Samuelsson, E. (1990). *Vinterdäcks väggrepp på is* [Road grip of winter tyres on ice]. VTI rapport 354. Swedish National Road and Transport Research Institute (VTI). http://www.diva-portal.org/smash/record.jsf?pid=diva2%3A674833&dswid=-2812

Norman, M. (2016). *Utvärdering av dubbdäcksförbud på Kungsgatan och Flemminggatan, effekten på luftkvaliteten, emissionerna till luften samt trafiken och dubbdäcksanvändningen* [Evaluation of the ban on studded tires on Kungsgatan and Flemminggatan, the effect on air quality, emissions to air and traffic and the use of studded tires]. SLB analys 8:2016. Environment and Health Administration for the city of Stockholm. https://www.slb.nu/slb/rapporter/pdf8/slb2016_008.pdf

Norwegian Public Roads Administration (2010). *FoU prosjekt Evaluering av forsterket kantoppmerking. Nedfrest longflex ogrumbleflex i Hedmark og Oppland* [R&D project Evaluation of reinforced edge marking. Milled longflex and rumbleflex in Hedmark and Oppland]. https://nmfv.dk/wp-content/uploads/2012/03/Evaluering_av_forsterket_kantoppmerking.pdf

OECD (2020a). *Mitigating microplastics in marine and freshwaters – A sectoral focus on textiles and tyres.* 14th Meeting of the Working Party on Resource Productivity and Waste 17-20 November. First draft. [Unpublished manuscript, draft 2020-11-02]. Working Party on Resource Productivity and Waste.

OECD (2020b). *Non-exhaust particulate emissions from road transport, an ignored environmental policy challenge.* OECD Publishing, Paris. https://doi.org/10.1787/4a4dc6ca-en

Paige, J. (2012). The Effect of Underinflation on Tire Operating Temperature. *Rubber & Plastics News*, November 26, 2012. https://www.rubbernews.com/assets/pdf/rn841521129.pdf

Pohrt, R. (2019). Tire wear particle hot spots – review of influencing factors. Facta universitatis, *Mechanical Engeneering*, 17, 17–27. https://doi.org/10.22190/FUME190104013P

Polukarova, M., Markiewicz, A., Björklund, K., Strömvall, A.-M., Galfi, H., Andersson Sköld, Y., Gustafsson, M., Järlskog, I. & Aronsson, M. (2020). Organic pollutants, nano- and microparticles in street sweeping road dust and washwater. *Enviromental International 105337*. https://doi.org/10.1016/j.envint.2019.105337

Polukarova, M., Gustafsson, M, Hjort, M., Agewall, J. & Wallgren, K. (2021). Estimation of total tyre wear in Sweden. [Unpublished manuscript].

Porto, M., Caputo, P., Loise, V., Eskandarsefat, S., Teltayev, B. & Oliviero Rossi, C. (2019). Bitumen and Bitumen Modification: A Review on Latest Advances. *Applied Sciences 9*(4), 742. https://doi.org/10.3390/app9040742

Regulation (EC) No 661/2009 of the European Parliament and of the Council of 13 July 2009 concerning type-approval requirements for the general safety of motor vehicles, their trailers and systems, components and separate technical units intended therefor. http://data.europa.eu/eli/reg/2009/661/2019-04-24

Regulation (EC) No 1222/2009 of the European Parliament and of the Council of 25 November 2009 on the labelling of tyres with respect to fuel efficiency and other essential parameters. OJ L 342, 22.12.2009, p. 46–58. http://data.europa.eu/eli/reg/2009/1222/oj

Regulation (EU) 2020/740 of the European Parliament and of the Council of 25 May 2020 on the labelling of tyres with respect to fuel efficiency and other parameters, amending Regulation (EU) 2017/1369 and repealing Regulation (EC) No 1222/2009. OJ L 177, 5.6.2020, p. 1–31. ELI: http://data.europa.eu/eli/reg/2020/740/oj

Research and Markets (2020). *Global and China Tire Pressure Monitoring System (TPMS) Industry Report, 2020-2026*. Retrieved 2020-12-20 from https://www.researchandmarkets.com/reports/5062101/global-and-china-tire-pressure-monitoring-system

Riksförbundet M Sverige (2020). *Vinterregler i Europa: Dubbade och odubbade vinterdäck, sommardäck, snökedjor och autosocks* [Winter rules in Europe: Studded and unstudded winter tires, summer tires, snow chains and autosocks]. Retrieved 2020-05-19 from https://msverige.se/resa-med-bil/bila-utomlands/bila-i-europa/vinterregler-for-dack-i-vara-europeiska-lander/

RISE (2019, December 12). *Ecodesign for green products.* Retrieved 2020-06-23 from https://www.ri.se/en/berattelser/ekodesign-miljovanliga-produkter

Salminen, K. (2014). *Parametrizing tyre wear using a brush tyre model.* [Master thesis, KTH Royal Institute of Technology]. https://www.diva-portal.org/smash/get/diva2:802101/FULLTEXT01.pdf

Sandberg, L. (Ed) (2012). *Reseavdrag och slopad förmånsbeskattning av kollektivtrafikbiljetter – Effektiva styrmedel som ger önskad effekt* [Travel deductions and abolished benefit taxation of public transport tickets – Effective instruments that provide the desired effect]. WSP Sverige AB. https://www.transportportal.se/Energieffektivitet/Energieffektivisering-och-%C3%B6kad-kollektivtrafikandel-reseavdraget-kollektivtrafikbiljetter.pdf

Sandberg, U., Ejsmont, J.A. (2002). *Tyre/Road Noise Reference Book*, (see figure 9.50). Informex HB, SE-59039 Kisa, Sweden (www.informex.info).

SFS 1994:1236. *Förordning (1994:1236) om producentansvar för däck* [Regulation (1994:1236) on producer responsibility for tyres]. Amended by SFS 2020:634. Swedish Ministry of the Environment. https://www.riksdagen.se/sv/dokument-lagar/dokument/svensk-forfattningssamling/forordning-19941236-om-producentansvar-for-dack_sfs-1994-1236

SFS 1998:808. *Miljöbalk* [The Swedish Environmental Code]. Amended by SFS 2020:1174. Swedish Ministry of the Environment. https://www.riksdagen.se/sv/dokument-lagar/dokument/svensk-forfattningssamling/miljobalk-1998808_sfs-1998-808

SFS 1998:812. *Lag (1998:812) med särskilda bestämmelser om vattenverksamhet* [Act (1998: 812) with special provisions on water activities]. Amended by SFS 2019:903. Swedish Ministry of the Environment. https://www.riksdagen.se/sv/dokument-lagar/dokument/svensk-forfattningssamling/lag-1998812-med-sarskilda-bestammelser-om_sfs-1998-812

SFS 1998:1276. *Trafikförordning (1998:1276)* [Traffic Ordinance (1998:1276)]. Amended by SFS 2020:86. Swedish Ministry of Infrastructure. https://www.riksdagen.se/sv/dokument-lagar/dokument/svensk-forfattningssamling/trafikforordning-19981276_sfs-1998-1276

SFS 2004:629. *Lag (2004:629) om trängselskatt* [Law (2004:629) on congestion tax]. Amended by SFS 2020:120. Swedish Ministry of Finance. https://www.riksdagen.se/sv/dokument-lagar/dokument/svensk-forfattningssamling/lag-2004629-om-trangselskatt_sfs-2004-629

SFS 2006:227. *Vägtrafikskattelag (2006:227)* [Road traffic tax law (2006:227]. Amended by SFS 2021:164. Swedish Ministry of Finance. https://www.riksdagen.se/sv/dokument-lagar/dokument/svensk-forfattningssamling/vagtrafikskattelag- 2006227_sfs-2006-227

SFS 2007:1157. *Lag (2007:1157) om yrkesförarkompetens* [Act (2007:1157) on Professional Driving Competence]. Amended by SFS 2021:23. Swedish Ministry of Infrastructure. https://www.riksdagen.se/sv/dokument-lagar/dokument/svensk-forfattningssamling/lag-20071157-om-yrkesforarkompetens_sfs-2007-1157

SFS 2013:251. *Miljöprövningsförordningen* [Environmental Examination Regulation]. Amended by SFS 2021:731. Swedish Ministry of the Environment. https://www.riksdagen.se/sv/dokument-lagar/dokument/svensk-forfattningssamling/miljoprovningsforordning-2013251_sfs-2013-251

SFS 2017:1201. *Lag (2017:1201) om reduktion av växthusgasutsläpp från vissa fossila drivmedel* [Act (2017: 1201) on the reduction of greenhouse gas emissions from certain fossil fuels]. Amended by SFS 2017:1233. Swedish Ministry of Infrastructure]. https://www.riksdagen.se/sv/dokument-lagar/dokument/svensk-forfattningssamling/lag-20171201-om-reduktion-av-vaxthusgasutslapp_sfs-2017-1201

SFS 2017:1334. *Förordning (2017:1334) om klimatbonusbilar.* [Ordinance (2017:1334) on climate bonus cars]. Amended by SFS 2021:200. Swedish Ministry of the Environment. https://www.riksdagen.se/sv/dokument-lagar/dokument/svensk-forfattningssamling/forordning-%2020171334-om-klimatbonusbilar_sfs-2017-1334

Skumlien Furusteh, I., Støhle Rødland, E. (2020). *Reducing the Release of Microplastic from Tire Wear: Nordic Efforts.* Nordic Council of Ministers. http://norden.diva-portal.org/smash/get/diva2:1515089/FULLTEXT01.pdf

Snökedjor.se. (2020, n.d.). *Snöstrumpor* [Snow socs]. Retrieved 2020-05-18 from http://www.snokedjor.se/-snostrumpor.html

SOU 2015:27. *Skatt på dubbdäcksanvändning i tätort?* [Tax on studded tire use in urban areas?] Report of the Particle Content Inquiry. Swedish Government Official Reports. [Government inquiry]. https://www.regeringen.se/rattsliga-dokument/statens-offentliga-utredningar/2015/03/sou-201527/

SOU 2017:11. *Vägskatt* [Road tax]. Report of the Road wear tax committee. Swedish Government Official Reports. [Government inquiry]. https://www.regeringen.se/rattsliga-dokument/statens-offentliga-utredningar/2017/02/sou-201711/

SOU 2019:36. *Skattelättnad för arbetsresor* [Tax relief on business travel]. Report of the Travel deduction committee. Swedish Government Official Reports. [Government inquiry]. https://www.regeringen.se/rattsliga-dokument/statens-offentliga-utredningar/2019/06/sou-201936/

Stevenson, K., Stallwood, B., & Hart, A. G. (2008). Tire Rubber Recycling and Bioremediation: A Review. *Bioremediation Journal, 12(1),* 1–11. https://doi.org/10.1080/10889860701866263

Sundt, P., Syversen, F., Skogesal, O., & Shultze, P-E. (2016). *Primary microplastic-pollution: Measures and reduction potentials in Norway*. Norwegian Environment Agency. https://www.miljodirektoratet.no/globalassets/publikasjoner/M545/M545.pdf

Svensk Däckåtervinning (2020). *Ny nytta för 94 550 ton däck bromsar resursslöseriet. Årsrapport 2019* [New utility for 94,550 tonnes of tires slows down waste of resources. Annual report 2019]. Swedish tyre recycling. https://www.sdab.se/media/1468/sdab-arsrapport-web.pdf

Swedish Environmental Protection Agency (2012). *Styrmedel för att nå miljökvalitetsmålen – En kartläggning* [Policy instruments to reach environment quality objectives: A survey]. https://www.naturvardsverket.se/globalassets/media/publikationer-pdf/6400/978-91-620-6415-0.pdf

Swedish Environmental Protection Agency (2016). *Styrmedel för minskad dubbdäcksanvändning* [Policy instruments for reduced use of studded tyres]. PM 2016-03-09. Case No NV-00416-16. https://dokodoc.com/styrmedel-fr-minskad-dubbdcksanvndning.html

Swedish Environmental Protection Agency (2017). *Mikroplaster – Redovisning av regeringsuppdrag om källor till mikroplasteroch förslag på åtgärder för minskade utsläpp i Sverige* [Microplastics - Report on a government commission on sources of microplastics and proposals for measures to reduce emissions in Sweden]. Report 6772. https://www.naturvardsverket.se/978-91-620-6772-4

Swedish Environmental Protection Agency (2019a). *Regeringsuppdrag att föreslå etappmål om dagvatten* [Government commission to propose intermediate targets for stormwater]. Case no: NV-08865-17. https://www.naturvardsverket.se/contentassets/34e231a6ea91468ba0168816d8e3abd1/redovisning-ru-etappmal-for-dagvatten-skrivelse.pdf

Swedish Environmental Protection Agency (2019b). Microplastics in the Environment 2019: Report on a government commission. Report 6957. https://www.naturvardsverket.se/globalassets/media/publikationer-pdf/6900/978-91-620-6957-5.pdf

Swedish Environmental Protection Agency (2020a). *Styrmedel för att förändra val och beslut som orsakar miljöproblem* [Instruments for changing choices and decisions that cause environmental problems]. Retrieved 2020-06-20 from https://www.naturvardsverket.se/Stod-i-miljoarbetet/Vagledningar/Samhallsekonomisk-konsekvensanalys/Hur-losa-miljoproblem/Utforligare-stod/Styrmedel/

Swedish Environmental Protection Agency (2020b). *Transporterna och miljön* [Transports and the environment]. Retrieved 2020-06-24 from: https://www.naturvardsverket.se/Miljoarbete-i-samhallet/Miljoarbete-i-Sverige/Uppdelat-efter- omrade/Transporter-och-trafik/

Swedish Environmental Protection Agency (2020c). *Producentansvar för däck* [Producer responsibility for tyres]. Retrieved 2020-06-05 from https://www.naturvardsverket.se/vagledning-och-stod/producentansvar/producentansvar-for-dack

Swedish Environmental Protection Agency (2020d, September 7). *Nu startar den nationella samordningen för en hållbar plastanvändning* [Now the national coordination for a sustainable use of plastics starts]. [News]. Retrieved 2021-02-01 from https://www.pressmachine.se/pressrelease/view/nu-startar-den-nationella-samordningen-for-en-hallbar-plastanvandning-24516?lang=en

Swedish Environmental Protection Agency (2021a). *Konstgräsplaners miljöpåverkan* [Environmental impact of artificial turf pitches]. Retrieved from https://www.naturvardsverket.se/amnesomraden/plast/om-plast2/konstgrasplaners-miljopaverkan

Swedish Environmental Protection Agency (2021b). *Bidrag för att minska utsläpp av mikroplaster och andra föroreningar via dagvatten 2021* [Grants to reduce emissions of microplastics and other pollutants via stormwater in 2021]. Retrieved 2021-05-10 from http://www.naturvardsverket.se/Stod-i-miljoarbetet/Bidrag/Utslapp-via-dagvatten-20201/

Swedish Government (2017a). *Det klimatpolitiska ramverket* [The climate policy framework]. [Article from the Swedish Ministry of the Environment, June 6, 2017]. Retrieved 2020-07-05 from https://www.regeringen.se/artiklar/2017/06/det-klimatpolitiska-ramverket/

Swedish Government (2017b). *Uppdrag att ta fram och sprida kunskap om mikoplastutsläpp från transportsystemet* [Commission to produce and disseminate knowledge about microplastic emissions from the transport system]. Commission for VTI, Government decision 2017-12-21, Ministry of Enterprise and Innovation.
https://www.regeringen.se/4b02db/contentassets/9b998a48d2ed4150a3c701ab2b264398/rb-ii-11-n17-07856-subt-uppdrag-att-ta-fram-och-sprida-kunskap-om-mikroplastutslappt-fran- transportsystemet.pdf

Swedish Government (2021). *Mål för transportpolitiken* [Objectives of transport policy]. Retrieved 2021-02-28 from https://www.regeringen.se/regeringens-politik/transporter-och-infrastruktur/mal-for-transporter-och- infrastruktur/

Swedish Ministry of Finance (2018, March 9) *En ny inriktning för beskattning av tung lastbilstrafik* [A new direction for taxation of heavy truck traffic]. Publ. March 9, 2018, Fi2018/01103/S2. Promemoria. Retrieved 2021-04-30 from https://www.regeringen.se/rattsliga-dokument/departementsserien-och-promemorior/2018/03/en-ny- inriktning-for-beskattning-av-tung-lastbilstrafik/

Swedish Ministry of Finance (2020). *Nytt miljöstyrande system för godstransporter på väg* [New environmental management system for freight transport by road]. Dir. 2020:38.Committee directive. https://www.regeringen.se/4a6c5c/contentassets/6e76b569e98645dab9b1a075aa478c93/nytt-miljostyrande-system-for-godstransporter-pa-vag-dir.-202038.pdf

Swedish Water (2016). *Avledning av dag- drän- och spillvatten. Funktionskrav, hydraulisk dimensionering och utformning av allmänna avloppssystem. Publikation P110 – Del 1*. [Diversion of storm water, drain and waste water. Functional requirements, hydraulic dimensioning and design of general drainage systems. Publication P110 – Part 1].
http://vav.griffel.net/filer/P110_del1_web_low_180320.pdf

Swedish Energy Agency (2018, June 1). *Ekodesigndirektivet* [Ecodesign directive]. Retrieved 2020-06-23 from http://www.energimyndigheten.se/energieffektivisering/jag-ar-saljare-eller-tillverkare-av-produkter/ekodesign-energimarkning-och-ce-markning/ekodesign/ekodesigndirektivet/

Swedish Energy Agency (2020, October 23). *Ecodesignprocessen* [The Ecodesign process]. Retrieved 2020-10-30 from https://www.energimyndigheten.se/energieffektivisering/lagar-och-krav/ekodesigndirektivet/ekodesignprocessen/

Swedish Transport Administration (2014). *Val av beläggning* [Selecting surface materials]. Report 2014:173. https://trafikverket.ineko.se/Files/sv-SE/12329/RelatedFiles/2014_173_val_av_belaggning.pdf

Swedish Transport Administration (2018). *Framkomlighetsprogram.Trafikverketsinriktning för hur Storstockholms primära vägnät används på bästa sätt* [The Swedish Transport Administration's focus on how Greater Stockholm's primary road network is used in the best way]. TRV 2018/84 794. https://Swedish Transport Administration.ineko.se/Files/sv-SE/50154/Ineko.Product.RelatedFiles/2018-_185_Framkomlighetsprogram_Swedish Transport Administrations_inriktning_for_hur_Storstockholms_primara_vagnat_an vands_pa_basta_satt.pdf#page=15

Swedish Transport Administration (2019). *Undersökning av däcktyp i Sverige – vintern 2019 (januari – mars)* [Survey of tire type in Sweden – winter 2019 (January – March)]. Report 2019:146. http://www.diva-portal.org/smash/record.jsf?pid=diva2%3A1357111&dswid=-9935

Swedish Transport Administration (2020a). *Krav – VGU, Vägars och gators utformning* [Requirements – RSD, Road and street design]. Publication 2020:029. https://Swedish Transport Administration.ineko.se/Files/sv-SE/71830/Ineko.Product.RelatedFiles/2020_029_vagar_och_gators_utformning_krav.pdf

Swedish Transport Administration (2020b*). Prognos för persontrafiken 2040 – Trafikverkets Basprognoser 2020-06-15*. [Forecast for passenger traffic 2040 – The Swedish Transport Administration's Basic Forecasts 2020-06-15]. Publication (2020:128). http://trafikverket.diva-portal.org/smash/get/diva2:1442656/FULLTEXT01.pdf

Tokvam AS (2020). *Spara bränsle och slitstål under plogning* [Save fuel and wear steel during plowing]. Retrieved 2020-06-30 from https://www.snowhero.tokvam.no/sv/spara-br%C3%A4nslekostnader-och-slitst%C3%A5l-vid-plogning#så_här_gör_du_för_att_spara_både_bränslekostnader_och_slitstål

Transport Analysis (2018). *ABC om styrmedel* [ABC on policy instruments]. PM 2018:2. https://www.trafa.se/globalassets/pm/2018/pm-2018_2-abc-om-styrmedel.pdf

Swedish Road Administration (2003). *Vägdikenas funktion och utformning – En beskrivning av multifunktionella diken* [Function and design of road ditches: A description of multifunctional ditches]. Publication 2003:103. https://Swedish Transport Administration.ineko.se/Files/sv-SE/11120/RelatedFiles/2003_103_vagdikenas_funktion_och_utformning.pdf

Swedish Transport Administration (2020c). *Sveriges vägnät* [Sweden´s road network]. Retrieved 2020-12-01 from https://www.Swedish Transport Administration.se/resa-och-trafik/vag/Sveriges-vagnat/

Swedish Transport Administration (2020d). *Prognos för godstransporter 2040 – Trafikverkets basprognoser 2020* [Forecast for freight transport 2040 – Swedish Transport Administration's basic forecasts 2020]. Publication 2020:125. http://www.diva-portal.org/smash/get/diva2:1442798/FULLTEXT03.pdf

Swedish Transport Administration (2020e). *Avvattning – Avvattning, Dimensionering och utformning* [Drainage – Drainage, Dimensioning and design]. Requirements, infrastructure regulation, TRVINFRA-00231 (Version 1.0). Publication date 2020-10-01. https://puben.Swedish Transport Administration.se/dpub/visa- dokument/bbe38e42-5c14-4703-a5ca-3261f034a02f

Swedish Transport Agency (2014, June 13). *Däcktrycksövervakningssystem* [Tyre pressure monitoring systems]. Retrieved 2020-05-20 from https://www.transportstyrelsen.se/sv/vagtrafik/Fordon/Fordonsregler/allmant-for-vagfordon/Dacktrycksovervakningssystem/

Swedish Transport Agency (2015). *Konsekvensutredning – föreskrifter och allmänna råd om bilar och släpvagnar som dras av bilar och som tas i bruk den 1 juli 2010 eller senare* [Impact assessment – regulations and general advice on cars and trailers towed by cars and put into service on or after 1 July 2010]. Registration no TSF 2014-7. https://www.transportstyrelsen.se/globalassets/global/regler/remisser/vagtrafik/tsfs-2010/konsekvensutredning.pdf

Swedish Transport Agency (2020a, September 30). *Vinterdäck* [Winter tyres]. Retrieved 2020-10-02 from https://www.transportstyrelsen.se/vinterdack

Swedish Transport Agency (2020b). *Bonus malus-system för personbilar, lätta lastbilar och lätta bussar* [Bonus malus system for cars, light trucks and light buses]. Retrieved 2020-10-23 from https://www.transportstyrelsen.se/sv/vagtrafik/Fordon/bonus-malus/

Swedish Transport Agency (2021). *Yrkesförarkompetens* [Professional driver competence]. Retrieved 2021-01-28 from https://www.transportstyrelsen.se/sv/vagtrafik/Yrkestrafik/Gods-och-buss/Yrkesforarkompetens/

Transport & Environment (2016). *Failure of Indirect Tyre Pressure monitoring systems puts drivers and road users at risk. Independent tests show indirect TPMS pass the regulatory test but fail to work on the road.* A briefing by Transport & Environment, November 2016. https://www.transportenvironment.org/wp-content/uploads/2021/07/2016_11_TPMS_report_final.pdf

Transport & Environment (2020). *Plug-in hybrids: Is Europe heading for a new Dieselgate?* https://www.transportenvironment.org/sites/te/files/publications/2020_11_Plug-in_hybrids_report_final.pdf

TSFS 2009:19. *Transportstyrelsens föreskrifter och allmänna råd om användning av däck m.m. avsedda för bilar och släpvagnar som dras av bilar (konsoliderad elektronisk utgåva); beslutade den 14 april 2009* [The Swedish Transport Agency's regulations and general advice on the use of tires, etc. intended for cars and trailers towed by cars (consolidated electronic version); decided on 14 April 2009]. Amended by TSFS 2019:44. https://transportstyrelsen.se/TSFS/TSFS%202009_19k.pdf

Tuonononen A. J. &Sainio P. (2014). Optimal proportion of studded tyres in traffic flow to prevent polishing of an icy road. A*ccident Analysis & Prevention 65*, 53-62 https://doi.org/10.1016/j.aap.2013.12.009

Töyrä, A., Doherty, A., Hammargren, G., Bern, A.-B., Morild, K., & Pyk, L. (2019). *Statistik om offentlig upphandling 2019* [Statistics on public procurement 2019]. Swedish National Agency for Public Procurement report 2019:5; Swedish Competition Agency report 2019:3. https://www.upphandlingsmyndigheten.se/globalassets/dokument/publikationer/statistikrapport_2019_webb.pdf

uCARe (2020, n.d.). *Project uCARe: You Can Always Reduce Emissions because you care.* Retrieved 2020-06-28 from: https://www.project-ucare.eu/

UNECE (2014). *Addendum 16: Global technical regulation No. 16: Global technical regulation on tyres.* http://www.unece.org/fileadmin/DAM/trans/main/wp29/wp29wgs/wp29gen/wp29registry/ECE-TRANS-180a16e.pdf

UNECE (2019). *World Forum For Harmonization of Vehicle Regulations (WP.29) How it works – How to join it.* Fourth Edition.

https://unece.org/fileadmin/DAM/trans/main/wp29/wp29wgs/wp29gen/wp29pub/WP29-BlueBook-4thEdition2019-Web.pdf

UNECE (2020, n.d.). *WP29 World Forum for Harmonization of Vehicle Regulations (WP.29).* Retrieved 2020-12-23 from https://unece.org/transport/vehicle-regulations/wp29-world-forum-harmonization- vehicle-regulations-wp29

Uppsala Municipality. (2019, November 6). *Dubbdäck i stan* [Studded tyres in the city]. Retrieved 2020-03-16 from https://www.uppsala.se/gator-och-trafik/utslapp-miljo-och-buller/dubbdack-i-stan/

Vaa T. & Giaever T. (2003). *Vinterfriksjonsprojektet – Studie av konsekvenser av endret piggdekkbruk* [The winter friction project: Study of the consequences of changed studded tire use]. SINTEF Internal report no. 2369. Norwegian Public Roads Administration. https://vegvesen.brage.unit.no/vegvesen-xmlui/bitstream/handle/11250/193937/vinterfriksjonsprosjektetnr2369.pdf?sequence=1&isAllowed=y

Van Zyl, S., van Goethem, S., Kanarachos, S., Rexeis, M., Hausberger, S., Smokers, R. (2013). *Study on Tyre Pressure Monitoring Systems (TPMS) as a means to reduce Light Commercial and Heavy- Duty Vehicles fuel consumption and CO2 emissions.* TNO 2013 R10986, final report. https://repository.tno.nl//islandora/object/uuid:84b183d4-904f-48dc-a2fd-4ee515e24b1a

Verschoor, A. J., & de Valk, E. (2017). *Potential measures against microplastic emissions to water.* RIVM Report 2017-0193. The Dutch National Institute for Public Health and the Environment. https://www.rivm.nl/bibliotheek/rapporten/2017-0193.pdf

VIANOR (2020*). FAQ: Ofta frågat om TPMS-system* [Frequently asked about TPMS-systems]. Retrieved 2020-10-01 from https://vianor.se/information-om-dack/tpms-system/tpms-faq/#Q6

Vogelsang, C., Lusher, A. L., Dadkhah, M. E., Sundvor, I., Umar, M., Ranneklev, S. B., Eidsvoll, D., Meland, S. (2018). *Microplastics in road dust – characteristics, pathways and measures.* Norwegian Environment Agency (Miljødirektoratet) and Norwegian Institute for Water Research (NIVA). Updated 2019 och 2020. https://www.miljodirektoratet.no/globalassets/publikasjoner/-M959/M959.pdf

VTI (2019). *Däck – vinterdäck* [Tyres – winter tyres]. Retrieved 2020-05-20 from https://www.vti.se/sv/forskningsomraden/vinterdack/

Wilson, J. (2020, March 4). *World's first device to capture harmful tyre particles invented by students.* [News] Imperial College. Retrieved 2020-06-29 from https://www.imperial.ac.uk/news/195595/worlds-first-device-capture-harmful-tyre/

Wadsten, E., Arm, M. (2008). *Skötsel av öppna vägdagvattenanläggningar* [Maintenance of open road stormwater facilities]. Publication 2008:30, Swedish Road Administration. https://Swedish Transport Administration.ineko.se/Files/sv-SE/11437/RelatedFiles/2008_30_skotsel_av_oppna_vagdagvattenanlaggningar.pdf

Wang, T. (2017) *Analysis on Tyre Wear: Modelling and Simulations.* [Degree project in vehicle engineering, KTH Royal Institute of Technology]. http://www.diva-portal.se/smash/get/diva2:1416550/FULLTEXT01.pdf

Wik, A. & Dave, G. (2005). Environmental labeling of car tires-toxicity to *Daphnia magna* can beused as a screening method. *Chemosphere (58):* 645–651. https://doi.org/10.1016/j.chemosphere.2004.08.103

Wik, A. & Dave, G. (2006). Acute toxicity of leachates of tire wear material to *Daphnia magna* – Variability and toxic components. *Chemosphere 16(10):* 1777–1784. https://doi.org/10.1016/j.chemosphere.2005.12.045

World Business Council for Sustainable Development (2020, n.d.). *Tyre Industry project.* Retrieved 2020-06-01 from https://www.wbcsd.org/Sector-Projects/Tire-Industry-Project

Österblad, M. (2021). *Utsläpp från vägmarkeringar – Toxicitetstest av lakvatten från vägmarkeringsprodukter med mikroalgen Raphidocelis subcapitata* [Emissions from road markings: Toxicity tests of leachates from road marking products on the microalgae *Raphidocelis subcapitata*]. [Master thesis, Department of Environmental Science, Stockholm University] https://www.diva-portal.org/smash/record.jsf?pid=diva2%3A1541844&dswid=-885

Appendix A. Extended summary table – potential policy instruments and measures

Table A1 below includes all potential policy instruments and measures surveyed, identified and prioritised in this report. The table is an extended version of Table 2a-d, with two additional columns depicting which category each policy instrument or measure belongs to and the actors that are important to implementation or enforcement. The following policy instrument categories have been used: Administrative, Financial, Educational, Research & development, Physical planning (definitions in Table 1), and Investigation.

Table A1. Extended summary table covering all potential policy instruments and measures targeting microplastics from tyre and road wear included in this report. The table refers to section and policy instrument or measure heading and includes a short description of each policy instrument or measure, the priority given to each instrument or measure and why, which policy instrument categories are involved, and who would be responsible for implementation or enforcement. Priorities have been colour-coded, with red for Highly Prioritised, yellow for Prioritised, pink för Highly Prioritised in the Next Step, and no colour for Not prioritised. Policy instruments concerning research and/or development have been highlighted in bold.

Section	Policy instrument or measure heading	Description of policy instrument or measure	Priority	Policy instrument categories	Important actors for implementation or enforcement
3.3.1.	Reduced road traffic (vehicle-kilometres).	All policy instruments and measures that reduce road traffic (i.e. vehicle-kilometres). This includes those that make it more difficult for private and goods vehicles to use the roads, as well as those that promote alternative means of transportation or the avoidance of travel, i.e. both carrots and sticks.	Highly prioritised for further investigation or research (due to effectiveness).	Administrative, Economic, Information-based, Research & development, Physical planning.	The Government and Riksdag, the Swedish Transport Agency, the County Administrative Boards, regional self-governing bodies, municipal joint committees, the Swedish Transport Administration, municipalities, research-funding organisations and others.
3.3.2.	Influencing the composition and development of the vehicle fleet.	a) Promote **research** on the importance of the weight, motor power and acceleration of cars for tyre and road wear, and b) reduce the percentage of heavier cars with more powerful engines and better acceleration (e.g. SUVs) for instance by taxes or a modified bonus-malus system.	a) Highly prioritised (because it may lead to an effective policy instrument in the next step). b) Prioritised for further investigation (due to effectiveness).	a) Research & development. b) Administrative, Economic.	a) The Government and Riksdag, national research-funding organisations and other authorities, the EU. b) The Government and Riksdag, the Swedish Transport Agency.

Section	Policy instrument or measure heading	Description of policy instrument or measure	Priority	Policy instrument categories	Important actors for implementation or enforcement
3.3.3.	Labelling of tyre wear propensity.	a) Promote and drive the **development** of a standardised method for measuring tyre wear, and b) introduce labelling of the wear propensity of tyres in the EU Regulation on tyre labelling.	a) Highly prioritised (because it may lead to an effective policy instrument in the next step). b) Not currently prioritised, must await a), but will then be highly prioritised (due to effectiveness).	a) Research & development. b) Administrative, Information-based.	a) The Government and Riksdag, national research-funding organisations and other authorities, the tyre industry, the EU. b) The EU.
3.3.4.	Tyres with low wear propensity.	Promote **research & development** of tyres with low wear propensity.	Highly prioritised (due to effectiveness).	Research & development.	The Government and Riksdag, national research-funding organisations and other authorities, the tyre industry, the EU.
3.3.5.	Tyre wear limits.	Develop EU limit values for tyre wear.	Not currently prioritised, must await 3.3.3a, but will then be highly prioritised for further investigation (due to effectiveness)	Administrative.	The EU.
3.3.6.	Ecodesign regulations concerning tyre wear and hazardous substances.	Introduce an EU regulation on ecodesign requirements for tyres, including a) limit values for tyre wear and b) restrictions or bans on hazardous substances.	a) Not currently prioritised, must await 3.3.3.a and 3.3.5, but will then be highly prioritised for further investigation (due to effectiveness). b) Not currently prioritised, must await 3,5,1a, but will then be highly prioritised for further investigation (due to potential effectiveness).	Administrative.	The EU.
3.3.7.	Global technical regulations regarding tyre wear and hazardous chemicals.	Include a) demands for lower tyre wear and b) restrictions or bans on hazardous chemicals in global technical regulations relating to tyres.	a) Not currently prioritised, must await 3.3.3a and 3.3.5, but will then be highly prioritised for further investigation (due to effectiveness), b) Not currently prioritised, must await 3.5.1a, but will then be highly prioritised (due to potential effectiveness).	Administrative.	Contracting parties to international agreements (UNECE), of which the EU is one.

Section	Policy instrument or measure heading	Description of policy instrument or measure	Priority	Policy instrument categories	Important actors for implementation or enforcement
3.3.8.	Restrictions or bans on the use of studded tyres.	Promote **research** into reducing the use of studded tyres its impact on a) emissions of tyre wear particles and b) road safety (friction and traction).	a) Prioritised (because it may lead to an effective policy instrument in the next step). b) Prioritised (due to the need for knowledge).	Research & development.	The Government and Riksdag, national research-funding organisations and other authorities.
3.3.9.	Restricting the usage period for non-studded winter tyres.	a) Introduce restrictions regarding the time of year when non-studded winter tyres may be used, e.g. through amendment of the Swedish Transport Agency Regulation (TSFS 2009:19) and b) complementing this with information campaigns.	A) Prioritised for further investigation (due to potential cost-effectiveness). b) Not currently prioritised (depends on the outcome of a).	a) Administrative. Information-based.	a) The Swedish Transport Agency and possibly the Government. b) The Swedish Transport Agency.
3.3.10.	Tyre pressure monitoring or more frequent air pressure checks.	To fund an **investigation** regarding which policy instruments or measures would be most appropriate for increasing the proportion of tyres used at the correct pressure (e.g. tyre pressure monitoring systems or more frequent air pressure checks).	Highly prioritised (due to potential effectiveness in the next step).	Investigation.	The government, the Swedish Transport Agency.
3.3.11.	Wheel alignment and tyre balance.	a) Promote **research** into the extent to which incorrect wheel alignment and tyre balance affect the amount of tyre wear particles being generated, and (b) investigate how more frequent checks of wheel alignment and tyre balance could be introduced.	a) Highly prioritised (because it may potentially lead to an effective policy instrument in the next step). b) Not currently prioritised (depends on the outcome of a).	Research & development.	The Government and Riksdag, national research-funding organisations and other authorities, the EU.
3.3.12.	Road markings with low wear propensity.	Promote research & development of road markings with lower wear propensity.	Prioritised (due to potential effectiveness).	Research & development.	The government and Riksdag, national research-funding organisations and other authorities, the EU, the road marking industry.

Section	Policy instrument or measure heading	Description of policy instrument or measure	Priority	Policy instrument categories	Important actors for implementation or enforcement
3.3.13.	Use of certified road markings.	Promote **research** into whether certified road markings are better from a microplastics perspective and b) introduce guidelines on using certified road markings on municipal roads.	a) Prioritised (because it may potentially lead to an effective policy instrument in the next step). b) Not currently prioritised (depends on the outcome of a).	a) Research & development. b) Administrative.	a) The Government and Riksdag, national research-funding organisations and other authorities, the road marking industry. b) The Swedish Transport Administration, municipalities
3.3.14.	Inlaid road markings.	a) Extend **research** of inlaid road markings and its impact on road marking wear, and b) investigate under what conditions inlaid road markings may be appropriate in the Swedish road network.	a) & b) Prioritised (because they may potentially to lead to an effective policy instrument in the next step, b) also because of potential cost-effectiveness.	a) Research & development. b) Investigation.	The government and Riksdag, national research-funding organisations and other authorities.
3.3.15.	Road surfacing materials that reduce tyre wear.	a) Promote **research** on road texture and develop road surfacing materials optimised for reducing tyre wear, and b) increase road maintenance.	a) Prioritised (due to potential effectiveness). b) Not currently prioritised (because other aspects are more important when road surfacing materials are chosen).	a) Research & development. b) Maintenance measure.	a) The government and Riksdag, national research-funding organisations and other authorities, the EU. b) The Swedish Transport Administration, municipalities.
3.3.16.	Road design that decreases tyre wear.	a) Promote **research** into the extent to which the layout of roads and streets affect tyre and road wear, and b) design roads and streets with fewer sharp bends and steep hills.	a) Not prioritised (see reasoning for b). b) Not prioritised (because other aspects are expected to be more influential, and that cost-effectiveness is expected to be low).	a) Research & development. b) Physical planning, Construction measures.	a) The government and Riksdag, national research-funding organisations and other authorities, the EU. b) The Swedish Transport Administration, municipalities.
3.3.17.	Speed limits and speed adaptations.	a) Promote **research** into the extent to which speed limits and speed adaptation can impact the generation of wear particles, and b) introduce speed limits and speed adaptations.	a) Highly prioritised (because it may potentially lead to an effective policy instrument in the next step). b) Not currently prioritised (depends on the outcome of a).	a) Research & development. b) Physical planning, Administrative.	a) The government and Riksdag, national research-funding organi-sations and other authorities, the EU, the tyre industry. b) The Swedish Transport Administration, County Administrative Boards. municipalities.

Section	Policy instrument or measure heading	Description of policy instrument or measure	Priority	Policy instrument categories	Important actors for implementation or enforcement
3.3.18.	Investment in eco-driving.	a) Provide information regarding the importance of driving style, b) increase the proportion of drivers trained in eco-driving, and c) promote **development** and use of effective systems to support eco-driving.	a) Highly prioritised (because of the value in raising awareness). b) Highly prioritised for further investigation (due to effectiveness and small investment). c) Highly prioritised (due to effectiveness).	a) Information-based. b) Economic, Information-based. c) Research & development.	a) Bodies and persons responsible for training of new drivers, professional driver certificates and eco-driving. b) The government and Riksdag, the Swedish Transport Agency. c) The government and Riksdag, national research-funding organisations and other authorities, the EU.
3.3.19.	Snow clearance optimised for reducing the wear of road markings.	a) Promote **research** or investigation into how snow clearance can be optimised to reduce the wear of road markings, b) develop a guidance, and c) include requirements in procurement processes.	a) Prioritised (because of low cost and that it may potentially lead to an effective policy instrument in the next step). b) & c) Not prioritised at present (depends on outcome of a).	a) Research & development. b) Information-based.. c) Administrative, Information-based.	a) The government and Riksdag, national research-funding organisations and other authorities. b) The Swedish Transport Administration and municipalities. c) National authorities (e.g. the Swedish Transport Administration), municipalities
3.3.20.	Green procurement.	a) Identify products and services that contribute to decreasing microplastic pollution caused by tyre and road wear, and b) include requirements in public procurement.	a) & b) Prioritised for further investigation (due to potential effectiveness and cost-effectiveness).	a) Investigation. b) Administrative, Information-based.	a) National authorities. b) National authorities, municipalities
3.4.1.	Collection of tyre particles during travel.	Promote **research, development** and evaluation of devices that can capture tyre particles from a vehicle in motion.	Highly prioritised (due to potential effectiveness and cost-effectiveness).	Research & development.	The government and Riksdag, national research-funding organisations and other authorities, the EU.
3.4.2.	Sustainable management of stormwater and masses contaminated with tyre and road wear.	Promote **research & development** of sustainable solutions for managing stormwater and masses containing tyre and road wear particles.	Highly prioritised (due to effectiveness).	Research & development.	The government and Riksdag, national research-funding organisations and other authorities, the EU.

Section	Policy instrument or measure heading	Description of policy instrument or measure	Priority	Policy instrument categories	Important actors for implementation or enforcement
3.4.3.	Cleaning of roads and streets, and optimisation opportunities.	a) Promote **research** into how street sweeping affects the dispersion of microplastics, and b) evaluate available optimisation opportunities.	a) Highly prioritised (because of need for more knowledge and that this may potentially lead to an effective policy instrument in the next step. b) Not prioritised at present (depends on outcome of a).	Research & development.	The government and Riksdag, national research-funding organisations and other authorities, the EU.
3.4.4.	Dust binding measures.	Promote **research** into how dust binding affects the dispersion of microplastics.	Not prioritised (due to expected low effectiveness).	Research & development.	Authorities, municipalities (bigger towns).
3.4.5.	Sustainable management of microplastics in snow from roads.	a) Promote **research** into whether microplastics in cleared snow is a potential problem and b) investigate appropriate ways to manage cleared snow.	a) Highly prioritised (due to the need for knowledge to assess the need for action). b) Not currently prioritised (depends on outcome of a).	Research & development.	The government and Riksdag, national research-funding organisations and other authorities, the Nordic Council of Ministers.
3.4.6.	Regulating the use of end-of-life tyres.	Introduce a) requirements relating to spread of microplastics in the producers' responsibility for end-of-life tyres, and b) notification requirements for facilities containing artificial turf or moulded granules, and riding arenas containing rubber or plastic.	a) Prioritised for further investigation (due to (low cost and potential effectiveness). b) Highly prioritised for further investigation (due to effectiveness).	Administrative.	The Government.
3.5.1.	Ban on hazardous chemicals in tyres and road markings.	a) Promote **investigations** to identify hazardous chemicals that are candidates for restrictions or bans, and b) introduce general or targeted bans or restrictions on hazardous chemicals within the EU.	a) Highly prioritised (because of likelihood to lead to an effective policy instrument in the next step). b) Not currently prioritised, must await outcome of a), but is thereafter likely to be highly prioritised (due to effectiveness).	a) Research. b) Administrative.	a) The government and Riksdag, national research-funding organisations and other authorities, the EU. b) The EU.

Section	Policy instrument or measure heading	Description of policy instrument or measure	Priority	Policy instrument categories	Important actors for implementation or enforcement
3.5.2.	Ecolabelling of tyres based on chemical content.	a) Develop criteria for labelling of tyres based on their chemical content, and b) ecolabel tyres based on approved content of chemicals.	*Voluntary labelling:* a) & b) Not prioritised (due to previous low level of interest from tyre industry). **Mandatory labelling:* a) Prioritised for further investigation (due to effectiveness). b) Not currently prioritised (must await out a), but is thereafter likely to be prioritised due to effectiveness). **This prioritisation was missing in the Swedish version of the report.*	a) Research. b) Administrative or Information-based.	Ecolabelling bodies, the EU.
3.5.3.	Ecolabelling of road markings based on chemical content.	a) Promote **research** into content, leaching, and effects of chemicals from road markings, and b) prepare criteria for ecolabelling of road markings.	a) Prioritised (due to need for knowledge required to assess risks and the need for action). b) Not currently prioritised (depends on outcome of a).	a) Research. b) Administrative or Information-based.	a) The government and Riksdag, national research-funding organisations and other authorities, the EU. b) Ecolabelling bodies, the EU.
3.5.4.	Tyres that are more easily degradable.	Promote **research** into the possibility of developing tyres that are more easily degradable.	Prioritised (because of need for knowledge and that this may potentially lead to an effective policy instrument in the next step).	Research & development.	The government and Riksdag, national research-funding organisations and other authorities, the EU, the tyre industry or industry association.
3.6.1.	Research into emissions, dispersion, effects and degradation.	Promote r**esearch** into emissions, dispersion, effects, and degradation of microplastics from tyre and road wear.	Highly prioritised (due to the need for knowledge to enable assessment of risks and the need for action).	Research & development.	The government and Riksdag, national research-funding organisations and other authorities, the EU.
3.6.2.	Standardised and automated methods for sampling, sample preparation and analysis.	Promote **development** of a) standardised methods for sampling, sample preparation, and analysis, and b) automated methods for analysis of tyre and road wear particles.	a) & b) Highly prioritised (due to need for knowledge regarding the extent of the problem).	Research & development.	The government and Riksdag, national research-funding organisations and other authorities, the EU.

Section	Policy instrument or measure heading	Description of policy instrument or measure	Priority	Policy instrument categories	Important actors for implementation or enforcement
3.6.3.	Networks of excellence and initiatives for knowledge-exchange and generation of new knowledge.	Support and encourage participation in networks of excellence on tyre and road wear, to exchange knowledge and generate new knowledge.	Highly prioritised (due to effectiveness ant the need for knowledge).	Research & development.	The government and Riksdag, national research-funding organisations and other authorities, the EU.
3.6.4.	Targeted guidance on measures for reducing microplastic pollution from tyre and road wear.	Produce guidance on voluntary measures to reduce the burden of microplastics from tyre and road wear.	Highly prioritised (due to potential cost-effectiveness).	Information-based.	National authorities, municipalities.
3.6.5.	Information campaigns concerning issues with microplastics from tyre and road wear.	Investigate whether it would be useful to inform target audiences about the issues with microplastics from tyre and road wear and what can be done to reduce microplastic pollution.	Prioritised (because it may lead to possible cost-effectiveness and potential effectiveness in the next step.	Information-based.	National authorities, municipalities.

ABOUT VTI

The Swedish National Road and Transport Research Institute (VTI), is an independent and internationally prominent research institute in the transport sector. Our principal task is to conduct research and development related to infrastructure, traffic and transport. We are dedicated to the continuous development of knowledge pertaining to the transport sector, and in this way contribute actively to the attainment of the goals of Swedish transport policy.

Our operations cover all modes of transport, and the subjects of pavement technology, infrastructure maintenance, vehicle technology, traffic safety, traffic analysis, users of the transport system, the environment, the planning and decision making processes, transport economics and transport systems. Knowledge that the institute develops provides a basis for decisions made by stakeholders in the transport sector. In many cases our findings lead to direct applications in both national and international transport policies.

VTI conducts commissioned research in an interdisciplinary organisation. Employees also conduct investigations, provide counseling and perform various services in measurement and testing. The institute has a wide range of advanced research equipment and world-class driving simulators. There are also laboratories for road material testing and crash safety testing.

In Sweden VTI cooperates with universities engaged in related research and education. We also participate continuously in international research projects, networks and alliances.

The Institute is an assignment-based authority under the Ministry of Infrastructure. The Institute holds the quality management systems certificate ISO 9001 and the environmental management systems certificate ISO 14001. Certain test methods used in our labs for crash safety testing and road materials testing are also certified by Swedac.

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