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Executive Summary

Transport sector emissions are a major source of greenhouse gases and other pollutants, such as particulate matter, and thereby contribute both to global warming and to public health issues at the local level. The Nordic countries are committed to reducing these emissions, and to creating a greener transport system. Emerging digitalized mobility solutions represent sharing economy solutions, that have a notable potential to reduce both emissions and kilometers travelled by car.

Digitalized mobility solutions, whether multimodal Mobility as a Service (MaaS) applications or separate services such as car sharing, provide the customer with an alternative to private vehicle ownership and use. The potential that shared mobility services have to reduce emissions and vehicle kilometers travelled (VKT) are, in this study, estimated based on findings from both available research (desk study) and modelling and calculations.

Many of the shared mobility services, such as MaaS applications, have only recently started to emerge. Hence there is only limited data currently available on the impacts of these services. One of the most studied shared mobility services is car sharing. According to the desk study results, Nordic households that replace using a private car with car sharing can reduce their VKT by approximately 30–45 %, and their greenhouse gas emissions by 130–980 kg CO_2e per year.

In this study, we looked at country level reduction potentials. If 5 % of households changed from car ownership to car sharing, we estimate this would have the potential to reduce greenhouse gas emissions by between 0,7–5,3% from the current baseline. Each Nordic country has a different potential.

In order to assess the potential future impact of MaaS in the Nordic countries, we have used the PETRA model by Ea Energy Analyses to project the development path for road transport's energy consumption, CO_2 emissions and total costs in the Nordic countries up to 2050.

There are still several barriers to creating a more transport-efficient society via wider adoption of MaaS and other digitalized mobility services. This includes legal, behavioral, financial and organizational aspects. Barriers can also stem from the customer needs and current service levels. In this study we present potential ways to overcome such barriers with incentives and policy instruments to encourage changing from car ownership to using shared mobility solutions. We specify what different actors, including governments, cities and private companies, can do to accelerate this change. Finally, we present policy recommendations for the Nordic countries, based on best practice case analysis. These include recommendations on how to reduce dependence on car ownership, reduce vehicle kilometers driven, and stimulate demand for smart mobility services and greener mobility systems.

This study has been initiated and financed by the Nordic Council of Ministers' Climate and Air Pollution group (KOL) and conducted by Gaia Consulting in cooperation with Ea Energy Analyses.

The project group's policy recommendations are:

- Recommendation 1. Launch a pan-Nordic Smart & Green Mobility-as-a-Service (MaaS) transport pass;
- Recommendation 2. Introduce incentives and tax benefits to support wider and faster adoption of MaaS and smart mobility services;
- Recommendation 3. Design car-free communities and stimulate the demand for new multimodal mobility services;
- Recommendation 4. Make employee commuting greener;
- Recommendation 5. Introduce comprehensive transport pricing across Nordic countries;
- Recommendation 6. Educate and build awareness for smarter and greener transport choices;
- Recommendation 7. Fast track implementation of MaaS; and
- Recommendation 8. Build a better and more comprehensive Nordic data bank.

1. Introduction

The transport sector is currently at a crossroads. There is increasing political demand to create a greener and cleaner transportation system. At the same time, the substantial emergence of digitalized mobility solutions and the sharing economy offers consumers more sustainable options. Cleaner technologies, such as electric cars, are increasing in volume, and new digitalized solutions are providing alternatives to private cars. Nordic countries are forerunners in both fields – Norway has the most electric cars in use in the world,[1] and in recent years, Finland and Sweden have promoted the concept of Mobility as a Service (MaaS), both at the government level and through companies such as MaaS Global and Ubigo.

The transport sector is a major source of greenhouse gas (GHG) emissions and other pollutants in the Nordic countries, as the sector still depends heavily on fossil fuels. In Sweden, transport accounts for a third,[2] and in Finland[3] and Iceland[4] a fifth, of the country's total GHG emissions. Road transport also generates other emissions, e.g. particulate matter, that effects human health. The long transportation distances in these sparsely populated regions increases the per capita transport emissions in the Nordic countries.

In recent years, the Nordic countries have set increasingly ambitious targets for reducing GHG emissions from transport. The European Union's common target is to reduce GHG emissions from the transport sector by at least 60 % from 1990 levels by 2050.[5] The Nordic countries, of which Denmark, Finland and Sweden are members of the EU, have also each set GHG emission reduction targets for transport, both at national and city level. For example, Finland aims to halve the emissions from transport by 2030 compared to the 2005 levels,[6] and Norway has set the goal that all new passenger cars and light vans sold in 2025 shall be zero-emission vehicles.[7] The Nordic countries also have initiatives to increase the amount of cycling and walking, which have positive effects both on human health, including reduced mortality through increased exercise,[8] and on the environment, by these being zero-emission mobility options.

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1 Euronews (11.4.2018). How oil-rich Norway is leading the world on electric cars.
2 Naturvårdsverket (2017). National Inventory Report Sweden 2017
3 Bird, T. (2017). Nordic action on climate change (2017). Nordic Council of Ministers, Copenhagen.
4 Iceland National Inventory Report 2017. Emissions of greenhouse gases in Iceland 1990-2015.
5 European Commission (2011). Roadmap to a Single European Transport Area - Towards a competitive and resource efficient transport system https://ec.europa.eu/transport/themes/strategies/2011_white_paper_en
6 http://www.ym.fi/en-us/the_environment/climate_and_air/mitigation_of_climate_change/National_climate_policy/Climate_Change_Plan_2030
7 Norwegian Ministry of Transport and Communications (2017). National Transport Plan 2018–2029
8 Pucher, J., *et al.* (2010). Walking and Cycling to Health: A Comparative Analysis of City, State, and International Data

The quality and accessibility of transport services has a major impact on people's quality of life. Transport also represents a major share of household costs, as in the European Union, on average 13 % of the household budget is spent on transport.[9] Therefore, the choices made between transport modes are important both economically and socially.

Through the emergence of more advanced and comprehensive digitalized shared mobility solutions, with options to create multimodal journeys easily through a single platform, the economic reasoning behind the use of a private car can also be challenged. Overall, these new mobility services have the potential to reduce vehicle kilometers travelled (VKT), GHG emissions and other air pollutants, compared to the use of private cars. This potential is further examined in this report, starting with the results from the desk study of available studies and reports (Chapter 2) and the new calculations of the potential (Chapter 3). The study also included modelling emission reduction potential from passenger transport in the Nordic countries by 2030 and 2050, using the Ea Energy Analyses' PETRA model (Chapter 4).

The latter part of the report focuses on barriers to developing a transport-efficient society and ways to overcome these barriers (Chapter 5). The incentives and policy instruments to substitute car ownership with mobility services are then discussed (Chapter 6), followed by a brief presentation of selected best practice cases from different countries (Chapter 7). The final chapter provides policy recommendations for the development of MaaS and other greener transportation systems in the Nordic countries (Chapter 8).

1.1 Definitions of digitalized mobility services

The following digitalized mobility services were selected for assessment, and included both in the desk study and in the calculations of the potential to reduce both vehicle kilometers travelled and GHG and other emissions:

- car sharing
- ride sharing
- bike sharing
- grocery home deliveries
- multimodal mobility services (Mobility as a Service, MaaS).

These five services were selected because of their nature as shared services, having the potential to reduce or even replace the use of a private car, especially in larger cities. These services are also highlighted in the relevant literature, and were recognized in

[9] EU Science Hub (2018). Transport sector economic analysis

the conducted interviews as the services with the most potential to reduce emissions and VKT. The selected services are briefly defined below.

1.1.1 Car sharing

Car sharing is a type of car rental model. Compared to traditional car rental, in car sharing people typically rent the car for short periods of time, often by the hour. Cars can also be picked up outside business hours, and are available around town.

The car sharing business models can be further divided into three categories: traditional, peer-to-peer and corporate. Traditional car sharing refers to a service, in which the cars are owned by a car sharing company. Peer-to-peer car sharing refers to renting cars from private owners, enabled through a technology platform. In corporate car sharing there is a dedicated fleet of vehicles at company premises for shared use by the company's employees.[10]

Car sharing systems can also be divided in a different way into three other categories: round-trip, free-floating and point-to-point. In round-trip car sharing the car is returned to the same (fixed) place it was taken from. In free-floating car sharing the car can be taken and returned anywhere inside the city boundaries or other specified area. Point-to-point car sharing has (fixed) locations for pick-up and return, but the car can be returned to a different location from the pick-up location.[11]

1.1.2 Ride sharing

Ride sharing is the sharing of a vehicle by passengers travelling to and/or from the same area. Ride sharing does not include trips where the driver makes a separate trip in order to take a passenger somewhere specific (for example taxi, Uber). Ride matching (matching of driver with empty car seats and passenger looking for ride) is generally assisted by a web/app platform. Ride sharing business models can be divided into three categories: fixed long-distance ride sharing, on-demand ride sharing and corporate ride sharing. In fixed long-distance ride sharing drivers advertise for empty car seats in advance for passengers looking for a ride. In on-demand ride sharing the ride matching is coordinated shortly before the trip and the travelled distances are shorter. The corporate model ride sharing is primarily used to share the costs of commuting.[12]

1.1.3 Bike sharing

Bike sharing means short-term bicycle rental available at unattended urban locations. Bike sharing makes use of applied technology (smart cards and/or mobile phone apps) to book and pay for the use of the bikes. The technology provides users with real-time

[10] Gaia Consulting (2015). Urban Mobility Information in Helsinki Region. Final report. Helsinki Business Hub.
[11] Le Vine, S. *et al.* (2014). Carsharing: Evolution, Challenges and Opportunities
[12] Gaia Consulting (2015). Urban Mobility Information in Helsinki Region. Final report. Helsinki Business Hub.

bike availability information on the internet/smart phones.[13] There are two main types of bike sharing: station-based bike sharing and free-floating bike sharing. In the station-based model the bikes are left and taken from a specific bike station. In the free-floating model, bikes can be left and taken from anywhere inside a specified area, and there are no fixed bike stations.[14]

1.1.4 Grocery home deliveries

Grocery home delivery is a service provided by supermarkets or other grocery companies, either via online shopping, or after shopping in the store, and consists of transport of the goods purchased to the customer's home. The groceries can also be delivered to another location, e.g. to a train station for commuters to pick up on their way home.

1.1.5 Multimodal mobility services (Mobility as a Service, MaaS)

Mobility as a Service (MaaS) combines multiple different transportation modes and mobility services, such as public transport, car sharing, taxis / ride hailing and bike sharing to a single consumer app. One example of such an app currently in use in the Nordic countries is Whim by MaaS Global,[15] in use in Helsinki. MaaS intends to provide a comprehensive mobility service to the customer, in order to replace private car use. For each individual trip the MaaS service provider arranges the most suitable transport means for the customer, be it public transport, taxi or car rental, or ride-, car- or bike-sharing. These transport means may also be referred to as MaaS services.

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[13] Midgley, P (2013). Bike sharing. Global consultation for decision-makers on imple-menting sustainable transport.

[14] Pal, A., Zhang, Y. (2017). Free-floating bike sharing: Solving real-life large-scale static rebalancing problems. Transportation Research part C: Emerging technologies. Volume 80, July 2017

[15] https://maas.global/

2. The contribution of digitalized mobility services to reduction of vehicle kilometers and greenhouse gas emissions

This Chapter presents a desk study of available data in relevant research reports and studies. The focus is on existing material with numerical data expressing the potential of the selected mobility services to reduce VKT and GHG. A short review of automated vehicles is also included here, as they represent an interesting future development in the Nordic countries, but no in-depth discussion on the topic is included. This desk study does not cover other emissions than GHGs, as such data was not readily available. Instead, other emissions are estimated in Chapter 3 through our own calculations. As many of the digitalized services are only now emerging on a larger scale, comprehensive impact data is not yet available on all of the selected services.

2.1 Car sharing

2.1.1 Reduction of vehicle kilometers travelled (VKT) from car sharing

According to Skjelvik et al. (2017), the key positive environmental impacts from car sharing can be attributed to changes in car ownership and VKT. Compared to those who do not use car sharing services, on average, users of car sharing services own fewer cars and drive less. The reasons behind the fewer VKT include that the car sharing cars are relatively less accessible, and at the same time, to the user, the cost per trip is more apparent than is the case of when using a private car. However, if the household does not have a car before joining a car sharing service, the impact is the opposite, as they drive more than before. Still, the net impact is a decrease in the number of kilometers travelled by car.[16]

The reductive impacts of car sharing on VKT, when compared to the use of a private car, vary considerably between studies, ranging from 18 % to 67 % VKT reduction.[17] At

[16] Skjelvik, J., Erlandsen, A., Haavardsholm, O. (2017). Environmental impacts and potential of the sharing economy. Nordic Council of Ministers, Copenhagen

[17] Kokkelman, C. (2016): Carsharing's life-cycle impacts on energy use and greenhouse gas emissions. In: Transportation Research 20 Part D: Transport and Environment, 47: 276-284.

the lower end of the scale, Nijland et al. (2015)[18] estimated that in the Netherlands in 2014, car sharing members drove 7500 km/year, compared to 9100 km/year before the start of car sharing, representing an 18% reduction. According to surveys conducted by Ryden and Morin (2005)[19] among car sharing members in Bremen and Belgium, the results showed a reduction of VKT by 28% in Belgium and 45% in Bremen. Studies on car sharing in North America have shown even higher reduction in VKT. Sperling et al. (2000)[20] estimated that carsharing reduces VKT by 30–60%, whereas Cervero et al. (2007)[21] estimated that users of the San Francisco-based City CarShare reduced their annual VKT by 67% in the long term. Martin and Shaheen (2011)[22] found, through a North American survey, that the average VKT by respondents decreased 27% after joining car sharing.

A Swedish study from Vägverket (2003)[23] estimates that car sharing can reduce the annual VKT compared to private car use by 30–60 %. However, this data is not based on surveys from the Nordic countries, but deduced from many different European studies, of which the Vägverket study noted Meijkamp (2000)[24], Muheim (1998)[25] and Bremen (2001)[26] as the best sources. These studies presented VKT reductions of 33 %, 36 % and 32 %, respectively. From this data, combined with the results of the newer European studies mentioned above, it can be estimated that the Nordic car sharing services could result in approximately 30–45 % reduction in VKT. It is important to note that these estimates are net reductions, as those users who did not own a car prior to using the service, will increase their VKT as compared to before joining the car sharing.

In some studies it has been estimated that there are differences between different types of car sharing in respect to the VKT reduction. E.g. the recent Finnish Transport Agency (2018) report estimates that round-trip car sharing and peer-to-peer car sharing would reduce the use of own car more than free-floating or point-to-point services. This is because round-trip and peer-to-peer services more likely replace the use of own car, and free-floating or point-to-point services are more likely to replace the use of public transport.[27]

2.1.2 Reduction of greenhouse gas and other emissions from car sharing

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[18] Nijland, H., Meekerk, J. & Hoen, A. (2015): Impact of car sharing on mobility and CO2 emissions. PBL Netherlands Environmental Assessment Agency, publication number 1842. July 2015.

[19] Ryden, C & Morin, E (2005): Environmental Assessment Report WP 6, deliverable D6.2, version 1.1, 18 January 2005.

[20] Sperling, D., Shaheen, S., Wagner, C. (2000) Carsharing—Niche Market or New Pathway? University of California, Berkeley, California.

[21] Cervero, R. Golub, A. and Nee, B. (2007) City CarShare: Longer-Term Travel Demand and Car Ownership Impacts. Transportation Research Record 2007, pp. 70-80.

[22] Martin, E.W. and Shaheen, S.A. (2011b). The Impact of Carsharing on Household Vehicle Ownership. Access 38.

[23] Vägverket (2003) Gör plats för svenska bilpooler!

[24] Meijkamp, R. (2000). Changing Consumer Behaviour Through Eco-Efficient Services; an Empirical Study on Car Sharing in The Netherlands. Faculty of Industrial Design Engineering. Delft, Delft University of Technology.

[25] Muheim, P. P. (1998). CarSharing - the key to combined mobility. Switzerland, Energie 2000, Bundesamt für Energie.

[26] Bremen, S. (2001). Impacts of Car-Sharing on the Environment and Mobility Pattern. TOSCA Training Seminar, Bremen

[27] Liikennevirasto (2018). Yhteiskäyttöautojen potentiaali ja vaikutukset käyttäjänäkökulmasta. Liikenneviraston tutkimuksia ja selvityksiä 25/2018.

According to Nemry et al. (2008),[28] the GHG emissions of a typical petrol car over its lifecycle can be divided into three main sources:

- production, maintenance, and disposal of the car (approximately 5 t CO_2e per car)
- the fuel transformation process upstream to fuel consumption (well-to-tank, approx. 7.5 t CO_2e per car)
- the emissions from fuel consumption when driving the vehicle (approx. 44 t CO_2e per car).

2.1.3 Emission reductions from car sharing from less production, maintenance and disposal of cars

It is clear that most of the GHG emissions from the car come from the fuel consumption of the vehicle while driving. Hence the amount of VKT reduced through car-sharing has the most effect on the greenhouse gas emission reductions from car-sharing. Still, as car-sharing cars can contribute to replacing personal cars, there is also a significant potential to reduce emissions from production, maintenance and disposal. The Boston Consulting Group (2016) found that each car-sharing car could potentially replace 4–13 personal cars. However, the replacement effect of one car-sharing car is reduced to 3–8 personal cars, when taking into account the sales of new cars to car-sharing fleets, which have a higher turnover rate (typically 3 years) than personal cars.[29]

According to Nemry et al. (2008),[30] the production, maintenance, and disposal of a private car generates approximately 5 tonnes CO_2e. When taking into account the reduction of 3–8 cars, the reduction of GHG emissions from car production, maintenance, and disposal could be around 10–35 tonnes CO_2e per car-sharing car. Taking into account the average life of a car of 12.5 years, and approximately 20 members per shared car, the reduction per car-sharing member household would be 40 to 140 kg CO_2e per year.[31] On the other hand, a Dutch survey by Nijland *et al.* (2015), estimated that the GHG emission reductions from changed car ownership due to car sharing amounts to 85 kg to 175 kg CO_2e per year per car-sharing member household.[32]

Another important aspect to note, when discussing less car ownership due to car sharing, is the "rebound effect" of where the money is spent instead of a private car. When households save money from not purchasing an own car, it is important to consider, if they use this saved amount to purchase other goods and services causing environmental harm. According to Skelvik et al (2017), examples from Denmark and

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[28] Nemry, F., Leduc, G. Mongelli, I. & Uihlen, A. (2008): Environmental Improvement of Passenger Cars (IMPRO-Car), Joint Research Centre, Institute for Prospective Technological Studies, Seville, Spain.

[29] Boston Consulting Group (2016). What's ahead for car sharing? The new mobility and its impact on vehicle sales.

[30] Nemry, F., Leduc, G. Mongelli, I. & Uihlen, A. (2008): Environmental Improvement of Passenger Cars (IMPRO-Car), Joint Research Centre, Institute for Prospective Technological Studies, Seville, Spain.

[31] Skjelvik, J., Erlandsen, A., Haavardsholm, O. (2017). Environmental impacts and potential of the sharing economy. Nordic Council of Ministers publication.

[32] Nijland, H., Meekerk, J. & Hoen, A. (2015): Impact of car sharing on mobility and CO2 emissions. PBL Netherlands Environmental Assessment Agency, publication number 1842. July 2015.

Norway indicate that the indirect rebound effect could be as high as 814 kg to 3 tons of CO_2e emissions per car sharing member per year, using data for emissions from average consumption patterns.[33]

2.1.4 *Emission reductions from car-sharing from less driving and more energy-efficient cars*

The estimates of GHG-emission reductions from driving a shared car vary considerably among studies, and among countries studied. The survey by Nijland *et al.* (2015)[34] of car sharing members showed that car sharing results in a net reduction of 90 kg CO_2e-emissions per household per year, compared to the baseline situation of no car sharing. However, Martin and Shaheen (2011)[35] came to a very different result, 840 kg CO_2e/year, when calculating the reduction potential in the United States. The longer annual distance travelled in the US compared to the Netherlands, and the less fuel-efficient cars in the US than in Europe could be contributing factors to this large difference.

The Swedish Vägverket (2003) study, which is based on several European survey studies but no Nordic data, show results in the range of 300–550 kg of CO_2e reduction/year per carpooling member. Per car-sharing car, the study estimates the range to be between 3000 and 8000 kg per year.[36]

Car sharing fleets typically consist of newer and more energy-efficient cars than the average personal cars. Many car sharing fleets also have a higher percentage of hybrid or electric cars compared to personal cars, such as the EkoRent service in Finland (100% electric cars) or the LetsGo service in Denmark (15 % electric cars). Bundesverband CarSharing (2010)[37] estimates that car-sharing fleets emit up to 15 to 20% less CO_2, in some cases up to 25 % less, compared to the average personal car, in respect to driven kilometers.

In total, the GHG-emission reductions from lower vehicle ownership and fewer kilometers traveled could range between 130 kg and 980 kg per member household per year. Nordic emission reductions are likely somewhat closer to the lower part of the interval than to the higher part.[38] The reduction of 130 kg CO_2e a year is comparable to driving 513 km by a private car, or to burning 64 kg coal. The upper end of 980 kg CO_2 reduction is comparable to driving 3866 km by car, or to burning 485 kg coal.[39]

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[33] Skjelvik, J., Erlandsen, A., Haavardsholm, O. (2017). Environmental impacts and potential of the sharing economy. Nordic Council of Ministers publication.
[34] Nijland, H., Meekerk, J. & Hoen, A. (2015): Impact of car sharing on mobility and CO2 emissions. PBL Netherlands Environmental Assessment Agency, publication number 1842. July 2015.
[35] Martin, E. & Shaheen, S. (2011): Greenhouse gas emission impacts of car-sharing in North America. IEEE Transactions on Intelligent Transportation Systems 12(4), 1074–1086.
[36] Vägverket (2003). Gör plats för svenska bilpooler!
[37] Bundesverband CarSharing (2010): The state of European car-sharing. Final Report 2.4 Work Package 2. June 2010.
[38] Skjelvik, J., Erlandsen, A., Haavardsholm, O. (2017). Environmental impacts and potential of the sharing economy. Nordic Council of Ministers publication.
[39] https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator

2.2 Ride sharing

2.2.1 Reduction of vehicle kilometers travelled from ride sharing

Ride sharing has the potential to reduce vehicle kilometers travelled, as several persons share one vehicle. In Helsinki, the impacts of two types of ride sharing services – shared taxi (minivan seating 6–8 persons) and shared taxi-bus (with 8–16 seats) – have been simulated in 2017. In the simulations, 11 different scenarios for trip replacements of trips by bus, car or taxi, between 20%–100% were used. (See Table 1).

Table 1: Different scenarios considered in the Helsinki shared mobility simulations (ITF, 2017)

Scenarios	Bus	Cars and taxi	Rail, metro and tram
1	Keep	100% of trips replaced	Keep
2	Keep	50% of trips replaced	Keep
3	Keep	20 % of trips replaced	Keep
4	Keep	Inside ring road I all trips replaced	Keep
5	100% replacement	100 % of trips replaced	Keep
6	100% replacement	50% of trips replaced	Keep
7	100% replacement	20 % of trips replaced	Keep
8	Replace trips where bus is feeder to heavy modes	100 % of trips replaced	Keep
9	Replace trips where bus is feeder to heavy modes	20 % of trips replaced	Keep
10	Keep only trunk lines (trips with headways 9 min or below)	100 % of trips replaced	Keep
11	Keep only trunk lines (trips with headways 9 min or below)	20 % of trips replaced	Keep

The results for vehicle kilometer reduction vary considerably between the scenarios, from -8 % (increase) to 33 % reduction in VKT, as can be seen from Table 2. The scenario resulting in the increase in kilometers is based on estimating a full replacement of bus travel and 20 % of personal/taxi car travel with the ride sharing services, and the scenario that results in the most reduction is estimating not replacing bus travel and replacing all car/taxi travel with ride sharing.[40]

[40] ITF (2017). Shared Mobility Simulations for Helsinki.

Table 2: Results of the Helsinki shared mobility simulations in terms of reduction of vehicle kilometers from ride sharing

Scenarios	Reduction of vehicle kilometers (% from baseline)
1	33
2	12
3	4
4	15
5	23
6	0
7	-8
8	29
9	2
10	25
11	-7
Average all scenarios	11,6

Source: ITF (2017)[41]

The impacts of ride sharing on VKT has also been studied in other countries, including China, Australia and USA. The results vary between studied cities and assumptions made. Based on the city of Changsha, China, Jalali *et al*. (2017) concluded that ride sharing has the potential to reduce total kilometers driven by about 24% on short trips, assuming a maximum distance between trips of less than 10 kilometers, and schedule time less than 60 minutes. The Chinese study also suggested that the potential of ride sharing to reduce vehicle emissions increases by 94%, if riders are willing to walk up to 3 kilometers instead of 2 kilometers to get a ride.[42] Goel *et al*. (2016) studied ridesharing in Melbourne, Australia, in a case where passengers are picked up and dropped off at predetermined stops. Their model suggested a 23–40% reduction in VKT.[43] A study on taxi ridesharing in New York City by Ota *et al*. (2015) identified reductions of 46% and 61%, respectively, in taxi trips if rides are shared among two and three passengers.[44]

2.2.2 GHG reductions from ride sharing

In the Helsinki shared mobility simulations (2017), the CO_2 reduction from the use of ride sharing services differed greatly between the 11 scenarios simulated. The scenarios, and the aggregate results per scenario for percentage reduction in CO_2 emissions in Table 3 below.

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[41] ITF (2017). Shared Mobility Simulations for Helsinki.

[42] Jalali, R., Koohi-Fayegh, S., El-Khatib, K., Hoornweg, D., Li, H., (2017). Investigating the Potential of Ridesharing to Reduce Vehicle Emissions. Urban Planning (ISSN: 2183–7635) 2017, Volume 2, Issue 2, Pages 26–40

[43] Goel, P., Kulik, L., & Ramamohanarao, K. (2017). Optimal pick up point selection for effective ride sharing. IEEE Transactions on Big Data, 3(2), 154–168.

[44] Ota, M., Vo, H., Silva, C., & Freire, J. (2015). A scalable approach for data-driven taxi ride-sharing simulation. In 2015 IEEE International Conference on Big Data (pp. 888–897). IEEE.

Table 3: CO2 emission reduction in different scenarios of the Helsinki shared mobility simulations (2017)

Scenarios	Reduction in CO2 emissions (% from baseline)
1	34
2	13
3	4
4	14
5	28
6	6
7	-3
8	31
9	4
10	30
11	-2
Average all scenarios	14,45

As the Table 3 shows, the CO_2 reductions are largest (34 %) in scenario 1, in which all trips by car and taxi are replaced by ride sharing services, and bus trips are kept normally. An increase of 3 % in CO_2 is seen in Scenario 7, which assumes replacing all bus trips and only 20% of car/taxi trips with ride sharing services in the Helsinki simulation.

Many of the other studies done on ride sharing focus more on reducing kilometers or congestion, and not on GHG reductions. However, the Chinese study in Changsha also presents quantified results in respect to GHG reduction, which are estimated at approximately 4.0 tonnes CO_2 emission reductions daily in the study area, if a conservative maximum distance of 2 kilometers between trips and schedule time less than 40 minutes is selected.[45] In Canada it has been studied that in the Greater Montréal Area, ride sharing and shared commuter shuttles could reduce GHG emissions of up to 174.2 tonnes of CO_2e over five years (or 3.8% of emissions from personal transportation) by capturing just 5% of personal car travel with ride sharing services.[46]

2.3 Bike sharing

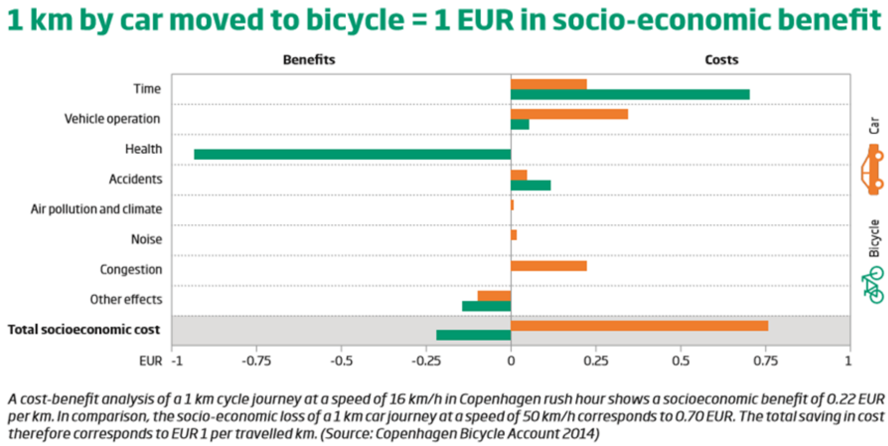
No comprehensive studies were identified on VKT or CO_2 emission reduction from bike sharing. However, there is a Danish study[47] on the socio-economic benefit potential obtainable from changing from private car to a bike on short journeys during rush hours in Copenhagen. The results are shown in the Figure 1 below.

[45] Jalali, R., Koohi-Fayegh, S., El-Khatib, K., Hoornweg, D., Li, H., (2017). Investigating the Potential of Ridesharing to Reduce Vehicle Emissions. Urban Planning (ISSN: 2183–7635) 2017, Volume 2, Issue 2, Pages 26–40

[46] The Atmospheric Fund and Coop Carbone (2016). Microtransit: An assessment of potential to drive greenhouse gas reductions

[47] Think Denmark (2016): Sustainable Urban Transportation – Creating green liveable cities

Figure 1: Socio-economic benefits from changing from private car to bicycle in Denmark[48]



2.4 Grocery home deliveries

Effects of grocery home deliveries in terms of VKT and CO2 emission reduction have been studied in Finland (Siikavirta *et al.*, 2008).[49] The study used the following cases:

1. E-grocery home delivery in three two-hour time slots between 17:00 and 21:00
2. E-grocery home delivery in one-hour time slots between 12:00 and 21:00
3. E-grocery home delivery to reception boxes (see figure 3) between 8:00 and 18:00
4. E-grocery home delivery once a week per customer between 08:00 and 18:00 to reception boxes (simulating the best possible case from the E-grocer's point of view, where orders are sorted by postal codes and divided evenly on all delivery days)
5. All 1,639 "orders" delivered separately, simulating the situation where households do the shopping themselves using their own cars.

Table 4 (next page). The results indicate that case 4 (efficient delivery once a week) has the most impact on VKT and the CO2 emissions generated. However, it is important to note that all studied cases result in a reduction of vehicle kilometers and CO2 emissions compared to baseline (Case 5.

[48] Think Denmark (2016): Sustainable Urban Transportation – Creating green liveable cities
[49] Siikavirta, H., *et al.* (2008). Effects of E-Commerce on Greenhouse Gas Emissions: A Case Study of Grocery Home Delivery in Finland

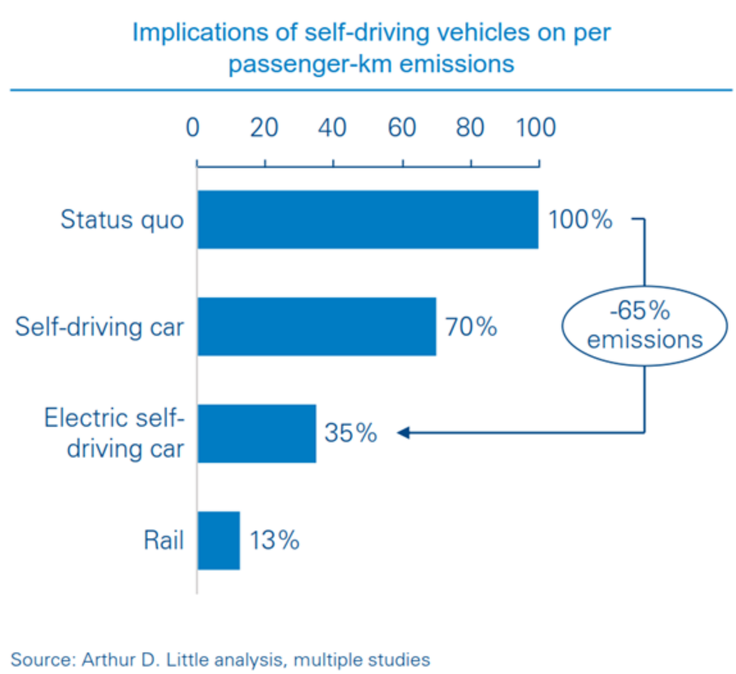
Table 4: Summary of results of Siikavirta et al (2008) on grocery home deliveries

Case	Distance driven (km) per 1639 orders	Reduction in distance driven compared with case 5	Vehicle type	GHG emissions, t CO2e	GHG reduction compared with case 5
1	2676	76,50 %	Van, diesel	0,80	58,20 %
2	5267	53,70 %	Van, diesel	1,58	17,70 %
3	1525	86,60 %	Van, diesel	0,46	76,20 %
4	822	92,80 %	Van, diesel	0,25	87,20 %
5	11365	0	Car, gasoline	1,92	0

2.5 Automated vehicles

Automated (driverless) vehicles are an important upcoming technology, that may revolutionize road transport in the Nordic countries too. Automated vehicles are not assessed in detail in this study in respect to VKT or GHG emissions, as there is not yet enough data to do calculations on their potential. However, some recent literature sources are examined below. The Future of Mobility 3.0-report by Arthur D. Little (2018) describes the effect of the use of automated vehicles on VKT and the corresponding GHG- emissions in the following Figure 2.

Figure 2: Implications of self-driving vehicles on passenger km emissions (source: Arthur D. Little, 2018)



The figure shows that non-electric self-driving cars reduce emissions from per passenger kilometers by approximately 30 %, and electric self-driving cars by approximately 65 %, compared to the current situation. The study also estimates a reduction of fatal road accidents by 90 %, if the entire world would change to automated vehicles.[50]

However, automatic vehicles do not necessarily reduce the amount of VKT. Whilst automatic vehicles might reduce traffic congestion by improving network capacity and traffic efficiency, they could also increase traffic volumes due to increased travel demand arising from improved travel convenience, and also because persons without a drivers' license can also use them. In the case of autonomous vehicle fleets, vehicle kilometers can also increase due to "empty" trips by the shared autonomous vehicles to pick up the next passenger, or to find a parking place. According to a recent study by Moreno et al. (2018), the total traveled distance increased by up to 8% after autonomous fleets were introduced. According to the study, current travel demand can still be satisfied with an acceptable waiting time when 10 conventional vehicles are replaced with 4 shared autonomous vehicles. [51]

The Danish government has also recently commissioned a study of the potential effects of autonomous vehicles. In the Danish study by the expert group "Mobilitet for fremtiden" (2018), the results indicate that automatic vehicles will make the use of cars even more attractive than currently, because of their convenience, and hence reduce use of public transport. As you can for example work in privacy when commuting using an autonomous vehicle, this could increase the use of cars for commuting. This in turn can increase the VKT. However, this study indicated autonomous cars are not likely to increase GHG emissions, as they are expected to be electric and the assumption is fossil-free electricity generation.[52]

2.6 Multimodal mobility services (MaaS)

Studies and calculations on the actual potential of Mobility as a Service (MaaS) to reduce vehicle kilometers and CO2 emissions are not yet available, as it is such a new mobility type. Arthur D. Little (2018) has listed all the current significant MaaS systems (see Figure 3.)

All of the listed schemes in Figure 3 combine public transport (metro, tram, bus, train, coach, monorail) with public individual transport (e.g. taxi, ride sharing, car sharing, car rental). Almost all of them also combine the former with soft mobility (walking, bike sharing, bike rental). Three of the listed MaaS services are located in the Nordic countries – Whim by MaaS Global in Helsinki (Finland), UbiGo in Gothenburg (Sweden), and Kyyti Group (in the figure named "Föli/Tuup") in Turku (Finland). All of the Nordic services are also among the most comprehensive according the modes integrated and depth of integration among the listed 10 services. All of the three Nordic

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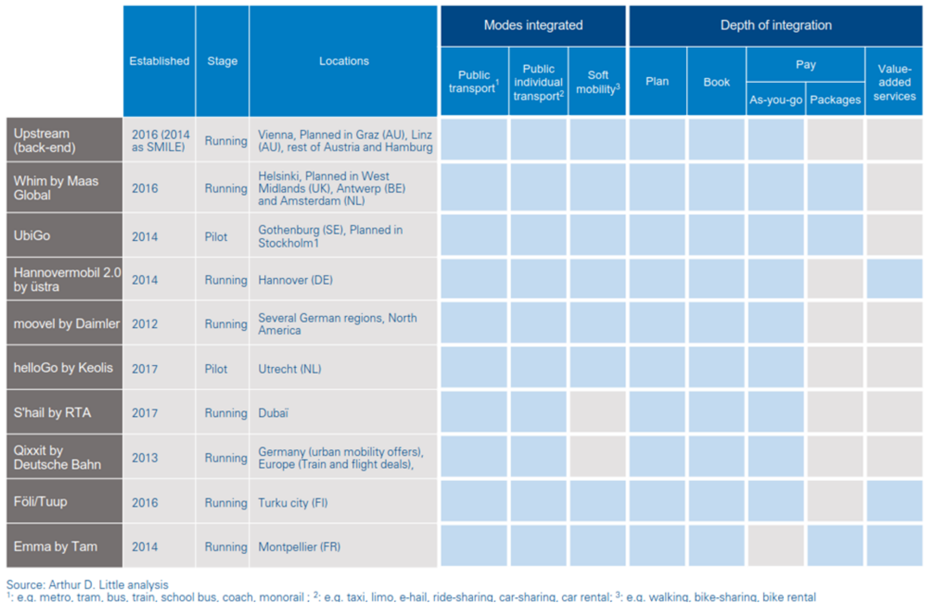
[50] Arthur D. Little (2018). The Future of Mobility 3.0. Reinventing mobility in the era of disruption and creativity

[51] Moreno, A. *et al.* (2018). Shared Autonomous Vehicles Effect on Vehicle-Km Traveled and Average Trip Duration. Journal of Advanced Transportation, Volume 2018, Article ID 8969353

[52] Expertgruppen Mobilitet for Fremtiden (2018). Afrapportering Marts 2018

services combine the modes of public transport, public individual transport and soft mobility.[53]

Figure 3: Current significant MaaS systems. Figure by Arthur D. Little (2018)[54]



Analysis done of the UbiGo trial in Gothenburg supported the estimate that the net-effect of the service was reduced environmental effects. However, there were users that changed their mobility habits into more car usage (taxi, car-pool) than before. More pilots and live trials are needed to see the large-scale effects of different MaaS-designs on the environment and VKT.[55]

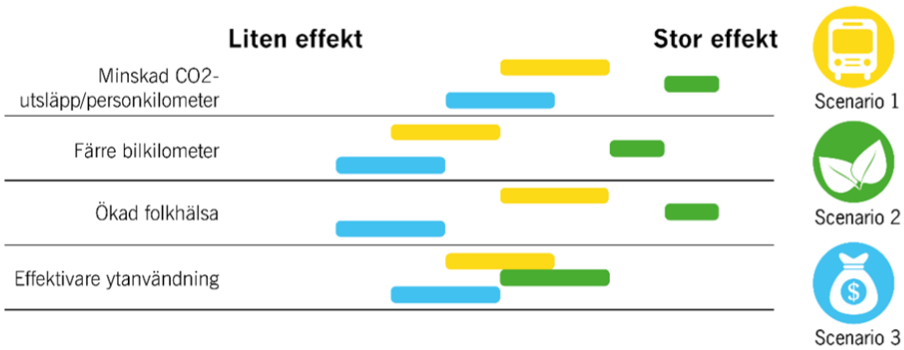
A Swedish study by Trivector (2016)[56] includes light scenario modelling of the effects of MaaS on VKT and GHG-emission reduction. The scenarios considered were:

1. Expanded public transport
2. Mastering a more sustainable social development (more MaaS users than in Scenario 1)
3. MaaS as a new business model for private actors.

The results of the study are summarized in Figure 4 (in the original Swedish).

[53] Arthur D. Little (2018). The Future of Mobility 3.0. Reinventing mobility in the era of disruption and creativity
[54] Föli/Tuup is currently known as Kyyti (name of the MaaS service) by the company Kyyti Group, https://www.kyyti.com/
[55] Viktoria Swedish ICT AB (2016). MOBILITY AS A SERVICE- MAAS. Describing the framework
[56] Trivector (2016): Konsekvenser av Mobility as a Service -report

Figure 4: Effects of MaaS on passenger km, VKT, CO2 emissions and public health in different scenarios



The MAASIFIE project (by VTT Technical Research Centre of Finland Ltd., AustriaTech and Chalmers University of Technology) also provides some indication of the impact of MaaS, but contains no concrete values for VKT or GHG-emission reduction. The study's results are presented in relation to impact areas in Figure 5. Amongst others, the results indicate an overall reduction in emissions, but an overall increase in total number of trips made.

Figure 5: Table showing results of the MAASIFIE project (2017) regarding the environmental, economic and social impacts of MaaS[57]

		Impact areas		
Level	KPIs	Environmental	Economic	Social
Individual /user level	Total number of trips made	x		x
	Modal shift (from car to PT, to sharing, to ...)	x		
	Number of multimodal trips (combining different modes of transport)	x		
	Attitudes towards PT, sharing, etc.	x		
	Perceived accessibility to transport			x
	Total travel cost per individual/household		x	x
Business/ organisational level	Number of customers		x	
	Customer segments (men/women, young/old, ...)		x	x
	Collaboration/partnerships in value chain		x	
	Revenues/turnover		x	
	Data sharing		x	
	Organisational changes		x	
Societal level	Emissions	x		
	Resource efficiency (roads, vehicles, land use, ...)	x	x	
	Citizens accessibility to transport services		x	x
	Modification of vehicle fleet (electrification, automation)	x		
	Legal and policy modifications	x	x	x

Overall positive increase/decrease	
Both positive and negative increase/decrease	
Overall negative increase/decrease	
Not possible to assess	

[57] Karlsson, M. *et al.* (2017). Mobility As A Service For Linking Europe (MAASIFIE) pro-ject. Impact Assessment, Deliverable Nr 4, Date 2017-04-10

3. Analyzing the impacts of digitalized mobility services

This chapter presents the results of a quantitative analysis of how the identified digitalized mobility services may contribute to reducing GHG emissions, other air pollutants and private car VKT. Factors considered in the analysis include, i.a.:

- Newer car fleet (e.g. through Business to Consumer (B2C) car sharing, B2C ride sharing)
- Increased ratio of goods/passenger per vehicle (e.g. grocery home delivery, ride sharing)
- Shortened journeys (e.g. car sharing, bike sharing utilized as a connection service to combine with public transport)
- Substitution of motorized transport entirely (e.g. bike sharing)

The most relevant digitalized services were selected for further analysis. These are car sharing, ride sharing, bike sharing, grocery home delivery and multimodal mobility services. For each service, the potential to reduce CO_2e emissions,[58] other air pollutants and VKT were calculated. Other air pollutants considered included CO, HC, NO_x, PM and SO_2. These pollutants do not contribute to global warming but have an impact on health at local level. For each service, the overall reduction potential of other air pollutants was estimated as a total, rather than individual values for each pollutant. As a reference, the relative proportion of other air pollutants is 84% CO, 11,7% NO_x, 4,0% HC, 0,3% PM and 0,1% SO_2.

3.1 Car sharing

As earlier stated in Chapter 2, car sharing can reduce VKT and the impact seen in studies range from 18% to 67%, when compared to the use of a private car. In the quantitative analysis of car sharing we took this as a baseline, and then assumed that the VKT for private cars could be reduced by 20–60%. We built two scenarios: in the low scenario 5% of households replace their own car with a shared one, and in the high scenario the

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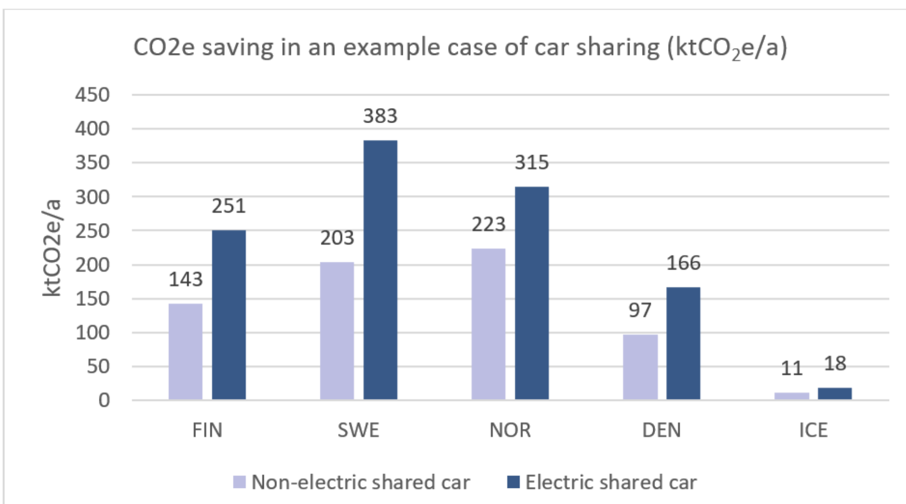
[58] CO_2e emission calculations include CO_2, CH_4 and N_2O. The conversion factors used are based on the 100 year Global Warming Potential, i.e. for CH_4 this is 21 and for N_2O 310. See for ex. https://unfccc.int/process/transparency-and-reporting/greenhouse-gas-data/greenhouse-gas-data-unfccc/global-warming-potentials

amount is 15%. We also analyzed two different bike sharing scenarios, i.e. 5% or 15%. of households that own at least one car use bike sharing.

The CO_2e saving and VKT reduction potential depends on the total passenger kilometers travelled on average during a day in the different countries. This distance varies between the countries from 35,6–47,2 km/person/day. The potential CO_2e savings are also affected by whether the shared cars are electric, hybrid or traditional non-electric cars. For electric cars we assumed the CO_2 emission rate to be 30,3 gCO_2/km[59] whereas for all passenger cars in traffic it is approximately 155 gCO_2/km.

Figure 6 (below) illustrates a particular example of the CO_2e saving potential at national level. In this example, 5% of households with at least one car change to car sharing. For those who change from private car use to car sharing, the VKT is estimated to be reduced by 40% of total passenger kilometers travelled, including commuting, leisure, shopping etc. Households that do not own a car and instead change from public transport (buses) to shared cars were estimated to represent 1% of all households.

Figure 6: CO2e saving potential in car sharing



In this example, the overall national CO_2e saving potential from car sharing is therefore estimated to be between 0,7–5,3% as compared to baseline. The relative potential is highest in Norway, where the average distance travelled per person in a day is longest. Electric cars have a significant impact on the CO_2e saving potential, representing an additional 70–80% saving over and above savings potentials from non-electric shared cars. For Norway, the additional benefit from electric cars is lower than in other Nordic countries since the average CO_2 emission rate for new cars in Norway is much lower than in other countries (i.e. 82 gCO_2/km in Norway and 123 gCO_2/km in Sweden). In the calculation it was assumed that shared cars are new cars and their CO_2 emission rate is therefore lower than the average of all cars in traffic. The overall potential VKT

[59] CO_2 emission rate for electric cars is estimated based on an average electricity generation mix and the same value is used for each country.

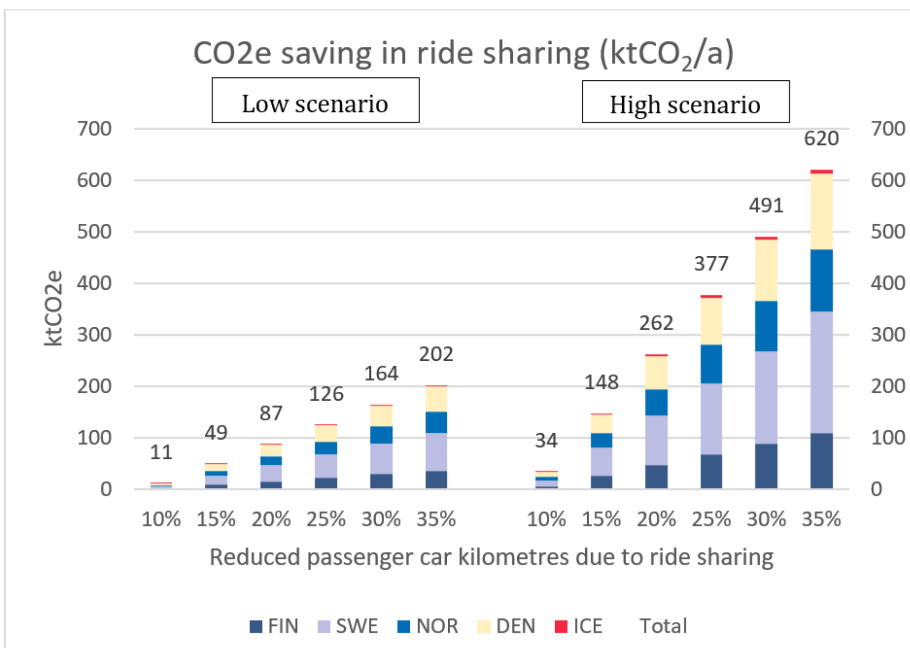
reduction for all Nordic countries is estimated around 3 000 million kilometers in a year and the reduction of other air pollutants around 2,5–17,8 kt/year.

3.2 Ride sharing

According to previous estimations and experience from ride sharing services, the potential of ride sharing to reduce VKT varies significantly according to the nature and type of service. Ride sharing can replace the use of buses, taxis and/or passenger cars. The VKT reduction potential is estimated to be between 10–60% (see also Chapter 2.2.)

Our analysis focused on commuting ride sharing potential, perhaps the most obvious type of shared ride target. The analysis included two scenarios, low and high, corresponding to 5% and 15 % of car owners switching to ride sharing. As a result, the overall use of private cars in commuting VKT is also reduced. The current share of all commuting done by private car lies between 77,5–82,5% in the Nordic countries. Figure 7 shows the CO2e reduction potential for the two scenarios, assuming that VKT reduction is between 10–35% (range that was estimated in section 2.2.1).

Figure 7: CO2e saving potential in ride sharing



Based on these assumptions, the scenarios indicate that ride sharing has the potential to reduce CO_2e emissions between 0,2–10,7%, as compared to baseline. The average length of commuting trips is quite similar in all Nordic countries (11,2–14,95 km/person/day). Therefore, the overall national emission reduction potential depends on the number of commuters, which in turn is related to population, and hence highest in Sweden.

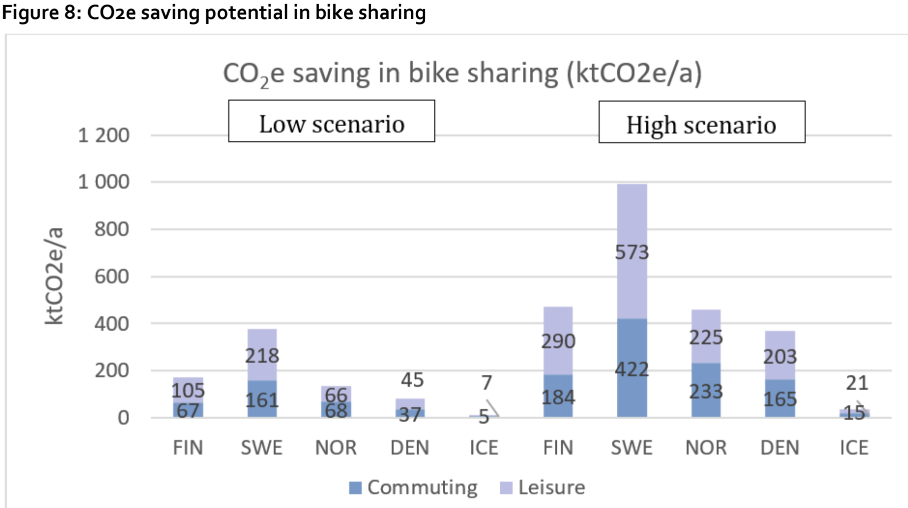
The VKT reduction potential for cars was estimated as 328–1 147 km/year in the low scenario and 983–3 441 km/year in the high scenario. The large variation is due to the wide range of reduced passenger kilometer (10–35%). The corresponding potential reduction of other air pollutants is between 0,1–1,0 kt/year in the low scenario and 0,2–3,1 kt/year in the high scenario.

3.3 Bike sharing

For bike sharing, there are no comprehensive studies or benchmark on the CO_2e emission or VKT reduction potential. Both reduction potentials depend on the type of transportation bike sharing replaces. Bikes are used for relatively short distances and therefore most likely replace transportation used for commuting and short leisure related trips.

In this analysis, we created two scenarios in which bike sharing replaces the use of buses and cars with a 50/50 ratio in both commuting and leisure related trips. In the high scenario, bike/walk reaches a 15% share of all transportation. In the low scenario, the bike/walk total share is 8%. By comparison, the current share of bike/walk in the Nordic countries is 3,7–6,0% of all transportation. The results of the analysis are shown below in Figure 8.

Figure 8: CO2e saving potential in bike sharing



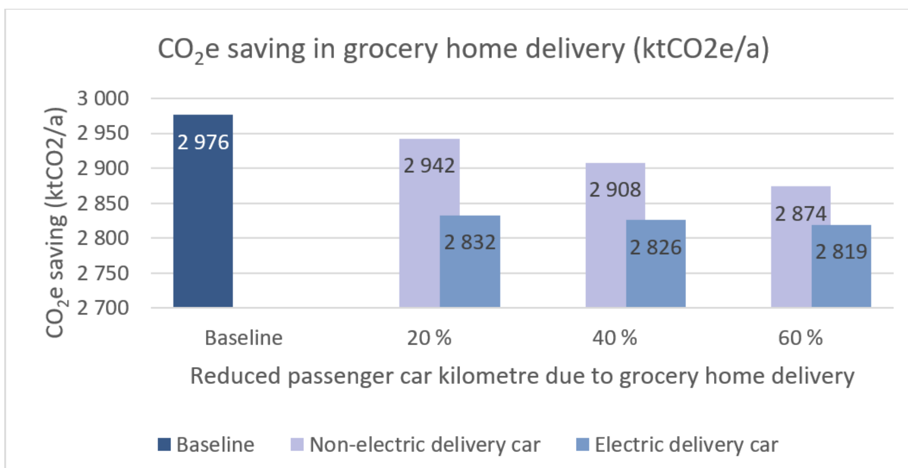
The estimated CO2e saving potential for bike sharing is 3,2–9,7% (low /high scenarios). The potential is relatively high in comparison with other MaaS services. This is mostly due to the versatility of bike sharing, as it can replace work related as well as leisure related trips. However, the most important reason for reduced CO2e emissions is that bike sharing substitutes motorized transport entirely.

The length of work-related trips varies in the Nordic countries between 11,2–14,95 km/person/day and the length of leisure related trips between 14,2–19,0 km/person/day. CO_2e saving potential and VKT reduction potential are calculated based on these figures. The total VKT reduction potential was estimated at 3 371–9 921 million kilometers/year in the low and high scenarios. The corresponding reduction potential for other air pollutants is around 3,9–11,8 kt/year.

3.4 Grocery home deliveries

Grocery home delivery is estimated to have a 17–87% GHG reduction potential and up to 92% reduction potential in VKT (Siikavirta et al, 2008). In the quantitative analysis the VKT reduction potential was estimated more modestly between 20–60%. Like with the other MaaS services, the analysis included two scenarios. In the low scenario, 5% of persons with own cars choose grocery home delivery and in the high scenario, 15% of persons with own cars choose home delivery.

Figure 9: CO2e saving potential in grocery home delivery

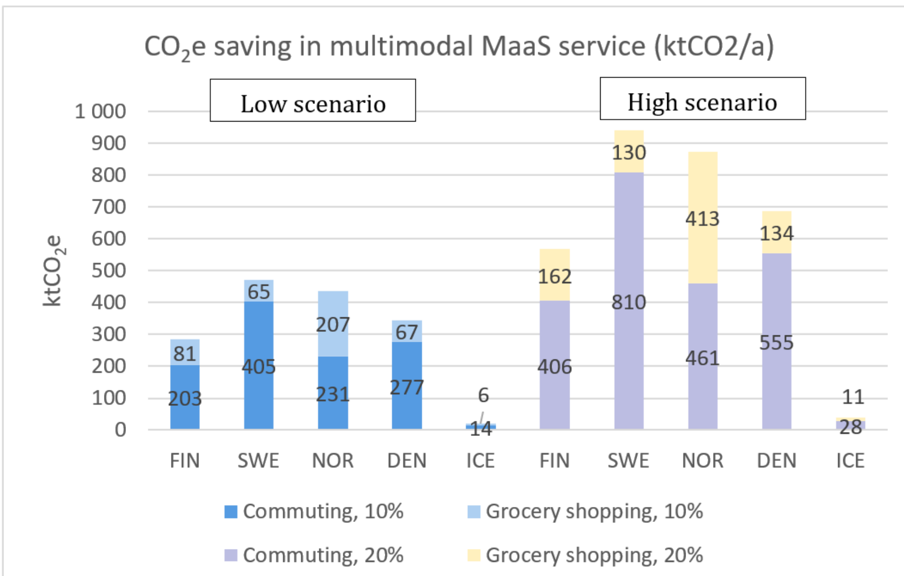


As with car sharing, also in grocery home delivery, the CO2e saving potential depends on whether the delivery car is fully electric, hybrid or traditional non-electric car. Above in Figure 8 the CO2e saving potential is shown for both non-electric and fully electric delivery cars. The shown example is for the low scenario (5% of grocery home delivery) and for three cases in which the reduced kilometers vary from 20% to 60%. For non-electric cars the amount of reduced kilometers has a greater impact since every driven kilometer generates more emissions. The overall CO2e reduction potential for grocery home delivery is estimated around 50–694 ktCO2e/year, which is 1,7–23,2% compared to baseline. The total potential VKT reduction was estimated in the two scenarios between 324–2 919 million kilometers in a year and the reduction of other air pollutants around 0,3–3,5 kt/year.

3.5 Multimodal mobility services (MaaS)

Multimodal MaaS services can include a variety of different MaaS service types and combine them in many ways. For the quantitative analysis an example case of multimodal MaaS service was created. The example case includes a ride sharing service for commuting trips (for 50% of the total trip) combined with a grocery home delivery service. Again, two scenarios were analyzed. In the high scenario 20% choose a multimodal MaaS service both in commuting and in grocery shopping, reducing the use of private cars with the same amount. In the low scenario, 10% choose a multimodal MaaS service. The CO_2e saving potential and VKT reduction potential are generated the same way as was described earlier in the corresponding chapters.

Figure 10: CO2e saving potential in multimodal MaaS service



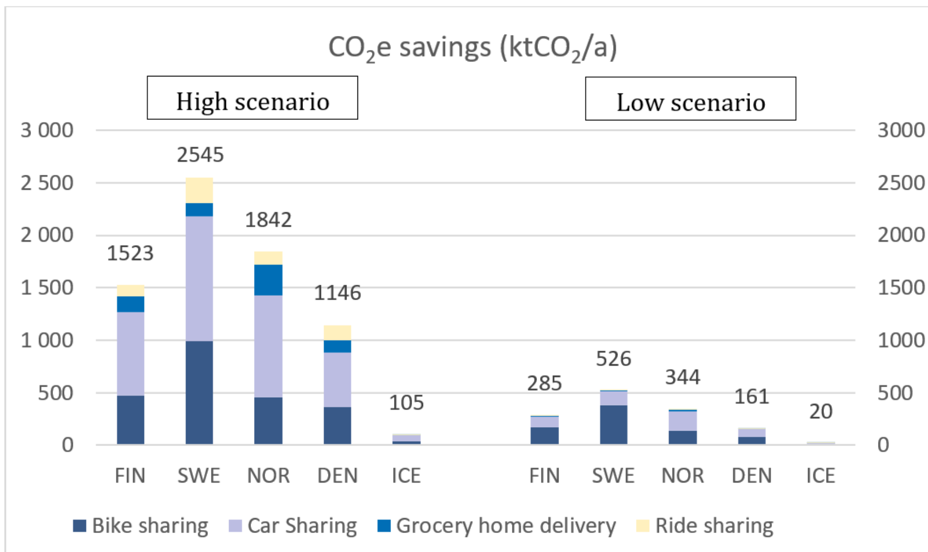
In this case, the overall CO2e saving potential (1 562–3 123 ktCO2e/year or 9,2–18,4%) is a combination of previously shown potential of ride sharing and grocery home delivery. Figure 9 shows that the different countries can benefit from different services. In Sweden for example the average length of a shopping trip is only 4,0 km/person/day as in Norway the same number is 17,46 km/person/day.[60] Another factor that influences the overall CO2e reduction potential is naturally the number of travelers. The total potential reduction in VKT for cars was estimated as between 8 630–17 261 million kilometers in a year, and the reduction of other air pollutants at 7,9–15,8 kt/year. It's important to notice that this is a combination of the other MaaS services and therefore the benefits can't be added to the ones defined for other services.

[60] It's important to note that the countries may have different ways of determining the trips.

3.6 Overall CO_2e saving and VKT reduction potential

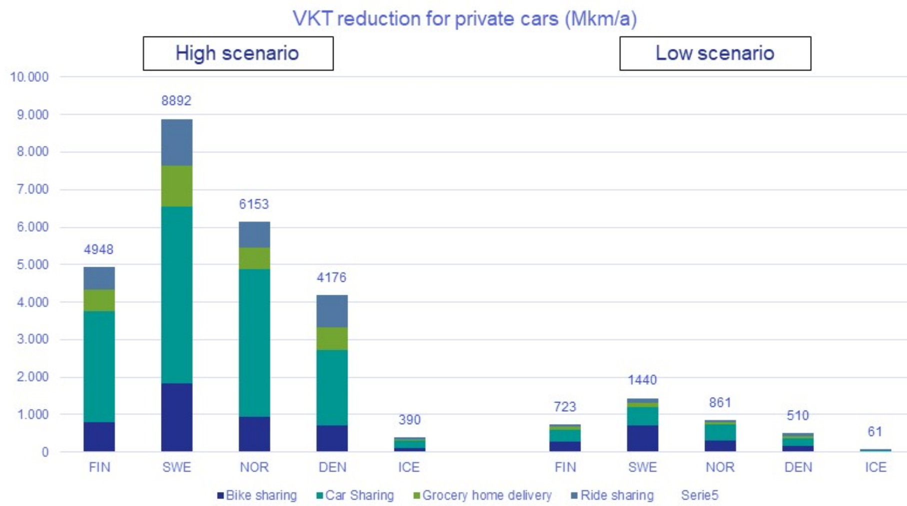
The overall CO2e saving potential for car sharing, ride sharing, bike sharing and grocery home delivery in the Nordic countries is shown in Figure 11. The overall saving potential was estimated between 1 337–7 161 ktCO2e/year in the low and high scenarios, which is 1,3–7,2% compared to baseline. The estimated highest CO2e saving potential in all countries was for bike sharing and car sharing, combined this represented 82% of all savings in the high scenario and 95% in the low scenario.

Figure 11: Overall CO2e saving potential of the MaaS services



The overall VKT reduction potential for the MaaS services in the Nordic countries is shown in Figure 12. The estimated overall potential was between 3 595–24 558 million VKT/year in the low and high scenarios. The reduced kilometers align with the CO2e saving potential in all countries. By comparison, the VKT reduction estimate for Finland would be 10,9% of the VKT with private cars in traffic (high scenario).

Figure 12: Overall VKT reduction potential of the MaaS services



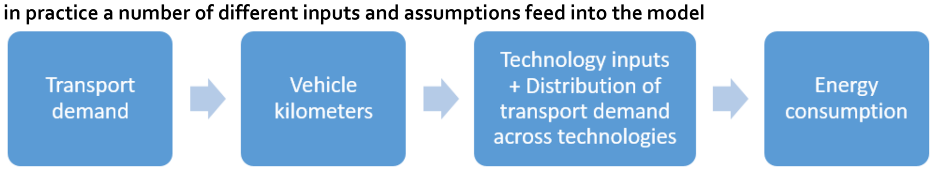
Finally, other air pollutants are also reduced due to digitized MaaS services. In the high scenario the potential of reduced air pollutants were estimated at 36 kt/year and in the low scenario at 7 kt/year in all Nordic countries. Other air pollutants include CO, HC, NOx, PM and SO2.

4. Modelling emission reduction potential from passenger transport

4.1 Reference Scenario

The scenario work employed the spreadsheet model PETRA, which is based on a number of inputs and assumptions, and projects the development path for road transport energy consumption, CO_2 emissions and total costs. It is a fleet model, in that it models the energy demand of each vehicle year over vehicle lifetime. The overall method utilized in PETRA is illustrated in Figure 13.

Figure 13: Overall methodology utilised in the PETRA model. Please note that this is a simplification, as in practice a number of different inputs and assumptions feed into the model



The PETRA model and scenario assumptions are described in greater detail in a separate working paper,[61] but the main elements include:

- Vehicle lifetimes follow a "lifetime curve", which describes what percentage of a model year is "alive" after X number of years.
- An age-dependent driving factor is implemented that factors into account that as vehicles age, they drive less km.
- The model incorporates an efficiency factor that adjusts for the fact that a vehicle's energy consumption per kilometer driven increases with the age of the vehicle.

4.1.1 *Methodology*

In order to assess the potential impact of MaaS, a reference scenario up to 2050 has been established for each of the Nordic countries. This can be regarded as an anticipated policy and technology scenario, where the following parameters were modelled given their anticipated development trajectories:

[61] Ea Energianalyse. (2015). Scenarieforudsætninger og modelbeskrivelse. København: Ea Energianalyse.

- Passenger vehicle fleet evolution for each country, including fleet composition (i.e. % of new vehicles that are EV, PHEV, gasoline, electric), vehicle efficiency, vehicle weight, % of km driven in electric mode in PHEVs, and battery sizes, cost and weight.
- CO_2 emissions from electricity and battery production
- Passenger transport activity for each country
- Biofuel usage for each country

While the above parameters are modelled under an anticipated development approach, the reference scenario is designed to allow for an impact assessment of varying degrees of MaaS implementation, and therefore involves a BAU approach in terms of each country's deployment of MaaS.

4.1.2 Key parameters and assumptions

Evolution of vehicle fleet

The most important factor in terms of impact on CO_2 and other emissions is the composition of the vehicle fleet. In addition to the above-mentioned PETRA model, Ea Energy Analyses has developed a vehicle transport model for use in analyzing future transport vehicle trends and cost developments. These analyses found that from a socioeconomic perspective, i.e. when all costs associated with vehicle ownership and use are incorporated, it is most likely that EVs and/or PHEVs will become cheaper than their gasoline and diesel counterparts before 2030, and perhaps prior to 2025.[62] [63] It is assumed that this socioeconomic tipping point will translate to a private end-user cost tipping point in the early to mid-2020s, thus driving EV and PHEV growth from this time period and accelerating through to 2050. Norway represents the most well-known example in this regard, because as soon as it was cost-effective to select an EV or PHEV over an ICE vehicle (both monetarily, but also incorporating other privileges related to parking and utilization of bus lanes), sales of electric drive vehicles grew rapidly.

Based on the assumption that it will be cost-effective for the majority of consumers to elect a PHEV or EV by 2040, it becomes more a question of how quickly this shift to electric vehicles will occur in each of the 5 Nordic countries. The future scenario assumptions therefore take their point of departure in the current distribution of new passenger vehicle sales and converge to a situation in 2040 that is dominated by electric vehicle sales. Some countries are already well on their way (Norway), so they are assumed to have higher electric vehicle penetration rates in 2030. In the longer term, it is assumed that a continuing fall in battery prices and increased energy density will result in the majority of commuters being able to rely on an EV for their driving needs, while larger geographic countries (Sweden, Norway, Finland) are assumed to rely on

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[62] Ea Energy Analyses. (2016). Green Roadmap 2030. Copenhagen: Ea Energy Analyses.

[63] Ea Energy Analyses. (2017). Green Transport Roadmap - 30% CO_2 reduction in EU road transport towards 2030. Copenhagen: Ea Energy Analyses, The Ecologocial Council, Energifonden.

PHEVs more than Denmark. Lastly, hydrogen and gas vehicles are assumed to have a limited role in the passenger vehicle segment, though they may play a more prominent role in the heavy transport sector.

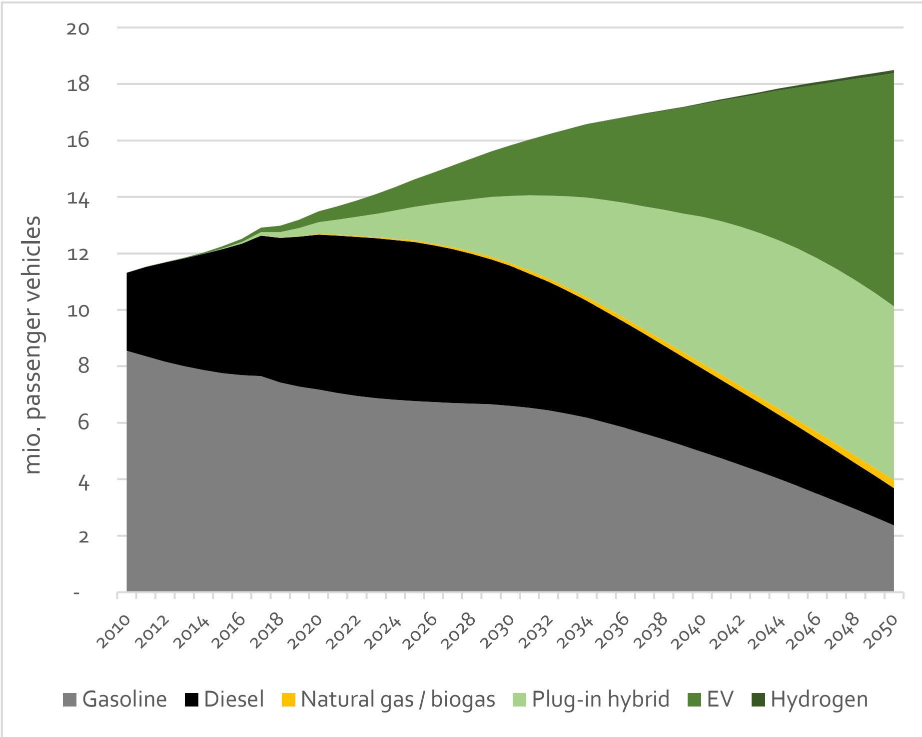
The historic development in new passenger vehicle sales (in %) for each country from 2014–2017, and assumed developments towards 2050, are displayed in Table 5.

Table 5: Historic development in new passenger vehicle sales (in %) from 2014–2018 and assumed developments towards 2050

	2014	2015	2016	2017	2018	2030	2040	2050
Denmark								
Gasoline	67	70	64	65	63	47	18	-
Diesel	32	28	36	35	35	18	10	-
Natural gas	0	0	0	-	-	-	1	2
Plug-in hybrid	0	0	0	0	1	20	40	21
EV	1	2	1	0	0	15	30	75
Hydrogen	-	-	-	-	-	-	1	2
Finland								
Gasoline	61	65	67	67	66	39	17	-
Diesel	38	35	32	30	29	15	10	-
Natural gas	0	0	0	-	1	1	2	3
Plug-in hybrid	0	0	1	2	4	25	40	25
EV	0	0	0	0	0	20	30	70
Hydrogen	-	-	-	-	-	-	1	2
Iceland								
Gasoline	44	44	46	40	41	38	17	-
Diesel	54	51	45	44	43	20	10	-
Natural gas	0	2	2	2	1	2	2	3
Plug-in hybrid	0	1	4	10	12	30	40	25
EV	2	3	2	4	3	10	30	70
Hydrogen	-	-	-	-	-	-	1	2
Norway								
Gasoline	33	32	34	29	25	15	9	-
Diesel	54	46	37	32	30	10	5	-
Natural gas	-	-	0	-	-	-	-	-
Plug-in hybrid	1	5	13	18	20	35	40	29
EV	13	17	16	21	26	40	45	70
Hydrogen	-	-	-	-	-	-	1	1
Sweden								
Gasoline	38	39	44	45	46	38	17	-
Diesel	58	57	52	49	47	20	10	-
Natural gas	2	1	1	1	1	2	2	3
Plug-in hybrid	1	2	3	4	5	30	40	25
EV	0	1	1	1	1	10	30	70
Hydrogen	-	-	-	-	-	-	1	2

Given the assumed new vehicle sales figures from Figure 14, and assumed vehicle lifetimes, the resulting evolution of the vehicle fleet for the 5 Nordic countries is displayed below.

Figure 14: Evolution in passenger vehicle fleet in the 5 Nordic countries in the Reference scenario



Passenger transport activity

The historic passenger transport activity figures have been collected from the various countries' government websites (i.e. Statistics Norway, Statistics Sweden, etc.) and these have been combined with the growth factors utilized in IEA's Nordic Energy Technology Perspectives 2016 4DS to produce the future assumed passenger transport activity values for each country.[64]

Table 6: Assumed passenger transport activity in the reference scenario (billion pkm) (IEA, 2016)

	2010	2015	2020	2025	2030	2035	2040	2045	2050
Denmark	50	55	59	62	66	70	72	76	79
Finland	65	66	68	71	74	76	78	80	81
Iceland	4	4	4	5	5	5	6	6	6
Norway	59	65	67	71	75	78	81	83	85
Sweden	108	112	115	121	127	131	134	138	142

Other scenario parameters

In modelling the entire passenger vehicle fleet there is an extensive list of assumptions that drive the analysis. The most vital remaining assumptions in developing the Reference scenario are listed in the table below.

[64] IEA. (2016). Nordic Energy Technology Perspectives 2016. Paris / Oslo: OECD/IEA, Nordic Energy Research.

Table 7: Additional relevant scenario parameters

Parameter	Methodology and rationale
Passenger vehicle weights	Separate weights for each vehicle category, in each country. Historic data inputs from European Environment Agency and the European Alternative Fuels Observatory Become lighter over the analysis period – driven by EU legislation
Motor efficiency	Slightly increasing over the analysis period – driven by EU legislation
Battery related	Batteries are expected to continue to become cheaper and increasingly energy dense, thus allowing for an extended electric range without rising costs. As PHEV batteries increase in capacity, it is anticipated that a growing % of km driven by PHEV will occur in all electric mode. CO_2 emissions associated with the production of batteries are included and are spread out over the anticipated lifetime of the battery on a gram CO_2 per km driven basis.[65]
CO_2 content of electricity	2016 average CO_2 contents of electricity are based on IEA's Energy System Overview's for each country.[66] Country-specific targets for the electricity sector are then applied to determine future evolutions for each country (i.e. Denmark's target of being able to supply 100% of its electricity demand via renewables by 2030)
Biofuel	The maximum amount that may be used for each country is based on the total biofuel usage in the IEA's Nordic Energy Technology Perspectives 2016 – 4DS Scenario As per EU legislation, liquid biofuels are assumed to have CO_2 reduction of 60% by 2020, and this is assumed to grow to 80% by 2050. Biogas is assumed to have a CO_2 reduction of 100% due to positive climate effects associated with its production.

The resulting evolution in energy demand for road passenger transport is displayed in the figure below.

[65] This calculation takes into account the assumed: CO_2 emissions per kWh of battery produced, size of the battery in each vehicle, expected battery life (expressed in km).
[66] IEA. (2018a). Denmark - Energy System Overview. Retrieved from IEA: https://www.iea.org/media/countries/Denmark.pdf; IEA. (2018b). Sweden - Energy System Overview. Retrieved from IEA: https://www.iea.org/media/countries/Sweden.pdf ; IEA. (2018c). Norway - Energy System Overview. Retrieved from IEA: https://www.iea.org/media/countries/Norway.pdf; IEA. (2018d). Finland - Energy System Overview. Retrieved from IEA: https://www.iea.org/media/countries/Finland.pdf

Figure 15: Development in energy demand from road passenger transport in the 5 Nordic countries in the Reference scenario

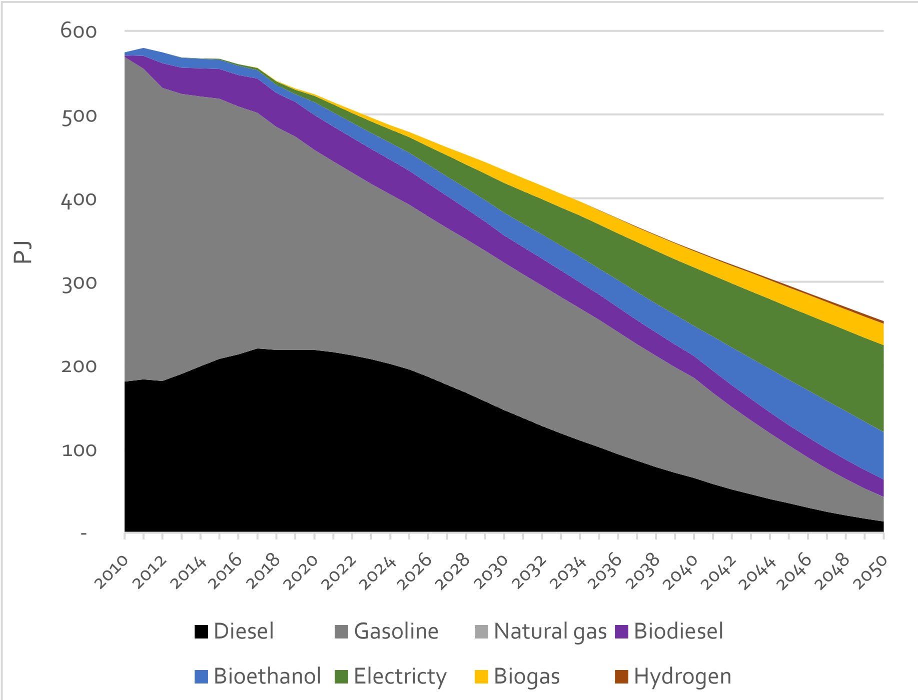


Figure 15 illustrates the large fall in energy demand that is expected to occur throughout the scenario period. Despite an anticipated increase in passenger transport work, this is possible due to the assumed increase in electrification, with electric drive vehicles being roughly 3 times more efficient than their ICE counterparts.

4.2 GHG emission reduction potential of reduced traffic work

4.2.1 Methodology

Utilizing the PETRA and vehicle transport models outlined above, the GHG emission reduction potential of reduced traffic work is estimated. Given estimated lower traffic work figures based on the findings from the previous chapter, two alternative scenarios to the reference scenario have been established. One is a low MaaS implementation (i.e. slightly less transport work relative to the reference scenario), while the other is a higher MaaS implementation scenario.

Table 8: Assumed reduction in transport activity relative to the reference scenario (%)

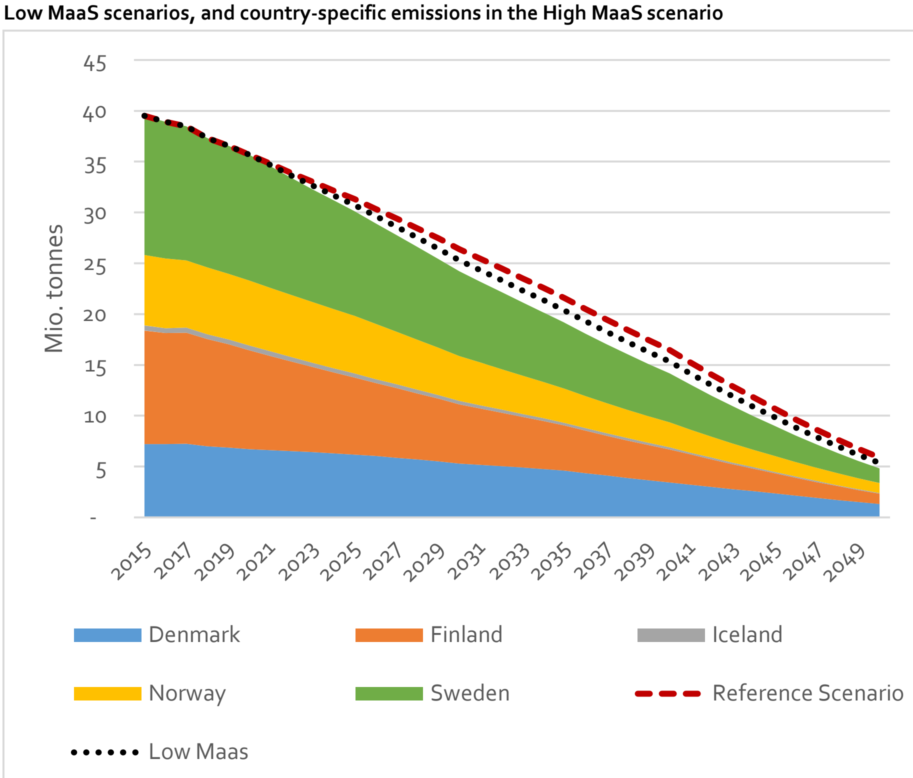
Scenario	2020	2030	2040	2050
Low MaaS	0%	5%	7.5%	10%
High MaaS	0%	10%	15%	20%

These two scenarios solely investigate the impact of less transport work, i.e. less personal transport km, while elements such as shifts from own personal transport to public transport (for example as a result of reduced car ownership) will be discussed in the following section.

4.2.2 Results

Figure 16 displays the total CO2 emissions from the 5 Nordic countries in the Reference and Low MaaS scenarios, as well as the country-specific emissions in the High MaaS scenario.

Figure 16: Total passenger transport CO2 emissions from the 5 Nordic countries in the Reference and Low MaaS scenarios, and country-specific emissions in the High MaaS scenario



In reviewing the figure, it is interesting to note that while the % reduction in transport work is phased in gradually, and therefore greatest at the end of the period, the largest total CO_2 emission reductions are realized much earlier in the period. The table below zooms in on particular years to highlight this point.

Table 9: CO_2 emissions from passenger transport in the Reference and low and high MaaS scenarios resulting in reduced transport demand (mio. tonnes)

Scenario	2020	2030	2040	2050
Reference	35.7	26.4	16.5	5.9
Reduction Low MaaS	-	1.09	1.15	0.53
Reduction High MaaS	-	2.19	2.30	1.06

The CO_2 emission reductions realized in 2030 due to reduced passenger transport work is almost the same as that in 2040, despite the fact that the overall transport work in 2040 is higher (recall Table 7), and the assumed reduction in transport activity in 2040 is 50% higher in 2040 relative to 2030 (Table 9). This is primarily due to the fact that the passenger transport sector becomes increasingly electrified over the scenario period, and as such the personal transport sector becomes less CO_2 intensive. This leads to a relevant observation, namely that implementing MaaS sooner rather than later is more CO_2 effective. This is for example the opposite with EVs, which will have a much larger CO_2 effect in later years as the CO_2 emission intensity of electricity falls.

4.3 GHG emission reduction potential of reduced car ownership

The second GHG emission reduction potential aspect investigated via the two transport models was the effect of reduced car ownership. Reduced car ownership does not automatically mean reduced emissions, as emissions are affected by the transport needs and choices of the individual. Reduction in car ownership may lead to emission reductions if the total kilometers travelled is reduced (as was outlined above), if ride sharing is thereby increased, and/or vehicles with lower emissions are utilized. Prerequisites for reduced car ownership are competitive public transport services and/or other mobility services, or reduction of transport needs (e.g. due to digitized services, spatial planning supporting e.g. walking-and cycling routes). The reduction potential of vehicle kilometers due to reduced car ownership was assessed by estimating the potential users of multimodal transport services in each country.

4.3.1 Methodology

It is assumed that reducing car ownership will result in a change in CO_2 emissions due to the following elements:

- A shift from one form of transport, i.e. driving in a vehicle, to for example taking the bus, train, or carpooling.

- Less passenger vehicle km due to the additional "hassle factor', i.e. with the car no longer being in the garage a former vehicle owner may be less likely to take a weekend drive to the country (renting a vehicle for this purpose has a much higher marginal cost than simply using their own vehicle previously).
- Average km driven per vehicle per year may increase as a result of ride sharing, etc. This would result in vehicles reaching their end of life sooner, and therefore a quicker turnover of the passenger vehicle fleet. This will result in lower emissions as vehicles are continually becoming more efficient.

In order to simulate the effects of reduced car ownership it is therefore necessary to make assumptions regarding how the transport work that would have been undertaken with the vehicle will now take place. Based on inputs from the analysis described in the previous chapter, the table below displays the assumptions utilized in the analysis assuming a 10% reduction in car ownership.

Table 10: Assumed reduction in transport activity relative to the reference scenario (%)

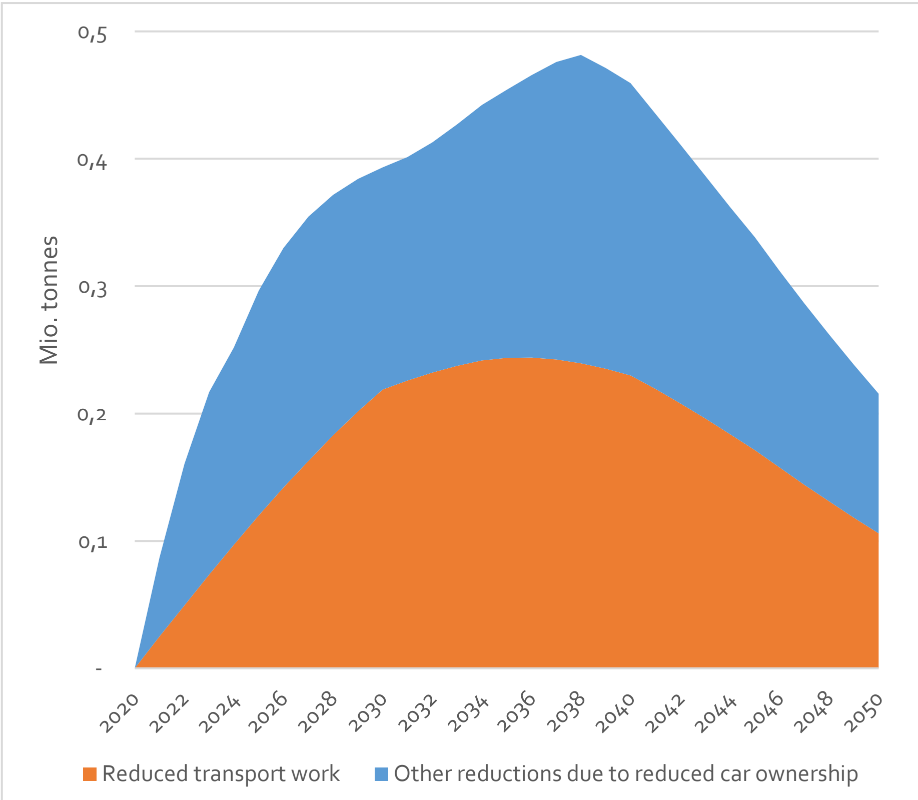
Alternative	% of previous transport work	Model implementation (with 10% reduction in vehicle ownership)
Walk, cycle, or reduced transport	20%	Reduce assumed passenger transport activity by 2%
Car share, ride sharing, ride hailing or utilization other family vehicle	40%	Increase assumed persons per car by 1%, and increase the vehicle weight accordingly[67] Increase annual assumed km driven per vehicle by 3%, and reduce the average lifetime of vehicle accordingly (3%)
Increased use of public transport	40%	Increase the passenger weight in the modelled public transport

4.3.2 Results

The anticipated results of a 10% reduction in vehicle ownership, given the assumptions outlined above are displayed in Figure 16. In order to isolate the effects of the 2nd and 3rd categories outlined in the table above (i.e. car share, ride hailing, increased use of public transport), the assumed 2% reduction in passenger transport activity that is brought about by a 10% reduction in vehicle ownership is displayed separately.

[67] Each 1% increase in vehicle weight results in roughly 0.7% increased energy demand.

Figure 17: Reduction in CO_2 emissions from road passenger transport in the 5 Nordic countries due to a 10% reduction in vehicle ownership rates



The figure illustrates that 10% reduction in vehicle ownership could lead to annual emission reductions, peaking close to half a million tonnes annually, with roughly half of this due to a reduction in transport work.

4.4 GHG emission reduction potential of better environmental performance of vehicles

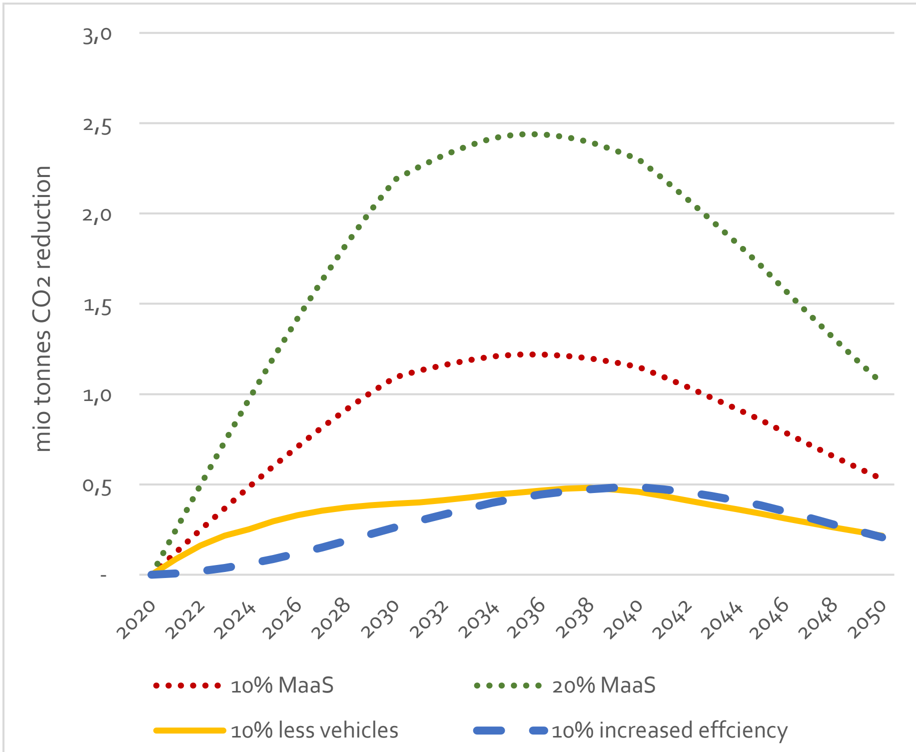
4.4.1 *Methodology*

It is interesting to compare the CO_2 emissions results from MaaS activities with other passenger transport emission reduction options. Therefore, an alternative scenario has been established that increases the vehicle efficiency of each vehicle type by 10% in 2030, relative to the reference scenario (i.e. higher efficiencies starting at 0% higher in 2020 growing to 10% higher by 2030 and maintaining this 10% higher efficiency through to 2050.)

4.4.2 *Results*

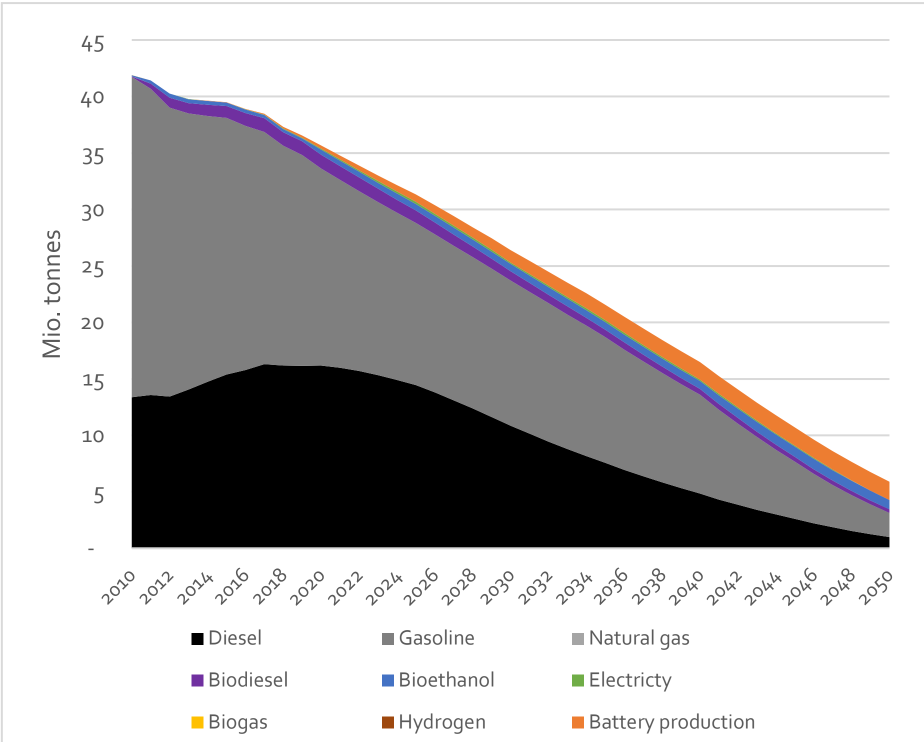
The figure below displays the CO_2 emission reductions associated with the phasing in of a 10% efficiency increase for each vehicle type (dotted blue line), and compares with this with the other scenarios described previously.

Figure 18: Reduction in CO2 emissions from road passenger transport in the 5 Nordic countries due to a 10% reduction in vehicle ownership rates compared with the other low MaaS, high MaaS, and reduced car ownership scenarios



On first glance it may seem counterintuitive that a 10% efficiency gain does not result in greater CO2 emission reductions relative to the other scenarios, however there are a few reasons for this. Firstly, the MaaS scenarios apply to all vehicles within the car fleet when it is implemented, whereas the increased efficiency only applies to new vehicles, in a phased in manner, starting in 2021. It therefore takes quite a few years before these affects can be felt by a large part of the car park. This also links to the 2nd portion of the explanation, and that is that by the time the efficiency improvements really become entrenched, the car park as a whole has become quite efficient and low CO_2 intensive due to the wide-spread electrification, combined with the very low CO_2 content of electricity in the Nordics. The figure below depicting the CO2 emissions from road passenger transport in the Nordics according to fuel clearly illustrates this diminishing role and effect of gasoline and diesel, while also highlight the extremely low CO2 content of electricity in the Nordics, which despite representing a portion of the energy supply (recall green portion of Figure 14), is nearly imperceptible in Figure 18.

Figure 19: CO_2 emissions from road passenger transport in the Nordics according to fuel. Battery production entails the additional CO_2 emissions associated with producing batteries, which are spread out over the lifetime of the battery



5. Barriers to developing a transport efficient society

The development of a transport efficient society is a key goal for many Nordic cities where smart city programs include sustainable transport. Both the public and private domain has seen a rapid development of different types of mobility services and service platforms. There are still many obstacles to overcome before transition to using mobility services (MaaS) and a society where private car ownership no longer is a necessity. The obstacles can be related to customer needs and service levels or social and behavioral aspects. They can also be related to financial incentives and cost structures, or they can be purely legal. The collaboration between private and public service providers is also a key element, as high-quality public transport will be the backbone of MaaS services in the Nordic countries (at least in cities). The following sections highlight some obstacles to development that have been identified in stakeholder interviews and in the desk study.

5.1 Customer needs and service levels

MaaS services compete with the use of other modes of transport, the most important being private car ownership. Currently car ownership is extensive and car use is perceived as relatively cheap, convenient and flexible. To abandon private car use for commuting and other transport needs, the user needs to have a good alternative that would provide added value and a service level that meets the individual transport needs.

The possibility to use MaaS services,[68] in the Nordic countries, which is usually a combination of public transport and other mobility services, is dependent on the individual transport needs and transport use cases. Even if public transport modes in the Nordic cities are widely used and are of high quality, the current mobility services fail to meet the user's needs in many cases. The starting point in planning services needs to be the life of the user, whether single, family or couple, and understanding that many differing transport needs need to be covered (e.g. commuting, transporting things, going overseas, going to hobbies, taking children to school and hobbies and running other errands). MaaS services need to have the same flexibility and security as private car use.

[68] By MaaS services we refer to all the transport modes (physical and digital services) which can be used through a MaaS app. These include e.g. car sharing, public transport and bike sharing.

Families with children were in the interviews specifically mentioned as not having their needs met by public transport services or multimodal services. Multiple places to commute to with time constraints are difficult to combine conveniently and flexibly with MaaS services. The time aspect is crucial – people are not willing to spend an extra hour daily on commuting due to using public transport and MaaS services. Costs figure in – if parking costs and road tolls punish users enough, people might reach the tipping point and abandon car use, despite the inconvenience.

Some interviewees felt that to create successful multimodal or MaaS services, the service levels need to be even superior to using private cars for commuting. There needs to be an added value or perks to using these services. One interviewee mentioned that even providing free public transport will not necessarily (as has been tested in Tallinn) lead to the abandonment of private car use.

Thus, convenience and service levels are key to developing transport efficiency. Convenience and service levels are partly dependent of fleet size (ride sharing, car sharing, bike sharing) and location. To provide the necessary service levels in car- or bike – sharing, the number of cars or bikes provided needs to meet demand and needs to guarantee the needed flexibility.

Good service levels can be provided in dense city areas near public transport hubs such as subways or train stations, but not necessarily in suburbs or rural areas. It may never be financially viable to have a car sharing fleet that is of a high enough density to meet suburban or rural needs. Presently many people do not consider the service levels of car sharing, or even bike sharing, to be good enough to make it possible to abandon private cars for last mile use in the suburbs.[69]

The location of shared cars or bikes needs to be close to demand, near the main transport hubs, and the means of transport needs to be available where and when needed. The main hubs by train stations or bus stations may well be easy to provide for, but services also need to exist at the other end of the commute. One barrier to providing a sufficiently dense fleet can be the lack of affordable parking spaces near the hubs or in cities in general. In Sweden, the DriveNow car sharing has had problems getting enough affordable parking spaces near transport hubs. The city of Stockholm felt that these spaces could not be allocated to the car sharing service in a "discriminatory way". In the suburbs, outside the dense city areas, a sufficiently dense network of shared cars or bikes can be expensive to maintain. Outside dense urban areas the private car will probably for some time continue to be a viable option, because providing good levels of shared services would simply be too expensive. Car ownership is attractive for many people, especially people living outside of city, in suburbs and in rural areas where it is very difficult to switch to mobility services.[70]

Ride sharing involves a demand meeting supply challenge. There needs to be a very large mass of users to overcome this barrier. The needs for place and time need to

[69] Interview Norway

[70] Interview Norway

converge for different users. In Norway these types of services are mainly used by students for longer distance travel to rural areas.[71]

Weather has been mentioned as a key factor impacting the use of MaaS. People do not want to wait outside in the rain or snow or cold for public transport or between modes of transport. Even waiting 15–20 minutes is considered being too much for the ordinary commuter.[72] For biking, the season is relatively limited because of Nordic weather constraints.

5.2 Behavioral and social barriers

Some barriers to using MaaS services are the subjective feelings associated with car ownership and use. The car offers a high level of convenience and flexibility that people value. The feeling of freedom and even the sense of exhilaration that some experience while driving offers additional added value.[73] A certain status is still attached to owning a car. There is still the ingrained idea that if you have a good job and are getting established in your life, a natural next step is owning a car. This idea has slowly been changing. One interviewee also mentioned that some, in particular perhaps older men, appear to have an emotional attachment to their car – such persons are unlikely to consider abandoning car ownership. As some interviewees pointed out, the best group of customers to approach when promoting Maas services are current public transports users, especially when testing services. However, the main target of MaaS services should be private car owners.

Another important aspect is the lack of privacy in ride sharing. Many people value the privacy of being in their own car while commuting. When considering ride sharing, people feel that a taxi can be shared, but not a private car, where there could be an element of communicating with strangers.[74] Security issues can also be important for people. The services need to be and feel safe, especially when transporting minors or other vulnerable customers.

5.3 Financial barriers

The investment in car ownership that has already been made is one of the greatest barriers for growth of car or ride sharing services. A car, once acquired, is perceived as a cheap means of transport when used on a day to day basis. There are, however, many hidden costs in owning and using a car, not necessarily perceived by the users as such. This includes investment costs and parking payments, which can be substantial in cities, and can be embedded as apart of e.g. rental or living expenses, or are expenses paid by

[71] Interview.
[72] Stakeholder interview Iceland
[73] Source stakeholder interview
[74] Several stakeholder interviews

employers. Other hidden costs include e.g. car insurance as well as service and maintenance costs. The price of using a car also doesn't necessarily consider externalities such as particle emissions, noise, CO_2 emissions or cost of accidents. Additionally, in the Nordic countries, a car is kept in use for at least 10–15 years, which means that the natural attrition is slow. Hence a natural transition of current car users to mobility services can be incremental and relatively slow. The high subsidies for electric vehicles (EV:s) in Norway promote private car use at the expense of public transport. Even though EV adoption for private commuting leads to more sustainable transport, it is not necessarily leading to the rapid development of MaaS services. MaaS services using EV:s would in many cases be a better solution than private EV ownership.

In the Nordic countries, economic barriers are especially important. There are certain tax benefits that exist for private car ownership and use. Mobility services, such as car- or ride sharing, do not come with the same tax benefits. One such example is the company car benefit.[75] Providing a company car (car benefit included in employment contract) is a common obstacle for using other modes of transports and is currently a driver for maximizing the use of the private car.[76] Another company benefit is free parking spaces at the office which promote own car use.

Some employers offer free public transport passes for their employees when they commute by public transport. Such passes may cover train or bus, if an employee lives in a suburban area and uses public transports. Often the employers/ employees can receive a tax reduction for the commuting cost. If an employee chooses to use private MaaS services instead of a public transport pass, the employee may not be able to obtain the same subsidy or tax reduction. To develop private mobility services, including last mile services such as car sharing etc. as a sustainable form of transports, some feel that it should receive the same subsidies or tax reductions as public transport modes. Government policy can thus in part define the business model of MaaS regarding public transport services and other services.[77]

However, another issue regarding the commuters' possible switch of from public transport to using MaaS, is that if commuters have used only public transport before, the switch could mean more emissions and vehicle kilometers. Therefore, switching from pure public transport use to MaaS services, which can include car use such as car- or ride sharing, is not a preferred option from the environmental point of view.

To create sustainable transport systems, and especially multimodal systems, the business models for MaaS providers and MaaS services[78] need to be viable. It must be possible to create services that are profitable. Several car sharing services in the Nordic countries have so far been unable to develop services profitably, especially outside larger cities. Profitable services require a large number of users as the margins are small. Another example is groceries home delivery, which has so far not been very successful at starting large scale services in the Nordics and especially not in rural areas

[75] Stakeholder interview Finland

[76] Stakeholder interview Finland

[77] Yanying Li, Tom Voege (2017). Mobility as a Service (MaaS): Challenges of Implementation and Policy Required

[78] By MaaS services we refer to the (physical and digital) transportation modes that can be used through a MaaS app.

or smaller cities.[79] One reason for this is that the grocery home delivery market is very price sensitive. One barrier to developing grocery home delivery services has been that large grocery chains in most Nordic countries dominate the market (oligopoly). They have a clear scale and price advantage compared with new entrants. The large chains in the Nordics have so far not developed their home delivery services very effectively – perhaps having a low incentive to do so – and the new entrants have difficulty keeping prices at a competitive level. Collecting groceries for home delivery is quite labor intensive. In some cases, it has been more feasible to deliver different wares separately instead of integrating them in the same delivery, leading to high transport emissions.[80]

5.4 Legal barriers

There are few purely legal limitations to developing Maas services in the Nordic countries. No legal barriers were mentioned for bike sharing. Some barriers have, however, been identified that impact other mobility services. One such barrier is taxi legislation, which in Norway limits unlicensed service providers from offering ride haling or sharing services, such as Uber, which is regarded as a taxi service. The new Finnish Act on transport services that came into force in July 2018 has removed one barrier to developing car sharing or ride sharing services.[81] The same type of process has been started in Denmark.[82]

However, regarding data sharing between MaaS operators, there could be legal barriers from the new EU General Data Protection Regulation (GDPR), which influences what personal data can be used and shared. Moreover, EU competition law also has a role to play in establishing a level-playing field, so that new monopolies in the area of mobility services can be avoided.[83]

Other legislative barriers have to do more with the indirect impacts. Firstly, the role of public transport providers can be limited by legislation to traditional public transport. Secondly, their role in the procurement of MaaS services, should they decide to procure these types of services, could in some cases restrict flexible and innovative ways to procure and develop services due to public procurement rules. [84]

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79 Stakeholder interview Norway
80 Interview Norway
81 Interview Norway.
82 Stakeholder consultation
83 MaaS Alliance (2018). Report from the 4th MaaS Summit.
84 Smith, Sochor *et al.* (2018). Public–private innovation: barriers in the case of mobility as a service in West Sweden

5.5 Open data and integrated service platforms

All types of mobility services are increasingly using mobile and application-based functions for presenting timetables, booking and payment of vehicles and rides. ICT-development has enabled a much better presentation of available transport services.[85]

Currently information about different Maas services is usually available on different platforms or applications, dedicated for one type of service. Information regarding public transport timetables and combinations as well as ticketing is often available from the same solution. One such example of public transport integration is Entur in Norway, which makes it possible to do travel planning and buy tickets for a trip using several modes of public transport. In most cases information about the services that private service providers offer is not integrated in the solutions/apps that provide information about public transport. This makes trip planning and buying multimodal services from end to end more difficult for the user.

The optimal solution would be to present information about the whole chain of transport services easily and conveniently. It should be possible to do travel planning, booking and buying all services from the same integrated app. Whim is one example of such a service. In general, this is not happening yet on a large scale, or including all different transport modes, which can in part limit the adoption of Maas services.

There are several reasons for this lack of integration of different services on shared platforms. The services are (with a few exceptions) relatively new. There is also competition regarding which will be the winning service platform or app where information on public transports and other private services, would be integrated. Some car hailing services, such as for instance Uber, do not want to share their data and prefer using their own platform. It is difficult for some service providers to give up data for the common good because of the fear of losing customers or control. The service providers do not realize that getting the public to use multimodal services would likely lead to increased use for different types of services.[86] Some interviewees felt that it may not be possible to integrate everything in one solution (app), as it would be difficult to provide a sufficiently high level of service in one single solution or to develop the services and the app in a flexible way.[87]

In the context of data sharing, the main issues are related to fairness and neutrality of the new MaaS ecosystem. Fairness in this context is not necessarily a question of profit, but more about the algorithms. From the transport service provider's point of view, the main question is whether they can trust that on a MaaS platform their services are displayed in a fair manner to the end users of the service.[88] An additional barrier is that some B2B agreements have special clauses that prevent reselling certain solutions.[89]

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[85] European MaaS Roadmap 2025, Deliverable Nr 2, March 2017
[86] Stakeholder interview Norway
[87] Stakeholder interview Norway
[88] MaaS Alliance (2018). Report from the 4th MaaS Summit.
[89] Stakeholder consultation

Access to data, including having open interfaces and possibilities to resell services, can also still be a problem when planning MaaS services and especially multimodal services. Most Nordic countries have opened up data for public and private stakeholders. Opening up data is beginning to make it possible to develop transport services and integrate different types of services. For instance, in Finland open data is in principle available, but not always in a technically feasible way that would make it possible to use it conveniently for service development. There still seems to be some issues regarding the practical usability of the data.[90]

5.6 Organizational barriers – Interaction between public transports and private operators

Open data and the use of ICT in urban services have been policies of many cities within the smart cities policy framework. In the transport service market, integration of data and payments from various transport modes is improving. Therefore, the foundation of implementation of MaaS exists in many cities. However, implementation of MaaS in a city may face some challenges. Public transport companies/providers often regard private MaaS services as competitors. Public transport is frequently subsidized by cities. If other private services make profits from its monthly subscriptions, it may reduce the profits made from sale of public transport tickets, which is seen as a risk by public transport service providers.[91]

Some studies have pointed out that public procurement is not very suitable for driving collaborative innovation. Negotiating private sector MaaS contracts brings additional challenges as the contracts would involve new products and services. The players in the transport ecosystem have very different ways of operating, which could create additional challenges when building cooperation between, for example, global enterprises, public transport service providers and local start-ups. An additional barrier can be the challenge of combining services multimodally. The unreliability of different modes could add up in intermodal trips leading to quality issues.[92]

Municipalities can influence mobility services development with urban planning. Urban planning of parking spaces or car free zones can have some impact on MaaS. Lack of parking spaces designated for car sharing vehicles creates obstacles for car sharing. In addition, the parking spaces can be so expensive that it becomes an obstacle. If Maas services are dependent on public transport services, which in most, if not all, Nordic cities, is the backbone of the MaaS concept, the MaaS services are limited to areas where public transport services exist. Different regions and municipalities organize public transport services and other transports in different ways. Principles regarding ticketing, communication of timetables, prices, technologies and

[90] Stakeholder interview Finland
[91] Stakeholder interview Denmark
[92] Smith, Sochor et al. (2018). Public–private innovation: barriers in the case of mobility as a service in West Sweden.

platforms differ. This can make it difficult to copy service models across different cases making the service models (including global approaches) more difficult to implement.[93]

5.7 Other barriers

The perceived increase in car use, which has been seen initially in some places (e.g. New York which in itself is a special case),seems to be something that can happen in a transitional phase, before people abandon private car use.[94] It is possible that this can make some political decision makers question if all physical MaaS transport services are beneficial when the main goal has so far been to promote public transport, which has for long been perceived as the most sustainable solution.

The issue of "social dumping" can also have an impact on future development. Platform economies like Uber and Airbnb, where practically anybody can provide the platform concept, become cheaper than hotels and taxi businesses, which have pay a livable wage to their employees. These services therefore squeeze the wages and benefits for workers. Taxi and bus drivers will also be losing their jobs as autonomous driving becomes mainstream. This could impact the political acceptability and reduce drive for promoting some of these services.[95]

5.8 Barriers for starting and running new businesses focused on Mobility as a Service and greener transport systems

Barriers to starting and running new businesses focused on Mobility as a Service include e.g.:[96]

- finding long term finance
- slow transition to open interfaces of public transport providers (such as ticketing and payment systems)
- slow decision making: new transport services often require enabling and supporting decisions by public officials
- acquiring critical customer base takes time, money, marketing skills and educational skills
- low user/resident density leads to higher operation costs (e.g. in route optimization)
- increased competition in large and medium sized cities

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93 Smith, Sochor *et al.* (2018). Public–private innovation: barriers in the case of mobility as a service in West Sweden

94 Source interview.

95 Stakeholder interview Denmark

96 NSB CoRe WP 3: Transport services benchmarking - Best practices from North Sea Baltic Commuting Corridors, and interviews with Maas Experts

- acceptable levels of service require a wide operational area, good availability and short walking distances
- uncertainty whether new mobility service may succeed in rural areas.

5.9 Summary of barriers

Table 11 summarizes the obstacles that have been identified in desk study and interviews of Nordic stakeholders.

Table 11: Summary of the barriers identified in this study

Barriers
Service levels
Inadequate density of services (number of shared cars, offered ride sharing services)
Individual needs that are difficult to meet with Maas
Lack of flexibility of Maas services
Lack of value added compared with private car use
Social and behavioral
Attitudes to car use (status, valuing privacy and flexibility)
Perception that private car use is cheap
Emotional aspects associated with private car use (pleasure, sense of freedom)
Safety issues with ride sharing or peer to peer services
Financial
Subsidies for public transports can distort transport markets
Tax incentives for company cars
Business model profitability
Profitability only in dense areas with PT hubs
Perceived cheap private car use
Expensive parking spaces for shared cars or lack of spaces
Subsidies for EVs for private use drive car ownership
Legal
Restrictions related to taxi legislation
Public procurement principles
Public transport role and possible related legal restrictions
Open data and service integration platforms
Access to open data (lack off or challenges with)
Resistance from public transport providers to integration of private mobility services in platforms
Lack of value added compared with private car use
Lack of integration of service platforms by private service providers
Organizational
Resistance to cooperation between some service providers
Different organizational cultures of different operators
Different approaches in different areas limit development
Procurement principles

6. Incentives and policy instruments to substitute car ownership with mobility services

Policy instruments for substituting car ownership with mobility services can take the form of carrots (incentives), that provide a reward for desired travel behavior, or sticks, that use disincentives to discourage undesirable travel behavior. However, carrots and sticks are frequently used in combination, as this can provide more effective results. Policy instruments can also be seen as "soft" or "hard" measures. Soft measures for substituting car ownership with mobility services can include e.g. information campaigns on mobility options, awareness campaigns on the impacts and costs of different travel modes and travel planners. Hard measures include laws, rules, taxes, subsidies and financing. Examples of these in substituting car ownership with mobility services include e.g. increasing taxes for private car use, changes in land use policy (e.g. regarding parking or roads), charging road tolls for entering congested areas, or giving subsidies for the use of shared mobility services.

Hard measures are likely more effective on people that are already used to the convenience of using a private car. Soft measures can be used to support transport policy initiatives and can be implemented alongside hard measures or on their own. Soft measures can play a key role in keeping people who have not yet developed private car dependence from doing so.[97] People whose lives are in a transition period (birth of a child, retirement, etc.) tend to respond more to changes in the relative attractiveness of different transport modes. Advertising campaigns promoting a modal shift towards public transport or shared mobility may thus be more successful if targeted at people in the process of important life transitions.[98] Also, the social norms of what is a normal form of transport and how it is accessed,[99] is changing, especially among the younger generations. As people are social beings, they don't want to act very differently from other people. Therefore, if the social norms are shifting towards shared mobility services and greener transport systems, e.g. because of increased climate change awareness, it can be a significant driving force behind the substitution of private car use with mobility services.[100]

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[97] Matyas, M. *et al.* (2018). The potential of mobility as a service bundles as a mobility management tool

[98] Santos, G. *et al.* (2010). Part II: Policy instruments for sustainable road transport. in Research in Transportation Economics, volume 28.

[99] E.g. through a mobile app

[100] Stakeholder comment, Finland

6.1 What can the government do to substitute car ownership with mobility services?

Governments are key actors in the shift from private car use towards shared mobility services, as they can use both hard and soft measures to speed up this transition. Some examples of policy instruments (sticks and carrots) governments can use are listed below:

- Comprehensive transport pricing: Governments can change the pricing of transport nationwide to reflect its actual costs, by internalizing the negative externalities of private car use (emissions, fine particles, noise, accidents, wasted time in congested traffic etc.). This includes e.g. charging drivers on road use (including congestion tolls or kilometer-based charges), increasing the CO_2-dependent part of taxes and charges, and more differentiation between low- and high-emitting cars. The tax levels should continuously be adjusted to take into account the development in technology.[101] Even though the emissions and congestion are at least partly already taken into account in Nordic transport pricing, there are not that many policy instruments on the other externalities. The use of shared mobility services could be made relatively cheaper than private car use, so that more people would choose these services over a private car. The effect of shared mobility services to reducing emissions and vehicle kilometers should be taken into account, when designing the pricing and taxation of transport.
- Government agencies can provide financial and other support for pilot projects in the fields of multimodal mobility and MaaS, or other projects aimed at developing cooperation (e.g. data sharing) between municipalities, public transport authorities, and private actors that provide shared mobility services.[102] Public support for MaaS can be provided for removing bottlenecks faced by private MaaS providers, such as IT-focused support (e.g. a helpdesk for implementing open interfaces), or supporting in sorting out other legal /bureaucracy issues regarding the innovative new service.[103] Governments should also support R&D projects in developing sustainable and low-carbon transport for the future, so that low-carbon technologies in the transport sector can be demonstrated and applied at a large scale.[104]
- Governments should consider the use of mobility services, such as car sharing, to have the same or better status than private car use in the case of tax reductions

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[101] Skjelvik *et al.* (2017). CO2 emissions and economic incentives - Recent developments in CO_2 emissions from passenger cars in the Nordic countries and potential economic incentives to regulate them
[102] K2, Paulsson (2018). Nya former av delad mobilitet och kollektivtrafik - Kunskapsöversikt av effekterna och effektiviseringsmöjligheter av nya former av delad mobilitet för kollektivtrafiken
[103] Stakeholder consultation
[104] Santos, G. *et al.* 2010). Part II: Policy instruments for sustainable road transport. in Research in Transportation Economics, volume 28.

from commuting ("kilometer allowance"). Currently users of shared cars or MaaS services in some of the Nordic countries don't get a tax deduction from using a shared car service (at least in the case of Finland) so according to interviewees, it puts them in an unfair position compared to private car owners.[105] The use of public transport is allowed and encouraged in tax deductions, however the use of shared cars or MaaS services is rarely mentioned or allowed. In Sweden, the use of a "borrowed car" (such as car-sharing car) is allowed in tax deductions from business trips, but in the case of commuting to work by car, also the Swedish tax rules refer only to the use of an own car or an employee-provided car.[106] However, in Denmark it is allowed to make tax deductions from carpooling by all the passengers in the car, also in the case the other passengers do not pay anything towards the transport.[107] An even more effective measure would be to remove the kilometer allowance from private car use, when travelling alone in the car, and to have the kilometer allowance only for shared services.

- Government agencies and public transport authorities can also subsidize travel using shared mobility services. The government could subsidize e.g. ride sharing services in commuting (e.g. through tax benefits or reduced road tolls or parking fees), as it reduces the amount of vehicle kilometers travelled and CO2 emissions because more people are using the same car. Ride hailing services could also be subsidized as long as the trips are available to or from public transport stations, which could increase the amount of public transport (rail, metro) users.[108] Governments could also provide some financial incentives for people to sell or scrap and recycle their cars.[109]
- The government can make the costs of private car use more visible, including cost of externalities such as CO2 and other emissions, to car owners through awareness campaigns. It is important to show the people that the cost of car use is not only the cost of petrol, when compared to e.g. public transport. Also, information on the costs and impacts of alternative transport should be visible for easy comparison.[110]
- Governments can stimulate the demand for new mobility services by lowering the barriers to enter the transport industry. For example, Finland's Act on Transport Services[111] establishes the preconditions for the digitalization of transport and enables a comprehensive overview of the Finnish transport system. The intention is to link different transport services, such as taxis and train journeys, into travel

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[105] Interviews with Finnish public and private experts
[106] Skatteverket webpages: https://www.skatteverket.se/servicelankar/otherlanguages/inenglish/individualsandemployees/declaringtaxesforindividuals/commondeductionsinthetaxreturn.4.7be5268414bea064694c75e.html
[107] Skat.dk webpages: https://skat.dk/skat.aspx?oid=2244504
[108] K2, Paulsson (2018). Nya former av delad mobilitet och kollektivtrafik - Kunskapsöversikt av effekterna och effektiviseringsmöjligheter av nya former av delad mobilitet för kollektivtrafiken
[109] Interviews with Norwegian experts.
[110] Interviews (Finland)
[111] https://www.liikennevirasto.fi/web/en/transport-system/the-act-on-transport-services#.W7XtdS-B3yU and https://www.lvm.fi/act-on-transport-services

chains. At the same time, the Act will facilitate market entry for new companies and alleviate the regulations in the transport sector. Smooth intermodal travel chains can only be achieved through interoperable transport service data, such as route, stop and schedule data, and payment systems. To achieve interoperability, the Act on Transport Services sets obligations for service providers to open their relevant data on mobility services via an open interface. Other mobility service providers and combination services also have to be given access to the interfaces for ticket and payment systems. Better utilization of shared data and data reserves creates opportunities for new business ideas.

- To reduce the CO_2 and other emissions from driving, governments can maintain and extend the economic incentives to buy electric and alternative fuel vehicles (electric vehicles, hybrid vehicles, cars utilizing modern biofuels) and for example charging infrastructure ; e.g. through tax exemption, exemption of VAT payment on purchase, free parking, no road user charges and ability to use separate (bus) lanes. [112] This has been successfully implemented already in Norway, where over 50 % of new car purchases are electric cars.[113] However, this does not reduce the use of private cars, only the environmental effects of driving.

6.2 What can cities, municipalities and public transport providers do?

Cities and municipalities are key actors in reducing private car use, as they control land use systems, such as parking spaces or car-free areas. Public transport providers on the other hand are the backbone of any MaaS system, and are key actors in making multimodal transport more smooth and easy to use. Examples of what cities and public transport providers can do to decrease the use of private cars are presented below:

- Cities and municipalities can allocate dedicated city space for shared mobility services. Municipalities can promote the integration of rental bicycle systems, car sharing services and other shared services by allocating spaces for them near public transport hubs for easy accessibility.
- "Personal emissions trading": the city (or government) can give incentives for using shared mobility services, cycling or walking – that reduce CO_2 emissions – to replace the use of own car. This is now being piloted in the city of Lahti in Finland[114], see the case example in the next chapter.
- Cities can make parking more expensive, to reflect the actual costs of land use. Now parking is often subsidized by the city, e.g. through cheaper residential

[112] Interviews (Danish)
[113] http://www.euronews.com/2018/04/11/how-oil-rich-norway-is-leading-the-world-on-electric-cars
[114] Urban Innovative Actions. Identify and test innovative solutions for sustainable urban development. http://www.uia-initiative.eu/en/uia-cities/lahti

parking in central areas of the city. Cities could impose higher parking fees for private cars and free parking for shared cars.[115]

- Cities can increase car-free areas in the city centers, both to make city centers easier for walking and cycling and to improve air quality, but also to reduce commuting by car.[116]
- Cities and municipalities can provide funding/support for actions to get transport providers on board the MaaS platforms; e.g. funding for implementation of data interfaces.
- Cities can also be bold in piloting the use of MaaS. Cities should also keep on lowering the parking costs for MaaS services – not only car sharing but also a wider MaaS service package.
- Cities and public transport providers can re-define public transport. Public transport can nowadays be considered also more widely than the traditional definition, as it can contain also other services which do not involve the use of a private car.[117]
- Public transport providers may promote the use of new shared mobility services by integrating them into their information and ticketing systems, as well as by developing pilot projects together with private actors based on the concept of multimodal mobility services.[118]
- Public transport providers should open their data to the MaaS service operators through technically feasible open interfaces, with conditions that suit both MaaS operators and public transport providers.[119]
- Bike sharing incentives: policies which can incentivize walking and cycling include increasing the coverage of dedicated cycle paths in cities, enabling safe crossings with shorter waiting times for cyclists and walkers, showers in offices, and lower speed limits.[120]
- Public transport operators should ensure that public transport use through a MaaS app is priced at a revenue-, tax- and price-neutral level compared to the direct sales of tickets.[121]
- Public transport service providers in different regions should aim to move towards a single ticketing system for the whole country – or even for all the Nordic countries together – in order to make the mobility services easier to use for the

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[115] Interviews with Danish experts.
[116] Interviews with Icelandic experts.
[117] Stakeholder consultation
[118] Interviews with Icelandic experts
[119] Interviews with Finnish public and private experts
[120] Santos, G. *et al.* (2010). Part II: Policy instruments for sustainable road transport. Research in Transportation Economics Volume 28, Issue 1, 2010, Pages 46-91.
[121] Sochor *et al.* (2017). A topological approach to Mobility as a Service: A proposed tool for understanding requirements and effects, and for aiding the integration of societal goals. ICoMaaS 2017 Proceedings.

customer. Currently only Denmark, Holland and Switzerland have country-wide ticketing systems in place.[122]

- In the route planner systems, including public transport routes and possibly other shared services, the environmental effect of the trip should be clearly marked with an easy to understand comparison. For example, the CO_2 emissions in grams is not easily comprehensible to an average passenger, but when the amount is compared to another figure from everyday life, it can send a clearer message. Furthermore, instead of passively presenting the information, the system could automatically select and present the journeys with the lowest environmental impacts, either pre-defined by the system or by the traveler's own preferences set in the personal profile.[123]
- Cities can promote the use of MaaS through dynamic procurement of transport services. This means that transport services should not be procured for too many years in order to provide public MaaS services that can develop with technological changes and customer needs. Cities need also to put structures in place that reduce potential negative externalities of some MaaS services (car-based services), such as congestion and pollution.[124]

6.3 What can companies do to reduce commuting by private car?

Companies have a large opportunity to affect the way their staff commutes to the office. Some examples of how they can reduce commuting by private car are given below:

- Companies can give financial incentives to their employees for choosing other forms of transport than private cars. Companies can subsidize public transport tickets for employees or create incentives for ride sharing for commuting trips. Larger employers can also organize ride sharing services for staff coming to work from the same area.
- Companies can provide their employees a MaaS subscription instead of a company car. This way they can provide their employees a possibility for using a wide range of transport options instead of a private car for their mobility and commuting.
- Companies can start charging daily for parking at company premises, instead of monthly fees or free parking. This means that the commuter needs to daily make the decision to pay for parking. This has already worked in reducing private car use in commuting in Seattle (USA), where the Bill & Melinda Gates Foundation switched from providing free parking spaces to charging daily for parking. Before

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[122] Interviews with Danish and Finnish experts.
[123] Kramers, A. (2014). Designing next generation multimodal traveler information systems to support sustainability-oriented decisions. In Environmental Modeling and Software Volume 56, June 2014, Pages 83-93.
[124] MaaS Alliance (2018). Report from the 4th MaaS Summit

the switch, approximately 90 % of staff drove to work alone. Charging $12 daily for parking led to this share reducing to 34 %.[125]

- Co-working hubs are increasing, and provide an opportunity for people that live further away from the company office to work in an office-like environment closer to home. The company could offer a combination of incentives for shared mobility solutions for commuting, such as going by bike to a nearby co-working hub.[126]
- Give employees benefits for walking and bicycling to work, e.g. a free lunch or a small monetary incentive per kilometer. Companies should stop subsidizing commuting by private car ("car benefit").
- Companies can make it easier to work from long distance, e.g. from home, by setting up good video- and teleconferencing systems, and encouraging staff to use them.
- Bike sharing providers should make their bike sharing systems simple, multimodally integrated and low-priced, offering high-quality bikes in a dense network. A user-friendly, app-based rental process and no advance registration increase usability and reduce entry barriers for new users. Furthermore, an integrated infrastructure including information and payment for other mobility services would help in reducing the use of private car.[127]

6.4 What can MaaS operators do to encourage substituting private car use?

MaaS operators, such as MaaS Global in Finland and Ubigo in Sweden, have a large role in making MaaS services approachable, easy to use and economically viable for the customer. They also have a significant role in establishing smooth cooperation with public transport providers. Some examples of how MaaS operators can encourage the substitution of private car use with shared services are listed below:

- MaaS operators should set up services that are risk free for consumers and easy to use. A low threshold for starting the use of the service, and an option for trial, is important. Daily pricing (in addition to monthly or annual pricing) should also be an option for the customer, to increase flexibility and lowering the threshold for commitment.[128] The MaaS operators should leave the choice to the customer to pick which services they need each day. For this they need a comprehensive offering of different services.
- MaaS operators should form roaming agreements with other MaaS operators (similar to mobile phone roaming agreements), either within the same country or

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125 The Seattle Times (10.8.2017). The not-so-secret trick to cutting solo car commutes: Charge for parking by the day.
126 Interviews with Swedish experts.
127 Roland Berger (2018). Bike sharing 5.0. Market insights and outlook.
128 Interviews with Swedish experts

neighboring countries. The roaming agreements would benefit greatly from the harmonization of interfaces between operators.[129]

- MaaS operators should prove to public transport providers and other MaaS ecosystem practitioners, that their business models are complementary and not competing. To gain wider acceptance, MaaS practitioners must demonstrate to one another that their business strategies and practices will not encroach on others' customer base and brand.[130]
- MaaS operators should also include long-distance trains in their service packages, to cover a larger share of mobility options for the consumer. Ideally, the MaaS service would cover the whole country, so the customer could seamlessly switch from one transport form to another through the same application.[131] However, the inclusion of trains in the MaaS services usually requires government-level help to have rail companies on board.
- MaaS operators can develop joint offerings and combine solutions with public transport. E.g. in Iceland there is an upcoming pilot, where students that purchase a monthly bus pass, also automatically receive a Zipcar subscription[132], co-develop green mobility offerings with cities and construction companies for new city neighborhood projects and co-create offerings/solutions connecting nearby cities.
- The MaaS operators should cooperate in seeking and developing innovative branding for the shared and multimodal mobility services, study different models for reciprocal data sharing, and work together to develop standardized model contracts to lower the transactions cost related to local implementations.[133]
- Education and awareness programmes should to be implemented jointly by MaaS operators, cities and governments, in order to increase awareness of the benefits and impacts of MaaS, and how it compares to private car use in terms of economic costs and socio-economic benefits.

6.5 What can Nordic countries do together?

Nordic countries have the opportunity to be world leaders in the advancement of shared mobility solutions and greener transport systems. Some examples of these are given below:

- Nordic countries could cooperate regarding the regulatory environment and government incentives. Cooperation across Nordic countries – to have a more

[129] Stakeholder consultation

[130] Sochor *et al.* (2017). A topological approach to Mobility as a Service: A proposed tool for understanding requirements and effects, and for aiding the integration of societal goals. ICoMaaS 2017 Proceedings.

[131] Interviews with Finnish experts

[132] Interviews with Icelandic experts

[133] MaaS Alliance (2018). Report from the 4th MaaS Summit

harmonized regulatory environment – would help scaling up the shared mobility services and cross-border use of the mobility services.[134]

- Nordic countries could share best practices, and experiences from pilot projects more extensively, so that the practices that have worked in one Nordic country could be taken on more swiftly in other Nordic countries.[135] Nordic countries could also fund joint foresight studies on a potential Nordic Single Market for mobility services.[136]
- Nordic countries could produce more data and evidence on the impacts of shared mobility services, and increase the knowledge base in the Nordic public sector through training sessions.[137]
- Regarding (shared) autonomous vehicles, it is important to have cross-border cooperation between Nordic countries, so it will be possible to drive across the border with the same autonomous vehicle. The data/information networks should work also cross borders.[138]
- Regarding the new EU regulation on providing information on shared mobility services,[139] the Nordic region could look into the option of creating a common datapoint, or to use open source elements and knowledge sharing to reduce cost of establishing national datapoints for mobility data and services.[140]

6.6 Other incentives to substitute private car use with mobility services

There are also other incentives for the customers to consider substituting private car use with shared mobility services. Some of these are listed below:

- Replacing private car use with mobility services can reduce the costs to the consumer, as car use is paid for only when there is a need to use it. Private cars are parked and unused most of the time, but still have high costs from purchase, insurances, repairs, cleaning etc. An information campaign on the actual costs from private car use, compared to other mobility options, could trigger some consumers to substitute car ownership with mobility services.[141] Replacing private cars with mobility services also reduce externalities, such as CO_2 and particulate emissions, as well as noise.

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[134] Interviews with Finnish experts.
[135] Interviews with Finnish experts.
[136] Stakeholder consultation
[137] Interviews with Finnish experts
[138] Interviews with Danish and Finnish experts.
[139] Commission Delegated Regulation (EU) 2017/1926 of 31 May 2017 supplementing Directive 2010/40/EU of the European Parliament and of the Council with regard to the provision of EU-wide multimodal travel information services 1
[140] Interviews with Danish experts.
[141] Interviews with Finnish experts.

- Behavioral change from private car use towards shared services needs active measures from all public sector stakeholders. MaaS needs a new mindset from public sector, private sector and the users of the services.
- Car sharing fleets can help in vehicle rightsizing, meaning that the size of the used vehicle is more optimal (in terms of size, luggage space and engine performance) than a private car. In the case of shared services, the choice of vehicle can be done according to the current need, and not according to the most demanding trip. This can lead to positive environmental effects, such as less CO_2 emissions. However, this demands a car sharing fleet with different types of vehicles.[142]
- Active commuting, such as increased biking and walking has a positive effect on people's health and mood. It has been studied that physical activity during commuting reduce mortality and cardiovascular diseases, among other benefits.[143] [144] Additionally, using a (shared) bike for commuting enhances the person's immediate wellbeing and reduces the amount of stress upon arrival at the workplace, compared to the use of a private car.[145]
- Integrated multimodal mobility services can make the use of public transport more tempting, as people can use other services (such as bike sharing, car sharing, ride hailing) seamlessly for the first- or last-mile of the journey.[146]
- Grocery home deliveries are a way to reduce VKT and the need for private car. Service providers can offer a discount for delivery services, and make the delivery as easy as possible for the customer. Grocery deliveries can also be combined with other mobility services, such as delivering the groceries to a cool storage at the train station for the customer to pick them up on a commuting trip.[147] If customers could get a monthly subscription to grocery and goods deliveries (through companies such as Amazon), combined with mobility services for commuting, it could ease the daily life of citizens in especially larger cities, and reduce the need of a private car.[148]
- Digital mobility services will also increase in rural regions, but they will be more based on demand-responsive transit (DRT). In rural areas, demand-based shared mobility services can substitute the use of own car, or increase the mobility service level from sparse bus services.[149]

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[142] Trivector (2016): Konsekvenser av Mobility as a Service -report

[143] Scott, L-A. et al. (2017). The effect of physical activity on mortality and cardiovascular disease in 130 000 people from 17 high-income, middle-income, and low-income countries: the PURE study. Lancet.

[144] Celis-Morales, C. et al. (2017). Association between active commuting and incident cardiovascular disease, cancer, and mortality: prospective cohort study. BMJ 2017;357:j1456

[145] Brutus, S. et al. (2017). Cycling, car, or public transit: a study of stress and mood upon arrival at work. International Journal of Workplace Health Management, 10(1), 13-24

[146] Pöllänen, Utrinainen, Viri (2017). Challenges in the Paradigm Change from Mobility as a Self-service to Mobility as a Service

[147] Interviews, Sweden and Finland.

[148] Interviews with Danish experts

[149] Interviews with Danish experts

6.7 Business opportunities for new companies focused on Mobility as a Service and greener transportation systems

Regarding the business opportunities for new MaaS service providers, the key question is whether there are possibilities for many small companies, or do a few large global companies take over the mobility services markets? Another key issue is, should there be publicly-owned structures to stimulate the demand and to lower the barriers to entry?

Companies such as MaaS Global (Finland) and Ubigo (Sweden) are illustrating that new local start-up firms can be successfully introduced in the Nordic markets, as they can tailor their offering based on a deeper understanding of local customers' needs. Cities can secure the gradual development of carless communities and neighborhoods by forming e.g. Public-Private Partnerships with selected mobility service providers. For Nordic companies emerging new business opportunities include e.g.:

- Business models based on providing subscription and/or transactional mobility services: e.g. MaaS Global and UbiGo create value via a set of contractual arrangements with different service providers and by re-packaging and bundling these services into a single offer. This value is captured via a subscription-based payment model.[150]
- Business models based on providing shared economy solutions: car sharing, ride hailing, peer-to-peer car sharing, bike sharing, fleet /ride sharing and crowdsourced logistics. Most of these services rely on providing access to a specific mobility service, and the operators do not need to own a vehicle fleet.
- Business models built around providing smart service solutions to multimodal MaaS services: these include multimodal smart payment systems, smart parking solutions, personal travel & trip planners, mobility service optimization, real time traffic management and telecommuting.
- Business models built around data: intelligent online services and interfaces such as open data, application programming interfaces (APIs) and cloud services.
- Business models built around low-emitting delivery of parcels and groceries (such as crowdsourced deliveries, use of drones and electric bikes)
- In the future, there will be also demand for building new business models around the utilization of automated electric vehicles and figuring out how low-emitting automated vehicles are efficiently integrated into the public transport system.

To enable a profitable market growth for greener mobility services and new mobility business, one should follow the guidance from the MaaS Alliance: "MaaS is a service and access promise to users. In a mobility context, a service promise means that users

[150] Sarasini, S., Sochor, L, Arby, H. (2017). ICoMaaS 2017 Proceedings 121: What charac-terises a sustainable MaaS business model?

always get a door-to-door solution from A to B or at least the best solution possible for them to travel from A to B".[151] The attractiveness of MaaS is thus based on the freedom and variety it offers to the user. MaaS should be the best value proposition for users, helping them meet their basic access needs and solving the inconveniences of the journey, like congestion, safety and security risks and inconsistent costs. The best value proposition is not limited to what is the quickest or most cost-efficient solution. Depending on the user's priorities it can also be the safest, healthiest, most environmentally-friendly, most aesthetically appealing or providing the best working-while-commuting facilities.

[151] MaaS Alliance (2017). Guidance and recommendations to create the foundations

7. Case analysis for policy recommendations

7.1 Case analysis

In the following sections, four different best practice cases are briefly presented. Each is focused on addressing how to achieve particular aims, as follows:

i. how to change people's attitude and behavior towards mobility in order to promote a shift from using private car to sustainable mobility choices;
ii. how an employer can, together with the city, encourage employees to leave their car home by introducing a combination of "carrot and stick" policies;
iii. how to design carless communities; and
iv. how to design national MaaS roadmaps.

Many of the interviewees in this study voiced the need to introduce a wide variety of differing policies, as any one single policy may not have far or wide enough impact on consumer behavior to change well established, deeply rooted commuting habits.

7.1.1 Case 1. Incentives for residents, Lahti city, Finland: CitiCAP-Citizens' cap and trade

Lahti is the pioneer city in Europe (if not the world) with respect to implementing a personal carbon trading scheme in order to tackle mobility CO_2 emissions and create new incentives for sustainable mobility. The "CitiCap" scheme aims to reduce transport emissions, offer residents a possibility to participate in tackling climate change in a new way, and to collect and make available digital data on mobility, thereby facilitating the development of new transport services to residents. The city expectancy is that at least 1,300 residents begin using an app, based on the logic behind carbon trading. The app will automatically track the user's travel mode, distance and time used and calculate their transport emissions. When the user chooses sustainable travel modes and thereby saves "carbon allowances", he/she earns virtual euros that can be used for different benefits and services, including bus tickets or shared car use. "Active cyclists will get gift cards to bike shops, and there will also be public transport tickets as prizes," says Saara Vauramo, Environmental Director of Lahti city. The pilot with residents is scheduled to being by Q3/2019.

The project is implemented in between 1/2018-12/2020 and it includes eight partners (Lahti city, two universities, one regional development organization and four SME's). The overall funding of the project is 4,7 million Euro.

7.1.2 The CitiCap objectives

1. Promoting a change in resident's behavior and personal attitudes towards sustainable mobility modes.
2. Providing strong incentives to urban mobility transformation by providing an innovative Personal Carbon Trading (PCT) scheme for single-city use
3. Enhancing the acceptability of mobility environment transition process, by creating a holistic master planning process with increased participatory possibilities of residents, NGO's, local companies and other end-users.
4. Decreasing global and local negative environmental effects of urban traffic.
5. Activating the use of different urban mobility data for new innovations to develop sustainable mobility and business opportunities
6. Creating new consumer markets for the low-carbon mobility services and products especially in medium-size cities
7. Developing Lahti into a cozy, sustainable city, where residents can live in a safer and cleaner environment

7.1.3 Project core activities include:

1. Co-creating and implementing a Personal Carbon Trading (PCT) scheme to reduce traffic emissions (mainly from personal commuting). This is the first city-wide pilot of a PCT within EU.
2. Developing a light and replicable open mobility data platform. The mobility data will be collected for three main purposes: a) data for the city's authorities, b) data for the PCT scheme use, and c) open access mobility data. The architecture of the data platform model may serve as an innovative practice, which can be utilized by other cities.
3. Constructing 2,5 km of Smart Bicycle Highway. This highway will be built using latest cycling city infrastructure planning guidelines in order to develop a safe, convenient and fast road for the cyclists. Furthermore, the highway will serve as a test bed for smart solutions which utilize and/or interact with the Smart Bicycle Highway and add value for cyclists.

PCT can be seen as a new way to positively incentivize low-carbon transport choices: instead of "the polluter-pays" and "user-pays" principles, the project suggests taking the approach of rewarding environmentally friendly behavior.

The project attempts to solve key challenges such as (i) how to change the mobility attitude and behavior of citizens and promote the shift from private car to sustainable mobility, (ii) how medium-size cities may develop their mobility environment: increase the use of sustainable mobility modes, enhance multimodality and reduce overall CO_2 emissions, bearing in mind the restrictions arising from medium sized cities not being able to utilize all mass transit options available to larger cities.

Lahti city is looking for partner cities for the PCT-project, especially from Scandinavia[152].

7.1.4 Case 2: Changing employees commuting habits: City of Seattle and Bill & Melinda Gates Foundation[153]

Background: A 1991 state law required Seattle and other metropolitan areas in Washington to adopt plans to reduce the number of commuting trips made by employees at large workplaces. Companies had to appoint a transport coordinator and make a "good faith effort" to reduce solo car commutes, through acts such as subsidizing public transport cards, providing bike facilities and facilitating carpools and van pools. The goal was to reduce the number of people driving alone to work, thus reducing the number of cars, pollution and traffic congestion. The state spends about $3 million a year on its Commute Trip Reduction program. This requires all companies with more than 100 employees who commute during normal hours to complete a biennial survey, cataloging how their employees get to work. In between 2005 and 2015, Seattle increased its rate of transit commuters and decreased its rate of solo drivers faster than any other major city in the United States.

Bill and Melinda Gates Foundation: In 2008, the Bill & Melinda Gates Foundation applied for permits to build its new, $500 million, boomerang-shaped headquarters across from Seattle Center. To ease the impact of 1,200 new full-time employees in the area, the Bill and Melinda Gates Foundation could no longer offer free parking, and at the same time reduce the number of employees who drove alone to work. The foundation initiated several changes and introduced "carrot and stick"- policies. First, charge for parking by the day and not by the month was introduced. The foundation established that this change doesn't cost the foundation or its employees any additional money and is easily replicable at workplaces with fewer resources to devote to the issue. Every employee, including the CEO, paid $12 a day to park in the Gates Foundation garage. Fees were capped at the neighborhood's market rate – $120 a month. So, the first 10 days a month that an employee drives alone cost $12 each; every day the rest of the month is free. However, making employees think about the daily rate of 12 dollars rather than at a fixed monthly cost, had a big impact on commuters' choices. In addition, all employees receive free public (ORCA) transit cards and a financial incentive – $3 a day – for choosing any alternative transport, Moreover, the foundation provided bike rooms which have a 24-hour access to bike storage, plugs to charge lights, a bike-repair station and pumps as well as showers.

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152 https://www.smartlahti.fi/citicap/

153 The Seattle Times (10.8.2017). The not-so-secret trick to cutting solo car commutes: Charge for parking by the day.

In 2008, nearly 90% of employees drove to and from work alone. A year after the new headquarters opened in 2011, the number was down to 42%, and in 2016 it was 34 %. In 2017, the Gates Foundation has more than 700 parking spots, between its own garage and spaces it leases. On a typical day, fewer than half of them get used. The charge by the day policy proved to be the single biggest factor reducing solo car commuting.

What was the key factor in achieving results in reducing solo car commuting?

According to Sohier Hall, the CEO of Luum: "The single most important factor in changing employees' commuting habits is having an employer that cares about changing those habits". A revamped parking policy is just one way of changing behavior: "A, charge for parking and B, turn that monthly charge into a daily charge so it becomes a daily choice".

7.1.5 CASE 3. KOMPIS – combined mobility as a service in Sweden[154]

The Swedish government is making a large effort to accelerate the development of combined mobility as a service in Sweden. KOMPIS ("Kombinerad Mobilitet som tjänst i Sverige") is a project funded by Vinnova, the Swedish Innovation Agency, and is part of the Drive Sweden's project portfolio. The program is driven by the recognized needs to, on one hand, act on the trends of digitalization and focus on services, and at the same time, react to the rising costs of conducting and developing public transport (Table 12) developed in the KOMPIS project supports the growth of new mobility services by creating favorable conditions and reducing barriers to the development and implementation of services, as well as conducting pilots with autonomous vehicles.

Table 12: Kompis roadmap towards shared mobility being a norm by 2028 (source: KOMPIS project. Adapted to MaaS level model, Drive Sweden, 2016)

Overskrift	Overskrift
MaaS Level 4 Integration of policy & control	Incentives and instruments (from the public sector) integrated in agreements and the service. The purpose is to steer towards the city's/public sector's objectives. Conditions for resale of the public sector's services
MaaS Level 3 Integration of agreements	Offer alternatives to car ownership. Subscription or packaged. Responsibility for the entire service. In relation both to customer and transport service provider. Combined payment for all services. Focus on household mobility requirements.
MaaS Level 2 Integration of booking/ticket/payment	Booking of and payment for services integrated in a service/app. No responsibility for the travel services, but for payment. Focus on individual journey from A to B.
MaaS Level 1 Integration of information	The services integrated at information level (e.g. multimodal travel planners). Users have agreements and relationships with various transport service providers. Separate payment solutions.
MaaS Level 0 No integration	Separate mobility services. Users have agreements and relationships with various transport service providers. Separate payment solutions.

[154] Kombinerad Mobilitet som Tjänst I Sverige (KOMPIS). https://kompis.me/

The KOMPIS program aims to create a norm of shared travel among commuters by 2028.

7.1.6 Case 4. Developing a carless city neighborhood: The Car-Free Living Program[155]

City officials, developers, smart mobility service operators and public transport agencies alike are increasingly viewing "carless city neighborhood" developments as an opportunity to design new areas that radically reduces the dependence on commuting by car. The reasons include aims such as:

- Developers want to save money by avoiding to build and maintain (underground) parking garages or –spaces.
- City officials want to react to the increasing cost of transport, and create livable, attractive and sustainable neighborhoods.
- Smart mobility operators are increasingly more open to combine their services into more compelling multimodal services packages.

Parkmerced, a housing project in a San Francisco neighborhood, includes a Vision plan - a neighborhood revitalization program [156] – and a Car/Free Mobility program, and serves as an example of ambitious, holistic solution to reduce commuting by car.

The Parkmerced Vision Plan integrates best principles of environmental sustainability and neighborhood livability. This includes designing a pedestrian-friendly mixed-use neighborhood with improved connectivity to public transit that radically reduces dependency on private cars. All amenities will be within comfortable walking distance from residences. The aim is to enable residents to meet most of their daily needs within the neighborhood by walking rather than by car. Among the Vision plan's urban mobility innovations is reconnecting the neighborhood to the rest of the city by adding three new Muni light rail-stations in the area. The greatest development intensity is planned around these new stations, capitalizing on the level of activity the new stations will bring to the district.

Car-Free Mobility program

Uber and the area's real estate development company (PM Labs) have designed a Car-Free Living mobility program to both stimulate car-free living at Parkmerced and to establish a sustainable, multimodal transport model. The Car-Free Mobility Living Program encourages residents to use public transport and ride share. The Program enables residents to choose a more affordable and sustainable alternative than car ownership. New residents who participate in the Car-Free Living Program receive a $100 monthly transport credit per apartment to use with:

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[155] www.parkmercedvision.com
[156] The plan will construct 5,679 net new residences for a total of 8,900 inhabitants

- Getaround (a ridesharing service),
- Clipper (a regional transport fare card, which provides access to metro, bus and train), and
- Uber (ridehailing).

Any resident can also catch a ride in an UberPool from Parkmerced to nearby public transit train stations for a flat rate of $5.

The monthly $100 subsidy comes with codes and directions on how to use these with Uber, Getaround and Clipper. Getaround's ridesharing service provides a solution for longer duration trips and it also might generate income for Parkmerced residents through enabling resident car owners to earn money from their car, when it is not in use.

Currently, more than 1 000 residents are benefiting from the Car-Free Living Program at Parkmerced. In the long term, the Program aims to reduce car traffic generated by Parkmerced residents by over 9 million miles (14,4 million kilometers) per year.

8. Policy recommendations

In Chapter 6 a wide range of incentives and policy instruments were presented. In this chapter, key policy recommendations are summarized, based on insights gained from the extensive literature review, expert interviews and the project's advisory group members. Many of the interviewed experts highlighted that the Nordic countries should lead the path towards faster adoption of Mobility as a Service and greener transportation systems. The policy recommendations aim to:

1. reduce the dependence on car ownership,
2. reduce the vehicle kilometers driven,
3. stimulate the demand for smart mobility services and greener mobility systems.

The following eight (Nordic and/or country level) recommendations require collaboration between cities, smart mobility service providers, governments, large employer organizations, public transport providers, area developers and legislators. Each Nordic country can naturally choose the most effective set of recommendations which assist in transitioning towards a transport efficient society.

8.1.1 Recommendation 1. Launch a pan-Nordic Smart & Green Mobility- as-a-Service transport pass.

Following the well-established tradition of Nordic collaboration in standardizing GSM networks, which enabled easy connectivity when travelling in Nordic countries, a pan-Nordic mobility pass would enable greener travel choices, locally and nationally, wherever you travel within the Nordic countries. The pass (an app) should highlight travel choices, guarantee best service availability, suggest best travel options and work on any mobile device. The service combinations would naturally vary per region/country, and would be automatically updated when a user moves from one location to another.[157] The pass could be piloted first with Nordic citizens and later be extended to, for example, all EU citizens.

The implementation of the mobility pass requires standardized solutions for shared mobility services, unified booking, payment & ticketing,[158] multimodal travel

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[157] As one of the interviewed experts stated: "People are too lazy to always seek for and update a different mobile app when they travel from one city to another (within the Nordic countries)".

[158] Stakeholder comment: "It would practically require all transport providers changing their ticketing model from ticket-based to ID-based systems so that a person entering a bus would not show a valid ticket but would identify himself, and the "back office' would know if he's eligible passenger or not. This transformation of ticketing systems would have to be accelerated first".

information and greener mobility systems (such as electronic cars, electronic bikes that are charged with renewable energy) and other MaaS services combined with the public transport.

Alternatively, the mobility pass could be enabled via roaming between MaaS operators in the Nordic countries (in a similar manner as in telecom). When a Whim customer travels from Helsinki to Stockholm, he or she can automatically use Ubigo's services in Stockholm (and vice versa).

Timeline of action: Synchronize the preparation work with national MaaS roadmaps (e.g. Sweden's Kompis) and with national transport growth programs (such as Finland's national growth program for Transport 2018–2022). A realistic launch window for the mobility pass is in between 2030–2040.

8.1.2 Recommendation 2. Introduce a combination of incentives and tax benefits to support wider and faster adoption of MaaS and smart mobility services.

Governments may choose to introduce a combination of the following incentives and tax benefits:

- Governments should consider how the use of mobility services, such as car sharing, could have the same or better status than private car use in respect to tax reductions for commuting costs ("kilometer allowance").
- Government agencies and public transport authorities should subsidize travel using shared mobility services, such as ride sharing services in commuting (e.g. through tax benefits or reduced road tolls or parking fees), as it reduces the VKT and CO_2 emissions when more people travel in the same car.
- Government agencies and public transport authorities could subsidize ride hailing services as long as the trips are available to or from public transport stations, which could increase the amount of public transport (rail, metro, bus) users.[159]
- Governments could also financially support the purchase of greener, less emitting cars (e.g. Norway's subsidy for electric/hybrid car purchases).
- Governments could introduce a special tax-free benefit to citizens (especially in the rural areas) that enable a citizen to earn up e.g. 10 000 euros per annum from peer to peer carsharing and/or carpooling services, in order to make this option attractive. Governments could further stipulate that the tax exemption could only be applied to low emitting vehicles (electronic and hybrid). One of interviewed experts highlighted that this type of an incentive could especially benefit more sustainable commuting practices in rural areas.

[159] K2, Paulsson (2018). Nya former av delad mobilitet och kollektivtrafik - Kunskapsöversikt av effekterna och effektiviseringsmöjligheter av nya former av delad mobilitet för kollektivtrafiken

- In order to reduce traffic congestion and air pollution, cities can introduce restricted traffic lane(s) reserved at peak travel times or longer for the exclusive use of vehicles with a driver and one or more passengers, including carpools, vanpools and transit buses. Access to the restricted lanes could be also granted to low-emitting vehicles (such as hybrid electric vehicles, plug-in hybrids, and battery electric vehicles).
- Nordic medium-size cities should offer new incentives to citizens to develop their mobility environment by increasing the use of sustainable mobility modes, enhance the multimodality and decrease the CO_2 emissions (while they cannot use all mass transit options that are available for larger cities). For example, the City of Lahti's pioneering personal carbon trading scheme (CitiCap) tackles mobility CO_2 emissions and creates new incentives for sustainable mobility. The Lahti city's mobility app will automatically track the user's travel mode, distance and time used and calculate their transport emissions. When the user chooses sustainable travel modes and manages to save carbon allowances, he/she earns virtual euros that can be used for different benefits and services such as bus tickets or shared car use. This type of scheme could be adopted by other cities. Trials and pilots should be encouraged and funded.
- Governments may adopt an innovative incentive from Austria: electric cars may drive 130 km/h on motorways, but normal cars are limited to 100 km/h.

Timeline of action: Combinations of the suggested incentives may have to be implemented sooner than later in order to achieve the ambitious national transport CO_2 emission reduction goals.

8.1.3 Recommendation 3. Design car-free communities and stimulate the demand for new multimodal mobility services.

Cities can foster the design of car-free communities and stimulate the demand for new greener transport services and systems. As illustrated by the Car-Free Living Program (see 6.1 Case studies), cities and smart mobility service providers can collaborate to design car-free communities, especially in new city neighborhoods. The key is to offer a wider selection of first and last mile solutions. Thus, the commuters choose which services they need each day to enable them to not use their own car. According to the interviewed experts, such services should be combined with public transport (building connections to nearby transit hubs/stations). The area developer (or the city) may also offer special perks to attract residents (e.g. free trial periods, free rides, monthly money deposits). Malmö's eco-neighborhood project also encourages the design of carless communities.

Cities can also stimulate the demand for new greener transport services and systems. Recently, the city of Reykjavik introduced a successful electric bike trial program[160] for its residents. The city offers free access to an e-bike for 6 months. The commuters can take the bike home and use it to commute in and around Reykjavik. The e-bikes are then returned to the city when the trial period ends. To minimize pilot program costs, the City of Reykjavik leases the e-bikes from a bike manufacturer. The bikes are returned to the vendor after the rental period, who then resells the bikes. The e-bikes are equipped with GPS, enabling the collection of real time data (how and when the bikes are used, where they are charged etc.). Usage data has been collected from over 100 users and all of the e-bike users have also been interviewed. These activities assist in planning for the actual launch of an electronic bike rental system in the near future. The trial also encourages citizens to use e-bikes for short commuting trips (instead of driving by car).

Timeline of action: Implement now

8.1.4 Recommendation 4. Make employee commuting greener.

Nordic cities should also apply progressive green policies and collaborate initially with the large sized employer organizations to green their commuting.

Chapter 7.1 case of the city of Seattle and a large employer organization (Melinda and Bill Gates Foundation) illustrated that cities can limit the amount of parking permits & -space and apply progressive greener policies. These policies aim to reduce the number of commuting trips made by employees at large workplaces. Companies and public organizations can appoint a transport coordinator, reduce solo car commutes by subsidizing public transport cards, provide bike facilities and facilitate carpools and van pools. The goal is to reduce the number of people driving alone to work and thereby reduce the number of cars on the road, pollution and traffic congestion. These type of carrot and stick policies seem to be easiest to implement when a company or a public organization move into new headquarters (or a new location). The key "stick" policy is to start to charge by the day for employee parking (instead of a monthly parking fee or offering free parking to employees).

Similarly, Nordic cities should also apply progressive green policies and collaborate initially with the large sized employer organizations to green their commuting. The incentive system should be tailored to fit with the Nordic values. For instance, the Bill and Melinda Gates Foundation's model of giving 3 dollars to employees when using alternative travel modes instead of using their own car might not be feasible as such in the Nordic context. Rather, the employers' organizations together with the city and MaaS service providers should offer a wide variety of transport options, even by sea/lake when feasible. Boat ride service[161] such as "Uber for boats" will begin serving commuters in Espoo and Helsinki in September 2018.

Companies can also provide their employees a MaaS subscription instead of a company car. This way they can provide their employees a possibility for using a wide range of transport options instead of a private car for their mobility and commuting.

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[160] interview with a Nordic expert, 30.8.2018. The city had over 1000 applicants to the free e bike program.

[161] https://www.hel.fi/uutiset/en/helsinki/bout-+ride-service

Timeline of action: Implement now

8.1.5 Recommendation 5. Introduce comprehensive transport pricing across Nordic countries.

Nordic governments need to change the pricing of transport nationwide in order to reflect actual overall costs, by internalizing the negative externalities of private car use (emissions, fine particles, noise, accidents, wasted time in congested traffic etc.). This includes e.g. charging drivers based on road use (including congestion tolls), increasing the CO_2-dependent part of taxes and charges to further differentiate between low- and high-emitting cars. Such tax levels should be adjusted on a continuous basis, in order to take into account the development in technology.[162]

Timeline of action: May have to be implemented sooner than later in order to achieve the ambitious national transport co2 emission reduction goals

8.1.6 Recommendation 6. Educate and build awareness for smarter and greener transport choices.

The greenest and healthiest travel choices are walking or biking. A Danish study has illustrated how much socio-economic benefit can be obtained by changing from a private car to the use of a bike for short journeys during rush hours in Copenhagen. A 1 EUR socio-economic benefit is achieved for each kilometer that is travelled by bike instead of a private car. The health benefits of biking and walking should be prioritized when making public infrastructure investments and when educating Nordic consumers.

A key barrier to wider adoption of Maas services is that potential customers do not know about the new services, and they have not tried out new services. In order to increase awareness of both the benefits and impacts of MaaS, and how it compares to private car use in terms of economic costs and socio-economic benefits, education and awareness programs should be implemented, preferably jointly, by MaaS operators, cities, public transport operators and governments. These players can jointly encourage commuters to try out new mobility services via e.g. changing the physical environment: e.g. positioning car sharing services nearby public locations with heavy pedestrian traffic and introducing barriers to private car use such as parking and road toll fees and replacing car lanes with bicycle lanes.

The educational actions should be targeted especially to current owners of private vehicles. For most people, a car is the first or second largest purchase they will procure during their lives. Yet, it is not utilized for about 90% of its useful life[163]. In order to encourage car owners to switch to more efficient and greener transport options, door-to-door mobility needs to be introduced to guarantee the same level of convenience

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[162] Skjelvik *et al.* (2017). CO2 emissions and economic incentives - Recent developments in CO_2 emissions from passenger cars in the Nordic countries and potential economic incentives to regulate them

[163] Morris, D. "Today's Cars Are Parked 95% of the Time," Fortune, March 13, 2016, http://fortune.com/2016/03/13/cars-parked-95- percent-of-time/

and flexibility that car owners are used to. The amount of options is also on the rise and the citizens need more information to make better informed decisions.

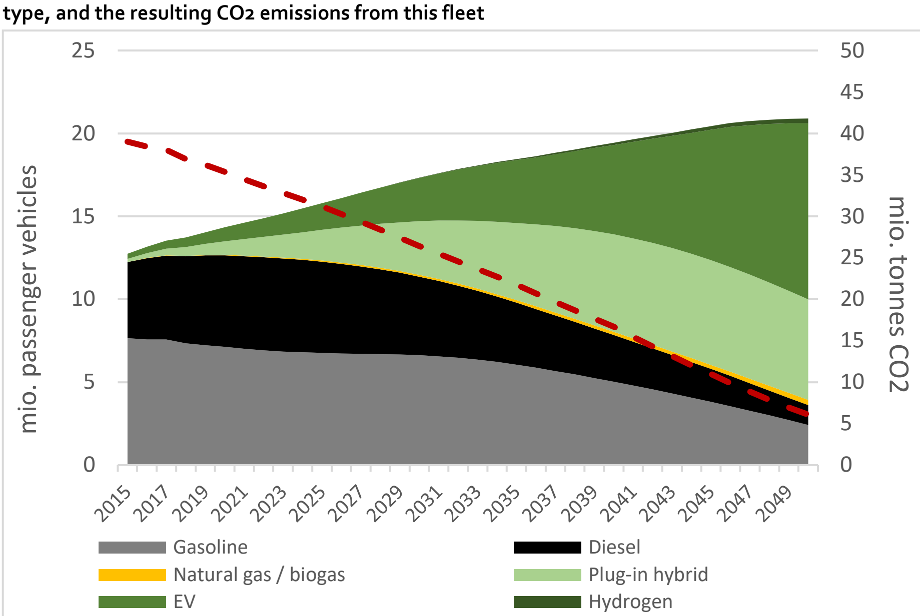
Nordic countries need to ensure resources for continuous research and that sufficient data becomes available.

Timeline of action: Implement now

8.1.7 Recommendation 7. Fast track implementation of MaaS.

In order to quantify the potential CO_2 emission reductions associated with the implementation of MaaS, the fleet model PETRA was utilized to model the development of the passenger transport sector for the 5 Nordic countries through to 2050. The first step of this analysis thus involved establishing a reference scenario for other alternatives to be compared with. The evolution of the passenger vehicle fleet in the reference scenario according to drivetrain type, and the resulting CO_2 emissions from this fleet, are displayed in Figure 20.

Figure 20: The evolution of the passenger vehicle fleet in the reference scenario according to drivetrain type, and the resulting CO2 emissions from this fleet



As can clearly be seen from the figure, passenger transport is assumed to become increasingly electrified towards 2050, which is presumed to be driven by lower battery costs and improved battery characteristics.

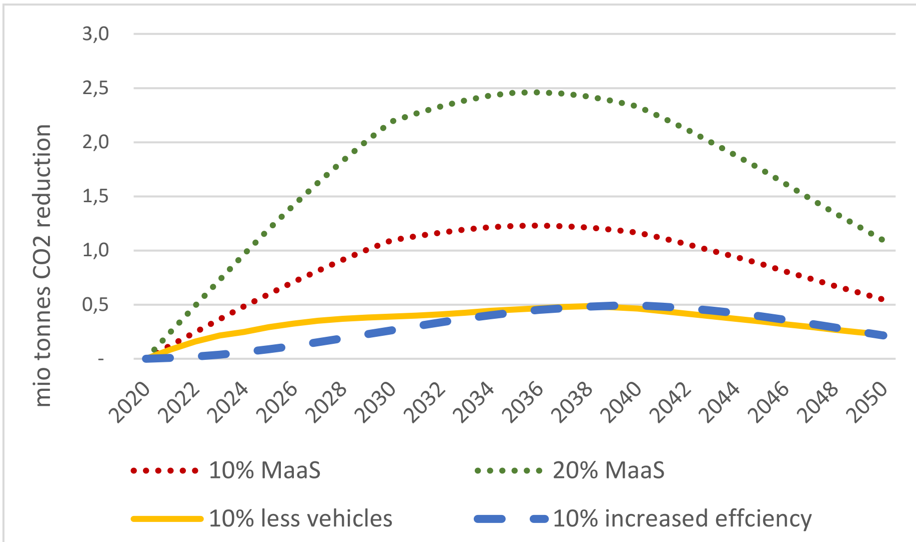
Four alternative scenarios were then established for comparison:

1. High MaaS implementation (20% less transport work when full phased in)
2. Low MaaS implementation (10% less transport work when full phased in)

3. Reduced vehicle ownership (10% less vehicle ownership)[164]
4. Increased efficiency of new vehicles (10% more efficient).

The reductions in passenger transport CO_2 emissions relative to the reference scenario via the 4 alternative scenarios are displayed in the figure below (note that all initiatives are phased in gradually and fully implemented in 2050).

Figure 21: . Reductions in passenger transport CO2 emissions relative to the reference scenario via the 4 alternative scenarios



On first glance it may seem counterintuitive that a 10% efficiency gain does not result in greater CO_2 emission reductions relative to the other scenarios, however there are a few reasons for this. Firstly, the MaaS scenarios apply to all vehicles within the car fleet when implemented, whereas the increased efficiency only applies to new vehicles in a phased in manner starting in 2021. It therefore takes quite some time before these affects can be felt by a large portion of the car fleet. This also links to the 2nd portion of the explanation, and that is that by the time the efficiency improvements really become entrenched, the car fleet is much less CO_2 intensive due to the wide-spread electrification, combined with the very low CO_2 content of electricity in the Nordic countries.

The CO2 emission reduction analysis utilizing the vehicle fleet model PETRA thus illustrates the importance of implementing MaaS sooner rather than later in the Nordic countries, i.e. before the personal transport sector becomes largely decarbonized. Contrary to developments such as the electrification of the passenger transport sector, which will become increasingly cost-effective at reducing CO2 emissions from the road

[164] Reduced vehicle ownership in the context of the third scenario above was assumed to result in increased:

- Walking, cycling, or simply not undertaking a trip
- Car sharing, ride sharing, or ride hailing
- Utilisation of public transport

transport sector as battery prices and the CO_2 content of electricity falls, the implementation of MaaS is more effective from a CO_2 reduction perspective while the transport system is still dominated by fossil fuels.

Even with large anticipated increases in the sales of new electric vehicles (EVs and PHEVs) in upcoming years, the passenger vehicle fleet will still be dominated by fossil-fuel based vehicles well into the 2030s, and it is therefore from now until then that it is most important to activate MaaS. Given that it will take some time to implement wide-scale MaaS, it is imperative to begin this process soon if the window comprising fossil-fuel based passenger vehicle transport is to be targeted effectively.

Timeline of action: Implement now

8.1.8 Recommendation 8. Build a better and more comprehensive Nordic data bank

Nordic countries should produce more local data and evidence on the CO_2 and other emission impacts of shared and multimodal mobility services.[165] This report's extensive literature analysis illustrated that the majority of data sources are currently found outside of Nordic countries, which may not be directly applicable to the Nordic context. Nordic evidence on the impacts of car sharing, ride sharing, bike sharing, grocery home deliveries and automated vehicles is still quite rare, and especially the impacts and benefits of multimodal services need to be studied further in the Nordic countries. Cities also want to learn more about new MaaS services' impact on e.g. land use and street planning.

Timeline of action: Implement now

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[165] Interviews with Finnish experts

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Sammanfattning

Transportsektorn är en betydande utsläppskälla för växthusgaser och andra luftföroreningar och bidrar därigenom både till global uppvärmning och inverkar på folkhälsan. De nordiska länderna har åtagit sig att minska utsläpp och skapa ett mer hållbart och klimatsmart transportsystem. Nya framväxande digitaliserade mobilitetslösningar exemplifierar delningsekonomiska lösningar, som har anmärkningsvärda potentialer att minska både utsläpp och körda bil kilometer.

Digitaliserade mobilitets tjänster, vare sig det är multimodala Mobility as a Service (MaaS) -applikationer eller separata tjänster som bil delning, ger kunden ett alternativ till privat bilägarskap och bilanvändning. I den här studien estimerar vi hur stor potential delade mobilitet tjänster har att minska utsläpp och körda fordon kilometer baserat på både tillgänglig forskning (skrivbordsstudie), modeller och kalkyler.

Många av de existerande delningstjänsterna inom mobilitet, som till exempel MaaS-applikationer, är relativt nyliga. Därmed finns det i skrivande stund endast begränsat med data om tjänsternas effekt och inverkan. En av de mest studerade mobilitetstjänster är bildelning. Enligt resultaten från skrivbordsstudien, ,kan nordiska hushåll som ersätter den egna bilen med bildelning minska sina årliga körda fordon kilometer med cirka 30–45% och sina växthusgasutsläpp med 130 – 980 kg CO2e per år. I den här studien tittade vi nationella minskningspotentialer. Om 5% av hushåll byter från bilägarskap till bildelning uppskattar vi att det har potentialen att minska växthusgasutsläpp med mellan 0,7 och 5,3% från den nuvarande basnivån. De nordiska ländernas potential är sinsemellan olika.

För att bedöma den potentiella framtida effekten av MaaS-lösningar i de nordiska länderna, har vi använt oss av Ea Energy Analyses PETRA-modell, som projekterar utvecklingen av vägtransport energiförbrukning, koldioxidutsläpp och totala kostnader i de nordiska länderna fram till 2050.

Det finns fortfarande flera barriärer för att skapa ett mera transporteffektivt samhälle genom en högre utnyttjning av MaaS och andra digitaliserade mobilitetstjänster. Barriärerna omfattar juridiska, beteendemässiga, ekonomiska och organisatoriska aspekter. Hinder kan också uppstå ur kundens behov och nuvarande service nivåer. I den här studien presenterar vi potentiella sätt att överkomma sådana hinder, genom att använda sig av olika motiverande lösningar och policy instrument som uppmuntrar byte från bilägarskap till användare av delade transportlösningar.

Vi specificerar vad olika aktörer, inklusive regeringar, städer och privata företag, kan göra för att påskynda förändringen. Till sist presenterar vi också policy rekommendationer för the nordiska länderna, baserade på en analys av bästa praxis. De inkluderar rekommendationerna om åtgärder för att minska bilägarskapsberoende, minska körda fordonskilometer, och hur man kan stimulera efterfrågan på smarta mobilitetstjänster och ett grönare transportsystem.

Studien har initierats och finansierats av Nordiska Ministerrådets Klimat- och luftföroreningsgrupp (KOL) och genomförts av Gaia Consulting i samarbete med Ea Energy Analyses. Projektgruppens policyrekommendationer är:

- Rekommendation 1. Lansera ett pan-nordiskt Smart & Grön Mobilitet- som-en-Tjänst (MaaS) transportkort;
- Rekommendation 2. Introducera incitament och skatteförmåner för att stöda en bredare och snabbare adoptering av MaaS och smarta transporttjänster;
- Rekommendation 3. Planera bilfria samhällen och stimulera efterfrågan på nya multimodala transport-tjänster;
- Rekommendation 4. Gör arbetspendling grönare;
- Rekommendation 5. Inför omfattande nordisk transport prissättning;
- Rekommendation 6. Utbilda och bygg upp medvetenhet om smartare och grönare transportval;
- Rekommendation 7. Påskynda MaaS implementering; och
- Rekommendation 8. Bygg en bättre och mera omfattande nordisk databank.

Appendix 1

Key baseline data for the quantitative analysis is shown below in Table 13.

Table 13: Trip length and amount data for the qualitative analysis

	Finland	Sweden	Norway	Denmark	Iceland
Total journey time (h/person/day)	1,22	0,95	1,28	0,95	
Total mileage km average (km/person/day)	41,0	38	47,2	35,6	
Number of trips per day (average) per person	2,73	2,7	3,26	2,9	4,2
Travel time average (h/person/trip)	0,45	0,36	0,38	0,33	
Length of the average trip in (km/person)	14,9	15	14,5	13,1	
Work/school travel km average (km/person/day)	11,2	13	13,22	14,95	
Time spent on commuting (h/person/day)	0,31	0,27	0,27	0,31	
Average number of commuting trips (day/person)	0,69	1,4	0,9	0,84	1,57
Average length of a commuting trip (km/trip)	16	10	16,3		
Average time per commuting trip (h/trip)	0,43	0,53	0,4		
Travel time for shopping/errands average (h/person/day)	0,37	0,63	0,47	0,31	
Average number of shopping/errands trips (person/day)	0,76	0,38	0,88	0,96	1,04
Travel mileages for shopping/errands average (km/person/day)	7,9	4	17,46	6,05	
Travel time for service/giving a ride average (h/person/day)	0,1		0,35		
Travel mileages for service/giving a ride average (km/person/day)	17,4		12,74		
Average number of service/giving a ride trips (day/person)	0,28		0,34		0,69
Travel time for leisure/visiting (h/person/day)	0,43	0,30	0,24	0,37	
Average number of leisure/visiting trips (person/day)	0,97	0,86	0,97	1,13	0,90
Travel mileages for leisure/visiting (km/person/day)	17,4	19	14,16	14,60	
Time spent for other travels than commuting (h/person)	0,92	0,58	1,014	0,64	
Average number of other than commuting trips (day/person)	2,04	1,3	2,36	1,91	1,57
Average length of other than commuting trips (km/person/day)	34,3	30	33,98	23,50	

Missing data in Table 13 was estimated based on the average numbers from other countries.

The sources for the data in Table 13 are the following:

- Finland: Liikennevirasto, 2018. Henkilöliikennetutkimus 2016. https://julkaisut.liikennevirasto.fi/pdf8/lti_2018-01_henkiloliikennetutkimus_2016_web.pdf
- Sweden: Trafik analys, 2017. The Swedish national travel survey 2015–2016. https://www.trafa.se/globalassets/statistik/resvanor/2016/rvu_sverige_2016-reviderad-7-juli.pdf
- Norway: Transportøkonomisk institutt, 2014. Den nasjonale reisevaneundersøkelsen 2013/14 – nøkkelrapport. https://www.toi.no/getfile.php?mmfileid=39511
- Denmark: Danmarks Tekniske Universitet, 2017. The Danish National Travel Survey. http://www.cta.man.dtu.dk/english/tvu/hovedresultater

- http://www.modelcenter.transport.dtu.dk/transportvaneundersoegelsen/hovedresultater
- Iceland: Capacent gallup, 2014. Ferðir íbúa höfuðborgarsvæðisins. https://reykjavik.is/sites/default/files/ymis_skjol/skjol_frettir/4024258_ferdavenjur_heild_041214.pdf

Table 14: CO_2 emission data for passenger cars

	Finland	Sweden	Norway	Denmark	Iceland
Passenger car CO_2 emissions g per km, average (all cars in traffic)	159	154	151		
Passenger car CO_2 emissions g per km, average (new cars 2017)	116,7	123	82	106	
Electric car CO_2 emissions g per km	30,3				

The sources for the information in Table 14 are the following:

- VTT, 2018. Yksikköpäästöt. http://lipasto.vtt.fi/yksikkopaastot/henkiloliikenne/tieliikenne/henkilo_tie.htm
- Liikennefakta, 2018. Hiilidioksidipäästöt. https://www.liikennefakta.fi/ymparisto/henkiloautot/hiilidioksidipaastot
- Trafikverket, 2018. Minskade utsläpp men snabbare takt krävs för att nå klimatmål. https://www.trafikverket.se/contentassets/07f80f01d92144eebf1a01fcb60ac923/pm_vagtrafikens_utslapp_180225.pdf
- Miljøkommune, 2018. Utslipp for kjøretøy og drivstoff. http://www.miljokommune.no/Temaoversikt/Klima/Klima--og-energiplanlegging/omregningsverktoy_tabeller/CO2-utslipp-for-ulike-kjoretoy-og-drivstoff-tabell/
- European Environment Agency, 2017. Monitoring CO2 emissions from new passenger cars and vans in 2016. https://www.eea.europa.eu/publications/co2-emissions-new-cars-and-vans-2016

Table 15: Other air pollutants for passenger cars and buses

	All countries
Passenger car CO emissions g per km, average	0,72
Passenger car. HC emissions g per km, average	0,034
Passenger car. NOx emissions g per km	0,1
Passenger car. PM emissions g per km	0,0026
Passenger car. CH_4 emissions g per km	0,0021
Passenger car. N_2O emissions g per km	0,0016
Passenger car. SO_2 emissions g per km	0,00081
Other traffic. CO_2 emissions g per km, average	trains, trams & metro 0 g
Bus traffic. CO_2 emissions g per km per passenger, average	52
Bus traffic. CO emissions g per km per passenger, average	0,06
Bus traffic. HC emissions g per km per passenger, average	0,009
Bus traffic. NOx emissions g per km per passenger, average	0,29
Bus traffic. PM emissions g per km per passenger, average	0,004
Bus traffic. CH_4 emissions g per km per passenger, average	0,0003
Bus traffic. N_2O emissions g per km per passenger, average	0,002
Bus traffic. SO_2 emissions g per km per passenger, average	0,0002

Source: VTT, 2018. Yksikköpäästöt.
http://lipasto.vtt.fi/yksikkopaastot/henkiloliikenne/tieliikenne/henkilo_tie.htm

Average household sizes, sources:

- Tilastokeskus, 2018. Kotitalouksien määrä, keskikoko, kotitalousväestön koko ja keskimääräiset kulutusyksiköt Suomessa vuosina 1966–2015. https://www.stat.fi/til/tjt/2015/02/tjt_2015_02_2017-03-24_tau_001_fi.html
- Statistics Sweden, 2016. Number of persons and households as well as persons per household 31 December 2014. http://www.scb.se/en/finding-statistics/statistics-by-subject-area/population/population-composition/population-statistics/pong/tables-and-graphs/yearly-statistics--municipalities-counties-and-the-whole-country/persons-and-households-as-well-as-persons-per-household-31-december-2014/
- Statistics Norway, 2017. Families and households. https://www.ssb.no/en/befolkning/statistikker/familie
- Statistics Denmark, 2017. THE AVERAGE DANE. https://www.dst.dk/en/Statistik/Publikationer/gennemsnitsdanskeren
- Eurostat, 2018. Average household size. http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=ilc_lvph01&lang=en

Population:

- Worldometers, 2018. Current World Population. http://www.worldometers.info/world-population/

Table 16: Modal split of transport by country

	Finland	Sweden	*Norway*	Denmark	*Iceland*
Passenger cars	82,5 %	79,9 %	*79,8 %*	77,5 %	*80,0 %*
Buses	7,6 %	5,4 %	*6,6 %*	6,8 %	*6,6 %*
Railways	5,2 %	9,3 %	*7,9 %*	9,3 %	*7,9 %*
Tram & metro	0,7 %	1,8 %	*1,0 %*	0,4 %	*1,0 %*
Bike/walk	4,0 %	3,7 %	*4,7 %*	6,0 %	*4,6 %*

Modal split for Finland, Sweden and Denmark (excluding bike/walk):

- European Commission, 2018. Transport in the European Union Current Trends and Issues. https://ec.europa.eu/transport/sites/transport/files/2018-transport-in-the-eu-current-trends-and-issues.pdf

The above mentioned source was complemented with bike/walk data from the following sources:

- Liikennevirasto, 2018. Henkilöliikennetutkimus 2016. https://julkaisut.liikennevirasto.fi/pdf8/lti_2018-01_henkiloliikennetutkimus_2016_web.pdf
- Trafik analys, 2017. The Swedish national travel survey 2015–2016. https://www.trafa.se/globalassets/statistik/resvanor/2016/rvu_sverige_2016-reviderad-7-juli.pdf
- Transportøkonomisk institutt, 2014. Den nasjonale reisevaneundersøkelsen 2013/14 – nøkkelrapport. https://www.toi.no/getfile.php?mmfileid=39511
- Danmarks Tekniske Universitet, 2017. The Danish National Travel Survey. http://www.cta.man.dtu.dk/english/tvu/hovedresultater
- http://www.modelcenter.transport.dtu.dk/transportvaneundersoegelsen/hovedresultater
- Capacent gallup, 2014. Ferðir íbúa höfuðborgarsvæðisins. https://reykjavik.is/sites/default/files/ymis_skjol/skjol_frettir/4024258_ferdavenjur_heild_041214.pdf

For Norway and Iceland the modal split of transport was estimated based on the average numbers from Finland, Sweden and Denmark.

Table 17: CO2 equivalent multipliers

CH_4 multiplier in CO2 equivalent emissions	21
N_2O multiplier in CO2 equivalent emissions	310

United Nations, 2018. Global Warming Potentials. https://unfccc.int/process/transparency-and-reporting/greenhouse-gas-data/greenhouse-gas-data-unfccc/global-warming-potentials

Appendix 2. Nordic experts interviewed for the report

Figure 22: Nordic experts interviewed for the report

Finland		
Laura Eiro	Director of Markets Unit	Ministry of Transport and Communications of Finland
Krista Huhtala-Jenks	Head of Ecosystem and Sustainability	MaaS Global Oy
Tommi Arola	Head Of Unit, Mobility innovations and R&D	Finnish Transport Safety Agency Trafi
Sweden		
Anna Kramers	Program manager, Sustainable accessibility and mobility services	KTH Royal Institute of Technology
Jan Hellåker	Program Director	Drive Sweden
Hans Arby	CEO	UbiGo
Steven Sarasini	Deputy Research Manager	RISE Viktoria
Denmark		
Per Skrumsager Hansen	Policy adviser	Ministry of Transport, Building, and Housing of Denmark
Jens Kristian Villadsen	Special consultant	Danish Transport, Construction, and Housing Authority
Søren Sørensen	CEO	SFMCON
Norway		
August Grønli	Business Developer	Nabobil
Ida Monclair	Senior Advisor	Norwegian Ministry of Transport and Communications
Jørgen Aarhaug	Senior Research Economist	Institute of Transport Economics (TOI)
Trond Hovland	Managing Director	ITS Norway
Iceland		
Torsten Hermandsson	Director of Transportation	City of Reykjavik
Viktor Steinarsson	Director of Information Technology	Vegagerðin - Icelandic Road and Coastal Administration

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Mobility as a Service and Greener Transportation Systems in a Nordic context

The transport sector is a major source of greenhouse gases and other pollutants. This study estimates the potential of digitalized mobility solutions, such as Mobility as a Service (MaaS), to reduce emissions and vehicle kilometers travelled in the Nordic countries. Also, to assess the potential future impact of MaaS, modelling is done to project road transport's energy consumption, CO2 emissions and total costs in the Nordic countries up to 2050. There are still several barriers to the wider adoption of shared mobility services. We present ways to overcome these barriers with incentives and policy instruments to substitute car ownership, and specify what different actors can do to accelerate this change. Finally we present policy recommendations on how to reduce the dependence on car ownership, reduce the vehicle kilometers driven, and stimulate the demand for greener mobility services.

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