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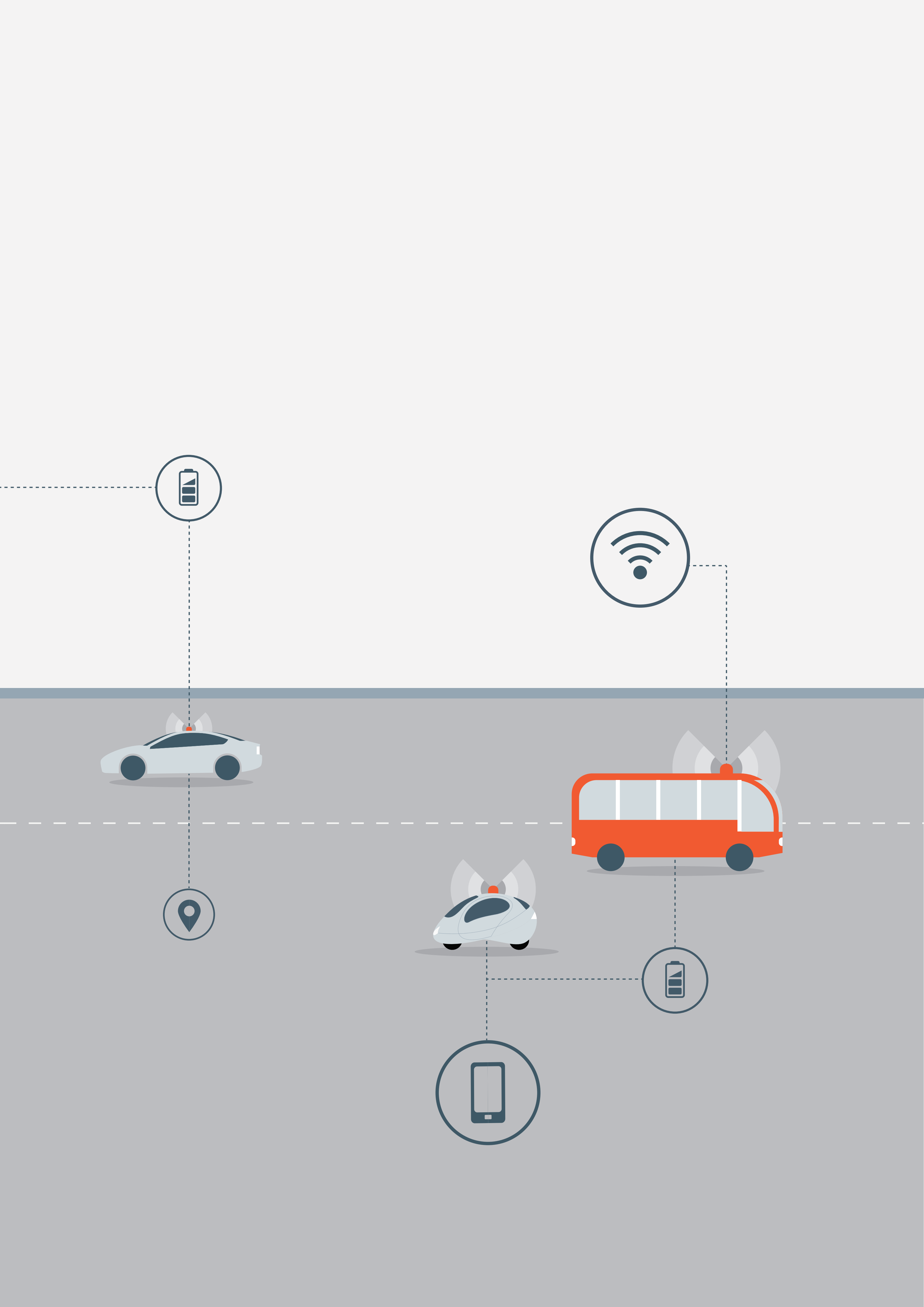
RUTER

THE OSLO STUDY – HOW AUTONOMOUS CARS MAY CHANGE TRANSPORT IN CITIES

REPORT



PREFACE

This study has been conducted between May 2018 and March 2019 by COWI and PTV on behalf of Ruter, the Oslo Region public transport company.

In this project we developed a traffic model for autonomous cars to investigate future scenarios for urban mobility in the Oslo region. The study is inspired by the Lisbon studies by the ITF-OECD.

Prior to this project, COWI was hired by Ruter to conduct an analysis of how technology can change mobility in cities. The knowledge from this analysis was carried forward into the current project, where COWI joined forces with PTV to see concrete results of different scenarios for the future.

This is the first study of its kind in Scandinavia, and among the first worldwide. We are proud to present the results from the project, and to provide more information to the debate on future mobility. We hope the work will contribute to increase the knowledge base for policy decision and a smoother transition to tomorrow's mobility systems.

We would like to thank Ruter for giving us the opportunity to conduct this study and for the useful feedback during the project.

For any inquiries, please contact

MR. ØYSTEIN BERGE,
PROJECT MANAGER

oybe@cowi.com
+47 930 41 416

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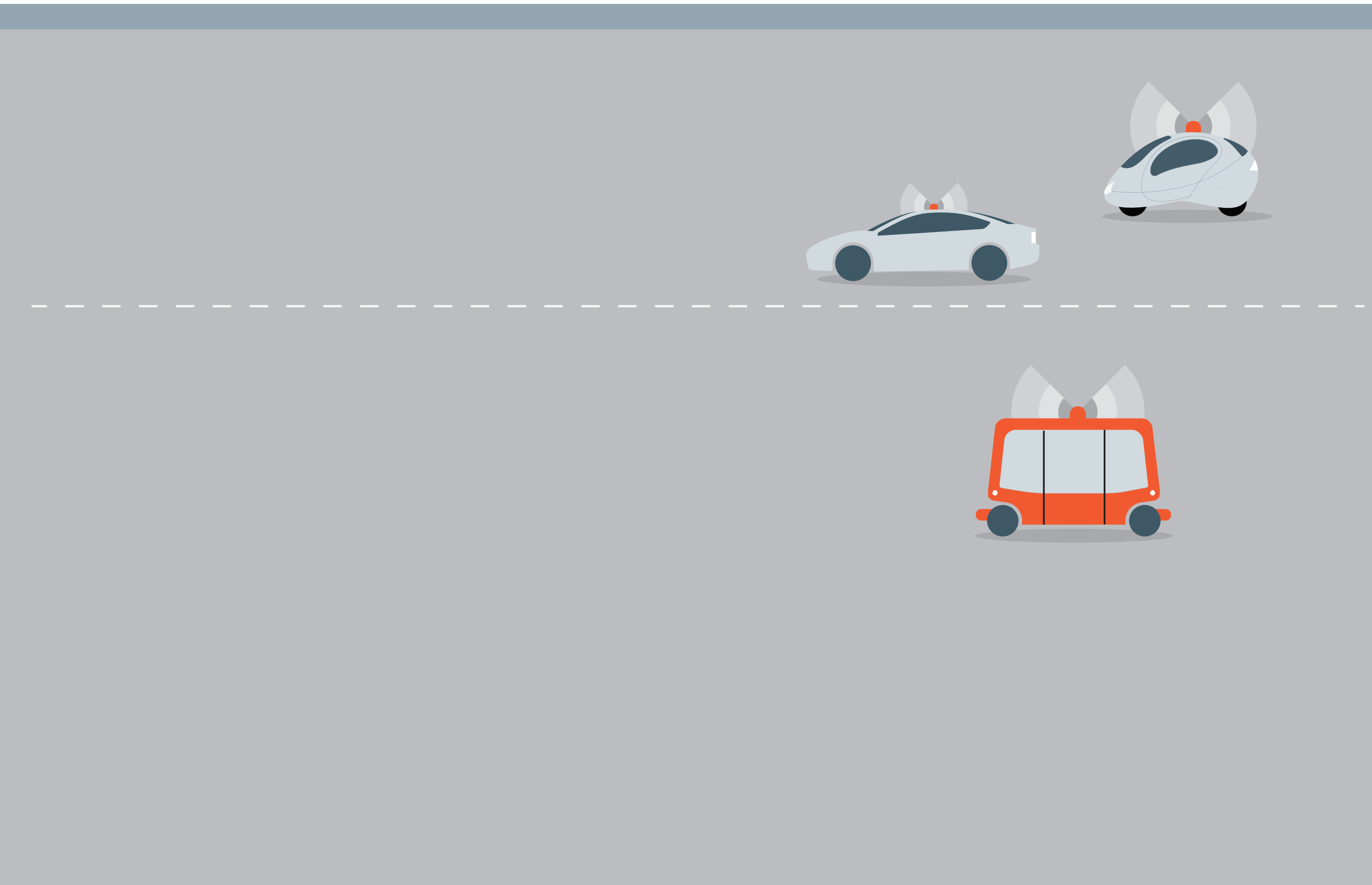


1 SUMMARY IN ENGLISH

BACKGROUND

The purpose of this study is to look into a future where autonomous vehicles and MaaS-based car sharing schemes have replaced private car ownership. MaaS stands for Mobility as a Service, which refers to a transportation system where users buy transportation assignments based on individual and current needs, instead of using a traditional transportation option. This report investigates some potential consequences of such a future for the Oslo region.

Experts differ on how the future of mobility will be and how soon it will come. But there is a consensus that technological development, autonomous vehicles and new MaaS concepts will challenge current transportation norms, infrastructure and urban development.

This study is inspired by similar studies in other cities, especially the studies from Lisbon. We have carried out calculations for different futuristic scenarios for the Oslo region by using a transport model developed to analyse consequences of autonomous cars and MaaS systems. Similar to the Lisbon study, we have based the calculations on the current transportation demand. With this knowledge of the trips in Oslo and Akershus, we have simulated a future with a full implementation of autonomous vehicles in a shared fleet, with and without ridesharing. Thus, allowing us to assess isolated effects of future transport systems and transportation concepts.

The scenarios are designed to capture the outer boundaries, or extremities, of a future where all cars are fully automated. Further analysis on more realistic scenarios are needed to give adequate tools for future planning. This study, for example, doesn't include a scenario where autonomous vehicles feed mass transit as a first and last mile service, which may be something we will see in the future. The study looks at road capacity challenges but does not include calculations of changes in travel time due to changes in traffic levels.

THE SCENARIOS

Six different scenarios were modelled in this study; four main scenarios and two sub scenarios that are variations of the main scenarios. Only the four main scenarios are discussed in this summary. The scenarios differ in how we will travel with the new MaaS concept. Will we travel alone, or will we share trips with strangers? The scenarios also distinguish themselves by which groups will adopt the new MaaS solutions. Will only car drivers adopt new concepts, or will bus and tram riders also shift towards MaaS solutions? And if so, will they shift to services similar to car users or to something more similar to traditional public transport.

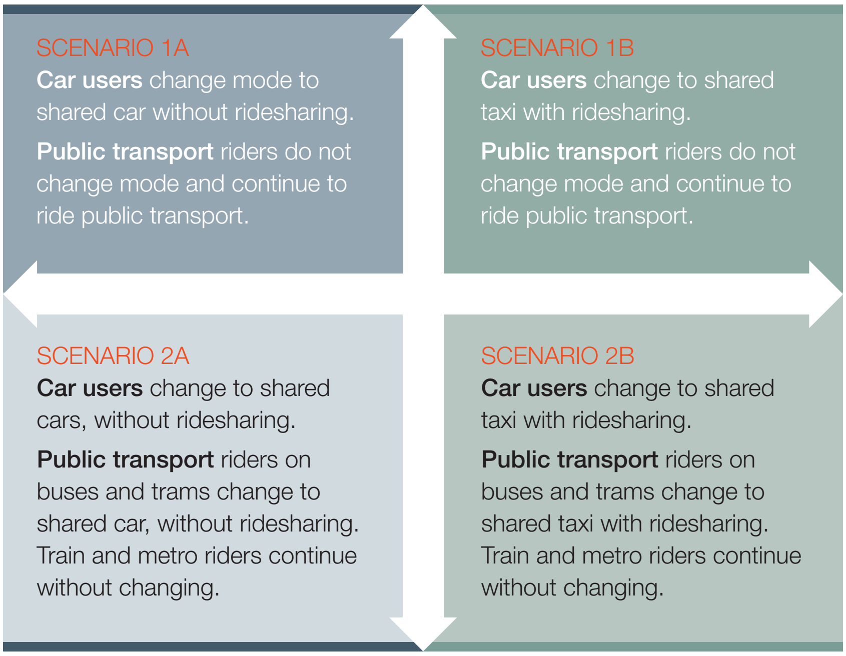


FIGURE 1-1 Scenario cross

The four main scenarios of the study are summarised in the scenario cross in Figure 1-1. The horizontal axis shows level of ride sharing. The vertical axis shows the market strength of public transport. In scenario 1a and 1b today's public transport users will continue to use public transport while private car users switch to a MaaS option. In 2a and 2b, all buses and trams will be replaced by a fleet of autonomous vehicles providing on demand door-to-door service. In both a-scenarios vehicles will be shared, but there will be no ride sharing. In the b-scenarios all transport will allow ride sharing.

The scenarios assume that users will act coherently as a group based on their modal choice when choosing their new transportation method. Either all public transportation riders will continue to use traditional public transport as today, or all public transportation riders who use buses and trams will shift to MaaS solutions. Train and metro users will not change their behaviour in any of the scenarios. In scenarios with only trains and metros, the remaining public transportation modes will be replaced by the new MaaS offers.

MAIN RESULTS

We have looked at effects on vehicle kilometres, fleet size and the level of service. A few of the key findings are presented in this summary. The results are compared with a base scenario, calculated with a traditional transport model.

Network impact (Vehicle kilometres)

BEST CASE:
Traffic reduction of **14 %** to **31 %**

WORST CASE:
Traffic volumes doubles, resulting in a complete traffic breakdown

The traffic volume, measured in vehicle kilometres driven, will, in the most positive scenario, be reduced by 14 %. This is scenario 1b, where public transport users continue to use public transport, and private car users start to share rides with others. The results are shown in Table 1-1. The potential traffic volume reduction is lower in this study compared to previous studies for Lisbon and Helsinki. This can partially be explained by the lower population density in the Oslo region. Furthermore, this study operates with a high service level for the MaaS system. This implies short waiting times and no long detours, resulting in lower effectiveness of the ridesharing system. If longer detours were allowed, each car would be able to accommodate more passengers. We have done sensitivity analyses to see the effects of allowing longer detours. They show that traffic volumes can be reduced by up to 31 % (compared to the 14 % in the main analyses), because of additional possibilities for ride sharing in scenario 1b.

TABLE 1-1 Changes in vehicle kilometres compared with the base scenario

1A	1B	2A	2B	
FROM PRIVATE CAR TO CAR SHARING	FROM PRIVATE CAR TO SHARED TAXI	FROM PRIVATE CAR, BUS AND TRAM TO CAR SHARING	FROM PRIVATE CAR, BUS AND TRAM TO SHARED TAXI	
+26%	-14%	+97%	+31%	CHANGE IN VEHICLE KM

Public transport riders may find the MaaS concept more attractive than their current mode of transport. In the scenario where both, car and public transport riders, change to a MaaS system based on individual driving (without ridesharing), the traffic doubles compared to the base scenario. Despite autonomous vehicles being able to use the road capacity more efficiently than human drivers, the current infrastructure would not manage to deal with such an increase. In the scenario where public transport riders change to MaaS systems with ridesharing, an increase of almost 1/3 compared with the base scenario is estimated. This would pose as a significant challenge for the road capacity and would be in conflict with the city's climate goals.

A scenario with autonomous vehicles feeding mass transit is not analysed in this study. A scenario of this kind could lead to a substantial reduction in vehicle kilometres by making public transport more attractive.

Operator Impact (fleet size)

Number of cars can be reduced by **84 %** to **93 %** in all scenarios

All scenarios show a significant reduction in the numbers of cars needed. In the scenario where all current car users switch to autonomous cars with ride sharing, 7 % of the current car fleet would be necessary to meet the transportation demand in the morning rush hours. Thus, making 93 % of the cars redundant. In the scenarios where all tram and bus riders switch to car sharing, only 16 % of the current vehicle fleet would be necessary. In addition, all busses and trams would be removed from the roads.

These two scenarios represent the best- and worst-case scenarios in the study. The number of cars needed lies between 7 % and 16 % of the current vehicle fleet, which means that the number of private cars on the roads in the morning rush could be reduced by between 84 % and 93 %. This illustrates that a radical reduction in the number of cars is feasible. Previous studies on regions of similar size as the Oslo region support this result.

Customer impact

In a future without private car ownership, we all travel either with public transport, a shared car fleet, by foot or by bicycle. Those who travel with a shared autonomous car may have to wait before a vehicle can pick them up and the vehicle may take a detour to pick up other passengers en route.

An average private car trip in the base scenario takes 12 minutes and is 12 kilometres long. Whereas an average trip with a bus or tram is 13 kilometres but takes 32 minutes.

In the scenario where private car users share cars without ride sharing (1a), the travel distance does not change. In the scenario where they also share rides (1b), the average distance increases. This is because the car may have to take a detour to pick up other passengers. The average detour in this case amounts to approximately one kilometre. For both scenarios the travel time increases. With car sharing, the waiting time and the time for boarding and deboarding causes an increase in travel time of of around six minutes on average. In the scenario with ride sharing, the travel time is increased by an average of around 8 minutes, compared to the base scenario.

In scenarios 2a and 2b, where current public transport users switch to a MaaS option, we obtain approximately the same results on average travel time and distance, as for 1a and 1b respectively. However, for the public transport users, there would be a significant reduction in travel time, from 32 minutes to 21 minutes on average.

Changes in travel time caused by a possible change in traffic congestion are not considered in the scenario results. Hence, the increased congestion due to a higher volume of car traffic, when public transport users switch to MaaS, will have a negative impact on travel time. The opposite may occur in scenario 1b, as the travel time may be lowered along with the reduction in vehicle kilometres caused by ride sharing.

Need for new infrastructure

MaaS systems will impose new requirements to the infrastructure. They will also have the potential to free up areas that are now used for parking. Curb side parking can be removed entirely from the inner city, providing opportunities for better urban development. Furthermore, an absence of parking requirements will benefit city development projects. At the same time, a MaaS system will also require some space and infrastructure. So-called PUDOs, which are zones for picking up and dropping off passengers, will need to be in place. Since there will be very high activity at the PUDOs in busy areas in the city centre, they will require space and infrastructure in order to work efficiently.

POLITICAL SIGNIFICANCE

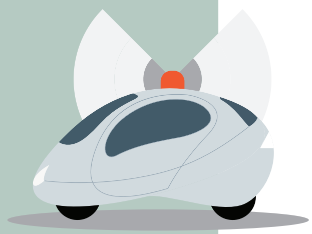
This study shows that shared transportation with a high level of service will not be sufficient to reach the traffic reduction targets in the Oslo region and will challenge road capacity. Hence, we cannot solely rely on autonomous vehicles in a MaaS concept to cater for all of our transportation needs. Traditional public transport combined with cycling and walking will be key elements in solving future urban mobility. Autonomous vehicles can help reaching the target, when integrated in a larger mobility system, but can worsen the situation if they are used as cars are today. Attractive public transport with integrated train, metro and bus services in combination with sufficient facilities for walking and cycling will assist in relieving the road network capacity. Integrating MaaS solutions into the public transport network will be a vital part of making public transport more attractive and competitive, especially in areas with low public transport coverage. The solution of tomorrow's mobility challenges lies within the combination of mass transit and integrated MaaS systems.

Oslo has ambitious environmental targets and has been appointed European Green Capital of 2019. In sustainable development, mobility plays an important role. Oslo has set a target of reducing car use by one third by 2030. Our study shows that there are uncertainties related to the effect of implementing autonomous cars on traffic. Without ridesharing, traffic would increase. Traffic would also increase, if MaaS became more attractive than traditional public transport. With ridesharing and a high share of public transport riders, the MaaS system can help to achieve the climate change adaption target. Although, this study shows that the traffic reduction potential is less than estimated in previous studies from other cities. In the most optimistic scenario a reduction of 14 % traffic is possible. Population growth will offset the reduction and in the coming years and lead to a traffic growth. This study assumes a very high level of service. When relaxing this precondition, by allowing longer waiting times before a vehicle shows up or permitting longer detours, the effect on traffic will be substantially better. The integration of MaaS systems into existing public transport is likely to lead to even better results concerning traffic reduction.

MODEL ASSUMPTIONS

We assume an optimal car fleet allocation to meet the transportation demand. In real life, there may be multiple competing MaaS providers that are not coordinated, resulting in the emergence of a suboptimal situation. This would likely lead to an increase in traffic compared to our optimal simulation results. Some other model assumptions are:

- Only trips starting and ending in Oslo and Akershus are included.
- Calculations are based on the transportation demand forecast for 2020 (the base scenario). The demand is estimated for peak hours from 6 a.m. to 10 am. on a weekday.
- Only car and public transport trips are calculated. Cyclists and pedestrians are assumed not to change their travel modes.
- Public transport riders who travel by train, both regional and local train and metro, will keep using these modes in all scenarios.



2 SUMMARY IN NORWEGIAN

BAKGRUNN

Hensikten med denne studien er å se inn i en fremtid der selvkjørende biler og MaaS-baserte bildelingskonsepter er dominerende. MaaS står for Mobility as a Service, og handler om en mobilitet der vi ikke selv eier en bil, men kjøper transport som en tjeneste. Denne rapporten undersøker potensielle konsekvenser av en slik fremtid for Oslo og Akershus.

Det er delte meninger om det i hele tatt vil skje store endringer, og i hvilket tempo de i så fall vil komme. Det er likevel ingen tvil om at teknologiutviklingen innen selvkjørende biler, og nye forretningsmodeller basert på MaaS-konsepter med høy grad av deling, utfordrer måten vi i tenker på transportsystem, infrastruktur og byutvikling.

Inspirert av tilsvarende studier i andre byer, hvor studier fra Lisboa har vært særlig sentrale, har vi gjennomført beregninger for ulike scenarioer for Oslo og Akershus. Som i Lisboa-studiene har vi tatt utgangspunkt i dagens transportetterspørsel. Basert på kunnskap om hvor alle reiser i Oslo og Akershus, har vi simulert en fremtid med full innfasing av autonome kjøretøy i en delt bilpark – med og uten samkjøring. Slik kan vi vurdere isolerte effekter av nye transportsystemer og konsepter.

Scenarioene er ment å representere ytterpunkter av hvordan fremtiden kan se ut, og skal dermed “spenne opp lerretet” for videre undersøkelser. Videre studier av mer realistiske scenarioer vil bidra ytterligere til vår forståelse av hva fremtiden kan bringe. Vi har i denne omgang ikke sett på et scenario der selvkjørende biler mater det tradisjonelle kollektivsystemet, og dette er noe foreslår å følge opp videre. Studien har ikke sett på endringer i reisetid som følge av endringer i kø.

SCENARIOENE

Vi har regnet på seks ulike scenarioer for hvordan fremtidens mobilitet kan se ut; fire hovedscenarioer og to delscenarioer. I dette sammendraget er kun resultater fra hovedscenarioene presentert. Scenarioene skiller først mellom hvordan vi ønsker å reise med de nye MaaS-systemene. Vil innbyggerne reise alene eller vil de samkjøre med andre de ikke kjenner? Deretter skiller vi scenarioene i hvem som vil benytte MaaS-tilbudet. Er det kun dagens bilbrukere som vil skifte til MaaS, eller vil også dagens buss- og trikkepassasjerer skifte til MaaS-tilbudet? Og vil disse kollektivpassasjerene benytte seg av et MaaS-tilbud som innebærer lik adferd som dagens bilister, eller vil de bli del av et tilbud med et MaaS-system bestående av en rekke minibusser?

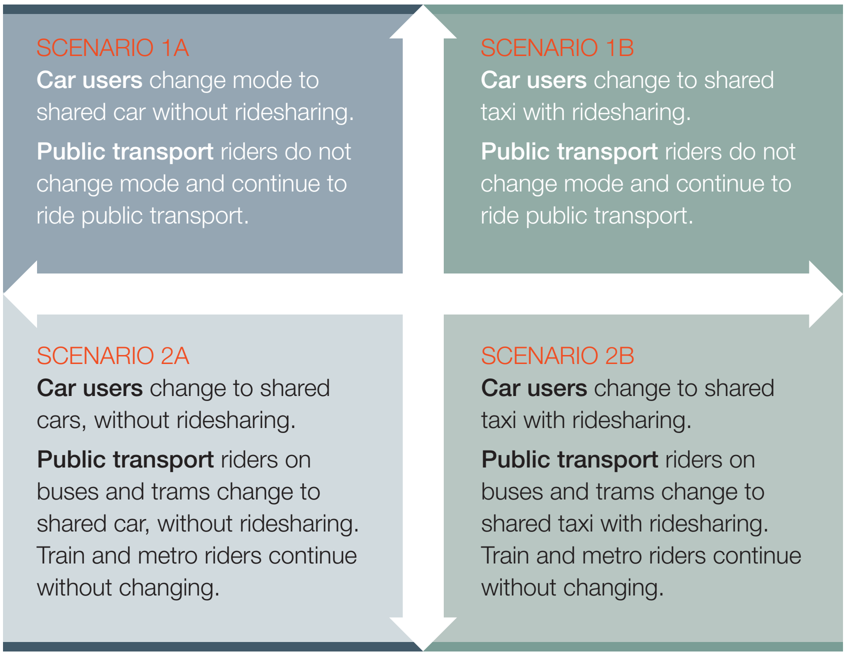


FIGURE 2-1 Scenariokrysset

Scenarioene som er analysert kan oppsummeres i scenariokrysset vist Figure 2-1. Det er fire hovedscenarioer, 1a, 1b, 2a og 2b. Langs den horisontale aksen deles det i grad av samkjøring. Den vertikale aksen deles etter hva kollektivbrukere vil gjøre: fortsette å reise med tradisjonell kollektivtrafikk eller gå over til mindre selvkjørende kjøretøy. I scenarioene 1a og 1b vil dagens kollektivbrukere fortsette å reise kollektivt, mens man i 2a og 2b vil erstatte det tradisjonelle kollektivsystemet med en flåte selvkjørende bilder. I a-scenarioene, 1a og 2a, vil kjøretøyene benyttes slik privatbiler gjør i dag – uten samkjøring med fremmede. I b-scenarioene vil all transport tillate samkjøring, og bilene man sitter i kan stoppe for å plukke opp andre på veien.

Scenarioene forutsetter at dagens bilbrukere vil agere som én gruppe i møtet med det nye transporttilbud. Det samme gjelder kollektivbrukere. Enten vil alle fortsette med tradisjonelle kollektivreiser, eller så vil alle i gruppen gå over til et MaaS-system. Kollektivreiser i simuleringene vil enten foregå som i dag, med busser, trikker, tog, T-bane og ferjer, eller kun av T-bane og tog. I scenarioer med kun tog og T-bane ser vi for oss at busser og trikker er erstattet av et nytt selvkjørende MaaS-tilbud.

HOVEDRESULTATER

Vi har sett på endringer i antall kjørte kilometer, hvor mange biler som trengs og servicenivå. Resultatene for scenarioene er sammenliknet med et basisscenario, som er estimert trafikk i Oslo og Akershus, i perioden fra klokken 6 til 10 en hverdag.

Effekter på veinettet (kjørte kilometer)

BEST CASE:
Trafikken reduseres med mellom **14 %** og **31 %**

WORST CASE:
Trafikken dobles, og veinettet bryter sammen

Trafikkvolumet, målt i kjørte kilometer, vil i det mest optimistiske scenarioet reduseres med 14 %. Dette er scenario 1b, der kollektivbrukere fortsetter å benytte kollektivtransport og bilbrukere aksepterer å samkjøre med fremmede. Resultatene er vist i Table 2-1. Potensialet for reduksjon i trafikkvolumer er lavere i denne studien sammenliknet med tidligere studier fra Lisboa og Helsinki. Dette kan delvis forklares med lavere befolkningstetthet i Osloregionen. Videre kan det forklares med høyt servicenivå i denne studien. I vår modellering har vi ikke tillatt lange ventetider eller lange omkjøringer for passasjerene, og det betyr lavere effektivitet i utnytelsen av de selvkjørende bilene. Vi har gjort en sensitivitetsanalyse der vi har tillatt lengre omkjøringer, og de viser at reduksjonen i kjørte kilometer kan bli 31 %, sammenliknet med 14 % i hovedanalysen.

TABLE 2-1 Endringer i antall kjørte kilometere sammenlignet med basis-scenarioet

1A	1B	2A	2B	
FRA PRIVATBIL TIL BILDELING	FRA PRIVATBIL TIL DELETAXI	FRA PRIVATBIL, BUSS OG TRIKK TIL BILDELING	FRA PRIVATBIL, BUSS OG TRIKK TIL DELETAXI	
+26%	-14%	+97%	+31%	ENDRING I KJØRETØYKILOMETER

For dagens kollektivbrukere kan ulike MaaS-konsepter være attraktivt. I scenarioet der både bil og kollektivtrafikanter går over til et MaaS-system basert på individuell kjøring i små, selvkjørende biler (uten samkjøring), viser beregningen at trafikken nesten vil fordobles sammenliknet med dagens trafikk. Selv om selvkjørende biler vil utnytte veinettet bedre enn bilister gjør i dag, er denne trafikkøkningen ikke mulig med dagens infrastruktur. Veikapasiteten vil ikke strekke til. Også i scenarioer hvor dagens kollektivpassasjerer bytter til MaaS-systemer, men med samkjøring, vil vi få en trafikkvekst på nesten en tredjedel. Dette vil gi en betydelig utfordring for veikapasiteten, og vil bryte med viktige samfunnsmål i Osloregionen.

Effekter for operatørene (flåtestørrelse)

Antall biler kan reduseres med mellom
84 % og **93 %** i alle scenarioer

Antall biler kan reduseres betydelig i alle scenarioene. I et scenario hvor alle dagens bilbrukere deler biler og benytter seg av samkjøring vil 7 % av dagens bilpark være tilstrekkelig til å dekke transportbehovet i morgenrushet. Det betyr at 93 % av bilene blir overflødige. I et scenario der alle som i dag benytter buss og trikk går over til å benytte delebiler på samme måte som dagens bilbrukere, vil 16 % av dagens bilpark være tilstrekkelig. Og i dette scenarioet vil i tillegg alle busser og trikker forsvinne fra gatene.

Disse to scenarioene representerer best- og worst-case-scenarioer i studien med et behov som spenner mellom 7 % og 16 % av dagens bilpark, noe som betyr at antall biler i morgenrushet på en hverdag i Oslo og Akershus kan blir redusert med mellom 84 % og 93 %. Dette illustrerer at det er snakk om en radikal reduksjon i antall biler. Tidligere studier fra Lisboa og Helsinki har kommet frem til tilsvarende resultater.

Effekt for de reisende (servicenivå)

I en fremtid uten privateide biler vil alle reise kollektivt, med en flåte av delebiler eller med sykkel og gange. De som benytter en delebil med samkjøring må som regel vente litt før de blir plukket opp, og kjøre en omvei dersom de skal hente andre passasjerer.

En gjennomsnittlig reise med bil i basisscenarioet tar 12 minutter og er 12 kilometer lang. En gjennomsnittlig kollektivreise med buss eller trikk er 13 kilometer lang, men tar 32 minutter i snitt.

I scenarioene der privatbilister deler biler (1a) og samkjører (1b), er det bare i 1b det er endringer i lengden på reisene. Det er fordi bilene noen ganger tar en omvei for å plukke opp nye passasjerer ved samkjøring. Gjennomsnittlig omkjøring i dette scenarioet er 1 kilometer. I begge disse scenarioene øker reisetiden. For scenarioet med delebiler (uten samkjøring) øker reisetiden med om lag 6 minutter i snitt. Dette er ventetid og tiden det tar å sette seg inn og gå ut av bilen. I scenarioet med samkjøring øker reisetiden med om lag 8 minutter sammenliknet med basisscenarioet.

Scenarioene 2a og 2b, der kollektivreisende med buss og trikk går over til MaaS, gir omtrent samme resultater for gjennomsnittlig reisetider og reiselengde som for 1a og 1b. Men for denne gruppen vil det være en betydelig reduksjon i reisetid, siden de har lenger reisetid i basisscenarioet. Reduksjonen i reisetid for dagens kollektivbrukere vil reduseres fra 32 i gjennomsnitt til 21 minutter.

I disse beregningene er det ikke tatt hensyn til endringer i reisetid som følge av endring i trafikkmengde. Vi kan likevel si at scenarioene med økt trafikkvolum vil gi økte køutfordringer, med påfølgende økning i reisetiden. I scenarioet som gir reduksjon i trafikkvolum, scenario 1b, vil køene bli mindre, og reisetiden i områder med køutfordringer vil kunne gå ned.

Behov for ny infrastruktur

MaaS-systemene i disse scenarioene vil stille nye krav til infrastrukturen. Men det vil også ha potensialet til å frigjøre store parkeringsarealer. Parkering kan fjernes helt fra byområder og dermed gi høyere by- og livskvalitet, og det vil gjøre fortetting enklere. Parkeringshus og kjellere blir kanskje overflødige og kan utnyttes til andre formål. Fravær av parkeringsnormer i utbyggingsområder vil gi bedre økonomi i byutviklingsprosjekter. Samtidig vil det bli behov for nye areal til områder for av- og påstigning for passasjerer i samkjørte selvkjørende biler. Spesielt i sentrale områder med høy aktivitet vil det kreve areal og en infrastruktur som legger til rette for dette.

POLITISK BETYDNING

Et av hovedfunnene i rapporten er at vi ikke belage oss på at selvkjørende MaaS-konsepter alene vil løse utfordringene med å nå målene for trafikkreduksjon i Oslo. Også i fremtiden vil en styrking av det tradisjonelle kollektivsystemet, sammen med økt andel sykkel og gange, være viktige elementer for å løse Osloregionens transportutfordringer. Gode togforbindelser, T-bane og et godt busstilbud vil sammen med tilrettelegging av sykkel- og gangveier være viktige virkemidler også etter at selvkjørende teknologi er en selvfølge. Nye MaaS-systemer som er en integrert del av kollektivtilbudet vil også kunne spille en viktig rolle gjennom å gjøre kollektivtransport mer attraktivt, spesielt for innbyggere som skal til eller fra områder med svak kollektivdekning. Løsningen på morgendagens mobilitetsutfordringer ligger i en kombinasjon av massetransportløsninger og integrerte MaaS-konsepter, samt en arealpolitikk som begrenser transportbehovet.

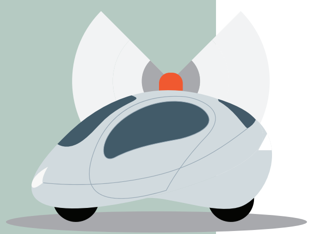
Oslo har en ambisiøs miljøpolitikk og er utnevnt Europas miljøhovedstad 2019. Mobilitet spiller en viktig rolle i å utvikle Osloregionen i en bærekraftig retning, og blant målene i Oslos klimastrategi er at bilismen skal reduseres med en tredjedel. Oslo-studien viser at det er usikkert hvilken effekt innføring av selvkjørende teknologi kan ha på samfunnet. Det vi likevel vet sikkert er at trafikken vil gå opp uten samkjøring. Det samme vil skje dersom MaaS-systemene blir mer attraktive enn tradisjonell kollektivtransport. Med samkjøring og en fortsatt høy kollektivandel kan MaaS-systemet bidra til å nå de ambisiøse målene for reduksjon i transport. I det mest optimistiske scenarioet er det kun en trafikkreduksjon på 14 prosent, og med befolkningsøkningen vil det ikke ta mange år før man allikevel kan ha en vekst i trafikken. Studien har høye krav til servicenivået (tillatt vente- og reisetid), og har ikke sett på et konsept der selvkjørende kjøretøy bringer folk til og fra kollektivknutepunkter.

Selvkjørende teknologi vil ikke i seg selv hjelpe oss til å nå klimamål eller gi oss bedre byutvikling. Men dersom vi klarer å benytte teknologien til å øke samkjøring og å gjøre tradisjonell kollektivtransport mer attraktiv, vil de utgjøre en viktig del av utvikling mot mer bærekraftig mobilitet i byene.

FORUTSETNINGER I MODELLBEREGNINGENE

Vi forutsetter en optimal allokering av bilene i den selvkjørende flåten. I virkeligheten kan det bli en rekke ulike leverandører av transporttjenester som ikke har integrerte systemer. Dette kan føre til en mindre effektiv allokering av biler, og dermed behov for en større flåte enn det vi har beregnet. Andre forutsetninger og spesifikasjoner i beregningene er:

- Kun reiser som starter og stopper i Oslo og Akershus er med i beregningene.
- Beregningen bruker etterspørsel fra trafikkmodeller for 2020
- Etterspørselen er beregnet for tidsrommet 6 til 10 om morgenen en ukedag.
- Kun bilreiser og kollektivreiser er med. Syklister og gående er ikke inkludert i beregningene.
- Reisende som benytter tog eller t-bane vil fortsette å bruke dette i alle scenarioer.



3 INTRODUCTION

Mobility in cities is changing. After more than half of a century with private cars as the main mode of transport, a transport revolution is expected.

New technology can play a key role in shaping the future of transportation. Autonomous cars can facilitate a shift towards a Mobility as a Service system (MaaS) where transport is considered a service provided to you rather than something you do yourself.

Several studies on how autonomous cars can change transport have been conducted in recent years. Most prominent are the OECD International Transport Forum's four Lisbon studies, followed by a Helsinki study and an Auckland study. The report you are currently reading is the Oslo study, where we have looked at the impact of autonomous cars on transport in the Oslo urban area.

Ruter asked COWI in 2017 to conduct a study of how technology can change mobility, and in 2018 COWI and PTV joined forces to develop a model that explores Mobility as a Service in the Oslo region.

The report you are currently reading will provide us with more knowledge about how a future with only autonomous cars may look like.The technology could help us reach the goals to reduce traffic and air pollution. However, autonomous cars could also increase traffic, thus make it more difficult to reach our goals. Whether new technology will be a blessing or a curse will depend on the way it is introduced to the society. Increased knowledge will help us make the right choices, making it easier to benefit from the technology.

This study is a first step towards quantifying how autonomous cars could change the Oslo region. Further analysis is needed to investigate different, and perhaps more realistic, scenarios for future mobility. A natural next step would be to look at scenarios where autonomous vehicles feed the existing public transport system. Similar studies for Lisbon have shown better results on traffic reduction. The model we have developed for this Oslo study provides a strong tool for such analysis.

4 SCENARIOS FOR FUTURE MOBILITY

4.1 PREDICTING THE FUTURE

There are plenty of reports and discussions about the future of transport. Most researchers agree that mobility is undergoing a broad change, which will change the way we move and how we perceive mobility. This will also affect the way we design cities. However, there is not yet a common understanding of how these changes will take place, how rapid they will be and what consequences they will entail. Furthermore, there are uncertainties tied to emerging business models and how the market will encounter these changes. The market consists of many different mobility needs and possibly many more suppliers of transport services.

The development is first and foremost driven by innovation in technology. Autonomous vehicles are no longer a farfetched dream, rather a close future. Autonomous vehicles connected to other road users and to the infrastructure will pave the way for new ways of transporting people and goods.

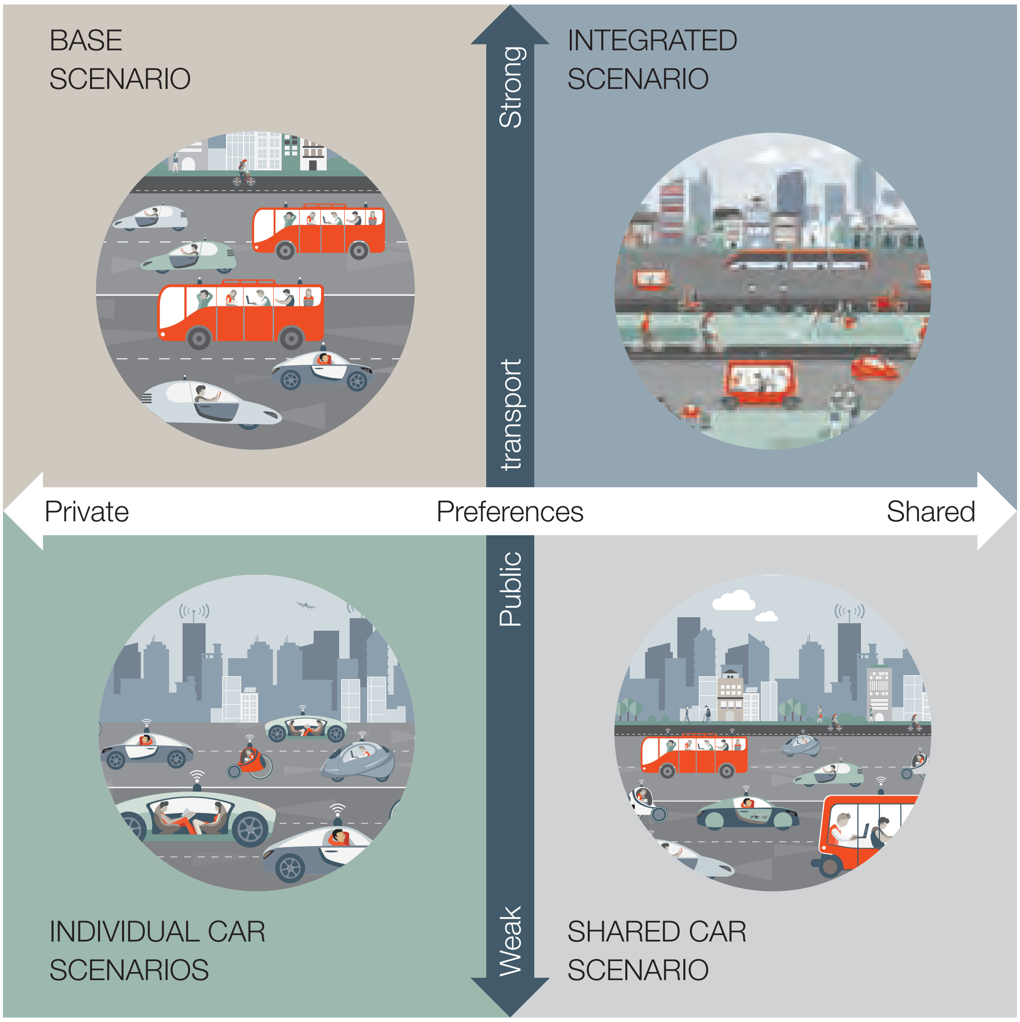
The development of the future mobility system can take different directions and it is therefore wise to describe several different possible future outcomes. Certainly, the mobility development will not continue as business as usual.

A reputable method to work with an uncertain future is to identify two critical uncertainties, each represented by an axis in a two-dimensional matrix. By combining the respective extremes of the critical uncertainties, it is possible to create four completely different future scenarios. These scenarios serve as a basis for the assessment of different future outcomes, which then can be compared and discussed.

4.2 TECH TRENDS 1 – SCENARIO CROSS

In the first phase of this project, "Technological trends 1"[1], we did a literature review, resulting in the development of the scenario axis. The scenario cross consists of four different future scenarios for mobility in the Oslo region, as shown in Figure 4-1. All vehicles are at self-driving level 5 in all scenarios, meaning that all vehicles will be driverless. There is no consensus when this technology will be implemented. The aim of the Oslo study is to foresee and elaborate the consequences of a fully automated fleet and digitalized transportation. Not to neglect that automatization will be introduced gradually, and it could take several decades before full autonomation is implemented.

1 *Teknologiske trender og betydning for mobilitet*, COWI for Ruter, 2017



SCENARIOS –
"TEKNOLOGISKE TRENDER 1"

The scenarios differ in the follwing dimensions (each represented by an axis): public transport and preferences. Public transport can be either strong or weak, and preferences could be private or shared.

- As a starting point, we have established a *base scenario*, which depicts the current forecast in traffic demand in 2020. This base scenario is a mix of privately owned cars and strong public transport – capturing the current transportation situation in Oslo.
- Cars in the *individual car scenario* are not necessarily owned individually, rather are they used as individual cars with only private travels or smaller private travels in groups. Public transport is quite weak.
- In the *shared car scenario*, the private vehicle fleet is completely or partially replaced by a high degree of car sharing and ridesharing.
- In the *integrated scenario*, there is a high degree of shared car and ridesharing, combined with strong public transport.

FIGURE 4-1 Scenarios from phase 1

One of the biggest uncertainties are the (road) users' preferences – will they prefer private and individual transportation, or will they prefer shared transportation. On the one hand, historically, people in Oslo have preferred private ownership. On the other hand, some trends indicate a shift in preference towards more sharing. This is especially prominent among younger people living in cities, where vehicles or rides do not necessarily need to be private or individual.

Another uncertainty is the future of public transport. Will the availability of autonomous vehicles outperform public transport, since they could potentially accommodate everyone, or will it improve the attractiveness of public transportation? The new trends could also add a new aspect to public transport, especially if demand-based ridesharing in smaller vehicles became widely adopted. Furthermore, a fleet of larger autonomous cars and smaller buses could be an important supplement or even a replacement for conventional public transport.

4.3 THE LISBON STUDIES

Several studies conducted by the OECD International Transport Forum (ITF) have inspired the Oslo study. The OECD has published a series of four reports on Lisbon over the last four years (see Figure 4-2). These studies extract data and model results from Lisbon to analyse potential consequences of autonomous vehicles in a fleet of shared cars in conventional size and/or minibuses.

The first report from 2015 focused on the consequences of a shared fleet of autonomous vehicles, that accommodated travellers within the borders of Lisbon city. This means that both the point of origin and destination had to be within Lisbon to be included. The future demand for transportation was forecasted using the national travel survey for Lisbon from 2010. The forecast demand in that survey is underestimated, because the population of Lisbon is expected to increase due to urbanization. However, this makes it possible to assess traffic and mobility in an autonomous and digital future, assuming all other features to be equal.

The scenarios examined by the first Lisbon study distinguished themselves, by the adoption level of automatization (50 % or 100 %). Furthermore this report modelled the presence of high-quality public transport (with or without subway) and the use of shared vehicles (individually used or rideshare). The main result in the first Lisbon report was that there was a huge potential to reduce the vehicle fleet. However, all scenarios without ridesharing would lead to big traffic congestion challenges, despite a significantly lower number of vehicles. This is because autonomous vehicles will also drive around empty between rides and thus increase the kilometres travelled.

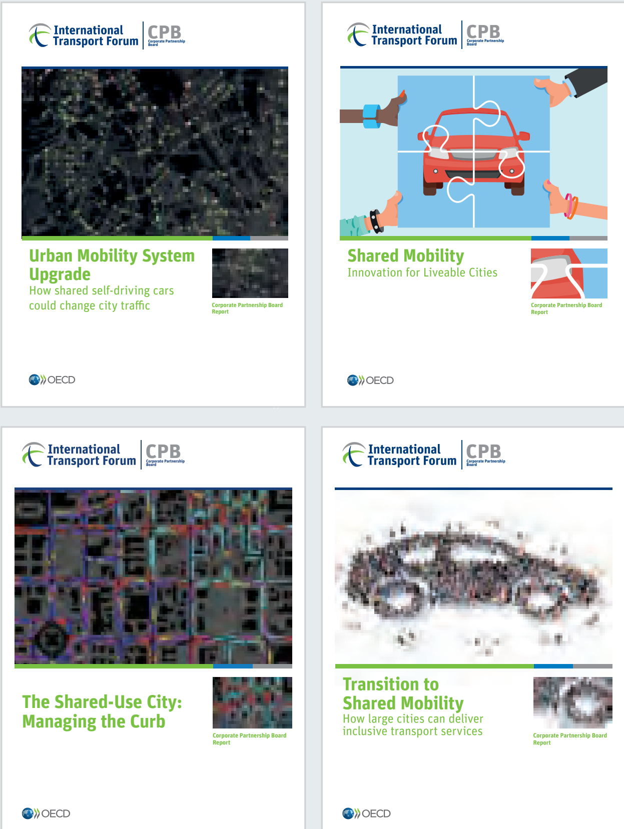
In the second Lisbon study from 2016 the focus changed, as they shed light onto ridesharing when having a fleet of autonomous vehicles. This study relies on the same data and includes the same geographical constraints as the previous study. The authors introduced two types of services that would handle ridesharing in a fleet of shared taxis and a fleet of taxibuses. The authors established a set of rules for the road users' modal shifts. Most car drivers are expected to make a modal shift towards shared taxis, while bus riders are expected to shift to taxibuses. Pedestrians remain pedestrians, subway and train users remain on the same modes, unless there is a taxi bus service that can replace the entire trip. In these cases, users are expected to perform a modal shift towards the taxibus.

Shared mobility in the second Lisbon study gives more positive findings on traffic flow compared to the first study, resulting in lower CO2 emissions.

In the third Lisbon study from 2017, the authors relaxed the geographical constraint to account for shared mobility in the entire region. Like in previous studies, they used current transportation behaviours to predict a future modal share. As they expanded the research area, the study could now include trips that start or end beyond Lisbon's borders, but the trips needed to be within the region. These trips are of significant volume and therefore beneficial to include. This study used the same modal shifts as previous studies. The new feature is that taxibuses would now be used whenever applicable to reduce first and last mile problem for travellers, when they primarily use ferries, trains and subways.

Results from the third Lisbon study were surprising, as central key performance indicators improved considerably, compared to the isolated studies, that only included the city of Lisbon. Modelling the scenario where conventional car and bus trips were replaced by car sharing taxis and taxibuses, the car occupancy rates increased, while vehicle kilometres travelled decreased. Thus, resulting in a large reduction of CO2 emissions in the outskirts of Lisbon city. This can partially be explained by multimodal rides, where taxibuses are more effective in terms of the first and last mile problem in sparse settled areas.

The fourth and most recent Lisbon study was published in early 2018. It elaborated on the consequences of well-established shared cars and ridesharing schemes for city planning and city design. Lisbon was just one of several cases that were researched and examined. The data gathered from the three previous Lisbon studies was converted via PTV Visum to a format that supports simulations in PTV MaaS Modeller. This report is an extension of the considerations and trade-offs that need to be weighted to be able to adjust our cities for future urban transportation. It also considers the possibility for radical changes in how we design our cities. Some changes that are likely to take place are a reduced need for curb parking space and a reduced number of parking lots. This could also affect the way we design and manage larger terminals. At the same time curb space is needed to pick up and drop off passengers in shared taxis and taxibuses.



LISBON STUDIES

The International Transport Forum (ITF) team at the OECD, has in recent years published a range of reports, focusing on a future with autonomous vehicles and new sharing concepts. To examine the real-life outcomes, they usually set a mid-sized European city as a case scenario.

Generally, the focus of the report is directed towards big disruptive change that technology effects. They also research new business areas that may unfold as MaaS gains a stronger foothold in cities.

Lisbon is a suitable city to be used as a case for future mobility studies. There are four reports published, where data from the city creates an opportunity for calculations of the consequences of autonomous vehicles. The demand is not amended for the future, as they use the current demand in their studies.

The focus on the first report from 2015 was a shared autonomous vehicle fleet. In 2016 the focus was ridesharing in a shared autonomous vehicle fleet. In 2017 they examined the consequences for the whole Lisbon region. The most recent report from 2018 examined how the city may change and the topic was managing the curb.

SOURCES:

ITF/OECD (2015). Urban Mobility System Upgrade. How shared self-driving cars could change city traffic
ITF/OECD (2016). Shared Mobility. Innovation for liveable cities
ITF/OECD (2017). Transition to Shared Mobility. How large cities can deliver inclusive transport services
ITF/OECD (2018). The Shared-Use City: Managing the Curb

FIGURE 4-2 The Lisbon studies – an overview

AUTONOMOUS VEHICLE TYPES AND SHARING CONCEPTS

The taxibuses are based on the same principle as shared taxis but can carry more passengers. For modelling purposes, the upper capacity of the taxibuses is set to 20 persons, although it could be possible to deploy smaller buses.

Shared cars
Passenger car with space for 4 passengers.

Used like today's private passenger cars by one person or small private travelling groups.

After disembarkation of the passengers, the vehicle either drives autonomously to the next user, or parks and waits to be assigned to a new user.

Shared taxi
Passenger car with space for up to 6 passengers.

Ridesharing with strangers based on similar itineraries.

A door to door service, that includes detours, when serving passengers with different origins and/or destinations.

Taxibus
Minibuses that can accommodate up to 20 passengers.

Ridesharing with strangers, based on similar itineraries.

A door to door service, that includes detours, when serving passengers with different origins and/or destinations.

FIGURE 4-3 Types of vehicles in the Oslo study

4.4 SCENARIOS IN THE OSLO STUDY

4.4.1 AUTONOMOUS VEHICLE CONCEPTS

The Oslo study introduces three new types of mobility services in the Oslo region. Common for these three services is that they are automated and digitalized (see Figure 4-3).

The concept of shared cars does not encompass ridesharing. In the current base scenario 88 % of all trips in a shared car are sole occupant trips, 10 % have 2 travellers, and 2 % have 3 or more persons that travel together[2]. Shared cars operate sequentially. They offer door to door transportation for the travellers (usually only one person). Once a service is completed, they get assigned to the next trip, which then again drives from door to door. Therefore, the car will at times be driving without passengers as it repositions between trip requests.

2 Norwegian National Travel Survey 2013/14

PREREQUISITES FOR THE MAAS CONCEPT: OPTIMIZATION IN A SHARED SYSTEM

The concept of Mobility as a Service is based on the idea that residents and road users do not necessarily need to own their transportation mode. Through an IT-platform they can make informed decisions based on their actual mobility need, as they can search for different modes. Furthermore, they can book and possibly pay for the service digitally.

Vehicles and trips are offered by different agents: Public transportation providers, car manufacturers, owners of city bike hiring schemes, etc. Optimization and dispatching could either be facilitated in a shared system or a sub separated system, where some providers use a joint system that for example serves as a common payment method.

Currently, no extensive MaaS systems, that could be a viable alternative to the use of private cars, exist. Therefore, the direction in which MaaS will develop is still uncertain at this time.

The Lisbon studies used a MaaS system, where all the cars for passenger transportation were optimized and dispatched by a large, shared dispatching system. The same assumptions lie in the foundation of this Oslo study.

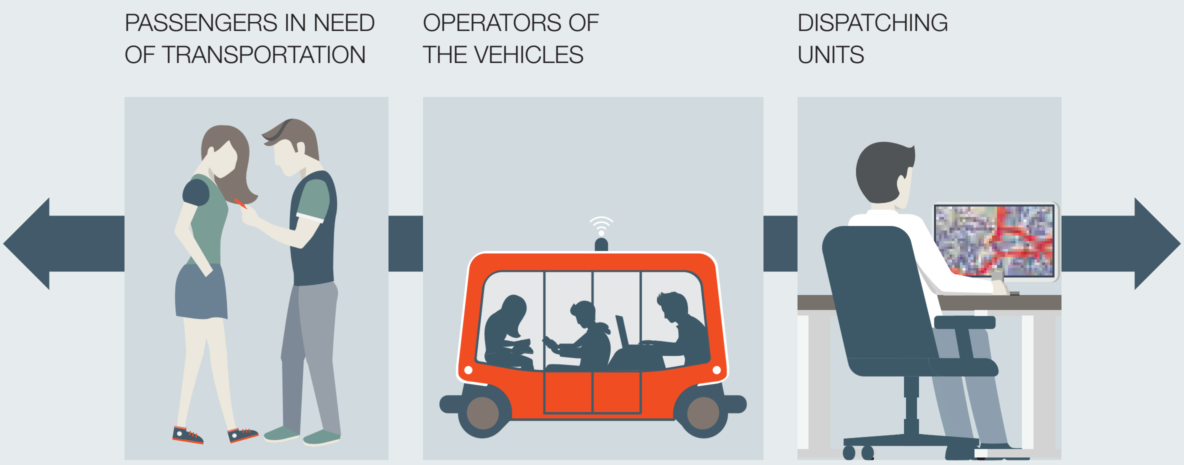


FIGURE 4-4 The MaaS concept in the Oslo study

Shared taxis and taxibuses are a concept of sharing both, vehicles and rides. A real-time based optimization of where to pick-up and drop-off passengers will use the actual demand in rides and space to allocate the taxis. The optimization rule will consider the level of service, for instance the maximum wait time for the passengers and how long of a detour, to accommodate other passengers, is acceptable.

Optimization happens in separate fleets for the three types of mobility services.

MODE	SHARED CAR	SHARED TAXI	TAXIBUS
BOOKING	Real time	Real time	Real time
FROM – TO	Junction-to-junction	Junction-to-junction	Junction-to-junction
WAITING TIME MAX.	10 minutes	10 minutes	10 minutes
BOARDING AND ALIGHTING TIME	1 minute	1 minute	1 minute
ACCEPTED DETOUR FACTOR	No detour	Max. detour Factor: 1.5 Max. Detour Time: 30 minutes Detour always accepted: 10 minutes	Max. detour Factor: 1.5 Max. Detour Time: 30 minutes Detour always accepted: 10 minutes

FIGURE 4-5 Level of service

4.4.2 MAAS CONCEPT AND LEVEL OF SERVICE IN THE OSLO STUDY

Mobility as a Service (MaaS) is a term that deems road users as flexible mobility seekers, not bound to use their own private vehicles. Instead, they use the service that suits their exact mobility requirement. They make their choice of travel mode ad-hoc from a range of transportation services supplied by the market. An overview of these modes is available on a digital platform, where the user can choose from and book according to their mobility needs.

MaaS operations rely on three central parts: Individuals that needs transportation, providers of transportation services, and a dispatcher that allocates transportation units to the user:

- For the individual mobility seekers, the digital platform, that is accessible by their cell phone, tablet or computer, is crucial when they need to book, pay or get information.

- The providers of transport can be companies that offer conventional public transport, providers of CaaS (Car as a Service), ridesharing schemes, etc.
- The dispatcher's main responsibility is to ensure smooth operation. The dispatcher is in control of optimisation. Additionally, the dispatcher oversees the logistics, the transportation requests, information, monetary flow, and the share between the providers.

MaaS has yet to be deployed on a large scale, but the interest in MaaS is evident. As of now, no one knows what kind of business models would succeed, if MaaS concepts become a reality. There have been experiments, pilot projects and implementation of different digital platforms around the world. Most of the MaaS real world testing is conducted in constrained geographical areas. Six projects have succeeded in supplying mobility across the modes. These are Whim, Moovel, Ubigo, Qixxt, Wienmobil and DiDiCuxing. Experience from these projects demonstrate that is difficult to establish cross-mode collaborations.

The Oslo study models shared MaaS concepts. Each of the three new mobility options – shared cars, shared taxis and taxibuses – are included in a pool of mobility options that can freely be dispatched to actual real time demand for transport. The only geographical constraint these modes have is that they serve within the boundaries of the Oslo region. The Oslo region consists of the metropolitan area of Oslo, thereby including its surrounding areas and the full Akershus county in this report. The implication of this is that all vehicles within this area can be allocated to all relevant requests within the Oslo region boundaries.

Optimization of the vehicle fleet in a shared dispatching system is an idealistic version of how MaaS could perform. Generally, it is harder to optimize the vehicle fleet when there are several providers that are competing. Such a scenario could lead to a suboptimal utilization of the vehicle fleet.

Vehicle kilometres travelled and vehicle hours travelled in the new mobility concept depend on the level of service and how well the system is optimized. Hence, the level of service is important for the use of resources and the required number of vehicles.

The new mobility concepts in the Oslo study are designed to serve all trips starting and ending in Oslo and Akershus. The demand for transport is taken from the traffic models covering the area. The fleet size is set to be large enough to serve all transport demand during peak hours in the morning.

The level of service is shown in Figure 4-5. All three mobility options will start assignment and allocation as soon as the booking is completed. Thus, it will be a real time allocation with a short delay. The principle with all the mobility options is that there will be a door-to-door service. However, in larger cities it is more practical to make the user walk to the nearest street corner, or for taxibuses to the closest collection point which may be located on larger streets. An assumption is that boarding and deboarding the vehicles takes one minute, regardless of the number of passengers involved.

SCENARIO 3A
Car users change to shared taxi without ride-sharing.

Public trans-port riders with bus and tram change to taxi bus with ride-sharing. Train and metro riders continue without changing.

SCENARIO 1A
Car users change mode to shared car without ridesharing.

Public transport riders do not change mode and continue to ride public transport.

SCENARIO 1B
Car users change to shared taxi with ridesharing.

Public transport riders do not change mode and continue to ride public transport.

SCENARIO 2A
Car users change to shared cars, without ridesharing.

Public transport riders on buses and trams change to shared car, without ridesharing. Train and metro riders continue without changing.

SCENARIO 2B
Car users change to shared taxi with ridesharing.

Public transport riders on buses and trams change to shared taxi with ridesharing. Train and metro riders continue without changing.

SCENARIO 3B
Car users change to shared taxi with ridesharing.

Public trans-port riders with bus and tram change to taxibus with ridesharing. Train and metro riders continue without chang-ing.

FIGURE 4-6 The six Scenarios in the Oslo Study

4.4.3 ESTABLISHMENT OF THE SCENARIOS IN THE OSLO STUDY

The scenarios in the Oslo study are based on the findings in the literature study in phase 1 of this project. To simplify the transition from the narrative scenarios (Figure 4-1) to the specific scenarios, we have chosen to itemize the scenarios by a number and a character. However, the same scenario axis is the basis for the modelled scenarios. There are six scenarios calculated in this Oslo study, which are described in Figure 4-6. In all three a-scenarios car users will continue as normal, which means they continue to ride privately in small vehicles and mainly alone. However, the vehicles are shared and used sequentially by different people. In the b-scenarios, car users will expand from car sharing to ride- and car sharing.

The scenarios 1a, 1b, 2a and 2b, emerge from the scenario axis that was developed in Technological Trends 1. In scenarios 1a and 1b the public transport demand continues to be as high as it is today. In scenarios 2a and 2b the new autonomous vehicles have outperformed the buses and trams. However, the mid-haul trains and metros will be unaffected by the changes in transportation.

In the scenarios 3a and 3b the bus and tram users shift to taxibuses that are more spacious. Taxibuses provide a different level of service than conventional terrestrial public transport. Therefore, these scenarios do not suit the scenario axis, and are accordingly placed outside the axis.

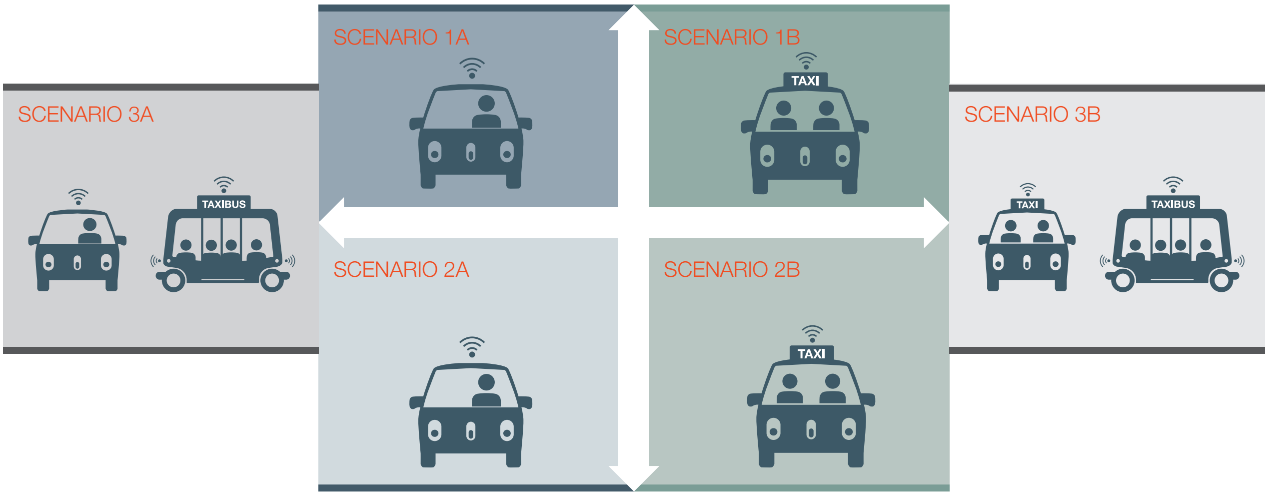


FIGURE 4-7 MaaS fleets in the six scenarios

These scenarios are extreme, since they imply 100 % utilization of the new mobility options. Furthermore, the whole vehicle fleet is autonomous and optimized in real time. At the same time, these scenarios are conservative, because they aggregate travellers into two categories – car users and public transport users. A stronger public transport scenario could have been modelled, where all car users in scenario 1b use shared taxi to and from public transport. Another similar scenario could have been that car users in scenario 3b also use taxibuses, or whenever applicable use them as a feeder service to public transport.

The following assumptions have been made about the behaviour of road users and users of buses and trams:

- All trips are within the Oslo region. This region includes Oslo and Akershus counties, depicted in Figure 4-8.
- Calculations are based on the transportation demand forecast for 2020 (the base scenario).
- Only car and public transport trips are calculated. Cyclists and pedestrians are assumed not to change their travel modes.
- To simplify, all car users' future modal choice is aggregated to the same mode. Likewise, all public transport riders' future modal choice is aggregated to the same mode.
- Current car users will, in the scenario with shared cars and no ridesharing, change mode to shared car. In scenarios with ridesharing all car users will change mode to shared taxi.
- Public transport riders who travel by train, both regional and local train and metro, will keep using these modes in all scenarios.
- Public transport riders that use bus or tram will, in scenarios with strong public transport keep this mode. In scenarios with weak public transport, they will switch to shared car (2a) or shared taxi (2b).
- In addition, there are two scenarios where all bus and tram riders will switch to using taxibuses (3a and 3b).
- Bus and tram users that mix buses, trams and trains on a single trip will, when they change to a MaaS system (2a, 2b, 3a and 3b), use shared cars, shared taxi or taxibuses from door to door.

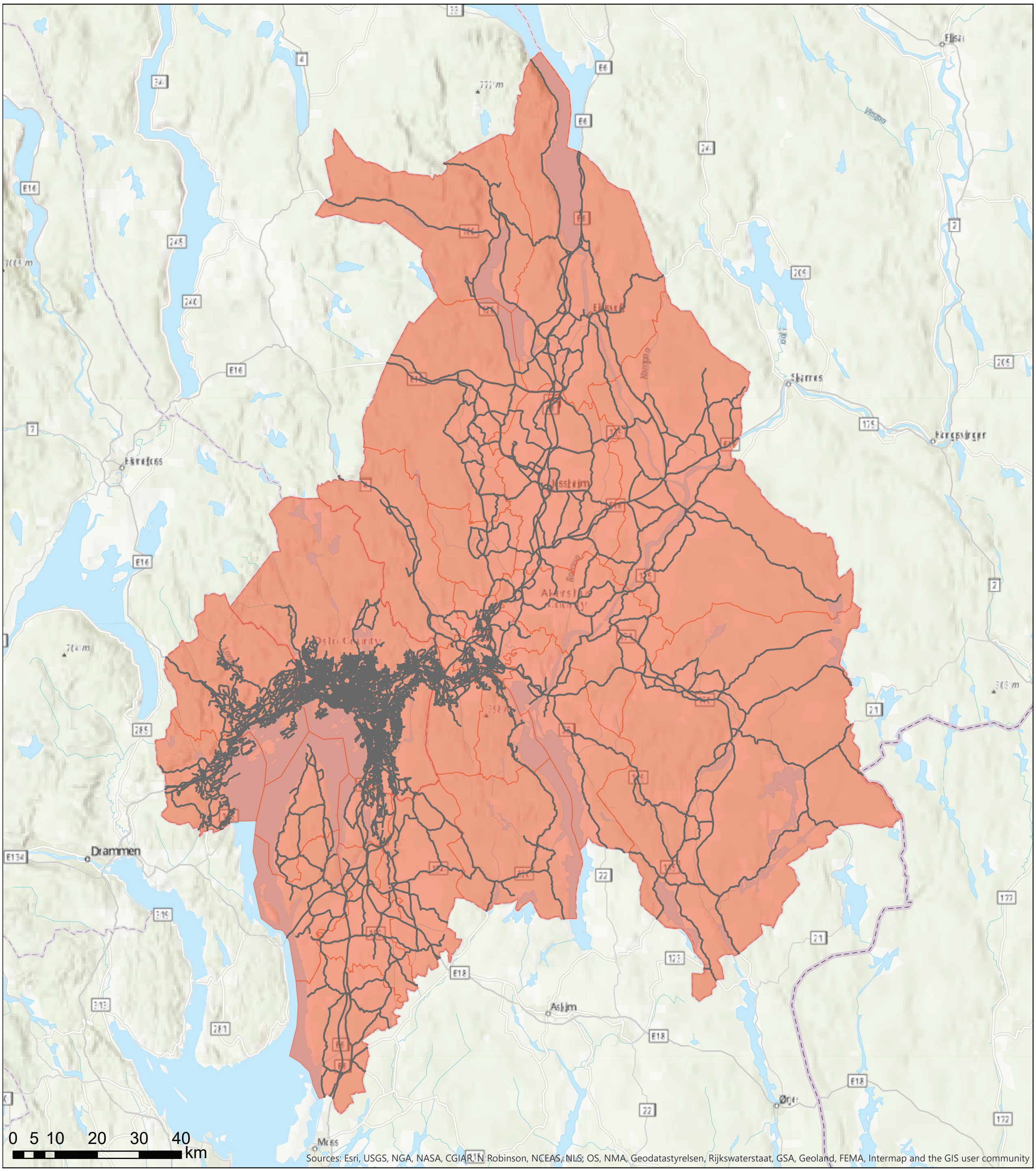


FIGURE 4-8 The catchment area in the Oslo study

Following principles about infrastructure and digital structure are assumed for the calculations of the model scenarios:

- Calculations are based on road and rail network for 2020.
- Shared cars, shared taxi and taxibuses will be able to find parking on the existing road network, when they are not in use.
- In densely populated areas the distance between stops is at least 200 meters to avoid too many stops.
- The time span is from 6 a.m.–10 a.m. in the morning rush on a weekday, as this is the time when the demand is at its highest.
- Dispatching happens per groups, which means that it separates between the categories: shared cars, shared taxis and taxibuses. Every vehicle is assigned to one of these three categories.

5 MODEL DESCRIPTION

5.1 WHAT IS THE MAAS OPPORTUNITY?

The way we choose to travel today is simple. It is largely based on whether we have access to a private car or whether there is a viable public transport option as an alternative. Other factors, such as the availability of parking, the cost of public transport and the journey time may also affect our decisions, notwithstanding whether walking or biking would be an alternative.

In the future things could be different. The single most important premise of future mobility is that there will be less private car ownership. This means opposed to owning a car, and therefore treating our means of travel as an owned asset, we will buy travel as an on-demand service, a kind of pay-as-you-go service.

New Mobility services, such as Uber, Lyft and other on-demand mobility services, are already appearing on our streets. In this regard, the future is already happening. These services do not only provide an alternative to the private car, leading to the anticipated reduction of car ownership levels, they are also viable options to existing public transport users and, certainly, people who may not have access to any form of transport currently.

The everyday phrase for these on-demand services is *"shared mobility"*. So, what is shared mobility?

Shared mobility can be described in two forms:

› Car sharing – where the vehicle is owned by a third party (the operator) and the customer has sole access to the vehicle during their journey.
› Ride Sharing – where the vehicle is owned by a third party and can be shared, in-ride, with other customers.

The concept of shared mobility sits within the wider "Mobility as a Service" (MaaS) framework, which also considers the ticketing and riding of a holistic integrated multi-modal transport system.

It is widely accepted that MaaS presents itself as a congestion busting solution to our busy cities, particularly in the cases of high ride sharing. But it is still very uncertain what proportion of ride sharing is necessary to reduce the congestion.

Previous studies have shown that only a fraction of the number of vehicles is needed to service the same car travelling population. Perhaps even as little as 10 % of cars will be required in the future. The flip-side is that MaaS vehicles will be in-service for many hours of the day, compared to the typical private car, which, on average spends less than one hour travelling per day. These extra hours in-service will undoubtedly include empty vehicles repositioning to meet new trip requests which could increase the number of vehicle kilometres travelled on the road network, thus worsening the congestion situation, a city's worst nightmare.

So, the advent of MaaS does not only present itself as an opportunity by reducing the physical number of cars, it is also seen by cities and highway authorities as a disruptor to our existing transport networks. If left unregulated, it is conceivable that MaaS could upset the balance of our transport networks and worsen travel conditions, rather than improving them.

5.2 WHY WE NEED TO SIMULATE SHARED MOBILITY?

The arrival of Mobility as a Service (MaaS) and, in particular *"shared mobility"*, will have a profound effect on society; the way we travel, and the way city infrastructure is managed. The advancements in technology and the new 'shared' approaches to the movement of goods and people have required a change to the traditional planning of transport and cities.

There are many variables that we cannot possibly know, that will shape the future of mobility. These include, but are not limited to, the fleet size (service provider costs), the quality of the service on offer (accessibility to the customer) and the ride experience (journey times and wait times).

To simply guess the combinations of the variables provides no confidence in the obtained results. Therefore, it is good practice to simulate many combinations of the variables so the full range of KPIs can be reported.

Only when we have simulated and understood the full range of model responses, we can take confidence in the outcomes.

5.3 HOW DO WE SIMULATE SHARED MOBILITY?

The concept of shared mobility is similar to that of planning logistics. A number of people (travellers) make an on-demand request to travel from A to B. Their personal requirements are spatially and time specific. The shared mobility service, comprising a fleet of vehicles, is available to take the travellers from A to B. In principle, this is comparable to individual parcels that need to be delivered to their destinations by a fleet of delivery trucks. The optimum solution is to match the trip requests to vehicles from the fleet. The solution is prepared using a complex algorithm that dispatches and routes the vehicles so that all travellers receive a ride, the overall fleet size is optimized, and the total distance travelled by the fleet is minimised.

The resultant solution, performed and presented within PTV's MaaS Modeller software, can be prepared for each combination of input variables. With a cleverly crafted KPI framework, each solution can be presented and compared against each other to help highlight the best combination of service provision (low operator costs) that also offers high quality customer satisfaction (low wait times, short journey times).

5.4 OTHER CONSIDERATIONS

The operator costs and customer satisfaction are two crucial outcomes of the simulation exercise. Other considerations, which can help shape the scenarios, include the geographic study area (e.g. specific zonal areas, corridors or free-floating solutions), traveller type (e.g. commuter, car traveller, public transport traveller) and the proportion of people in society who may choose the shared mobility solution as an alternative to current choices. This latter point can be assumed (simple process) or calculated through a transport travel behaviour model (complex process).

5.5 IMPORTANT OUTCOMES

All shared mobility studies should consider what the important outcomes are and how to measure them. These may come in the form of:

- NETWORK IMPACTS – reduced or increased overall vehicle kilometres travelled, how will congestion change?
- OPERATOR IMPACTS – what fleet will be required, what are the operating costs (fuel, driver hours, maintenance, etc,)?
- REVENUE MODELS – which fare model produces a positive outcome, can a business model be made?
- CUSTOMER IMPACTS – how long will customers wait for a vehicle, will the journey times be acceptable, how many customers will be served, and how does the service compare with today?

The future of mobility is uncertain. Only by testing the combinations of many of the unknown variables and by measuring their impacts against each other and against desired outcomes, can the possible impacts of MaaS and shared mobility be explored. With this understanding comes knowledge, which leads to informed and confident decision making.

5.6 VISUM MODEL IMPORT

PTV MaaS Modeller requires a PTV Visum model in order to function. The MaaS Modeller engine uses Visum for the simulation and for the presentation of results. The zone system, network and travel demand from the existing transport model for Oslo (RTM23+) were imported into Visum.

It should be noted that the full demand model was not transferred to Visum for this study (mainly because of the limited timeframe of the project). Therefore, this study cannot and does not examine the propensity for people to change modes of transport to or from shared mobility. This study focuses only on examining the shared mobility requirements to fulfil different levels of passenger demand and the likely outcomes for operators, customers and the city with such a service in place.

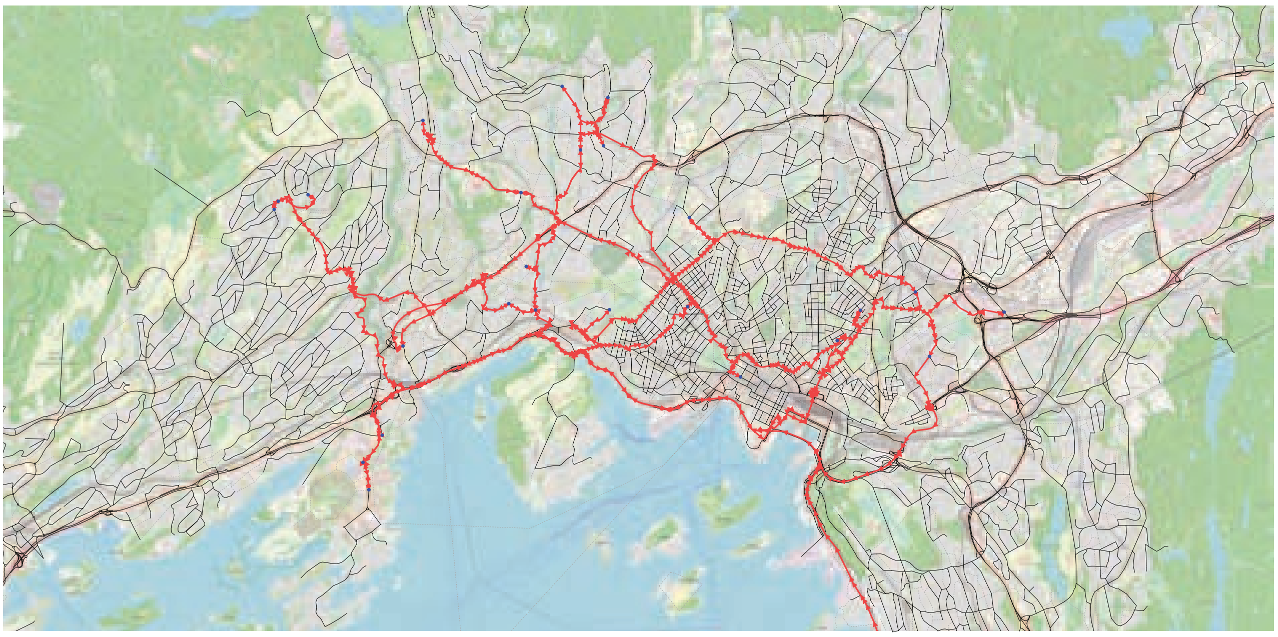


FIGURE 5-1 Example of an autonomous vehicle tour from PTV MaaS Modeller

TABLE 5-1 Scenario Specification

	DEMAND		SERVICE SPECIFICATION		SERVICE VEHICLE		
	CAR USER	PT USER	CAR SHARING	RIDE SHARING	SHARED CAR	SHARED TAXI	TAXIBUS
SCENARIO 1A	X		X		X		
SCENARIO 1B	X			X		X	
SCENARIO 2A	X	X	X		X		
SCENARIO 2B	X	X		X		X	
SCENARIO 3A	X	X	X	X	X		X
SCENARIO 3B	X	X		X		X	X

TABLE 5-2 MaaS Simulations by scenario

	SCENARIO 1A	SCENARIO 1B	SCENARIO 2A	SCENARIO 2B	SCENARIO 3A	SCENARIO 3B
CAR	CAR SHARE	RIDE SHARE	CAR SHARE	RIDE SHARE	CAR SHARE (AS 1A)	RIDE SHARE (AS 1B)
PT (BUS & TRAM)			CAR SHARE	RIDE SHARE	RIDE SHARE (AS 3)	RIDE SHARE (AS 3)
FLEET SIZE	9	9	7	7	X	7
WAIT TIME	4	4			X	
DETOUR	X	8	X		X	7
TOTAL	13	21	7	7	X	14

5.7 SHARED MOBILITY ASSIGNMENT

MaaS Modeller prepares simulations based upon the optimised dispatching of vehicles matched to trip requests, within the requirements of the service to be simulated. Figure 5-1 shows an example of the journey of a vehicle in MaaS Modeller. Accordingly, PTV MaaS Modeller does not assign shared mobility vehicles based on typical highway assignment equilibrium or convergence criteria.

The demand, service specification, and vehicles used in each scenario are outlined in Table 5-1 to ease the comparison between the scenario.

62 MaaS Modeller simulations of the six shared mobility scenarios were carried out and prepared for this study. Different numbers of simulations, using different input parameters were run for each Scenario. The number of simulations by scenario and parameter are summarised in Table 5-2.

The parameters examined in the study are the fleet size, wait time, and detour. For all a-scenarios the detour time in the vehicle was not a parameter option, as these scenarios were simulating car sharing only, not ride sharing, and therefore no passenger is subject to any form of detour time on their journey beyond the wait time for the vehicle (this does not apply to passengers using taxibuses with ride sharing in scenario 3a).

The outcome of the wait time parameter changes in scenario 1a was evaluated during the project. The parameter outcomes were relatively minor and therefore not considered vital for testing within scenario 2a, where the large volume of passengers meant long running and processing times for each simulation.

Scenario 3a uses a combination of the scenario 1a car passenger car sharing and scenario 3b public transport passenger ride sharing, therefore no extra simulations were required to evaluate and compare scenario 3a.

The parameters and assumptions for this study in PTV MaaS modeller are described in detail in a report by PTV.

6 RESULTS

This chapter presents the results from this Oslo study. First, we look at impacts on fleet size, before we describe the effects on vehicle kilometres. We look into the level of service, which helps explain some of the results and gives useful knowledge on the efficiency of the system and how it will work for the customers. We also look at the road network and some geographical aspects of the results. A sensitivity analysis shows how the results are changing when we relax the assumptions in the model.

6.1 FLEET SIZE

The fleet size has been identified for each scenario. The base scenario demand is stipulated by the calculations in the existing traffic model for Oslo (RTM23+) for the year 2020. RTM23+ encompassed the Oslo region, which includes Oslo and Akershus counties. According to existing calculations in RTM23+ for the year 2020, there will be around 401,000 people that travel in a car as driver or passenger and around 210,000 people that use bus or tram services as their main transport mode, or as a part of their travel by public transport. These numbers are for a weekday in the morning rush between 6 a.m. and 10 a.m.

Most cars in the base scenario will only drive one trip during this time span. In 88 % of these trips only a driver will be present without any passengers. As a result, there will be a need for 352,000[3] cars in 2020 to serve the 401,000 person trips. These cars will need a parking spot most of the time. It is not possible to get forecasts of the fleet size for trams and buses in the same way as for the cars. The vehicle fleet and vehicle kilometres are shown in Table 6-1, with these prefixes:

› 1a and 1b: Same level of service and application of the buses and trams as in 2020.
› 2a and 2b: Buses and trams become redundant, as their demand is catered for by the new MaaS system with shared cars and shared taxis.
› 3a and 3b: Buses and trams become redundant and their services may shut down, as their demand is covered by the new MaaS with taxibuses.

A future transport system with only autonomous vehicles can in all scenarios maintain the current level of service with a substantial reduction in vehicles required. The calculations are done during the morning rush hour, when peak demand is reached. Therefore, the morning rush hour is decisive for the needed fleet size. However, the model does not include idle time, such as time for refuelling, maintenance, cleaning and other servicing, for the vehicles. Idle time does not significantly impact the model, as most of these activities would happen outside the morning rush time span.

3 There are 637,000 registered cars in Oslo and Akershus. But only 352,000 are in use during the morning peak hours according to RTM23+. We use 352,000 as the base comparison

TABLE 6-1 KPI for fleet size and vehicle kilometer in MaaS system

	BASE	1A	1B	2A	2B	3A	3B	3
						FROM BUS AND TRAM TO TAXIBUS		
	PRIVATE CARS 2020	FROM PRIVATE CAR TO CAR SHARING	FROM PRIVATE CAR TO SHARED TAXI	FROM PRIVATE CAR, BUS AND TRAM TO CAR SHARING	FROM PRIVATE CAR, BUS AND TRAM TO SHARED TAXI	FROM PRIVATE CAR TO CAR SHARING	FROM PRIVATE CAR TO SHARED TAXI	FROM TRAM AND BUS TO TAXIBUS
PERSON TRIPS	611,000	401,000	401,000	611,000	611,000	611,000	611,000	210,000
FLEET SIZE	352,000	33,000	26,000	55,000	40,000	49,000	42,000	16,000
FLEET SIZE COMPARED TO BASE (PCT. OF BASE)	-	9%	7%	16%	11%	14%	12%	5%
VEHICLE KM (MILLION)	4.4	5.5	3.7	8.6	5.7	7.3	5.5	1.8
PCT. CHANGES IN VEHICLE KM COMPARED TO BASE	-	+26%	-14%	+97%	+31%	+67%	+27%	-

The largest fleet size reduction compared to the base scenario is reached in scenario 1b, where ride sharing is implemented for all car passengers. In this scenario only 26,000 cars, or 7 % of the current fleet, are needed. Reduction is also evident in scenario 1a, where car sharing is implemented but trips remain private. This results in 9 % of the current fleet size to be required.

The smallest reduction of fleet size occurs at scenario 2a, where bus and tram riders shift to the MaaS system and chose private trips in shared cars. This scenario can meet the service requirements with 56,000 cars, equivalent to 16 % of today's fleet size. Scenario 2b includes ridesharing and reduces the needed fleet size to 11 % of the current number. Compared to scenarios where only car users are included in the new MaaS system, it is possible to optimize the use of the fleet and get a higher occupancy, by going from sharing cars to also sharing the ride (from scenario 1a/2a to 1b/2b). This is due to the higher volumes of passengers requesting a ride sharing trip, which enables better optimisation and usage of the fleet.

Scenarios 3a and 3b are based on a modal shift for all users of buses and trams to a new MaaS system consisting of taxibuses. At the same time today's car users behave exactly like in scenario 1a and 1b, changing to a MaaS system of shared cars and shared taxis. There will be a requirement for 16,000 taxibuses to accommodate the previous bus and tram riders. The introduction of a completely new system of taxibuses means that scenarios 3a and 3b need two separate dispatching systems. This implies a less effective utilization of the vehicle fleet going from car sharing to ride sharing, than in scenarios 2a and 2b.

To summarize the essential finding: all scenarios can reduce the vehicle fleet size substantially. Thereby freeing land areas which today are reserved for curb parking, parking lots and general parking areas, especially needed in dense urban areas, where land areas are a scarce resource. This would create new possibilities to make city areas more attractive for pedestrians, cyclists and futuristic transportation modes. Autonomous vehicles will also reclaim freed up areas for service needs and curb space for loading and offloading passengers. Curb space function and curb space price models will need a redesign. This also goes for space in front of terminals and other transportation hubs (see also chapter 6.8).

6.2 VEHICLE KILOMETRES

Repercussions of a reduced vehicle fleet will be visible on the road networks. However, traffic volume and hence traffic flow quality is dependent on total vehicle kilometres travelled. The number of vehicle kilometres travelled for each scenario is showed in Table 6-1.

Only scenario 1b achieves a reduction in vehicle kilometres travelled. This reduction amounts to 14 % compared to the base situation. The reduction is smaller than estimated in studies of other cities. One explanation may be that the Oslo study presumes a higher level over service than comparable studies. As shown in the sensitivity analysis in chapter 6.6, the reduction is increased to 31 % when longer detours to pick up other passengers are allowed.

Scenario 1a increases the vehicle kilometres travelled by 26 %, because the vehicles will drive empty between customers.

If bus and tram riders shift towards private vehicle trips in a MaaS system, the vehicle kilometres travelled will increase. In scenario 2a it would almost be doubled, and in 2b the vehicle kilometres travelled would increase by 31 %. This is likely to impose road capacity challenges, as discussed in chapter 6.5. Scenarios 3a and 3b slightly decrease the vehicle kilometres travelled on the road networks in comparison to scenarios 2a and 2b. This is because public transportation users shift to a taxibus system and not smaller shared cars or shared taxis. Despite this, these scenarios increase the vehicle kilometres travelled, which could pose a challenge for road capacity. Scenario 3a increases the vehicle kilometres travelled by 67 % and scenario 3b by 27 %.

In a MaaS system a part of the vehicle kilometres travelled are ”empty” kilometres, where the vehicle is driving without passengers to pick up its next passenger. The number of ”empty” kilometres is highest in the scenarios without ridesharing (1a, 2a and 3a). In these scenarios between 24 % and 28 % of the vehicle kilometres travelled are without a passenger (see Table 6-2). In the scenarios with ridesharing (1b, 2b and 3b), the share of vehicles kilometres travelled without a passenger lies between 14 % and 19 %.

TABLE 6-2 KPI for vehicle kilometres – empty and in service

	BASE	1A	1B	2A	2B	3A	3B	3
						FROM BUS AND TRAM TO TAXIBUS		
	PRIVATE CARS 2020	FROM PRIVATE CAR TO CAR SHARING	FROM PRIVATE CAR TO SHARED TAXI	FROM PRIVATE CAR, BUS AND TRAM TO CAR SHARING	FROM PRIVATE CAR, BUS AND TRAM TO SHARED TAXI	FROM PRIVATE CAR TO CAR SHARING	FROM PRIVATE CAR TO SHARED TAXI	FROM TRAM AND BUS TO TAXIBUS
VEHICLE KILOMETERS – IN SERVICE (MILLION)	4.4	4.0	3.1	6.1	4.6	5.5	4.7	1.5
VEHICLE KILOMETERS – EMPTY VEHICLE (MILLION)	0	1.5	0.6	2.4	1.1	1.7	0.9	0.2
VEHICLE KM (MILLION)	4.4	5.5	3.7	8.6	5.7	7.3	5.5	1.8
VEHICLE KILOMETERS SHARE – IN SERVICE	100%	73%	83%	72%	81%	76%	84%	86%
VEHICLE KILOMETERS SHARE – EMPTY VEHICLE	0%	27%	17%	28%	19%	24%	16%	14%

6.3 FLEET UTILIZATION

Key figures concerning fleet utilization in the respective scenarios are shown in Table 6-3. Mean occupancy refers to the average number of persons in a car when the vehicle is in service. The vehicle is defined as 'in service' when the vehicle is driving with or without passengers and as 'in operation' only when the vehicle is carrying passengers.

In the base scenario this occupancy is 1.14, signifying that almost 9 out of 10 car trips only serve the driver. The average occupancy in the base scenario is sourced from The Norwegian National Travel Survey 2013/14.

In scenarios 1a and 2a the vehicle utilization is between 0.79–0.80 when the vehicles are in service, compared to 1.14 today when the vehicles are in operation. For around 27 %–28 % of the service time, the vehicles will be driving empty (see Figure 6-2). This gives the impression of low utilization of the cars when there is no ride sharing.

The utilization could be even lower during other times of the day, when trips are more spread throughout time and space. Utilization during peak demand is higher, because residents have more similar and predictable travel patterns. On the other hand, there can be a lot of empty cars in peak hours, driving back to the suburbs empty to pick up more people commuting into the city centre (see also chapter 6.2).

TABLE 6-3 KPI for fleet utilization

	BASE	1A	1B	2A	2B	3A	3B	3
						FROM BUS AND TRAM TO TAXIBUS		
	PRIVATE CARS 2020	FROM PRIVATE CAR TO CAR SHARING	FROM PRIVATE CAR TO SHARED TAXI	FROM PRIVATE CAR, BUS AND TRAM TO CAR SHARING	FROM PRIVATE CAR, BUS AND TRAM TO SHARED TAXI	FROM PRIVATE CAR TO CAR SHARING	FROM PRIVATE CAR TO SHARED TAXI	FROM TRAM AND BUS TO TAXIBUS
MEAN OCCUPANCY – IN SERVICE	1.14	0.79	1.62	0.80	1.62	1.10	1.62	1.68
MEAN OCCUPANCY – IN OPERATION	1.14	1.14	1.86	1.14	1.89	1.40	1.89	1.94
MEAN OPERATION DISTANCE [KM]	12	166	144	153	143	148	133	112
MEAN OPERATION TIME [H]	0.2	3.2	3.0	2.9	3.0	2.9	2.8	2.5

The scenarios with ridesharing (shared trips) 1b, 2b and 3b have an improved utilization level compared to the current value, as the mean occupancy rate would reach 1.62-1.64 when the vehicle is in service (mean occupancy 1.86-1.94, when the vehicle is in operation). The reason the occupancy rate is not higher than 1.64 in scenario 3b, is because 2/3 of the trips are identical to scenario 1b, where car users change modes. Another reason is that the taxibuses have 1.68 passengers per trip, which is only slightly better than shared taxis.

Surprisingly the taxibuses do not significantly improve the occupancy rate. This is mainly caused by using the same standard of service for taxibuses and shared taxis (regarding waiting time and maximum allowed detour) and lower passenger demand. A Sensitivity analysis, where the service level is relaxed, is described in chapter 6.6.

A way to improve the mean occupancy rate, could be through fixed scheduled taxibus routes, with a detour booking system. This could either be facilitated through the taxibus itself, or by a separate taxibus collecting passengers and driving them to a larger transportation hub. The fare for taxibus tickets is an important factor for its success, however, this is not included in the model calculations.

In the base scenario a car in the Oslo region drives a length of 11.7 kilometres in the timespan from 6 a.m. to 10 a.m. (average length of journey). The average time spent driving is 12 minutes, which means that the car stays idle for 3 hours and 48 minutes, equivalent to 95 % of the time. In all the calculated scenarios the car utilization is far better for shared cars, shared taxis and taxibuses. All the vehicles drive more than 100 kilometres within the four-hour timespan. The highest utilization of the fleet happens in scenario 1a, where the length of driving is 166 kilometres and time in operation is 3 hours and 12 minutes (average length and time).

The lowest operation distance of 112 kilometres is reached with taxibuses. Partially explained by a smaller vehicle fleet. Another explanatory factor is that the optimization for taxibuses is less efficient due to lower passenger numbers.

Figure 6-1 shows the key figures for the vehicle fleet and fleet utilization per hour during the selected timeframe. The demand peaks between 7 a.m. and 8 a.m. A slightly lower demand is being recorded from 6 a.m. to 7 a.m. and 8 a.m. to 9 a.m. The lowest level during the morning peak is between 9 a.m. and 10 a.m.

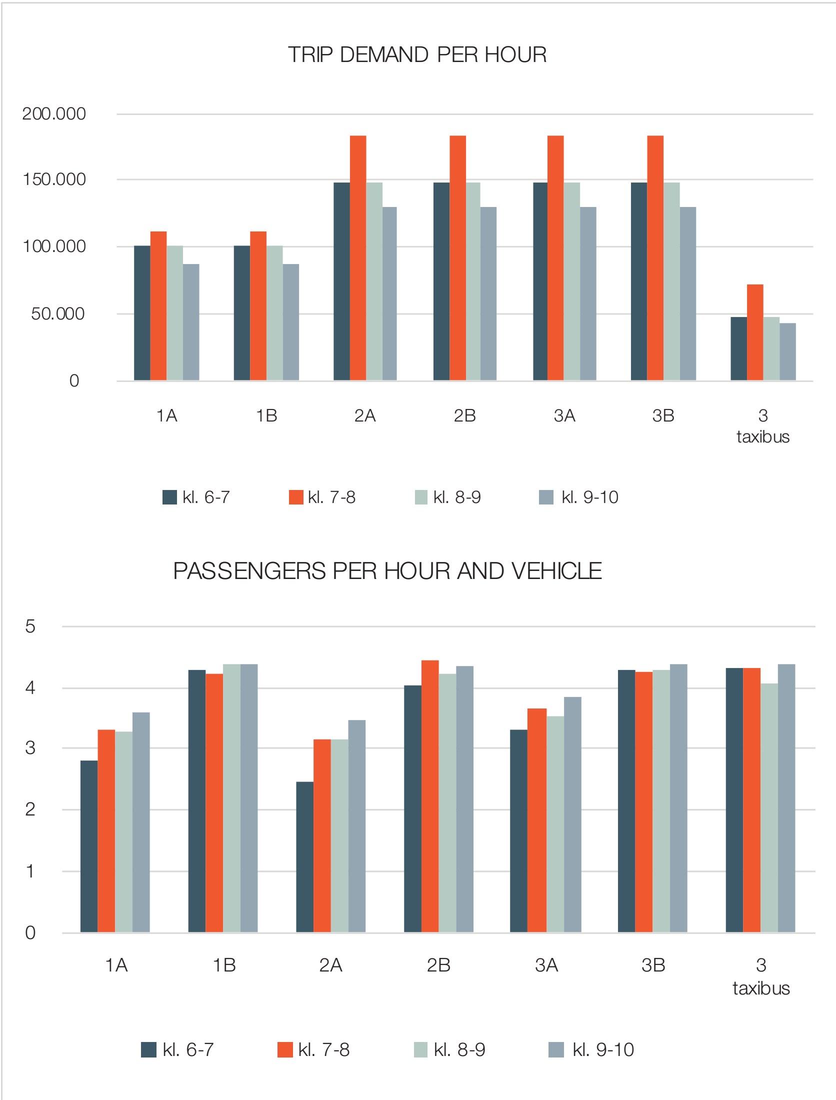


FIGURE 6-1 Trip demand and fleet utilization per hour

Figure 6-2 shows the distribution of the car occupancy rate, the number of passengers in the car during their service time. The figures show, as expected, that there are more passengers per trip in the scenarios with ridesharing, than in scenarios without ridesharing. With ridesharing it is likely that the vehicles will be occupied by two or three people. It is unlikely to see five or more people use shared taxis and taxibuses simultaneously. The capacity for taxibuses is set to a maximum of 20 people, although it could be lowered without changing the results. The taxibuses could consequently be replaced by smaller vehicles, like shared taxis, without requiring an increase in the number of vehicles, since taxibuses only have more than 6 passengers in less than 0.2 % of the time in service. A reduction of taxibuses to shared taxis and in a shared fleet with the other MaaS fleet in scenario 3b will result in scenario 2b.

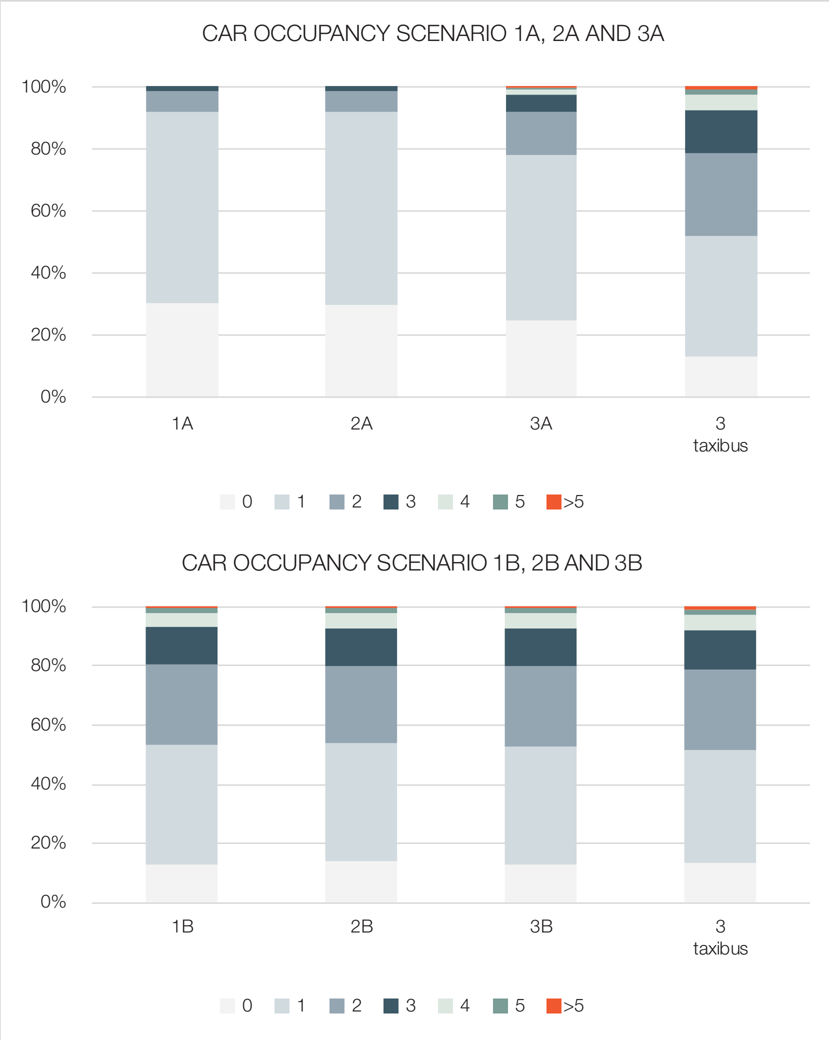


FIGURE 6-2 Distribution of car occupancy rate between scenarios

6.4 LEVEL OF SERVICE

Table 6-4 shows the key performance indexes for the different scenarios. In the base scenario for year 2020, an average vehicle trip takes 12.3 minutes and travels 11.7 kilometres. An average public transport trip that includes bus and/or tram in the year 2020 lasts for 31.6 minutes and travels 13.3 kilometres.

In scenarios 1a and 2a the average travel distance is 11.4 kilometres. The small difference from the basis can be explained by the calculation methods. The base scenario relies on the calculation of the distances between zones, whereas the future scenarios calculate distance between pick-up and drop-off point anywhere within the zone area (PUDOs). The remaining scenarios show longer travel distance than the base scenario, although none of the remaining scenarios involve long detours.

The average accumulated travel time in scenarios 1a and 2a is 18.3 minutes and encompasses: waiting time, boarding time and driving time.

The longest trips regarding both distance and time in the scenarios with ridesharing are the trips with taxibuses. The difference of 3a and 3b in comparison with scenarios 1b and 2b is low.

TABLE 6-4 KPI for level of service

	BASIS	1A	1B	2A	2B	3A	3B	3	BASIS
						FROM BUS AND TRAM TO TAXIBUS			
	PRIVATE CARS 2020	FROM PRIVATE CAR TO CAR SHARING	FROM PRIVATE CAR TO SHARED TAXI	FROM PRIVATE CAR, BUS AND TRAM TO CAR SHARING	FROM PRIVATE CAR, BUS AND TRAM TO SHARED TAXI	FROM PRIVATE CAR TO CAR SHARING	FROM PRIVATE CAR TO SHARED TAXI	FROM TRAM AND BUS TO TAXIBUS	PUBLIC PASSENGERS IN BUS/TRAM 2020
AVERAGE TRIP DISTANCE [KM]	11.7	11.4	12.6	11.4	12.6	11.9	12.7	12.9	13.3
AVARAGE TRIP TIME – TOTAL	12.3	18.3	20.5	18.3	20.7	19.2	20.7	21.0	31.6
AVERAGE WAITTIME [MIN]	0.0	4.1	2.9	4.0	2.8	3.6	2.8	2.6	5.7
AVERAGE TRIP DURATION [MIN]*	12.3	14.1	17.7	14.3	17.9	15.6	17.9	18.3	25.9
AVERAGE DETOUR TIME (RIDE) [MIN]	-	2.0	5.5	2.0	5.6	3.3	5.6	5.7	-

The waiting time from the time of booking a trip until the arrival of the vehicle averages roughly 4 minutes in scenarios 1a and 2a. In scenarios 1b and 2b, which include ridesharing, the waiting time is reduced to just below 3 minutes. The shortest average waiting time registered was 2.6 minutes for taxibuses. This may be influenced by the fact that public transport demand is more gathered in areas where public transport exists today, rather than car users, which is spread around whole the area.

The average waiting time distribution for the scenarios is shown in Figure 6-3, separated into a- and b-scenarios, car sharing and ridesharing respectively. In more than 30 % of the cases in the a-scenarios, there is less than one minute of waiting time. For the b-scenarios, this share amounts to more than 40 %. One criterion for the shared mobility system is that everyone must be served within 10 minutes. In the a-scenarios the waiting time is distributed more evenly across the available 10 minutes. In the b-scenarios there is a steady decrease towards the maximum available wait time.

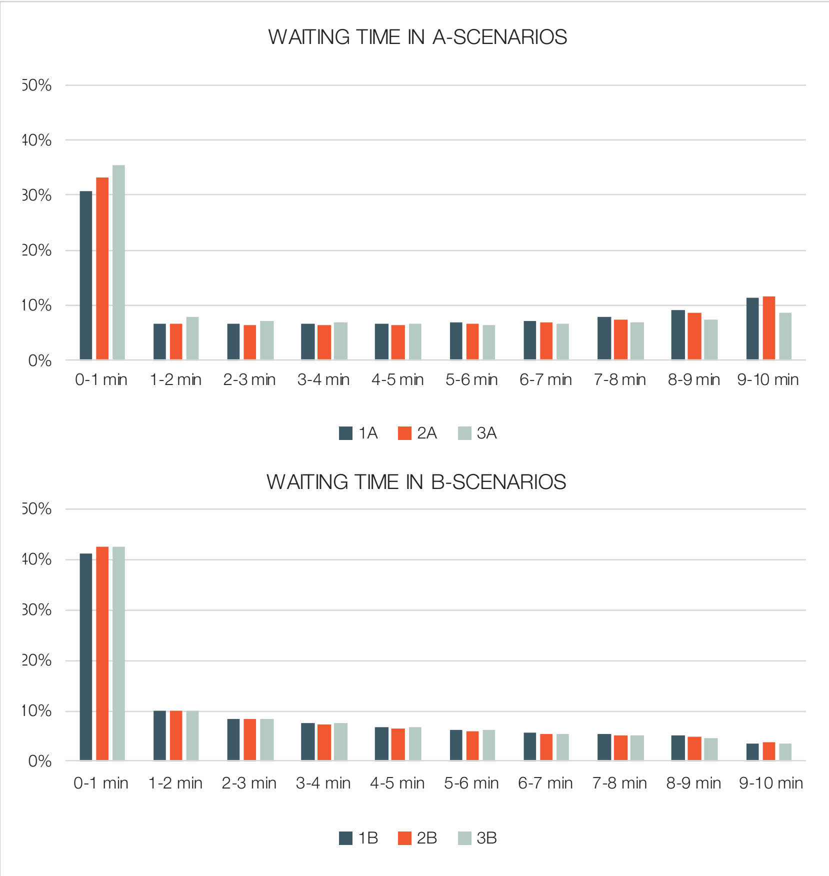


FIGURE 6-3 Average waiting times for different scenarios

The average prolongation of driving time in scenarios without ridesharing is 2 minutes. This is due to a fixed time of 1 minute each for boarding and alighting. With ridesharing, the prolongation of driving time increases to an average of 5.5-5.7 minutes for both shared taxis and taxibuses.

The average travel time prolongation caused by detours for scenarios that include ridesharing can be seen in Figure 6-4.

The comparison between the base and the modelled scenarios is slightly distorted. In the base scenario a trip starts in the car. In real life, most people will have to walk to the car, and during winter some will have clear off ice and snow before driving. In the scenarios, however, the passenger spends one minute on boarding and deboarding, which is not the case in the base scenario. But they spend no time walking to and from the PUDO, which may be at the nearest street corner. More importantly, in our calculations the travel time does not include changes in congestion due to increased or decreased traffic. The best-case scenario will reduce traffic, remove congestion and, thus, yield a shorter travel time than shown in the results. On the other hand, scenarios that lead to an increase in traffic are likely to increase congestion, which leads to an underestimation of travel time. These factors should be taken into consideration, when interpreting the results.

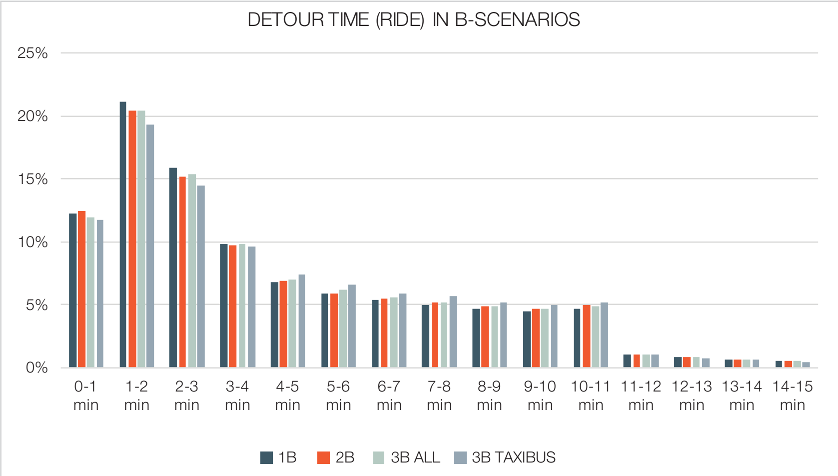


FIGURE 6-4 Average travel prolongation in b-scenarios (detour on the ride in the vehicle)

6.5 NETWORK IMPACT

Figure 6-5 shows the peak hour traffic volumes in the base situation in the year 2020.

Future traffic volumes on the network of roads were calculated for each scenario, to get an impression about where and how autonomous cars can affect the traffic in the future. In this report the focus is put on the expected changes in traffic demand for the best-case scenario 1b and the worst-case scenario 2a.

The only scenario that shows a net reduction of the vehicle kilometres is scenario 1b. In this scenario, all car users shift from own private cars to a shared car fleet of small vehicles with ridesharing. This is considered the best-case scenario. All other scenarios show an increase in vehicle kilometres travelled. Although it should be noted that the removal of buses and trams will contribute to a higher road capacity. However, this would not be enough to mitigate traffic flow challenges in most scenarios. The worst-case scenario is 2a, where the vehicle kilometres driven are almost doubled.

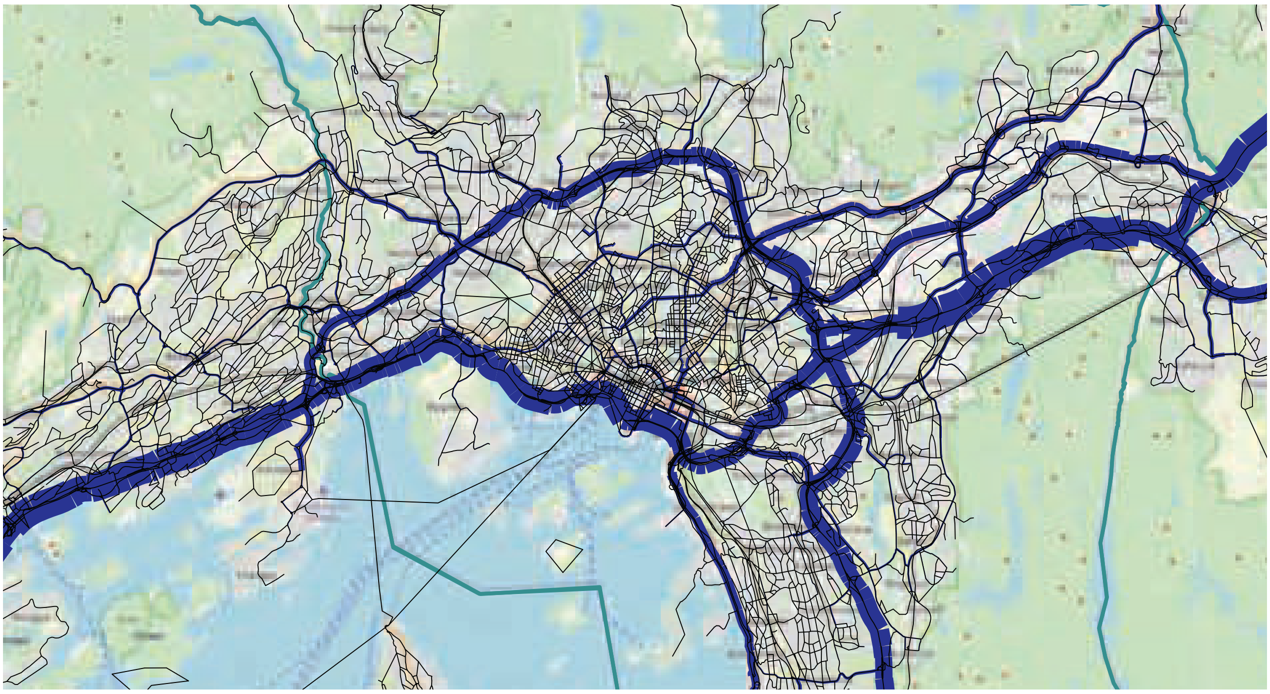


FIGURE 6-5 Private transport volume in base (period 7 a.m. – 8 a.m.)

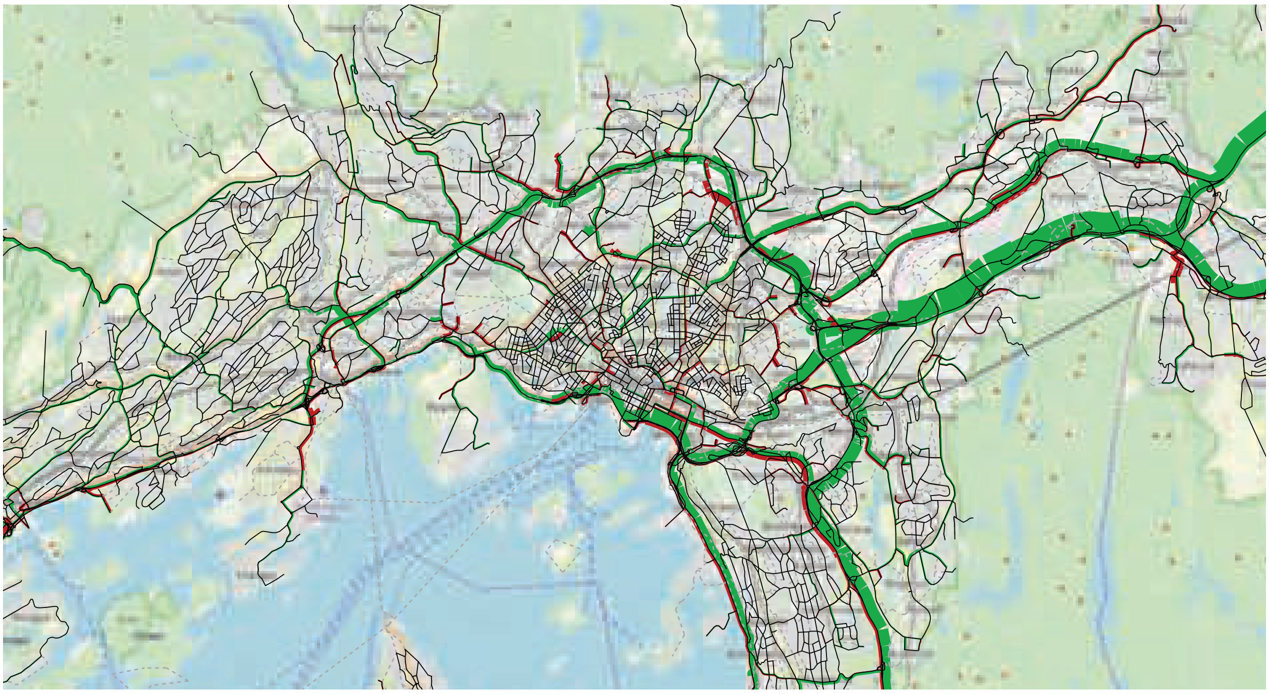


FIGURE 6-6 Network impacts flow volumes, scenario 1b vs base (green=traffic reduction, red=traffic increase)

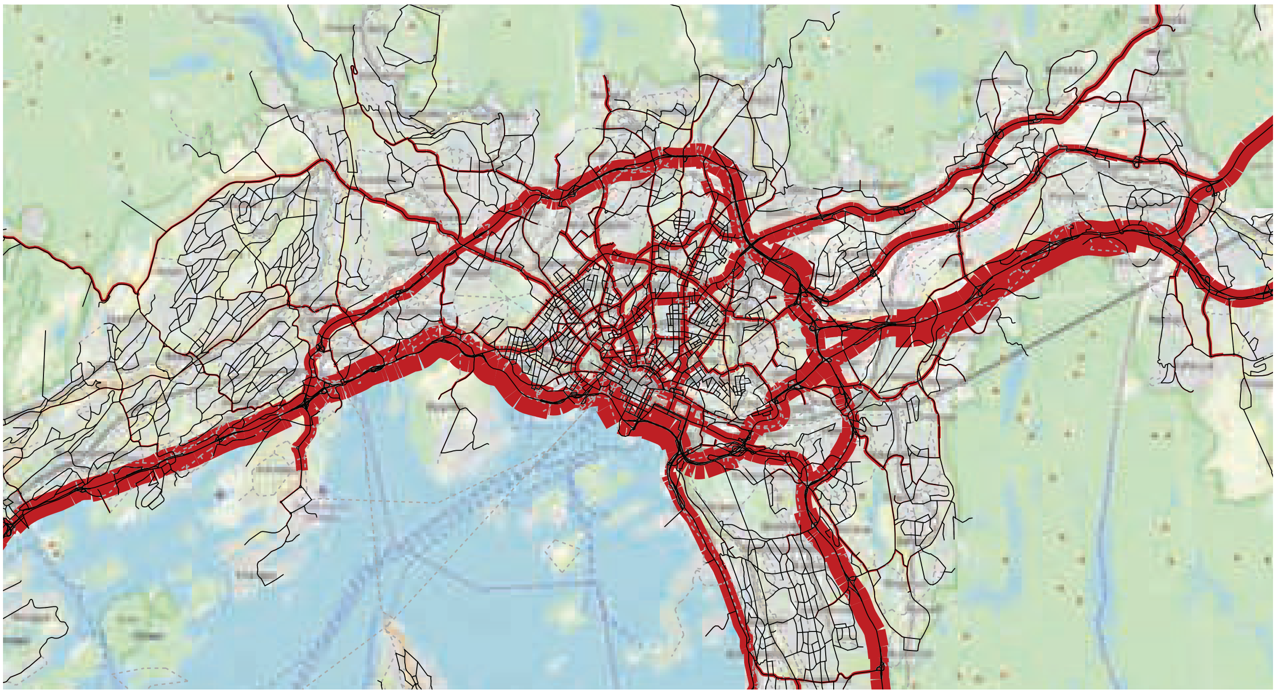


FIGURE 6-7 Network impacts flow volumes, scenario 2a vs base (green=traffic reduction, red=traffic increase)

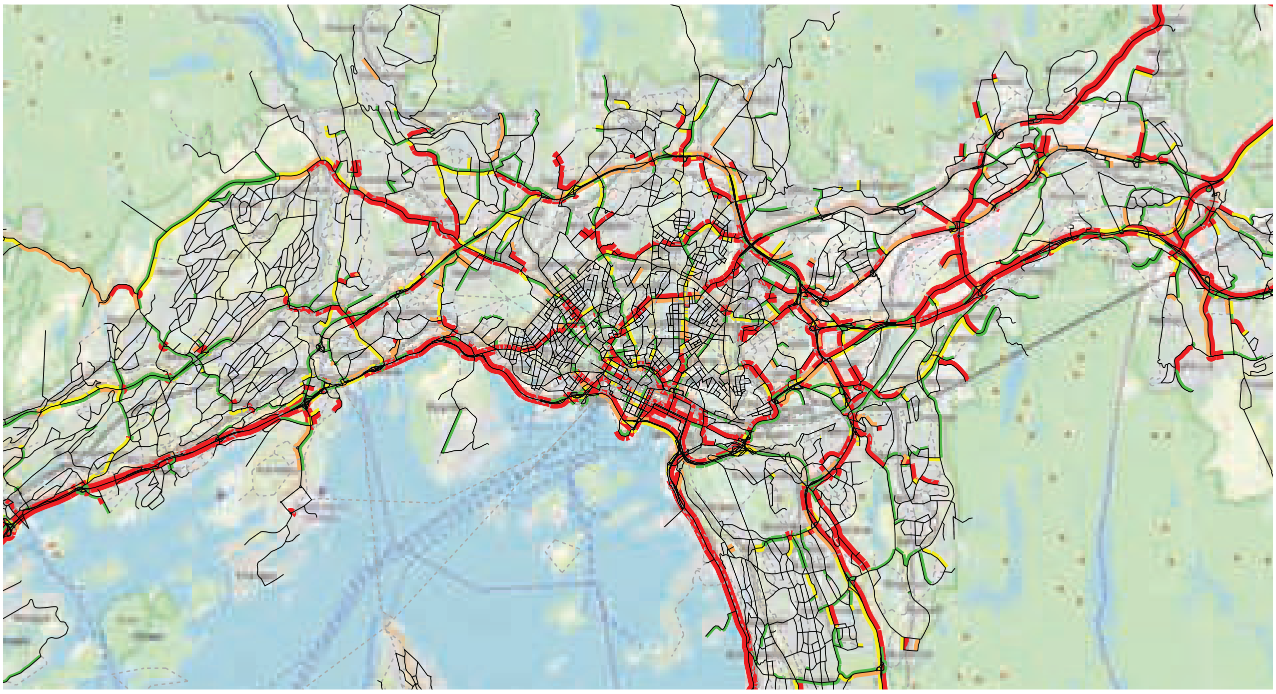


FIGURE 6-8 Volume / capacity ratio in base (period 7 a.m. – 8 a.m.)

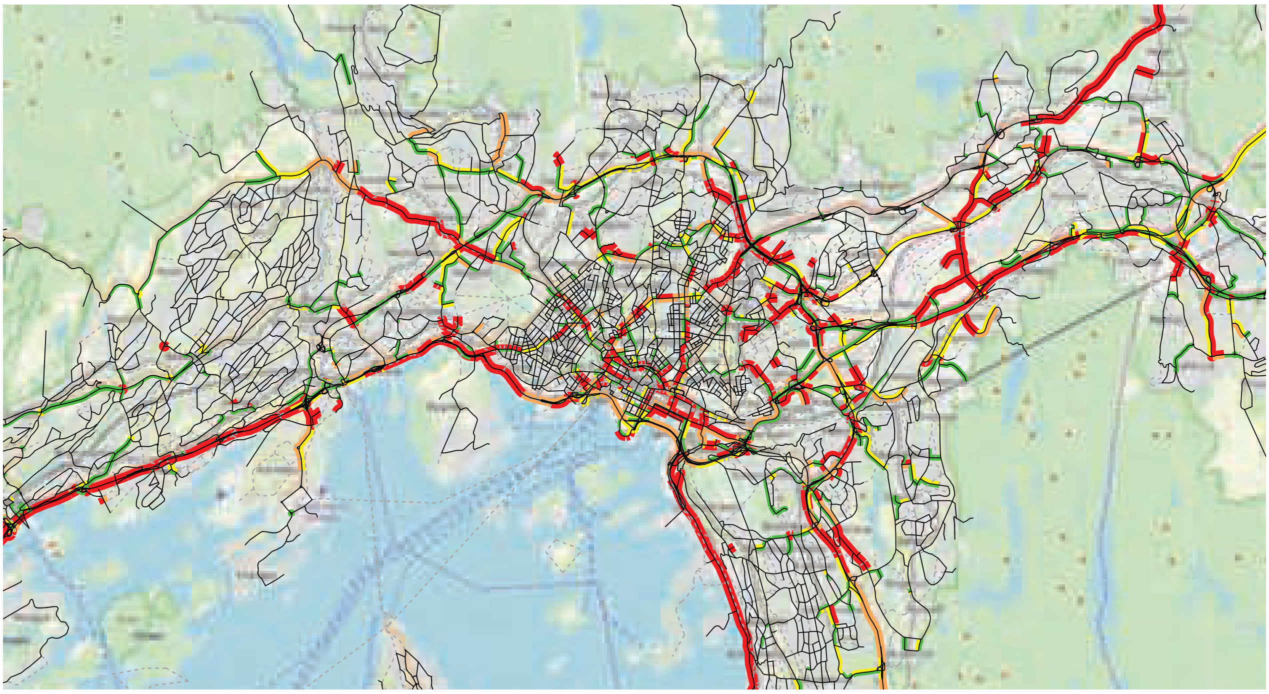


FIGURE 6-9 Volume / capacity ratio in scenario 1b (period 7 a.m.– 8 a.m.)

The effects on traffic levels in scenario 1b is shown in Figure 6-6. The figure illustrates a reduction of traffic on most of the road network. The main roads from the east will benefit from the largest reduction in traffic. The entire main network within Oslo will experience some congestion relief, although for some of the roads there will only be a slight decrease in demand. Few roads in the inner-city boundaries will have less traffic. In the western part of Oslo nearly no changes are shown.

Figure 6-7 shows the effect on the traffic flow in scenario 2a. This figure describes a growth in traffic demand on almost all roads. The roads that experience most oversaturation are the arterial roads into Oslo. All main roads towards Oslo from the east and west will be oversaturated, leaving the ring road with unbearable traffic loads. This could lead to a complete breakdown of the traffic in Oslo.

In scenario 2a a new phenomenon of reversed rush hour traffic occurs. This happens as empty vehicles return from a trip to the inner city of Oslo back to the suburbs, just to pick up a new person on their way to work in central Oslo. The large growth of vehicles traveling out of Oslo in the morning rush will be remarkable on main roads, especially those going eastwards.

To show the scenarios' influences on the congestion on the road network, the traffic volume and the road capacity in the morning rush hour is compared. Figure 6-8 shows the base situation in the year 2020.

The volume / capacity ratio for scenario 1b shows that the traffic congestion situation in the morning rush hour will be better than in the base scenario (see Figure 6-9). Though, several roads will still have difficulties to handle the traffic flows.

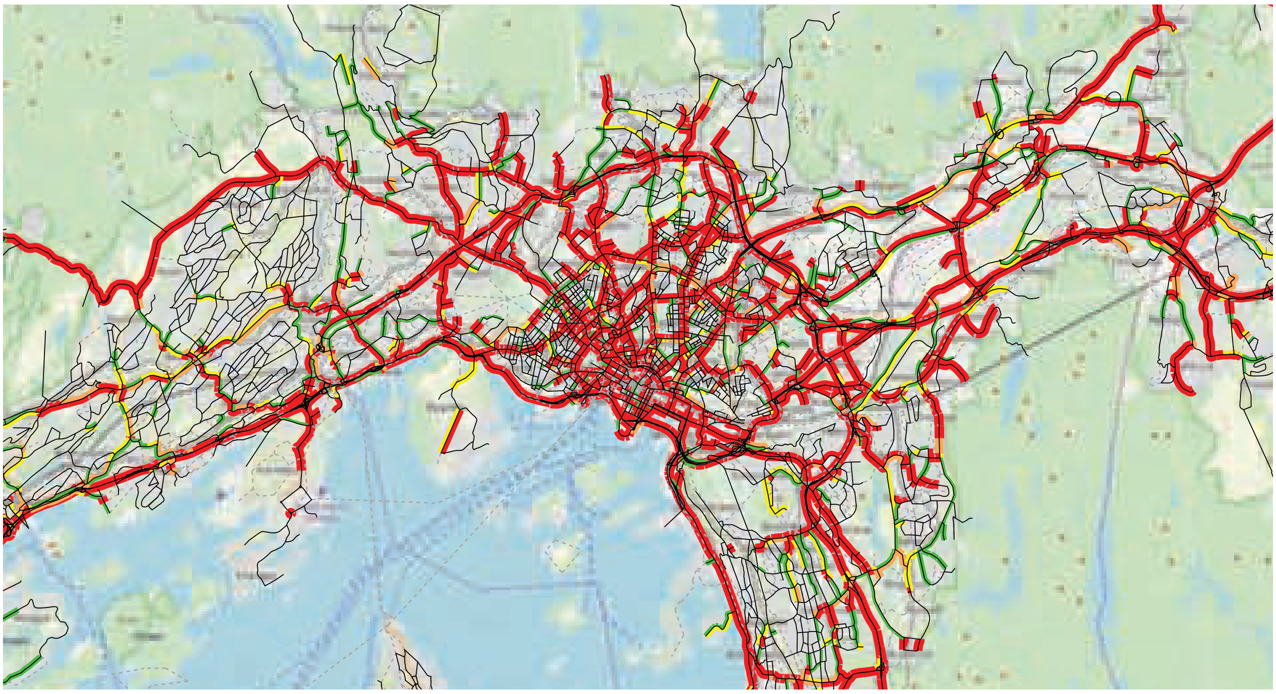


FIGURE 6-10 Volume / capacity ratio in scenario 2a (period 7 a.m. – 8 a.m.)

FIGURE 6-11 Cross section locations

The volume / capacity ratio for scenario 2a, shows that traffic congestion in the morning rush hour will be much worse in this case than in the base situation (see Figure 6-10). Nearly all roads are coloured red and the road network can't handle the traffic flows of the morning peak.

The changes in the traffic volume demand for 6 cross sections on the main roads are shown in Table 6-5 (see Figure 6-11 for the respective locations). The road capacity in the base road network (from RTM 23+) is also shown in the table.

In the ridesharing scenario 1b, nearly all locations have a reduction in traffic volume compared to the base situation, with the traffic going into the city from the east and south showing the biggest decline.

In scenario 2a without ridesharing, all cross sections have a big increase in traffic volume compared with the base situation. Many roads experience more than twice as much traffic, which would cause much more congestion. Several roads would not be able to handle the rush hour traffic.

TABLE 6-5 Traffic volumes and capacity on 6 cross sections in the morning rush hour (period 7 a.m. – 8 a.m.)

		BASIS		SCENARIO 1B		SCENARIO 2A	
POINT	DIRECTION	TRAFFIC VOLUME	RTM23+ ROAD CAPACITY	TRAFFIC VOLUME	CHANGE COMPERED TO BASIS	TRAFFIC VOLUME	CHANGE COMPARED TO BASIS
1	NORTH	4,016	3,350	3,061	-24%	6,306	+57%
	SOUTH	2,781	3,350	3,064	+10%	6,376	+129%
	TOTAL	6,797	6,700	6,125	-10%	12,682	+87%
2	WEST	5,922	6,000	4,152	-30%	9,744	+65%
	EAST	4,881	4,500	4,668	-4%	10,718	+120%
	TOTAL	10,802	10,500	8,821	-18%	20,462	+89%
3	EAST	3,387	4,500	3,638	+7%	7,841	+132%
	WEST	4,826	4,500	3,743	-22%	8,623	+79%
	TOTAL	8,213	9,000	7,381	-10%	16,464	+100%
4	WEST	4,729	3,350	4,645	-2%	7,981	+69%
	EAST	4,831	4,750	4,857	+1%	8,558	+77%
	TOTAL	9,561	8,100	9,502	-1%	16,538	+73%
5	EAST	2,779	3,350	2,283	-18%	5,661	+104%
	WEST	2,917	3,350	2,475	-15%	5,471	+88%
	TOTAL	5,696	6,700	4,758	-16%	11,131	+95%
6	WEST	4,087	3,200	3,802	-7%	7,991	+96%
	EAST	4,199	3,200	3,981	-5%	8,491	+102%
	TOTAL	8,286	6,400	7,783	-6%	16,482	+99%

6.6 SENSITIVITY ANALYSIS

All the main scenario results were compared using the same parameter assumptions. The objective of this chapter is to illustrate the sensitivity of the results to input parameter changes as a sensitivity analysis. The level of service of the MaaS concept modelled in the study is high, and the sensitivity analysis shows that we can see stronger effects on results by changing the level of service.

6.6.1 DETOUR FACTOR AND WAITING TIME

In the final scenarios analyzed, the prerequisites are that passengers will be served with a MaaS system tolerating a detour factor of 1.5 and a maximum wait time of 10 minutes.

Changing the prerequisites will change the results. For instance, in scenario 1b, changing the service level accepted by changing the detour factor to 2.0 or the maximum wait time to 20 minutes yields the results presented in Table 6-6. Both changes will lead to a MaaS system operating at a lower level of service.

A change of the detour factor from 1.5 to 2.0 can increase the trip length and time for the passengers but will give the MaaS system more freedom for system optimization. This is because it will be left with more possibilities to plan ridesharing between passengers. The results show, that with the relaxation of the service standard by increasing the detour factor, a further possible reduction in vehicle kilometers travelled, from 14 % to 31 % compared to the base scenario, is possible. The required fleet size can be reduced from 26,000 to 20,000 and the average occupancy for vehicles in operation increases from 1.62 to 2.48. For the passengers the increased detour factor will increase the average trip by 2.2 kilometers and 5.3 minutes.

TABLE 6-6 Results from the sensitivity analysis in scenario 1b

	BASIS	1B	1B	1B
DIRECTION	PRIVATE CARS 2020	"FROM PRIVATE CAR TO SHARED TAXI	FROM PRIVATE CAR TO SHARED TAXI	FROM PRIVATE CAR TO CAR SHARING
ASSUMPTIONS				
DETOUR FACTOR	-	1.5	2.0	1.5
WAITING TIME MAXIMUM	-	10 MIN	10 MIN	20 MIN
RESULTS				
FLEET SIZE	352,000	26,000	20,000	26,000
FLEET SIZE PROPORTION OF BASIS		7%	6%	7%
VEHICLE KM (MILLION)	4.4	3.7	3.0	3.8
VEHICLE KM CHANGE COMPARED TO BASIS		-14%	-31%	-13%
MEAN OCCUPANCY – IN OPERATION	1.14	1.62	2.48	1.61
AVERAGE TRIP DISTANCE [KM]	11.7	12.6	14.8	12.6
AVARAGE TRIP TIME – TOTAL	12.3	20.5	25.8	20.6
AVERAGE WAITTIME [MIN]	0.0	2.9	3.5	3.0
AVERAGE TRIP DURATION [MIN]*	12.3	17.7	22.2	17.6
AVERAGE DETOUR TIME (RIDE) [MIN]	-	5.5	10.1	5.5

A higher maximum wait time of 20 instead of 10 minutes may also lead to an increased average wait time for passengers, but is beneficial for the MaaS system, since it will have more time to pick-up the passengers and therefore leaves more room to optimize the system. The results show, that relaxing the service standard by increasing the wait time only has minor impacts on the results. The vehicle kilometres travelled, and the required fleet size are approximately the same. For the passengers the increased wait time also only has a minor effect, since the system still manages to complete almost all pickups within 10 minutes, which was the original maximum value.

6.6.2 SERVED PASSENGERS

All the scenarios require the MaaS systems to satisfy 100 % of the passenger demand. A MaaS system without a fleet size big enough to serve all the passengers results in some people not being able to use MaaS for their journey. Changing this prerequisite will have an impact on the results. Figure 6-12 shows the share of served passengers in the scenarios for different fleet sizes (with a detour factor of 1.5 and maximum wait time of 10 minutes).

The figures show that a smaller fleet in the MaaS system can still serve a high percentage of the passengers. In scenario 2b 30,000 vehicles can serve 92 % of the passengers, which is only 75 % of the fleet size required to serve 100 % of the passengers under these conditions.

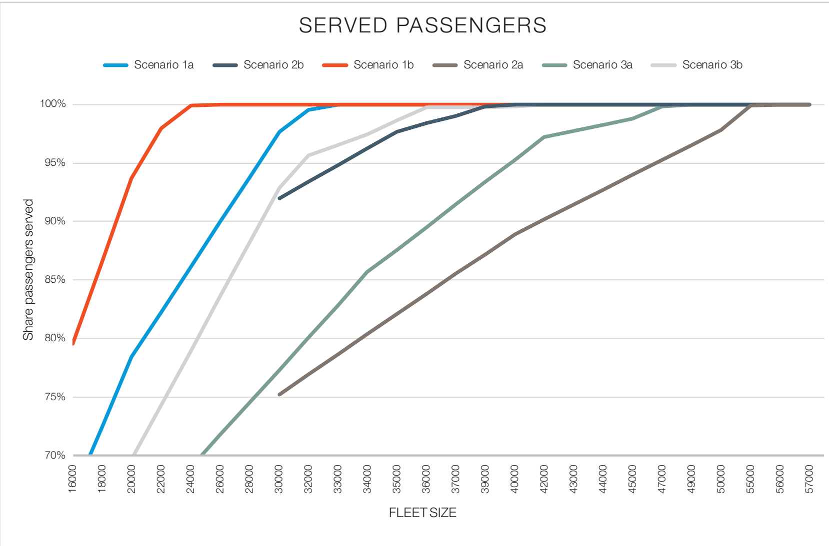


FIGURE 6-12 Share of served passengers in the scenarios for different fleet sizes

Table 6-7 shows a comparison between the final scenario, a scenario where 98 % of the passengers are served and a scenario where the fleet size is reduced to around 75 % of the fleet size in the final scenario. The comparison is done for the best-case scenario 1b and the worst-case scenario 2a.

TABLE 6-7 Results of the sensitivity analysis

	1b	1b	1b	2a	2a	2a
	From private car to shared taxi	From private car to shared taxi	From private car to shared taxi	From private car, bus and tram to car sharing	From private car, bus and tram to car sharing	From private car, bus and tram to car sharing
Person trips	401,000	401,000	401,000	611,000	611,000	611,000
Share served passengers	100 %	98 %	94 %	100 %	98 %	89 %
Fleet size	26,000	22,000	20,000	56,000	50,000	40,000
Fleet size proportion of basis	7 %	6 %	6 %	16 %	14 %	11 %
Vehicle km (million)	3.7	3.7	3.5	8.6	8.3	7.4
Vehicle km change compared to basis	-14 %	-16 %	-20 %	+97 %	+91 %	+70 %
Mean occupancy – in operation	1.62	1.61	1.62	0.80	0.80	0.80
Average trip distance [km]	12.6	12.6	12.7	11.4	11.3	11.3
Average trip Time – total	20.5	20.7	20.8	18.3	18.5	18.5

In this study, all travellers are served by a MaaS system or public transport. If some travellers were excluded from this system, a considerably smaller vehicle fleet could be sufficient without lowering the level of service. The travellers who are not served are likely to be those living in the most rural areas with little traffic. It may be a better solution to let some people, living in areas that are difficult to cover by MaaS, keep their private cars.

6.7 PICK-UP AND DROP-OFF LOCATIONS

On the one hand, the usage of autonomous vehicles comes with a large reduction of demand for parking in all scenarios. On the other hand, new activities, that require an alternation of road and city space, will emerge. These activities are related to design criteria of space reserved to pick-up and drop-off users of a MaaS system. A good design and practice of these locations will improve the traffic flow quality.

Freed parking space along a road could be transformed into pick-up and drop-off locations. In addition, current parking hubs and terminals could be used as pick-up and drop-off hubs.

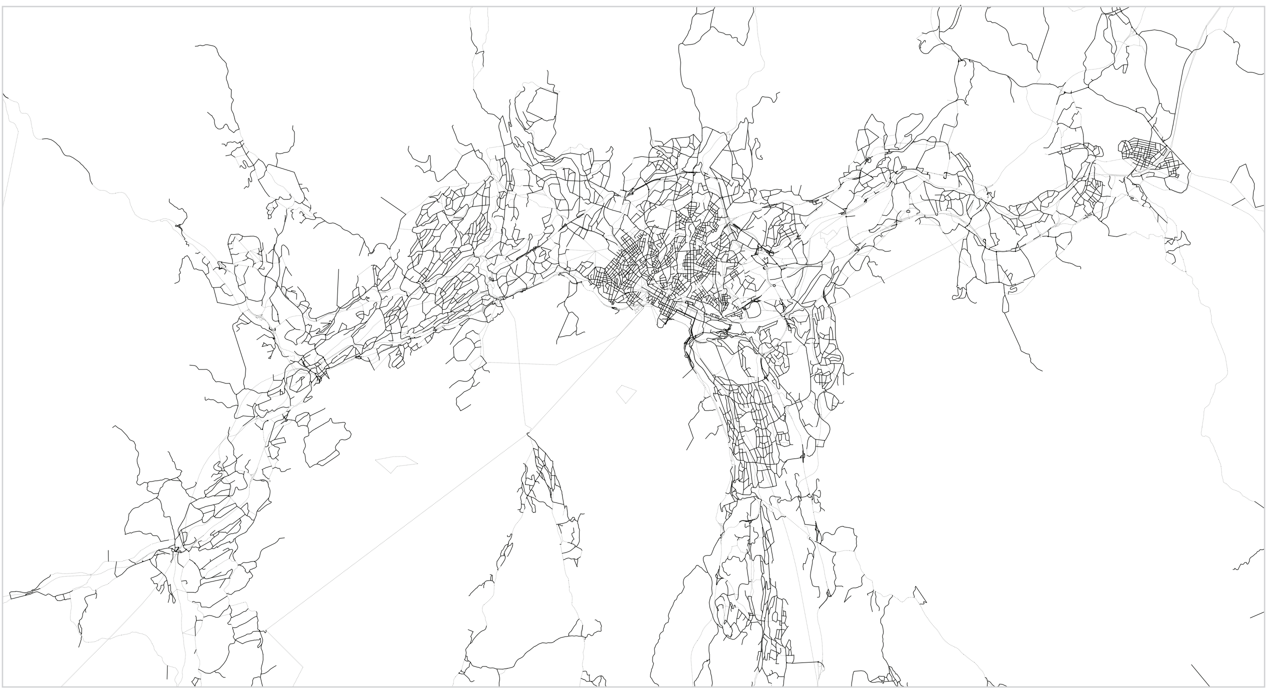


FIGURE 6-13 Links for PUDOs

FIGURE 6-14 Example of PUDOs within Oslo

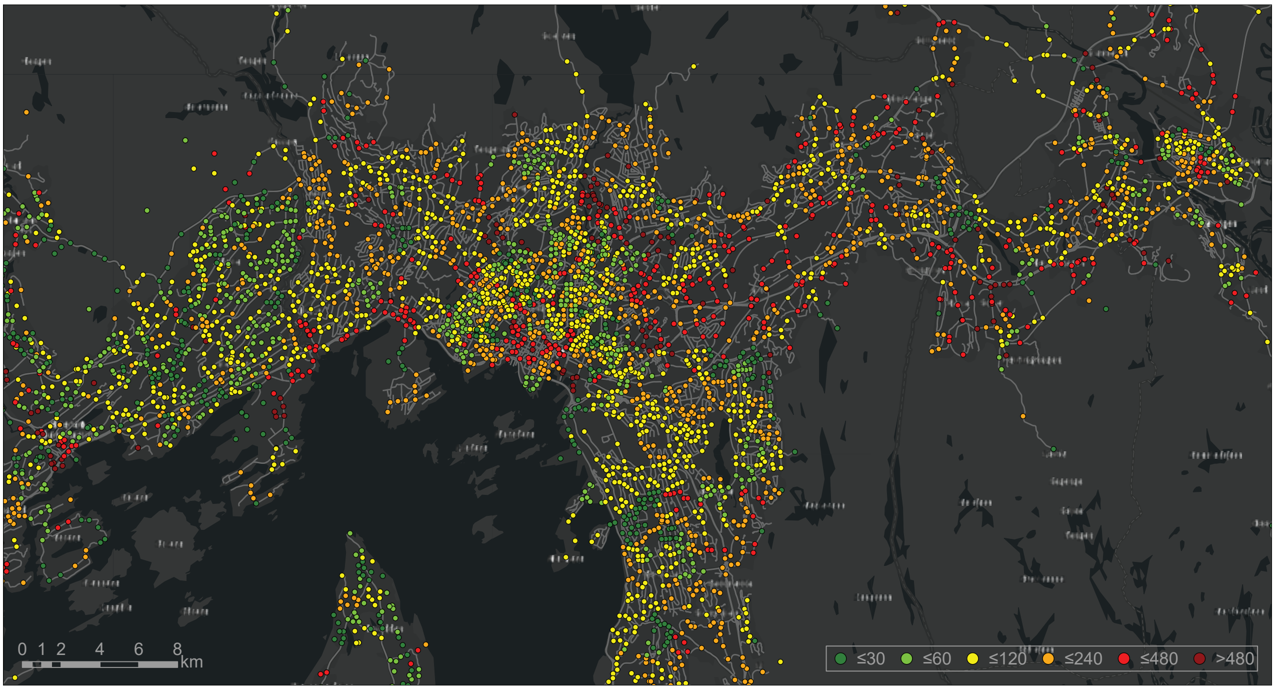


FIGURE 6-15 Scenario 1b PUDO activity

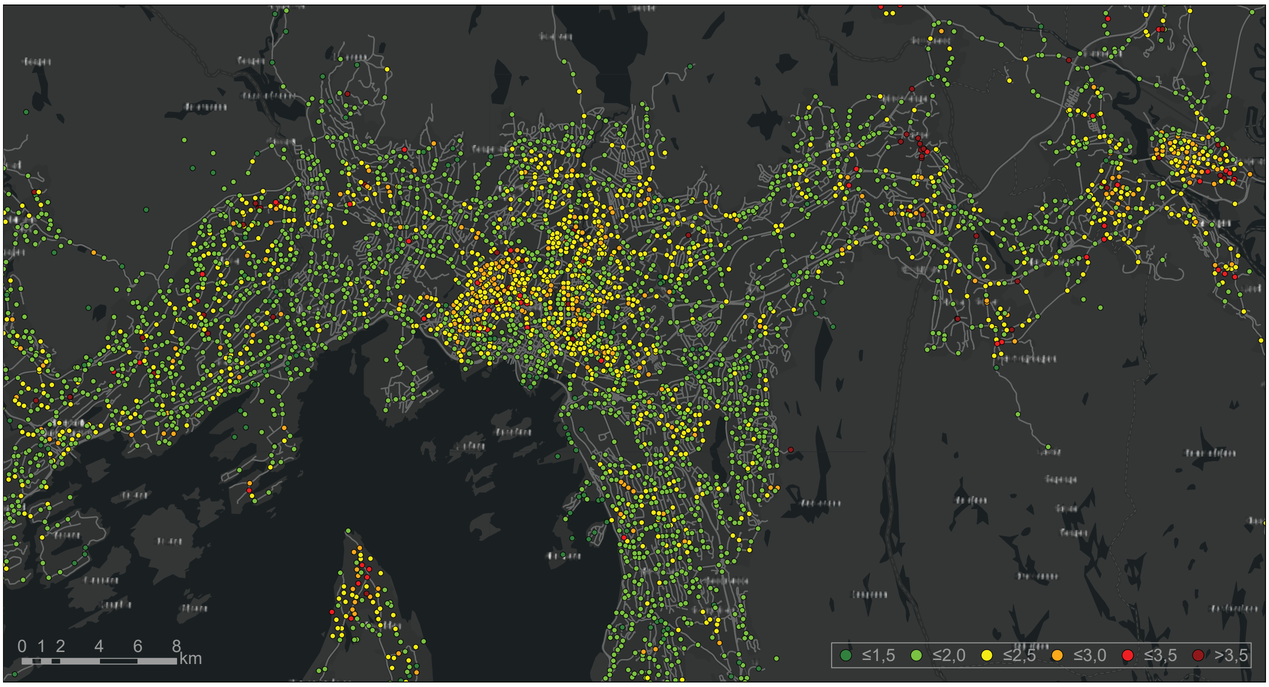


FIGURE 6-16 Scenario 1b PUDO average detour experienced

Calculations make it possible to assess where in Oslo initiatives, that support efficient pick-up and drop-off activities, would be required. These calculations yield results regarding how many locations would be needed for the desired service level. Results also show where it is suitable for multiple small pick-up and drop-off locations to be accumulated into larger hubs.

The pick-up and drop-off (PUDO) locations within the model are designed to replicate a door-to-door service. Therefore, most nodes of the model were allocated as PUDOs, as long as they fulfilled certain conditions. The road network that the nodes were located on was specified as:

› Must allow Car traffic on the road.
› Must not have more than two lanes of traffic.
› Must not have a speed of over 60 km/h.
› Must not be located in any tunnels or on overpasses.

These specifications ensured that the PUDO points used in the model are all located on roads with a high likelihood of cars being able to stop by the side of the road, rather than on busy highways. Figure 6-13 gives an example of the roads that PUDOs were allowed to be on, shown as a solid black line. Roads that could not have PUDOs are shown as a dotted grey line.

Further checks on the PUDO allocation were made to ensure that all zones within the model had at least one PUDO assigned for the passenger demand to be allocated to and that all PUDO points were connected to each other for the assignment of the vehicles. Finally, if any PUDOs were less than 100 meters apart from each other, they were thinned out to ensure that, despite having many PUDOs in the model, there was still an opportunity for passenger ride sharing to occur at busy PUDO points. Figure 6-14 shows the wide spread of PUDO points used in the model.

The PUDO activities are shown for the two contrasting scenarios regarding traffic flow, the best-case and the worst-case scenarios, respectively 1b and 2a.

Figure 6-15 shows the demand of the different PUDOs in Oslo and the surrounding areas for scenario 1b. This scenario involves a MaaS system with ridesharing. The demand for transportation is the same as in 1a, but it does not include ridesharing. This scenario would therefore require different criteria for shaping the city and surrounding areas.

It is to be noted that there are several PUDO locations in close proximity, these could possibly be be merged and transformed into larger PUDO hub locations in the future.

Figure 6-16 shows the average detour experienced[4] by the PUDO boarding location for scenario 1b.

4 Detour experienced = $\frac{\text{Wait\_time + In-Vehicle\_Time}}{\text{Direct Travel Time}}$

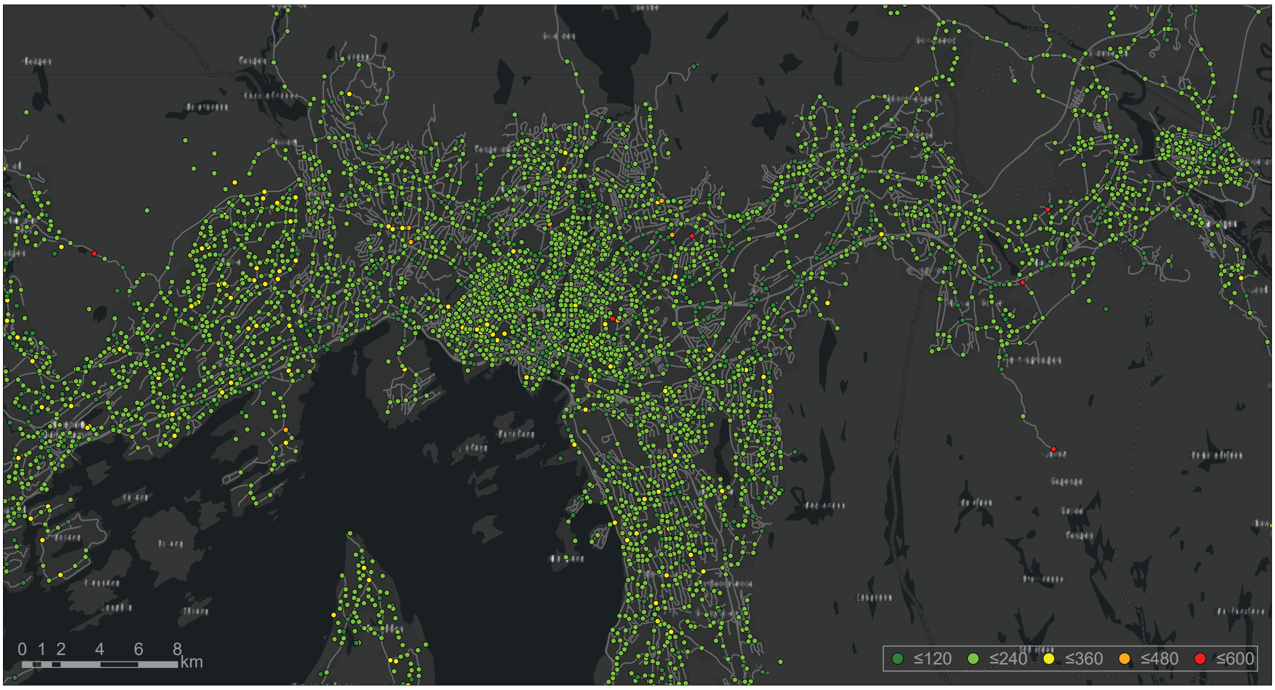


FIGURE 6-17 Scenario 1b PUDO average wait time

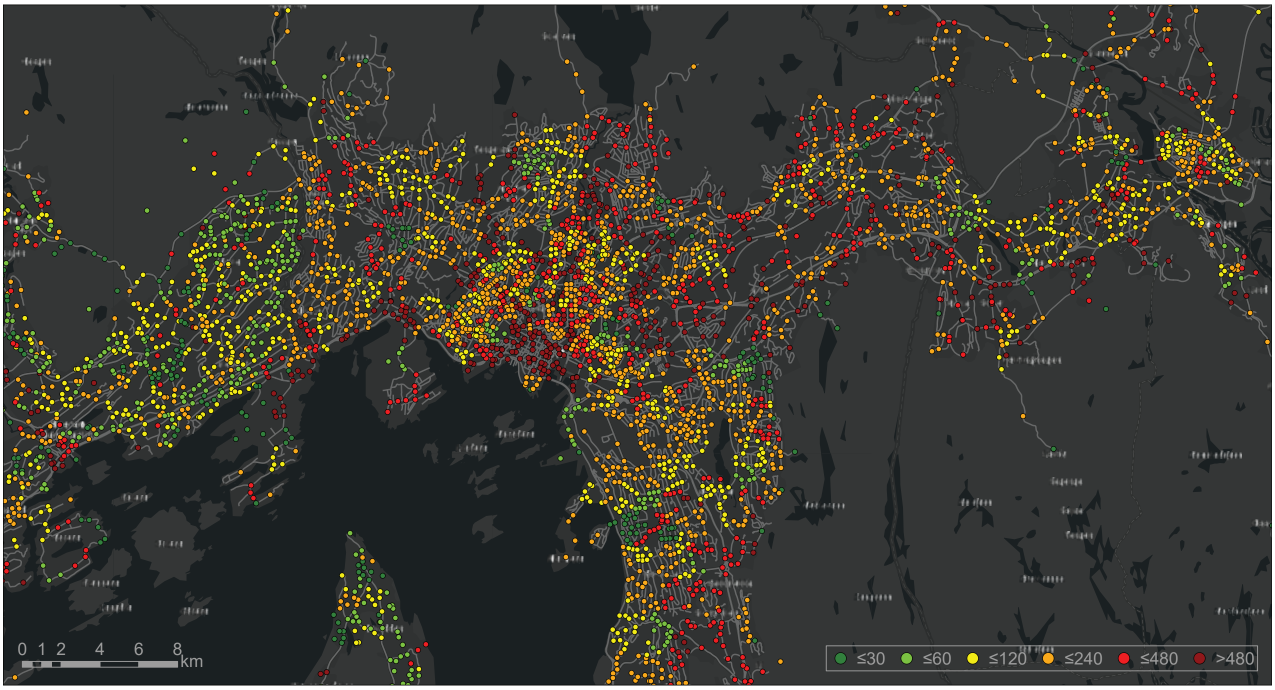


FIGURE 6-18 Scenario 2a PUDO activity

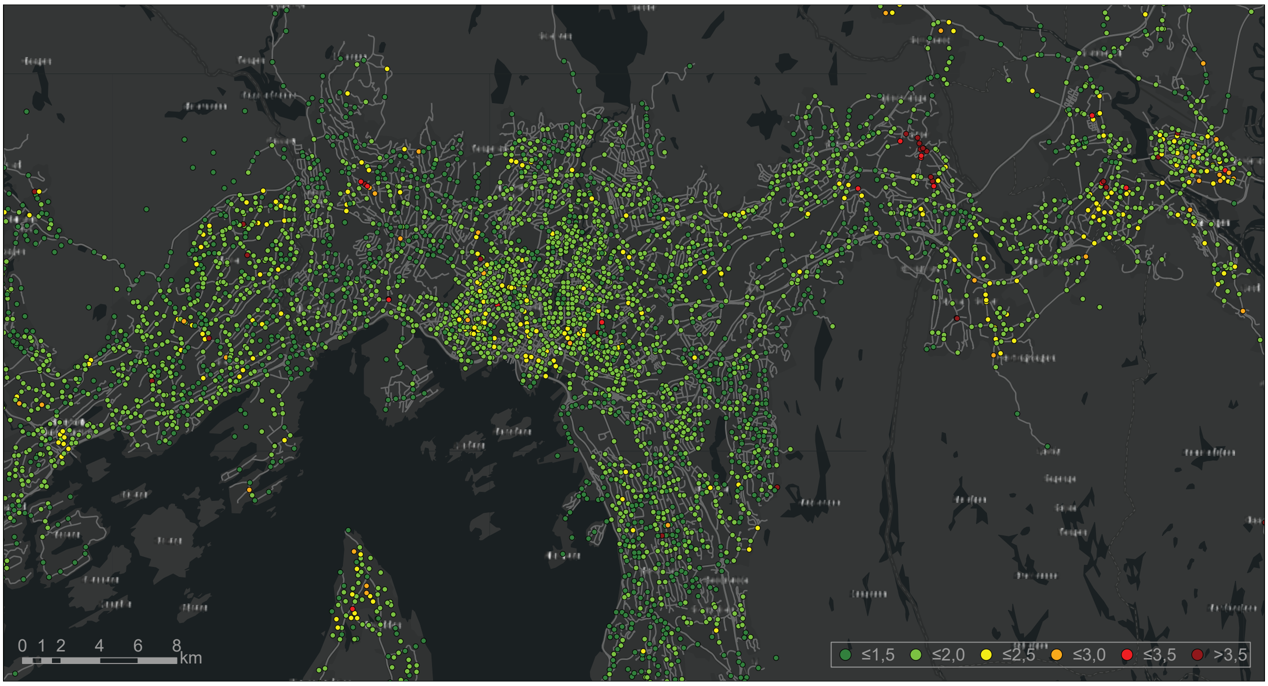


FIGURE 6-19 Scenario 2a PUDO average detour experienced

Figure 6-17 shows the average wait times at the PUDOs in scenario 1b. The general trend is that wait time increases where demand is lower. This also applies to current public transport. The difference is that the MaaS system does not have a fixed service schedule. Users cannot time their arrival at the PUDOs after ordering a MaaS vehicle. This raises the question about waiting facilities being required at the PUDOs, especially the ones with many passengers boarding and alighting (see also chapter 6.8).

In Figure 6-18, the demand of the different PUDOs in Oslo and its surrounding areas is shown for scenario 2a. This scenario involves a MaaS system without ridesharing. Since the number of person trips in scenario 2a is 50 % higher than in scenario 1b, the PUDO activities are also higher and several PUDOs in Oslo have more than 1,000 persons boarding and alighting (red marks).

Figure 6-19 shows the average detour experienced by PUDO boarding location in scenario 2a. The detour experienced in scenario 2a is based only on the wait time, since the detour during the ride is zero, as this scenario doesn't include ride sharing.

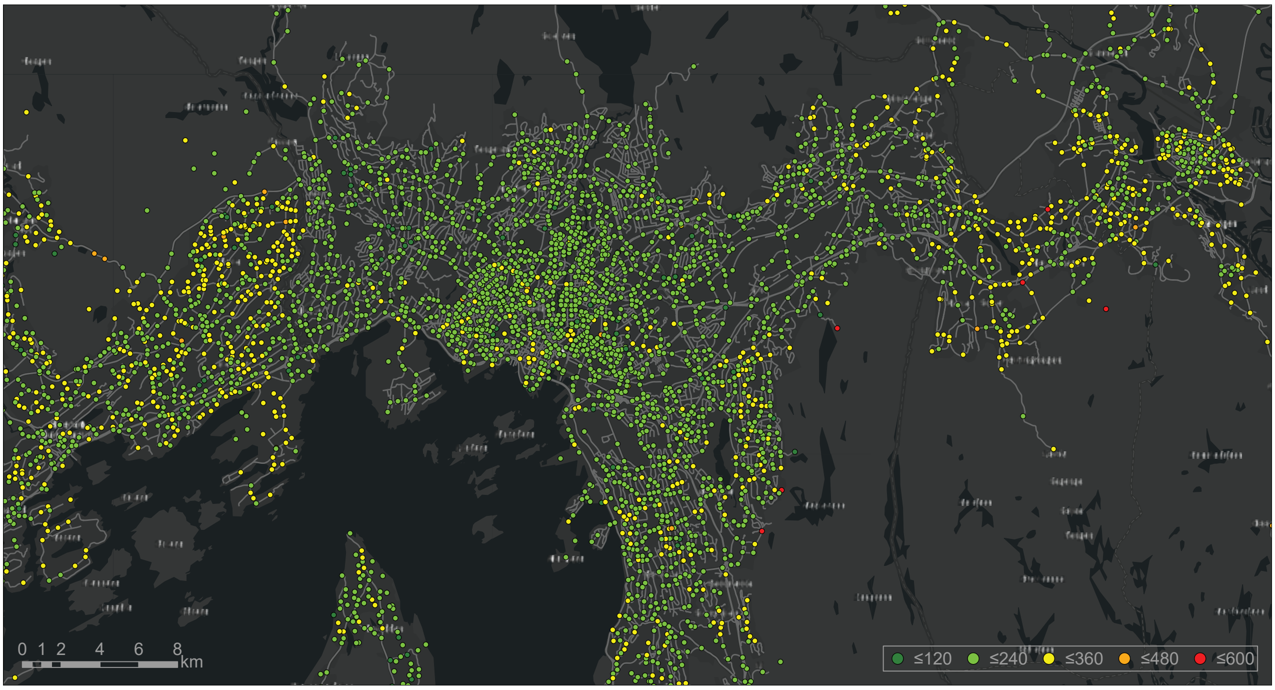


FIGURE 6-20 Scenario 2a PUDO average wait time

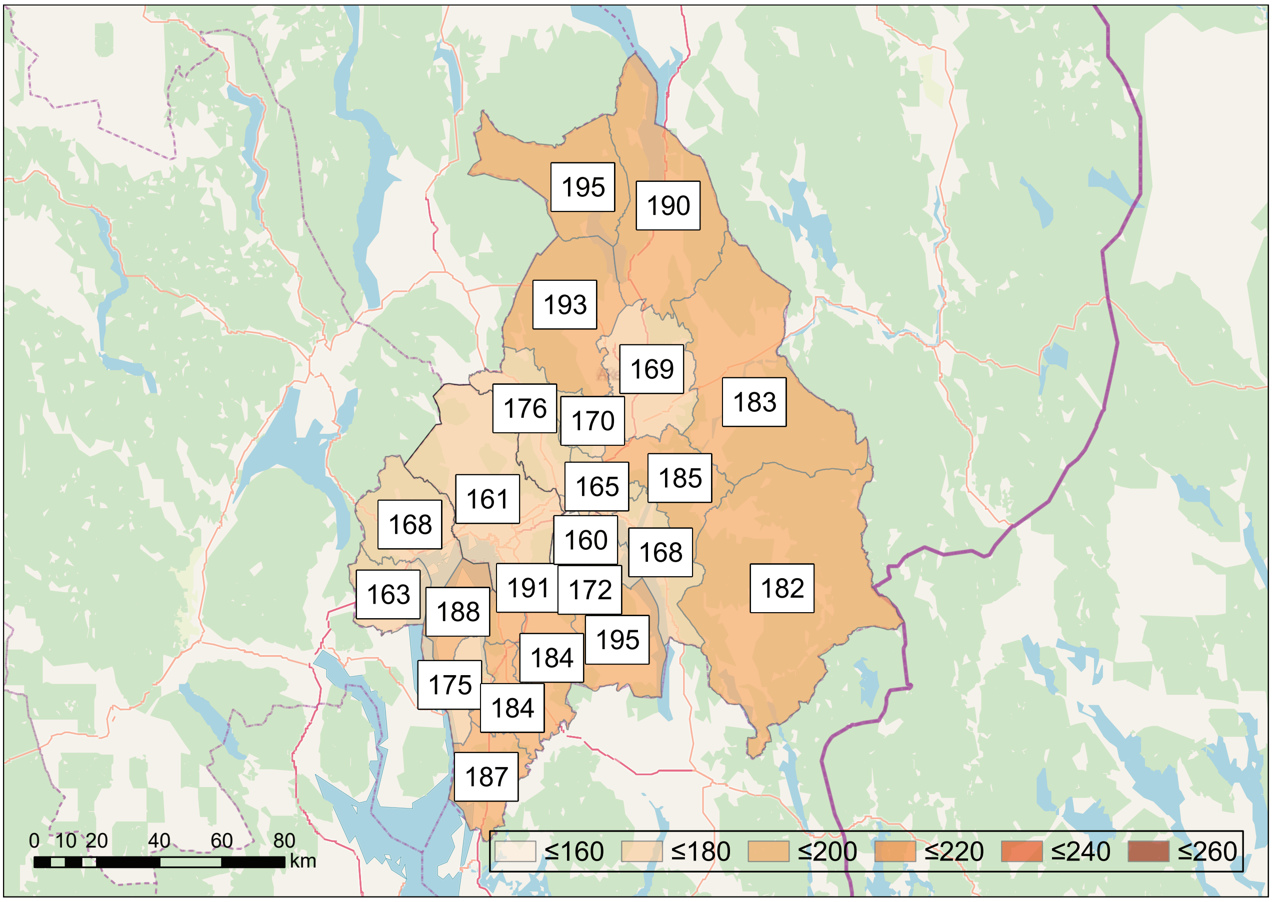


FIGURE 6-21 Scenario 1b PUDO average wait time by municipality

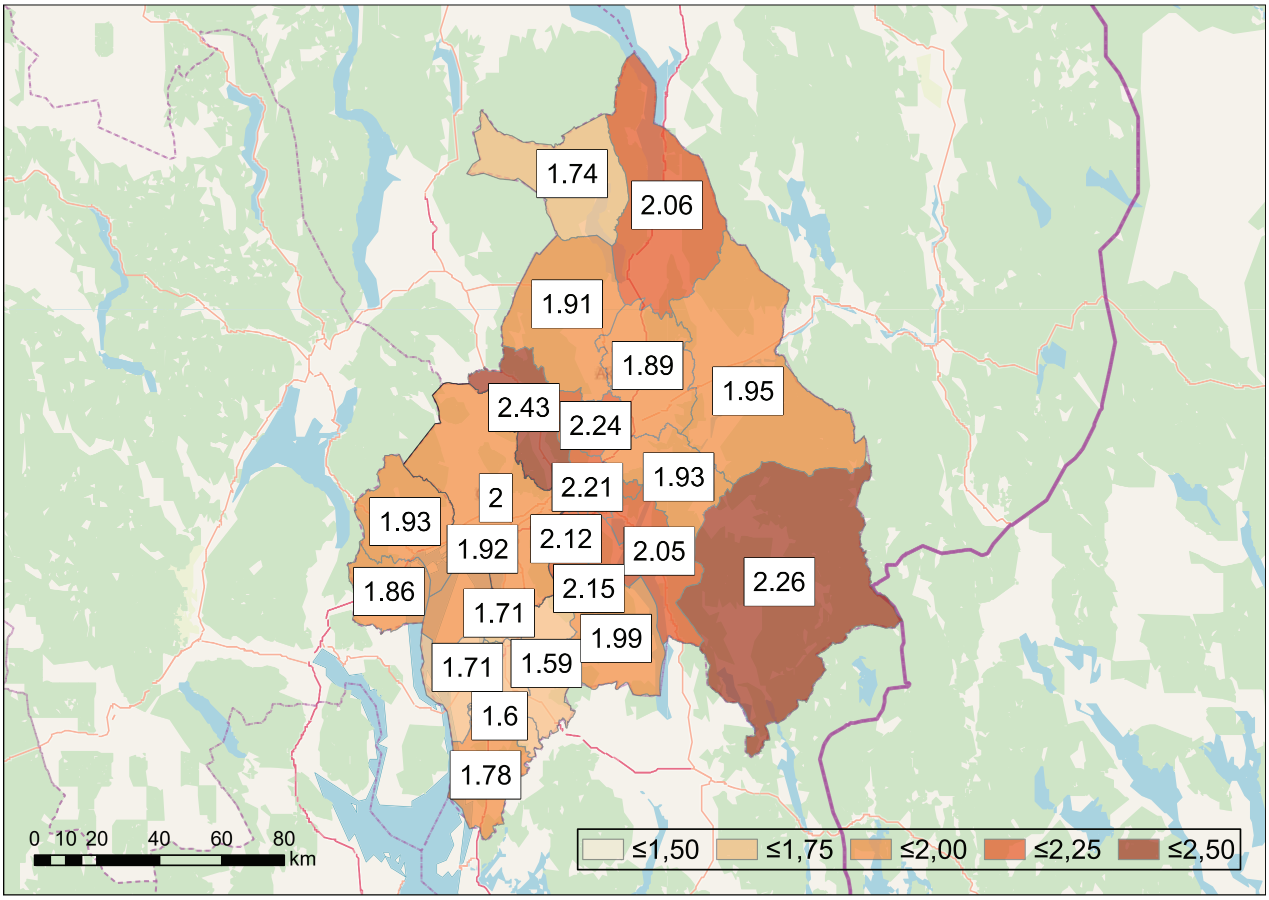


FIGURE 6-22 Scenario 1b PUDO average detour experienced by municipality

Figure 6-20 shows the average wait times at the PUDOs in scenario 2a.

The average wait time for each municipality in scenario 1b is shown in Figure 6-21. In scenario 1b, due to the smoothing of customer levels of service across the region, there do not appear to be any municipalities with significantly higher or lower average wait times.

The average detour experienced at PUDO locations can also be averaged across all the PUDO locations within each municipality covering Oslo and Akershus. Aurskog-Høland, Rælingen, Lørenskog, Skedsmo, Gjerdrum and Nittedal are the municipalities that have the longest average detour experienced in the scenario 1b, whereas Ski and Ås have some of the shortest average detour experienced (see Figure 6-22).

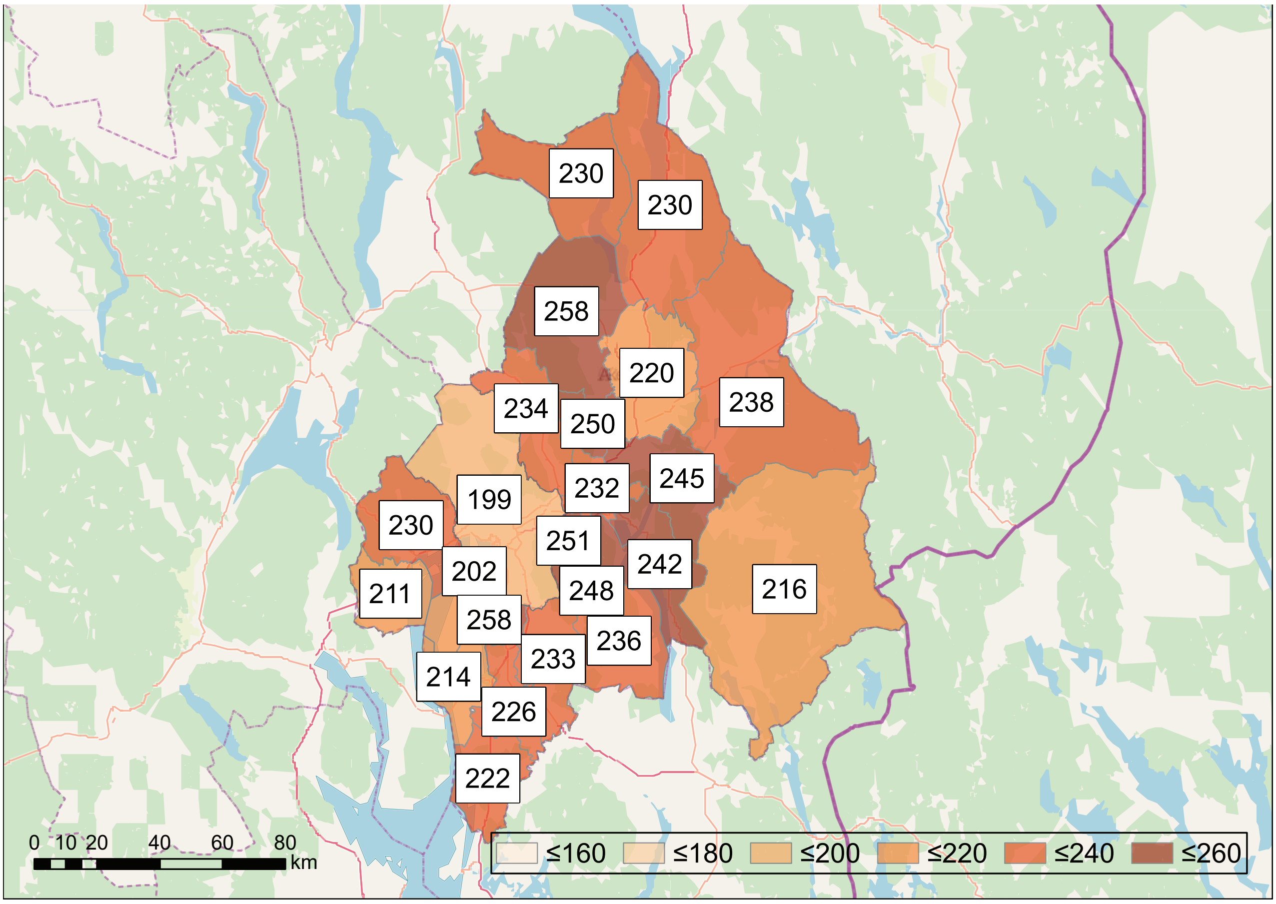


FIGURE 6-23 Scenario 2a PUDO average wait time by municipality

The average wait time at PUDO locations within each municipality covering Oslo and Akershus in scenario 2a are shown in Figure 6-23. Nannestad and Oppegård have the longest average wait times, while Nesodden and Oslo have some of the shortest average wait times.

The average detour experienced at PUDO locations within each municipality covering Oslo and Akershus in scenario 2a are shown in Figure 6-24. In scenario 2a, this number is based on the wait time, since the detour during a trip is zero, as ride sharing is not included. Nittedal and Gjerdrum are the municipalities that show the highest numbers, while Ski and Ås have some of the shortest average detour experienced.

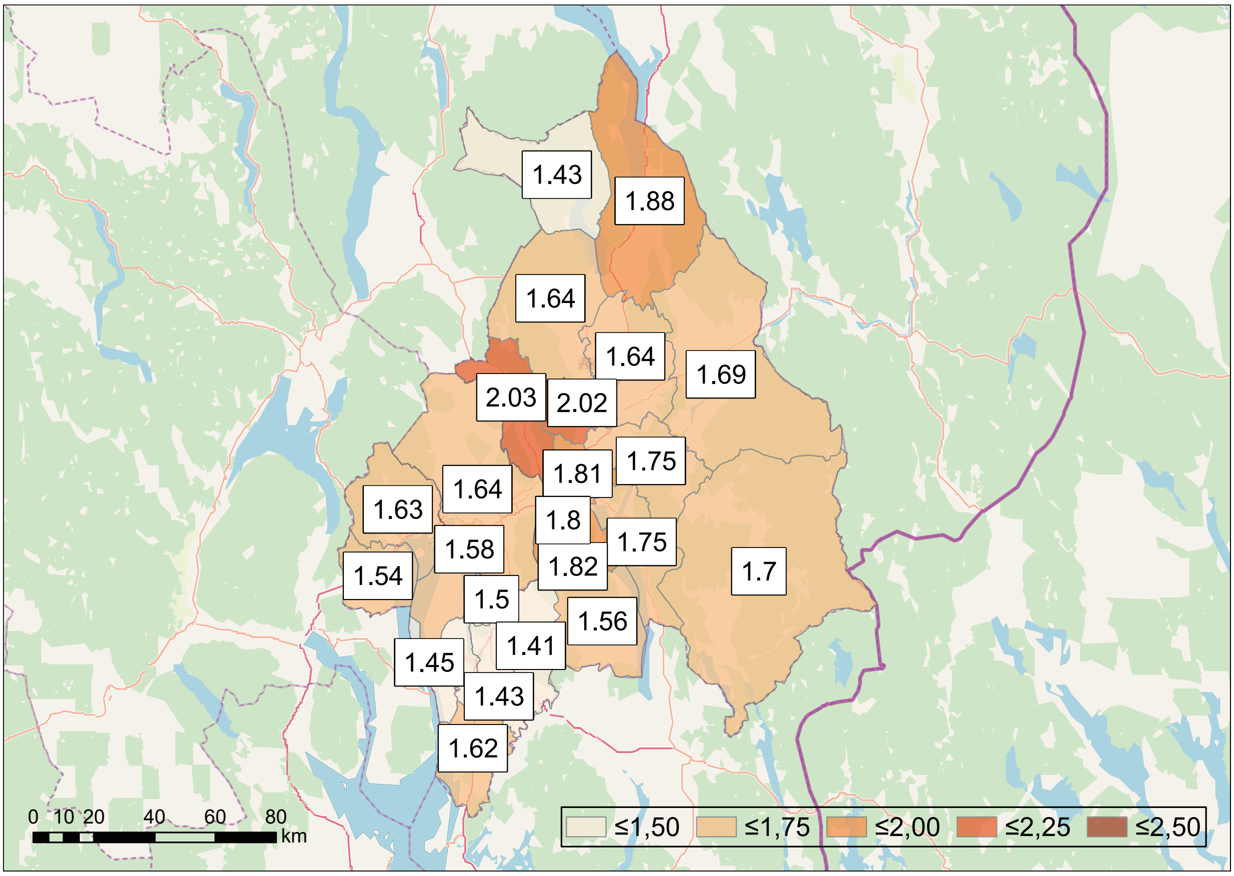


FIGURE 6-24 Scenario 2a PUDO average detour experienced by municipality

6.8 PARKING AND CITY PLANNING

With the prerequisites and assumptions used in the calculations it is possible to conclude that a large reduction of vehicles is feasible, while still accommodating the movements of the population of the Oslo region. Even in the worst-case scenario (2a) the vehicle fleet is reduced to 16 % of the current fleet. In the best-case scenario, the vehicle fleet reduces to 7 % of the current fleet size. These results match the conclusion made in the Lisbon studies.

A well-developed MaaS system requires new standards for infrastructure and releases a vast amount of area currently reserved for parking. However, MaaS vehicles will also require areas where they can be charged, cleaned and maintained.

Curb side parking will not be necessary anymore to an extent where it will almost not be visible. This gives the city an option to redesign curb space to cater for pick up and drop off locations of the MaaS system. One challenge will be the transformation from fee-based parking to fee-based pick up/drop off areas, especially for the busiest pick-up/drop-off locations, that may require a large area. For the road administrators this could result in a large loss of income.

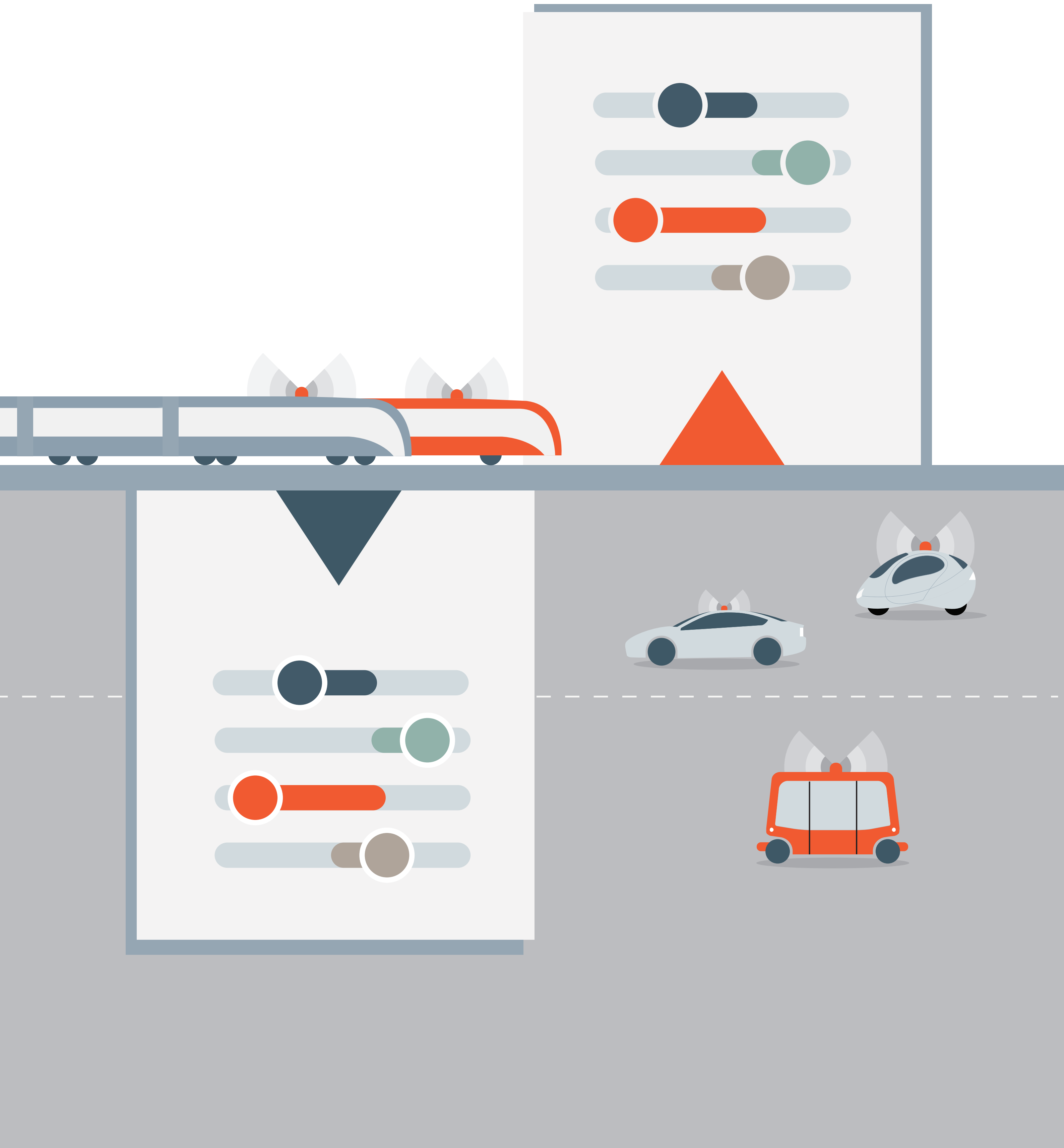
Parking could be removed from the inner city to increase city quality and the quality of life. Taking this a step further, parking garages, parking lots or parking basements could be transformed into housing, meaning that the area could be populated more densely. This could also improve the economy through real estate development.

The potential consequences of removing parking are huge. Current city planning needs to meet the current and future needs. There are different opinions on when autonomous vehicles will be ready to commence service and how fast ridesharing will be phased in. This report shows that considerations about the future of transport should already be undertaken today, to ensure that robust planning, that is prepared for autonomous vehicles within the city, is carried out.

6.9 FUTURE MAAS ANALYSIS

This study of how autonomous vehicles may change the future transport contained the analysis of six MaaS scenarios. It could be interesting to perform more MaaS scenarios, that were not possible within the scope of this study. Possible interesting future analysis could be:

- Geographical areas The MaaS system in this study is handling a big area covering both Oslo and Akershus counties. Possible future analysis could be done for smaller areas such as separate suburban areas or the inner city.
- Passenger level of service The MaaS system in this study is defined to provide the passengers a service with low detour factors and wait times. Future analysis for other assumptions about the passenger level of service could be conducted and with different assumptions depending on the current use of transport (public transport or private transport).
- Pick-up/drop-off locations The MaaS system in this study has a pick-up/drop-off location at nearly every road corner (replicating a door-to-door service). Possible future analysis could include fewer pick-up/drop-off locations, which is likely to result in a higher occupancy of vehicles through ridesharing.
- Partial integration phases The MaaS system in this study assumes a 100 % migration from the existing transport types to the new MaaS system. Possible future analysis could be looking into the transitions phases, where the MaaS system is only partly integrated or only parts of the trips are migrated to MaaS.
- Feeder service The MaaS system in this study allows the passenger to use the MaaS vehicles for the whole trip from home to work, even if it is a long trip where it would make more sense to use a train or metro for a part of the trip. Possible future analysis could be to use MaaS systems in suburban areas as a feeder system to the train network for the trips going towards Oslo city. This has been done in one of the Lisbon studies, for example.
- MaaS fleets The MaaS system in this study is handled as one or two systems. The passengers can use a MaaS vehicle for the whole trip. Possible future analysis could be to introduce several separate MaaS systems such as a MaaS system in a suburban area for local trips and as a feeder to the trains, a MaaS system handling longer trips that naturally do not include trains and/or a MaaS system for trips inside the inner city of Oslo.
- Vehicle capacity The MaaS system in this study has fixed capacities for shared cars, shared taxis and taxibuses. Possible future analysis could introduce other vehicle capacities into the MaaS system. This should be done together with new assumptions to promote ridesharing, like fewer pick-up/drop-off locations or a lower passenger level of service.



7 COMPARISON WITH ITFS CASE STUDIES

7.1 KPIS IN OSLO COMPARED WITH FIVE OTHER CITIES

In addition to the Lisbon studies, the OECD/ITF has carried out three other case studies on Helsinki (Finland), Dublin (Ireland) and Auckland (New Zealand)[5]. The University of Stuttgart has carried out a similar study for the Stuttgart region[6]. All six studies have, like this Oslo study, the whole region as their catchment area. The size of the areas, population numbers and population densities in the regions are shown in Table 7-1. Figure 7-1 shows the current mode shares for the regions.

TABLE 7-1 Area and population studied cities

	OSLO	LISBON*	HELSINKI	DUBLIN	AUCKLAND	STUTTGART
Area (km²)	5,400	3,000	800	7,000	2,200	3,700
Population (millions)	1.3	2.8	1.1	1.8	1.3	2.7
Population density (inhabitants versus area)	241	933	1,375	257	591	730

* Shared mobility: Innovation for livable cities. 2016

5 ITF/OECD, Shared Mobility Simulations for Helsinki, 2017. ITF/OECD, Shared Mobility Simulations for Dublin, 2018. ITF/OECD, Shared Mobility Simulations for Auckland, 2017.
6 Markus Friedrich & Maximilian Hartl, MEGAFON: Modellergebnisse geteilter autonomer, Fahrzeugflotten des öffentlichen Nahverkehrs, VDV, 2016.

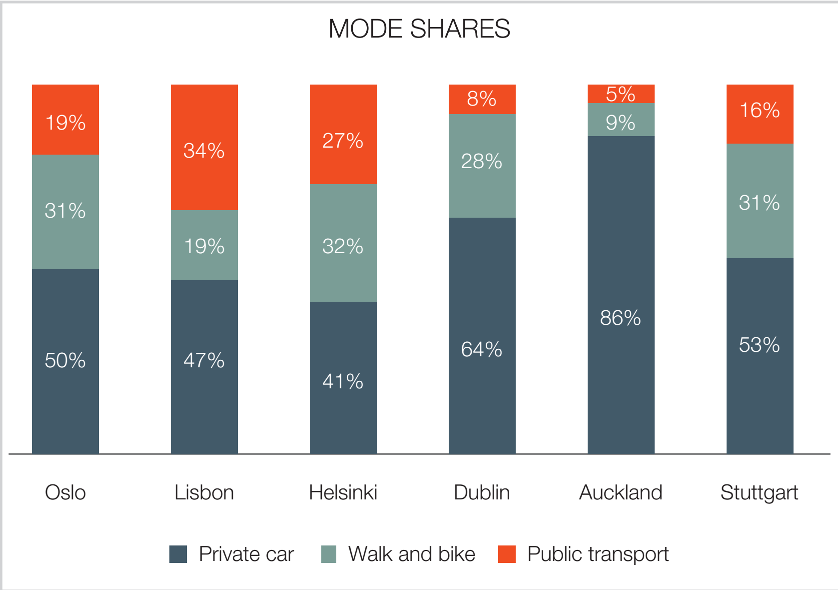


FIGURE 7-1 Travel mode shares in the base for the different studies[7]

Looking at the different case study reports, the Oslo study has the lowest population density, which is caused by expanding the study area to include Akershus county. Furthermore, in the Oslo, Helsinki and Dublin studies a large portion of the population either walks or bikes. The proportion of the population that uses public transport is lower in Oslo compared to Lisbon and Helsinki, but higher than Dublin, Auckland and Stuttgart.

The most optimistic scenario regarding the reduction of vehicle kilometres driven, is the scenario where all car users start to share their rides, and public transport users continue using public transport services. Different approaches for the calculations are used in the ITF, Stuttgart and the Oslo studies. The most comparable cross study scenarios are presented in Figure 7-2, which shows the required fleet necessary. Common conclusion for the cross-city studies is that it is possible to cater for transportation demand, by slicing the vehicle fleet to under 10 % of the current fleet size. This finding is shared by the Oslo study.

Figure 7-3 shows the calculated reduction in vehicle kilometres driven in the five cities in a future where all car users share cars and use ridesharing. For Lisbon and Auckland, it was calculated that it is possible to reduce the traffic by over 50 %, which is a notable congestion relief. Oslo achieves a lower reduction than the other cities.

7 Source. Oslo: Prosam-rapport, 2013/2014.

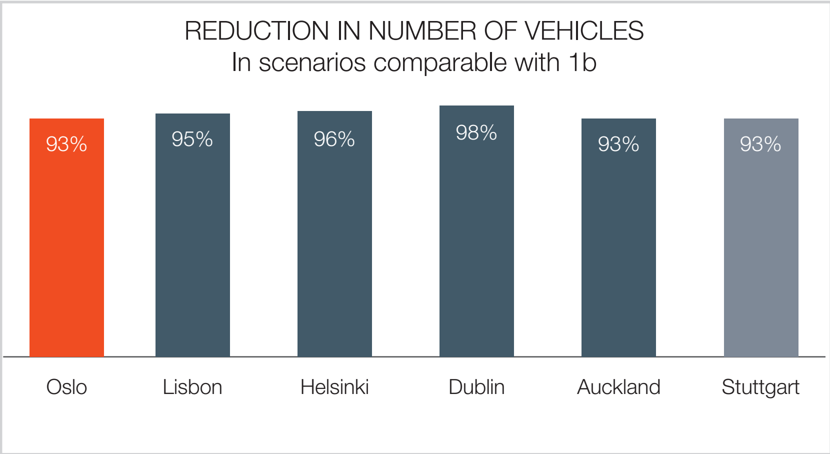


FIGURE 7-2 Reduction in number of vehicles

Oslo distinguishes itself with a reduction of only 14 % of the vehicle kilometres. The difference can mainly be explained by the different assumptions made in the calculations. The sensitivity analysis shows that allowing a lower level of service will lead to a 31 % reduction in vehicle kilometres, which is more in line with studies from other cities. Furthermore, a partial explanation is the different modelling software applied. The geographically large area in the Oslo study, which encompasses Oslo and Akershus counties, makes it difficult to use the MaaS vehicle fleet effectively.

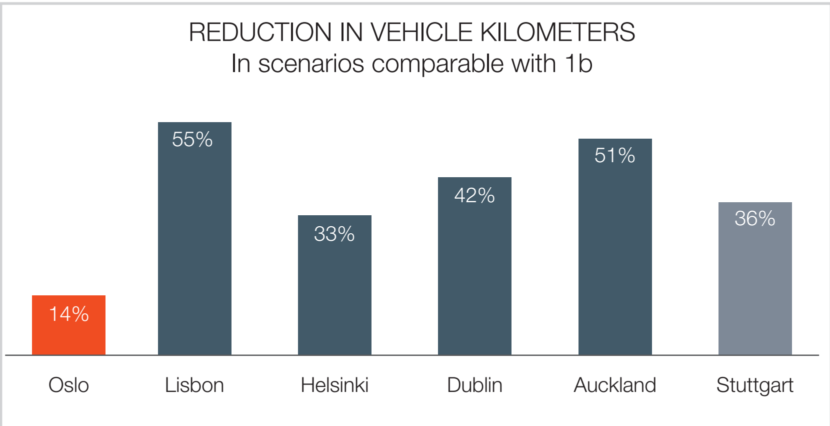


FIGURE 7-3 Reduction in vehicle kilometres

8 POLICY INSIGHTS

The study confirms that future solutions for autonomous mobility in cities can take very different forms. Each scenario in the analysis can be enabled through specific decisions on a number of public and private matters, which thus contributes to shaping a new reality for urban transportation and the utilization of the public space. Depending on how these decisions will shape the future in the direction of one of the six scenarios in the study – or other hybrid scenarios combined among these. It is clear that the impact on travel time and resources spent on providing the mobility can vary substantially and thus be subject to political interest in achieving the zero-growth ambition for private vehicle transport in major Norwegian cities.

Among the most important matters to consider are:

AVAILABILITY OF TECHNOLOGY

Prognoses indicate that fully autonomous vehicles will be available within around 10-15 years from now. Though, the exact time is unknown – it might be sooner, it might be later. A full transition from conventional driving to autonomous mobility might be even further decades into the future due to the fleet turn-over rate. Thus, the timing for private business strategies, public transport strategies and action plans for investments in infrastructure is key to supporting a potential transition. The question is when to start acting on the possibilities to make way for a feasible transition.

CONSUMER (AND COMMERCIAL) PREFERENCE

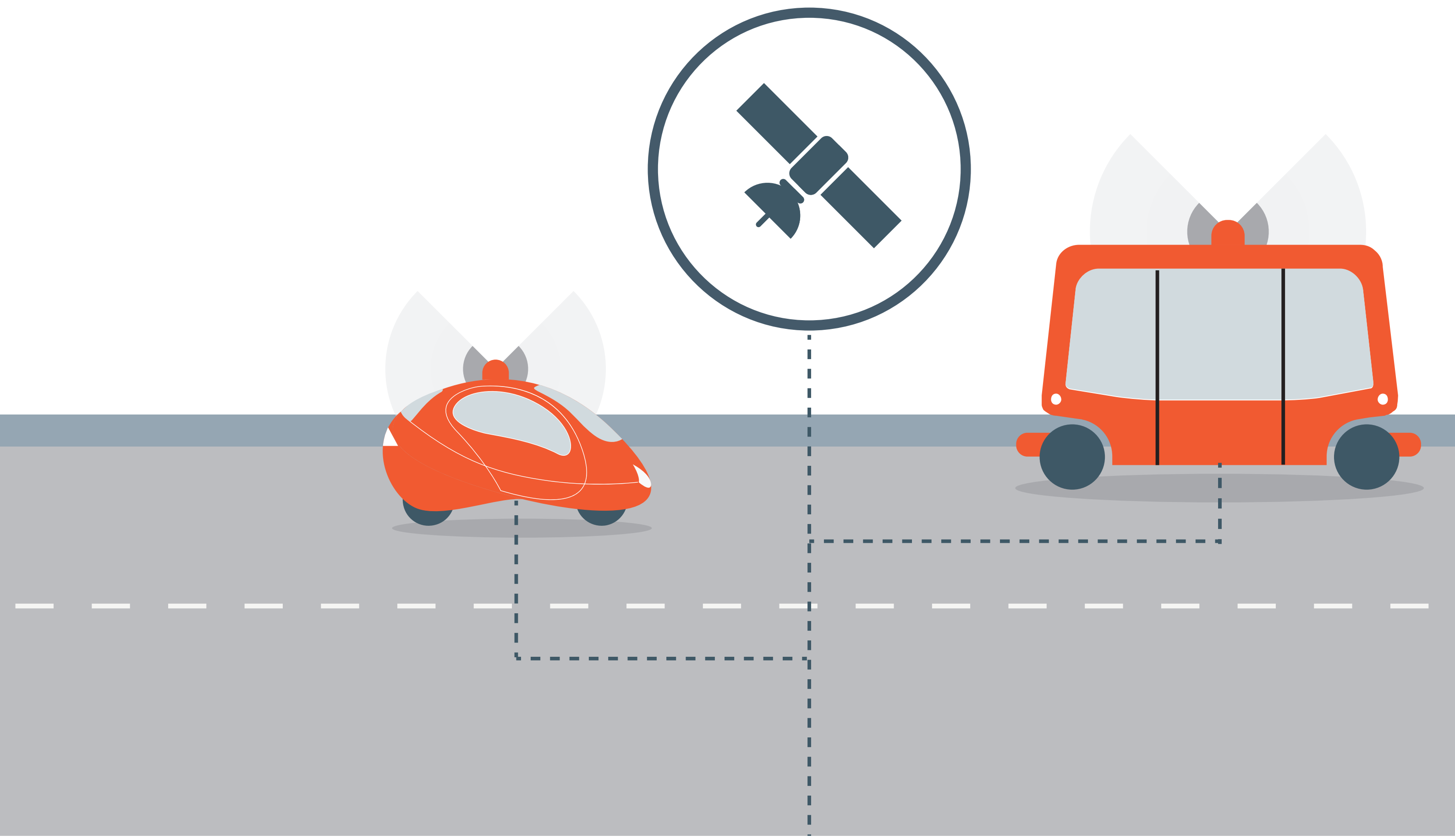
The decisions of private individuals as well as private companies and public entities on whether to maintain an individual approach to transport or shifting towards accepting shared rides is key to redeem the benefits on a better utilization of the vehicle fleet/fleets and the respective infrastructure.

BUSINESS MODELS

While the autonomous technology is the technical prerequisite for MaaS there is also a need for the development of business models for one or more transport providers in a certain area. The public/private interface also needs to be decided on regarding ownership and operation of the platform for MaaS providers, data use and ownership, payments, etc.

PUBLIC INVESTMENT PLANS

All scenarios entail a need for investments in infrastructure. This is either new infrastructure to facilitate mobility for a growing volume of traffic and/or investments in redesigning urban streets in a transition from traffic flow and parking availability to facilitating passenger access to the system in an adequate geographical density. The investments might also comprise intelligent transport systems to support traffic flow, access points to the public transport system, etc.

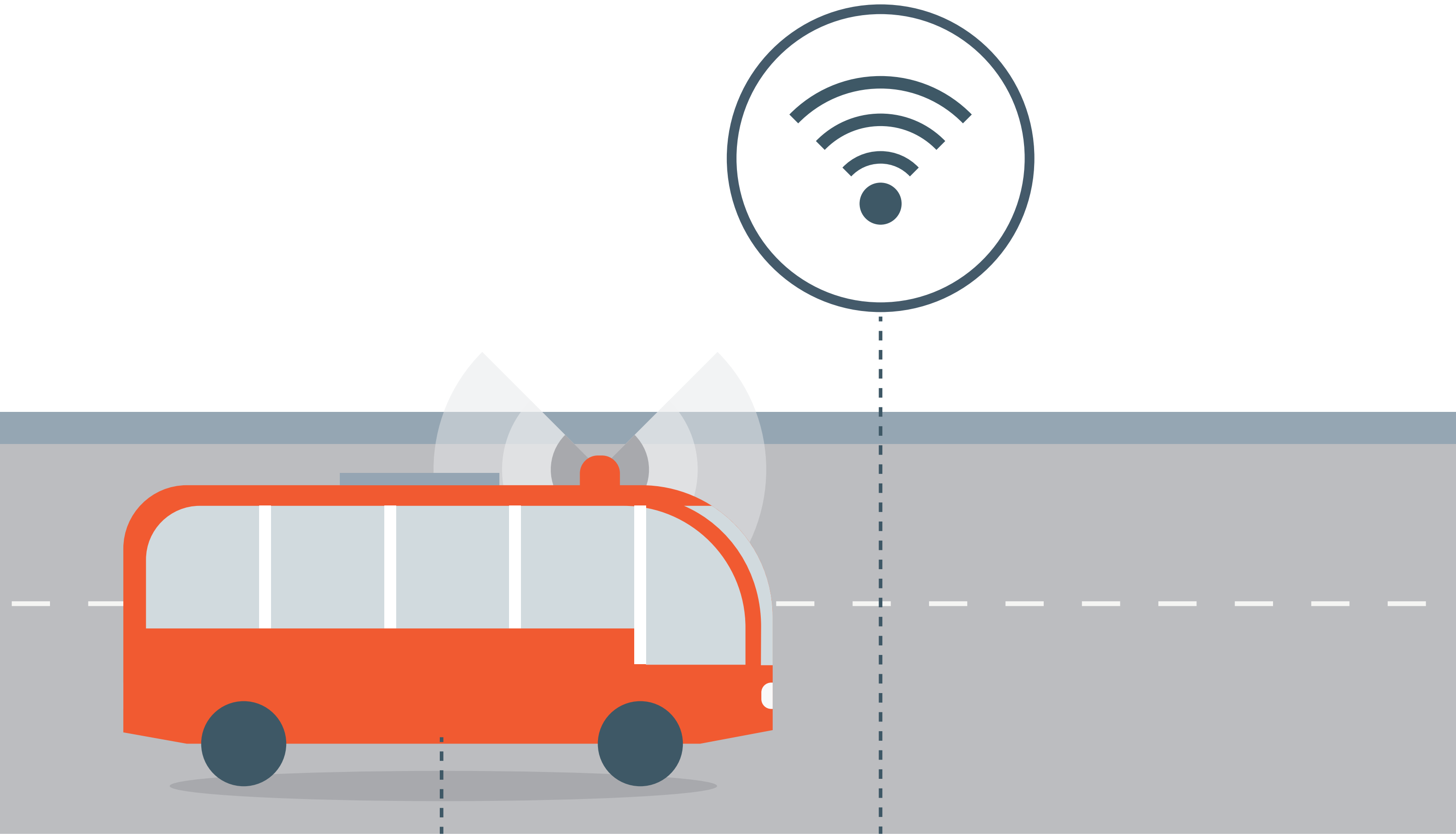


THE ROLE OF STATE, REGIONS AND MUNICIPALITIES

Public entities will have different roles in facilitating a transition. Standardisation promotes economy of scale and competition and thus efficient/affordable solutions. The more cities basing their solutions for infrastructure and business platforms on a standardized approach, the greater is the chance of service providers being able to deliver the service at an attractive price level. This might be the role of the state – to provide standardization and rules, to engage in supra-national agreements/treaties and generally exercise the sectorial responsibility in defining the framework for new transport solutions. For Regions and Municipalities, the decisions to be made might, to a greater extent, concern investments in rebuilding the infrastructure to facilitate MaaS, but also to establish political objectives on how to utilize the urban transport infrastructure and draft rules on empty driving, kilometres spent searching for parking, etc.

POLICIES AND TAXATION

The promotion of a certain scenario can be supported by policies leading to legislation on the environmental and climate aspects of transport. This could further be a matter of taxation policies towards types of vehicles, autonomous technology and/or transport behaviour, the latter e.g. in the form of area-wide road pricing to reduce congestion.



These are just some of the matters to consider, where public and private decisions directly engage in shaping the future and affect the rate of change. There are more factors to be considered in a total overview of the impact of a radical change from conventional car traffic to urban MaaS solutions. Among these we find the difference in the rate of private and commercial turn-over in vehicle technology, the impact on the value of time in socio-economic infrastructure analyses, the will to maintain public transport services versus introducing potentially cheap individual autonomous transport, the air quality, the road traffic noise and road safety, just to mention a few.

ADDRESS COWI AS
Karvesvingen 2
Postboks 6412 Etterstad
0605 Oslo
Norway
PHONE +47 02694
WWW cowi.com