TØI report 1840/2021

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Changes and Challenges in Future Transport

Drivers and Trends

TØI Report
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Sammendrag:

En rekke megatrender som påvirker både person- og godstrafikk synes å drive fram mange radikale innovasjoner i transportsektoren. De viktigste antas å være teknologiske, sosiale og miljø- og klimatrender knyttet til digitalisering samt delingsøkonomi, urbanisering og demografiske endringer. Denne rapporten fokuserer på endringer og utfordringer innen framtidig transport, og på hvordan de forannevnte megatrendene kan ha betydning for person- og godstransport, særlig i urbane områder.

Summary:

Several megatrends, affecting both passenger and freight transport, seem to be driving a set of radical innovations in the transport sector. Most important are technological, social and environmental trends related to digitalisation and the sharing economy, urbanisation, demographic shifts and climate change. This report focuses on changes and challenges in future transport, and on how the beforementioned megatrends may affect passenger and freight transport, particularly in urban areas.

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Preface

This report focuses on changes and challenges in future transport, on how technological, social and environmental trends may affect passenger and freight transport in the years to come. Transport in a digital age forms the core of the report and it is based on a literature review and on examination of statistical sources.

The report is a part of the deliveries from the project “Digitalisation and mobility (DIGMOB): Smart and sustainable transport in Urban Agglomeration” which is financed by the Norwegian Research Council for the period 2018-2021.

The report is written by Magnus Anderson from RISE Viktoria, Bjørg Langset Flotve and Ove Langeland from The Institute of Transport Economics. Eivind Farstad has been responsible for the quality assurance of the report and Trude Rømming has prepared the report for publication.

Oslo, April 2021
Institute of Transport Economics

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List of Terms

3PL	Third Party Logistics, a term used to describe a company who owns and operates few if any trucks or other vehicles but focuses instead on supply chain integration and end to end services utilizing outsourcing of mainly truck operations.
API	Application Programming Interface, a computing interface that defines interactions between multiple systems
Geofencing	Virtual perimeter for a real-world geographic area, most often with specific traffic regulations for that area
TMC	Traffic Management Centre, traditionally a combination of human operators and advanced digital systems that inform about and manage traffic disruptions in a metropolitan area.
OEM	'Original Equipment Manufacturer', in the automotive industry this term is used to describe a vehicle manufacturer
ITS	Intelligent Transport Systems and services. Traditionally with a focus on digitalized road side equipment, but now used to describe many types of digital system support for road traffic.
Extended vehicle	A conceptual framework defining a vehicle data exchange architecture. ISO 20077-1:2017 Road Vehicles. More information can be found at Car Data Facts, operated by ACEA
CEN	The European Committee for Standardization
UVAR	Urban Vehicle Access Regulation, similar to 'Geofencing' but with a more limited field of application.
ACEA	European Automobile Manufacturers' Association
CAV	Connected automated vehicles
ADS	Automated driving systems

Summary

Changes and Challenges in Future Transport

Drivers and Trends

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Several megatrends, affecting both passenger and freight transport, seem to be driving a set of radical innovations in the transport sector. Most important are technological, social and environmental trends related to digitalisation and the sharing economy, urbanisation, demographic shifts and climate change.

Transport in a digital age forms the core of this report and the project of which it is a part. The research project DIGMOB[1] examines and provides solutions to effectively link digitalisation and transport innovations for passenger and freight mobility in order to obtain a more efficient and sustainable urban transport system. Both freight transport and individual mobility in urban areas are increasingly reaching its limits since the process of urbanisation has caused continuous rising demand for urban mobility systems.

In urban areas with a well-developed transport system, further investments in physical infrastructure will often result in marginal improvements and declining marginal returns. However, digitalisation of the transport system may lead to significant improvements both in economic, environmental and social terms. The application of information and communication technologies (ICT) and Intelligent Transport Systems (ITS) can make transport safer, more efficient and more sustainable for all modes of passenger and freight transport. Moreover, the integration of emerging technologies can create new services and are key to support jobs and growth in the transport sector.

Disruption and transition of future transport

Transport demand is expected to grow significantly in the next decades for both passenger and freight transport. However, the rate of change together with increasing complexity of society, makes future projections of transport rather uncertain. The transport sector is in a fundamental transition process due to, amongst others, new technology, climate change, demography and new customer demands. It is also reasonable to assume that the ongoing covid19 pandemic will leave lasting traces both in terms of demand and supply for transport due to changes in work and consumer preferences. However, the accurate long-term impacts of the pandemic is difficult to estimate but we can probably expect a more flexible transport system in the future.

Transport is historically strongly related to population growth, economic activity measured by GDP and to international trade activity. With more people follows more mobility and an increased demand for passenger transport. Population growth also increases the production and consumption of goods and the demand for freight transport. The demand

[1]The project Digitalisation and mobility (DIGMOB): Smart and sustainable transport in Urban Agglomeration is financed by the Norwegian Research Council for the period 2018-2021.

for passenger and freight transport also increases by growth in disposable income and with growth in international trade.

The global demand for passenger and freight transport is expected to triple in the period 2015 to 2050. The strongest growth in passenger transport demand will be in Asia, and in urban regions. Shared mobility and public transport is expected to be responsible for larger parts of the increasing demand in passenger transport, but the private car will still dominate in non-urban transport. Most freight is travelled by sea, particularly over long distances, and this pattern is expected to be fairly similar also in the future.

Travel demand projections for passenger and freight transport in Norway 2016-2050 also indicate a growth in demand. The number of trips is expected to increase roughly in line with the population, the passenger car and air modes showing the highest growth rate. The freight transport sector in Norway has been characterised by growth and structural changes the past decades and projections indicate that the demand for freight transport will continue to increase. The main part of total freight transport travels by sea, followed by road whereas rail makes up the smallest part.

Disruption and pathways

Disruption in the transport sector takes place on different levels and various scales, on product categories, on sector level or as impacts across multiple sectors. The main factors which particularly drive disruptive changes are related to production costs, quality of new technologies and processes, changes in consumer or business customer preferences, laws and regulations and access to important resources.

Disruptive changes are often a result of a combination of the different drivers. New vehicle and fuel technologies (electrification) and new business models for mobility (shared mobility) together with digitalisation and automatization (ICT, ITS and AI), may result in a modal shift for both passenger and freight transport, and thereby lay the foundation for disruptive changes and a transition to a more efficient and sustainable transport system.

With digitalisation and technological innovations becoming ever more important for achieving the goals of smart and green transport and, increasing landscape pressure (climate change) combined with more mature niche innovations (technological and social), this may spur transition processes in urban transport and mobility, both at levels of behavioural changes and policy-making. The rapid electrification of the car fleet in Norway also illustrates the importance of financial incentives for accelerating disruption in transport.

Digitalisation and technology trends

Digitalisation has been at the forefront of mobility of people and goods for quite some time and with an increasingly stronger urban focus. Digitalisation is the motor of the ongoing 'servitisation' of the automotive industry and various design patterns of digital services and platforms are being developed. EU-directives stipulates that novel digital services and infrastructure should be introduced to improve safety, sustainability and mobility. The private sector is also highly active in developing digitalised services and infrastructure pertaining to the transport sector.

Data

The growth of data and its value are the key driver of the digital economy, and the ongoing proliferation of AI depends on it. From an innovation perspective, any piece of useful data can be viewed as a highly malleable complimentary asset forming an essential component of a digitalised service. From an economic perspective data has several defining features in comparison to other resources. Firstly, data is non-rivalrous and can be used by any number of applications or algorithms simultaneously. Secondly, data is also non-fungible which means that as opposed to money, certain data cannot be substituted for another one due to the uniqueness of each data point. Thirdly, data is an experience good; its utility is not obvious until analysing it. Finally, data tends to increase the amount of data by implication.

In the logistics industry, data sharing is on the one hand ubiquitous and a foundation on which globalized trade rests. Keystone 3PL (Third Party Logistics) actors integrate their partners in vast information networks spanning the globe, sending and receiving updates on transhipments and informing planning and authorities. On the other hand, for reasons of competition among firms, information sharing beyond the customary business networks is a notoriously difficult proposition in an information-driven business such as logistics. Additionally, consistent supply chain transparency remains difficult even within such networks.

A large amount of research networks, non-government and government bodies around the globe strive to further digital freight standards. New approaches to logistics and data sharing are also constantly being tested in living labs across the globe. Entrenched business models and high perceived risks of data sharing are among the main barriers to adopting more open decentralized ways of coupling freight and logistics providers across supply chains.

Analytics

Data must be analysed to obtain its full utility and analytics can be described as a combination of one or more of descriptive, predictive and prescriptive analytics activities. A *descriptive* analysis of traffic information would aspire to accurately determine and describe the current state of the traffic system. A *predictive* analysis would attempt to accurately forecast a future state of the traffic system. Finally, *prescriptive* analytics seeks to accurately gauge the optimal action to take in each traffic situation.

One should be aware of possible "algorithmic bias", several interpretational fallacies of data driven algorithmic decision making exist, including commercial, political and racial implication. While the mere implementation of an AI-driven decision process may indicate fairness and objectivity, the result can be the opposite unless care is taken to avoid such issues. Regardless of the type of analysis performed, data access and analytics capabilities are highly interdependent and they frequently join forces as two main building blocks of digital platforms.

Digital platforms and ecosystems

Three related concepts play important roles in data driven innovation – networks, platforms and ecosystems. Ranging from digitalised automotive modular vehicle platforms to data driven information service platforms, these platforms and their surrounding ecosystems are key to the development of new services and offerings to businesses, authorities and citizens alike. The rise of digital platform companies has led to the emergence of new types of competition in many sectors, including transportation.

A network's value is a function of its size. A direct "network effect" implies that the more firms are actively adopting new standards the more valuable the network using them becomes for other firms. However, "indirect network effects" also occurs when a platform depends on two or more user groups. This type of mutual dependence promotes the emergence of digital platforms. Such platforms can be conceptualized as interfaces between other artefacts and they are often embodied in products, services, and/or technologies.

The description of data, analytics, networks, platforms and ecosystems is highly relevant to understand the current digitalisation of the transport sector and the various platforms that exist. Examples of platforms and initiatives mentioned in this report is the *The City Innovation Platform* (CIP), *The National Data Warehouse for traffic information* (NDW), *Traffic Management as a service* (TMaaS), *The Extended Vehicle concept and "neutral server*" and *Geofencing.*

Automation

All modes of transportation are affected by automation, prominent examples are the Swedish Einride which is producing autonomous electrical trucks and in the marine sector this is exemplified by the new Norwegian vessel Bastø Fosen VI. However, there are still both technological and regulatory hurdles to overcome before widespread adoption can take place. The SAE (Society for automotive engineering) scheme has five levels, ranging from Level 0 (fully manual) to Level 5 (fully automated). On Levels 0 – 3 a human driver is in the vehicle and either drives or is prepared to take over the driving task when the system requests it. In Levels 4 – 5, the vehicle can also handle exceptional situations, negating the need of human drivers. Most AVs (autonomous vehicles) still require a safety driver in the vehicle to warrant safety, due to a combination of ADS (Automated driving systems) limitations and regulatory constraints.

One can distinguish between four broad types of ADS (corresponding to Level 3 and 4) currently in development for use on public roads and that are expected to become mainstream within 5-10 years – *Automated shuttles and taxis* addressing first- and last-mile trips which are expected to revolutionize passenger mobility, *Automated goods delivery vehicles* which address the first- and last-mile urban delivery, between hubs or the final delivery destination, *Automated truck platooning on highways* which is anticipated to improve efficiency of freight transport in terms of reduced fuel consumption and road utilisation and - *Automated driving on highways* both for passenger and freight vehicles on specific highways.

Key benefits, challenges and development

Key benefits related to CAV (connected automated vehicles) are *improved safety* by eliminating accidents caused by distraction, driving under influence and speeding; *improved transport efficiency* by smoothing the traffic flow; *greater access to mobility* by enabling flexible, on-demand, and driverless transport; *higher productivity* by making commuting into productive time and make it possible for businesses to operate with fewer drivers; and *reduced need for new infrastructure* by increasing highway capacity.

Main challenges and development trends are related to technical limitations, linking the digital and physical infrastructure, general acceptance and trust and the need for proper regulatory framework to ensure good interaction between humans and technology. Automated and connected vehicles are slowly merging into connected automated vehicles (CAVs). Such vehicles, in combination with other parallel trends such as artificial intelligence, electrification and shared economy, hold the potential for a safer, more efficient, accessible, equal and inclusive mobility. However, due to current limitations of technological capability as well as trust, security, safety and regulations, many challenges remain for fully reaching the benefits of CAV.

Social trends

Transport is strongly affected by global megatrends such as urbanisation, ageing societies and digitalisation. Changes in urban and demographic structures lead to changes in transport demand. Growth in urban population usually increases movements of passengers and freight, and urbanisation often implies longer travel distances. Digitalisation plays an important role in meeting new transport demand and it also affects the working life and consumer preferences. The intersecting trends of urbanisation, an ageing population and digitalisation affect both passenger and freight transport.

Urbanisation

Urbanisation can lead to increased demand for public transport and to higher walking and bicycling shares in the inner city but also to increased car-based transport in the larger city-regions. The result depends on whether urbanisation is characterised by a compact city or by a city-sprawl development. Whether the demand for transport will increase or decrease is unclear.

People are walking or biking or using public transport much more in the cities than in the city regions. The car is the primary means of transport in the hinterland, and the inhabitants there travel more than the average in Norway. When cities grow due to urbanisation, the strongest growth also take place in the urban fringe zones and not in the inner city. This kind of urbanisation, therefore, may lead to more driving and associated problems related to emissions, congestions and urban land-use. Electrification of vehicles may reduce emissions problems but not solve the land-use problems. A smart city-approach, using digital technology to support city operations related to transport and land-use, may help cities to make urban transportation more efficient and safe.

Demographical change

More people usually means more transport, both passenger and freight transport. An ageing society is also increasingly important for the transport demand and for the mode of transport which is required. Elderly people often use public transport more frequently than younger people. Where the population live and work will also influence their demand for transport as well as their travel mode choice.

The "wave of elderly", will probably increase the need for transport and transport services. In Norway, the age group 75+ years will grow in the coming years and these elderly persons will probably have a different travel pattern than earlier cohorts. Several of them both have a driver license and a car, and they will probably be in a better health condition when getting older. Reduced travel activity due to health issues will probably occur later in life for many of these new seniors. All this indicates that the demand for mobility will increase, and that there will be more elderly car drivers in the traffic in the years to come. Smart urban transport, therefore, must respond to different urban transport demands generated from both urbanisation and population trends. It must coordinate both urban freight and passenger flows by use of digital technologies.

Digitalisation – changes in work, industries and consumer preferences

Digitalisation affects jobs to a greater of lesser extent in all sectors, and particularly the organisation of work in many service markets. *E-commerce* matches demand and supply of goods, and all kinds of services and information are delivered and exchanged by platforms through *e-work* and *e-communication*. One can distinguish between three generations of telework – *the home office* where the workplaces in or close to the employees' homes are remote, cheap and ecological, but also stationary; *the mobile office* where employees not only work at their home office but could perform their work from many places, such as home, cafes, libraries and *the virtual office* which is accessible anywhere at any time.

Digitalisation of transport may both reduce or enhance the demand for transport by means of telecommunication. Complex relations between ICT and transport and between new technology and human behaviour, therefore, makes it difficult to estimate both substitution and enhancement effects both on short and long terms.

Telework and passenger transport

Telework enables employees to work at a distance and this has the potential to reduce unnecessary work-related travel, particularly the daily commuting. However, there is no reduction in daily travel time for employees who carry out their work both at home and at the office (part-day telework). Telework may also increase the demand for travel because teleworkers use the saved time to make additional trips, for instance to go shopping. Telecommuting may also affect housing location and thereby transport demand because the distance to work may become less important.

The Covid19 pandemic has led to an unplanned and massive growth in working from home, particularly in high-tech sectors and for high-skilled employees. This comprehensive experiment may lead to changes in industrial structures, organisation of work and employee attitudes, and it may be a tipping point for home working. However, how this may affect the demand for transport in the next round is not easy to predict.

E-commerce and freight transport

The rapid growth of the Internet has led to a significant increase in e-commerce the past years and it is one of the fastest growing marketing channels for different kinds of products and services for consumers. E-commerce has augmented the importance of freight transportation but exactly how it will affect freight transport and logistics is not quite clear. It can both increase and decrease the amount of travel and it can alter the travel patterns of individuals in different ways; online retailing can be a complement to, or it can be a substitute for, traditional retailing. However, fast and flexible deliveries, home deliveries and growth in return deliveries (reverse logistics), are assumed to increase freight volume in residential areas. This may produce negative effects like congestion, noise and environmental concern from increased traffic. Urban areas with high population density will be particularly exposed to negative effects of increasing freight volume from e-commerce.

Climate and environmental trends

Climate and environmental challenges will enforce regulations for decarbonisation of transport and promote use of zero-emission vehicles for both passenger and freight transport. New vehicle and fuel technologies (electrification) and new business models for mobility (shared mobility) together with digitalisation and automatization (ICT and ITS), are supposed to result in a modal shift for both passenger and freight transport, and thereby lay the foundation for disruptive changes and a transition to a more efficient and sustainable transport system.

The transport system, and particularly the road transport system, is vital for people's daily mobility and for freight transportation. However, climate change has increased the vulnerability of the transport systems. It makes a transition to sustainable transport more urgent because transport, not only contributes to climate change, but also because it suffers severely from the consequences of climate change. Therefore, climate change is a driver for sustainable transport in a double sense.

Transport and exposures to climate change

The transportation system faces both direct and indirect vulnerabilities or "pathways of disruption". The focus is often on direct physical impacts of climate change such as extreme weather events (flooding, landslide, heat waves etc.) on the transport system (washout of bridges, blocked roads etc.), or on direct non-physical impacts on human health and travel behaviour. However, indirect vulnerabilities due to increased complexities within and interconnections between the transport system and other critical infrastructure, is likewise important. The transport system is closely interlinked to the electricity system and the ICT-system and both can be exposed to extreme weather events. Power failure may lead to disruption in transport and communication system, and a breakdown in the ICT-system will disrupt traffic management system, real-time traffic and so forth. Therefore, the need for making the transport system more robust and resilient by mitigation and adaptation measures has increased considerably because of climate change.

Digitalisation and decarbonisation of transport

The transport sector relies heavily on fossil fuels, which is detrimental to both the global climate and the local environment. In order to reduce GHG emissions in the transport sector, the Norwegian government has launched several measures related to fuel and technology innovations but also to facilitate the use of digitalisation, such as intelligent traffic systems, autonomous driving, and shared mobility.

Extended use of digital technology may lead to less cars and less driving if it is combined with proper legislation and change of attitudes related to sustainable transport. Digital technologies may encourage the uptake of shared mobility and connected and autonomous vehicles and improve public transport. This may have a substitution effect and reduce transport demand, but only time will show if this will happen.

1 Introduction

1.1 Short description of the DIGMOB project

This report focuses on changes and challenges in future transport, on how technological, social and environmental trends affect passenger and freight transport. These trends are global in nature but they unfold in national modifications. Transport in a digital age forms the core of the report and the project of which it is a part. The research project DIGMOB[2] examines and provides solutions to effectively link digitalisation and transport innovations for passenger and freight mobility in urban agglomerations, in order to obtain a more efficient and sustainable urban transport system.

The project applies both qualitative and quantitative methods. Through analysing different Norwegian city-regions and urban agglomerations characterised by different size, different growth dynamics and different mobility challenges, the project intends to develop an understanding of the various factors that may affect success and failures of transformation to sustainable urban mobility. The project is carried out in several sequential but partly overlapping stages.

The main research question of DIGMOB is: *How can digitalisation and transport innovations contribute to more efficient and sustainable passenger and freight transport in urban agglomerations?*

The main research question is followed up by five sub-questions:

1. What exactly is the role of and how important are technological innovations/digitalised interfaces for bringing about transitions in urban mobility for urban passenger and freight transport?
2. What are the most efficient measures for bringing about modal shifts and intermodal travels, shared mobility and integrated mobility (MaaS) in urban passenger transportation?
3. What are the most promising measures for obtaining smart and green urban logistics, including modal shift and inter-modality?
4. How important is public-private coordination for achieving smart and sustainable urban mobility?
5. In what regards is urban mobility and accessibility similar or different across urban neighbourhoods/Norwegian cities.

The DIGMOB-project covers a broad array of issues regarding digitalisation of transport. This report concentrates on some of the most important changes and challenges in future transport related to new technological trends, primarily digitalisation, but it also focuses to some extent on societal and environmental trends which may have impacts on future transport. In order to design an adequate policy, it is important to understand the role these different trends play in the possible transition from an unsustainable to a more sustainable transport system.

[2]The project Digitalisation and mobility (DIGMOB): Smart and sustainable transport in Urban Agglomeration is financed by the Norwegian Research Council for the period 2018-2021.

1.2 Background and trends in transport

Several megatrends seem to be driving a set of radical innovations in the transport sector – urbanisation, demographic shifts, climate change, digitalisation and the sharing economy. Urbanisation has been one of the dominant contemporary processes as a growing share of the global population lives in cities. Considering this trend, urban transportation issues are of foremost importance to support the passenger and freight mobility requirements of large urban agglomerations (Spickermann et al 2014, Roumboutsos et al 2014). Transportation in urban areas is highly complex because of the modes involved, the multitude of origins and destinations, and the amount and variety of traffic. Traditionally, the focus of urban transportation has been on passengers, since cities were primarily viewed as locations of human interactions with intricate traffic patterns linked to commuting, commercial transactions and leisure/cultural activities. However, cities are also locations of production, consumption and distribution and accordingly activities linked to movements of freight. Conceptually, the urban transport system is intricately linked with urban form and spatial structure and, urban transit and urban freight (logistics) are important dimensions of mobility, notably in high density areas.

Cities and regions are dependent on an efficient and environmental-friendly freight transport system and a corresponding system for individual mobility for catering to travels related to work, service, social, school and leisure purposes. However, both urban freight transport and individual mobility in urban areas are increasingly reaching their limits since the process of urbanisation has caused continuous rising demand for urban mobility systems. The result is recurrent congestion, reduced accessibility and negative environmental impact (Dacko and Spalteholz 2014, Wegner 2013). Urban transport, therefore, is increasingly challenged and there is an imminent need for solutions which can provide both economic, environmental and social opportunities and benefits. However, in urban areas with a well-developed transport system, further investments in physical infrastructure usually result in marginal improvements and declining marginal returns (Rodrique et al 2017). However, digitalisation of the transport system may result in significant improvements both in economic, environmental and social terms. The application of information and communication technologies (ICT) and Intelligent Transport Systems (ITS) can make transport safer, more efficient and more sustainable for all modes of passenger and freight transport. Moreover, the integration of emerging technologies can create new services and are key to support jobs and growth in the transport sector.

This report is based on a desk study/literature review and on examination of statistical sources, and it describes trends and drivers for transition to smart and green urban transport. The applied literature is related to trends and challenges in future transport system, such as urbanisation, technology shifts/digitalisation and the sharing economy and its impact on urban mobility and transport system. The report is organised as follows: Chapter 2 gives a broad overview of disruption and trends of future transport, of drivers and possible pathways of transitions in transport. The next three chapters examine in more depth impacts on transport of significant technology trends (3), social trends (4) and climate and environmental trends (5). Chapter 6 concludes the paper by summarising main challenges and possible solutions for future transport.

2 Disruption and transition of future transport

Transport demand is expected to grow significantly in the next decades for both passenger and freight transport (KPMG 2018, IFT 2019). However, the rate of change together with increasing complexity of society, makes future projections of transport more uncertain. The transport sector is in a fundamental transition process due to, amongst others, new technology, climate change, demography and new customer demands. It is also reasonable to assume that the ongoing covid19 pandemic will leave lasting traces both in terms of demand and supply for transport due to changes in work and consumer preferences. However, the accurate long-term impacts of the pandemic is difficult to estimate but we can probably expect a more flexible transport system in the future.

This chapter will give a short overview of possible development trends of future transport based on different scenarios for global and national development. Next follows an overview of some drivers for disruptive changes in transport. Finally, a summary of some possible pathways of transformation of the transport system and the role of digitalisation in this process, is given. How the disruptive developments (particularly digitalisation) which will affect and transform future transport will be elaborated in further detail in chapter 4,5 and 6.

2.1 Future transport demands

This section first present the demand for passenger transport globally and nationally and then describe the equivalent development for freight transport. The demand for both passenger and freight transport is expected to grow in the years to come, although the future is uncertain. Transport is historically strongly related to population growth, economic activity measured by GDP and to international trade activity. With more people follows more mobility and an increased demand for passenger transport. Population growth also increases the production and consumptions of goods and the demand for freight transport. The demand for passenger and freight transport also increases by growth in disposable income and with growth in international trade (globalisation) (IFT 2019).

2.1.1 Global demand for passenger transport

According to scenarios presented in the Transport Outlook there is a growing global demand for passenger transport in all regions in the world (IFT 2019). The demand is expected to triple in the period 2015 to 2050, from 44 trillion to 122 trillion passenger-kilometres (see figure 2.1). However, the geographical distribution of the demand will change significantly as the share of the OECD-countries will decrease from 43 % of passenger movements in 2015 to 24 % in 2050. The strongest growth in demand will be in Asia, as China and India will be responsible for one-third of passenger travel by 2050 compared to a quarter in 2015.

Urban regions will account for an increasing part of global GDP, 81 % in 2050 compared to 60 % in 2015. This will change the urban mobility pattern, shared mobility and public transport is expected to be responsible for larger parts of the increasing demand in passenger transport (see figure 2.2). The private car will still dominate in non-urban transport.

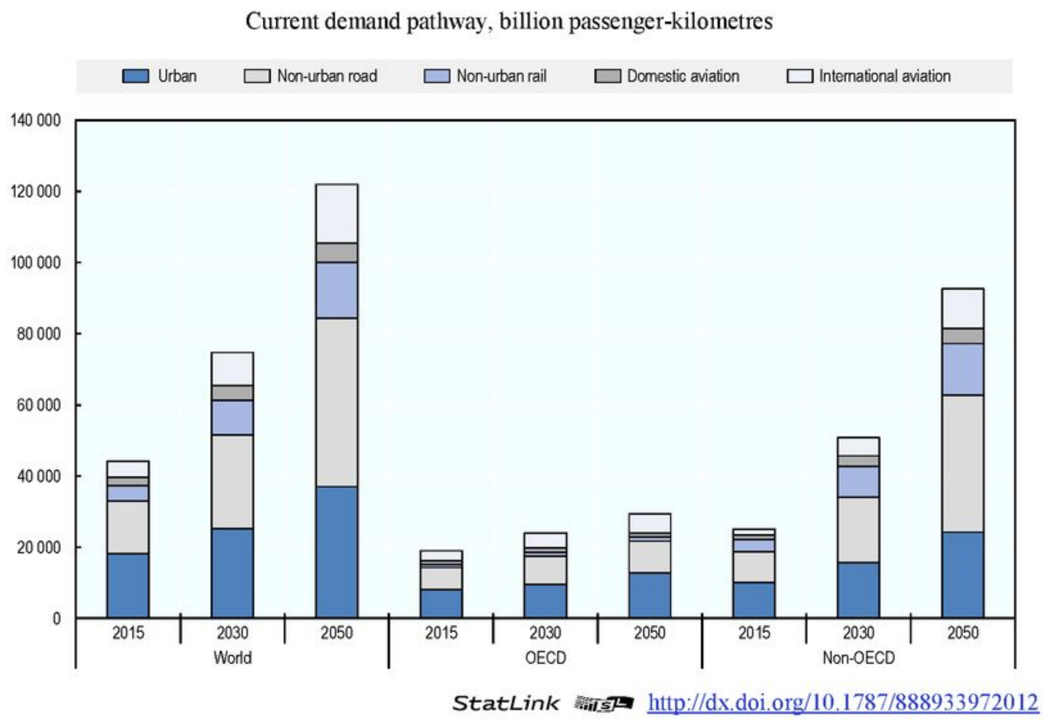

Figure 2.1: Demand for passenger transport by type.

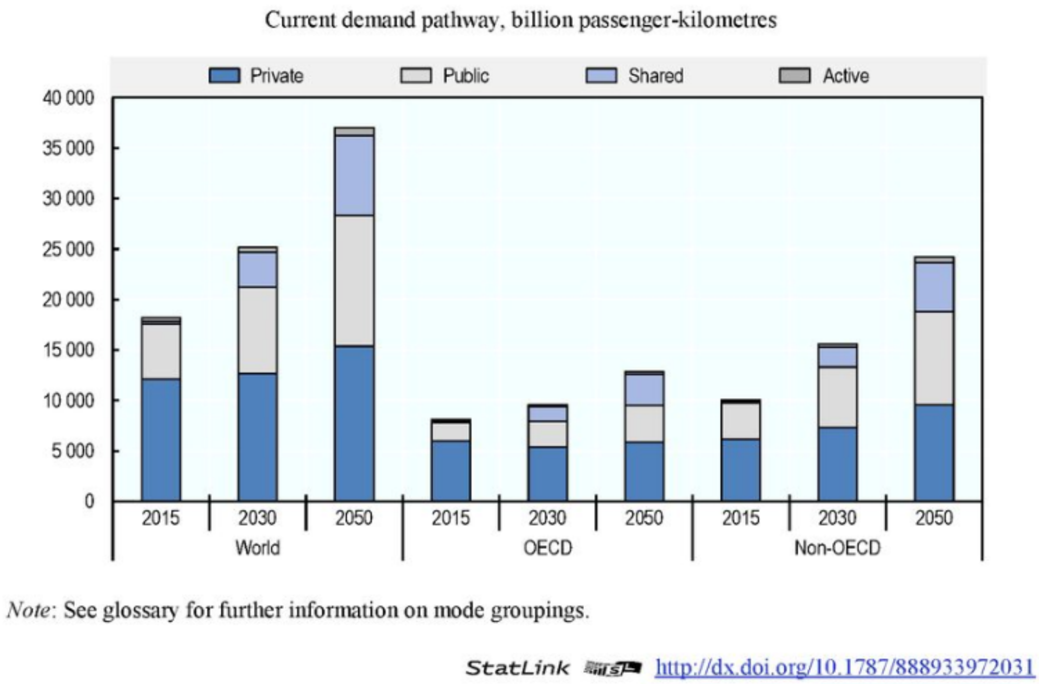

Figure 2.2: Urban travel by mode group.

2.1.2 Prospects for passenger transport in Norway

Travel demand projections for passenger transport in Norway 2018-2050 also indicate a growth in demand. The number of trips is expected to increase roughly in line with the population, the car driver mode showing the highest growth rate (Madslien et al 2021a). The transport demand is expected to increase with 35 % from 2018 to 2050, from 59 730 to 74 794 mill. passenger-kilometres per year. The population will grow with app. 13 % in the same period. Figure 2.3 shows the historical development in transport work from 1995 to 2018 and the projections from 2018 to 2050. There are no estimates for shared mobility in the Norwegian travel demand projections.

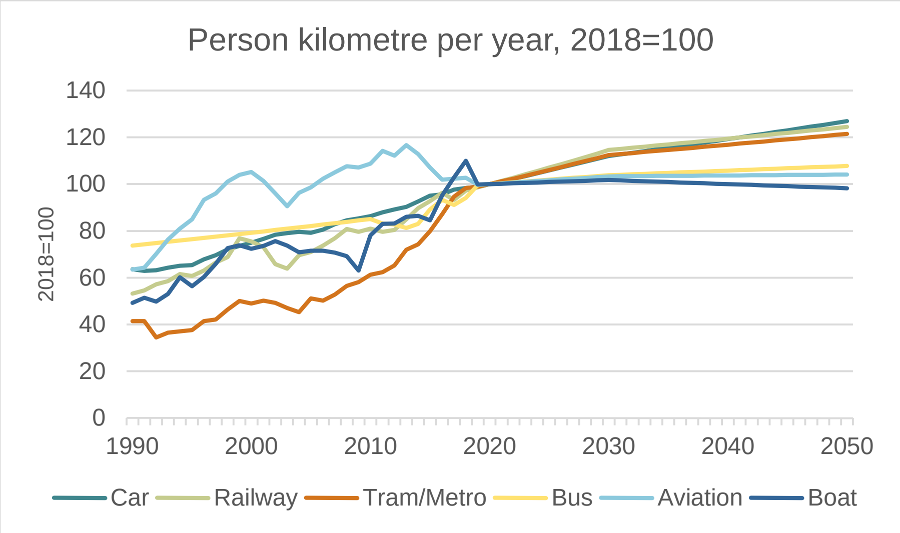

Figure 2.3: Historical development and projections for passenger transport in Norway. Source: TØI report 1824/2021.

2.1.3 Global freight demand

As for passenger transport, the global freight demand is expected to triple between 2015 and 2050. Most freight is travelled by sea, particularly over long distances, 70 % in 2015, whereas 18 % by road, 9 % by rail and 2 % by inland waterways. This pattern is expected to be fairly similar also in the future (IFT 2019).

However, the projections for freight demand are even more uncertain than for passenger transport. Freight demand is closely connected with economic growth and international trade activity and for now the global economy is instable (economic crisis, pandemic) and there is strong disagreement over international trade policy.

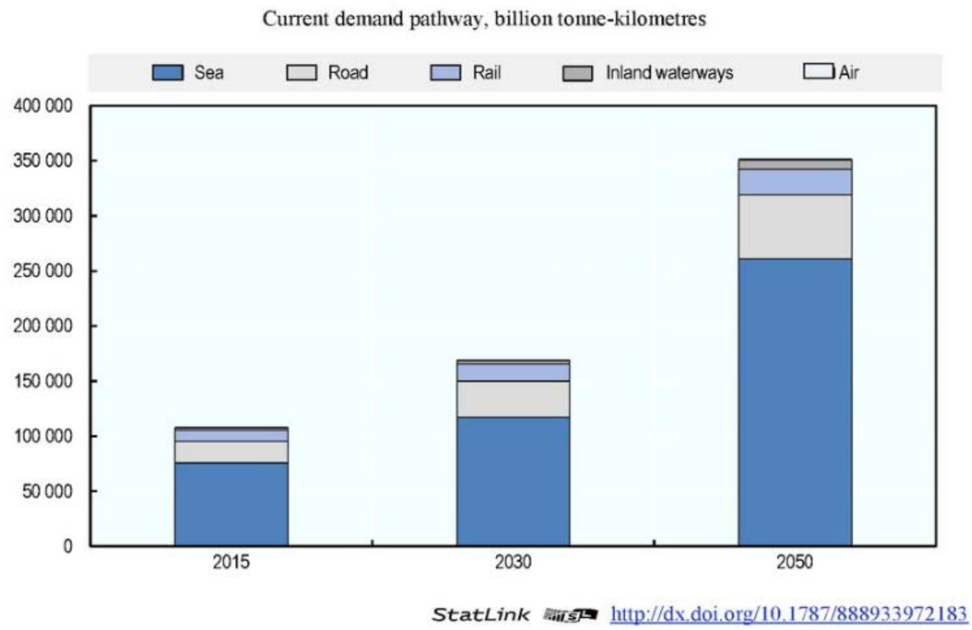

Figure 2.4: Projected freight demand by mode.

2.1.4 Projections of freight transport in Norway

The freight transport sector has been characterised by growth and structural changes the past decades and projections indicate that the demand for freight transport will continue to increase. The main part of total freight transport takes place by sea, followed by road whereas rail makes up the smallest part. In the period 2018-2050 the strongest growth for freight transport is expected for road which will be more than doubled, followed by rail which will increase with 44 % and sea transport by 30 %. The growth, especially by sea, will be lower if we include raw oil, natural gas and ore. Figure 2.5 shows the historical development and the projections for 2050 (Madslien and Hovi 2021b).

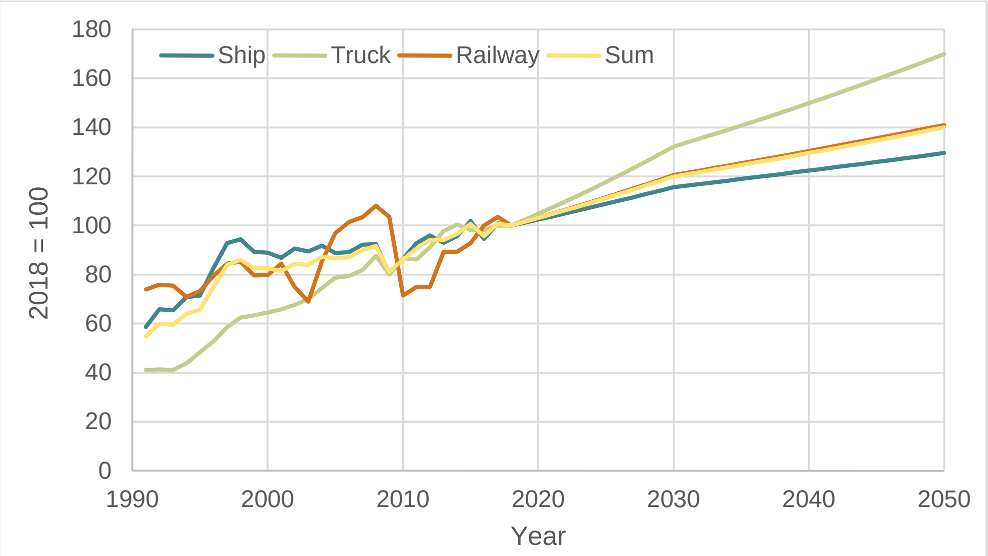

Figure 2.5: Historical development and projections for freight transport in Norway (exclusive transit of ore, crude oil and natural gas).
Source: TØI report 1824/2021.

2.2 Drivers for disruptive changes

Disruption takes place on different levels and various scales, on product categories, on sector level or as impacts across multiple sectors. Transport Outlook 2019 points to five main factors which particularly drive disruptive changes (IFT 2019 pp4):

- *Cost: new technologies and/or processes make old ones uncompetitive in terms of production costs – the new ones become so cheap that old ones become unprofitable.*
- *Quality: new technologies and/or processes raise the quality of products or services to a level that makes old ones uncompetitive.*
- *Customer: significant changes in consumer or business customer preferences make previous products or services unattractive compared to new ones.*
- *Regulation: new laws or regulations no longer permit old ways of working – for example environmental or labour protection rules – or allow new ways of doing things that previously were not allowed.*
- *Resources: previously important resources are no longer readily available or previously inexistent or inaccessible resources now become available.*

Disruptive changes are often a result of a combination of the different drivers. Decarbonising transport, for instance, is one of the main challenges today, and particularly to do it in a way that maintain passenger mobility and freight flows. Environmental and climate regulation force the car industry to produce low- or zero-emission cars and non-renewable resources (oil) will probably become less accessible or gradually more expensive to use. This development paves the way for new technologies, such as the electrification of vehicles. Supportive policies and advancements of battery technology have encouraged the adoption of electric vehicles in many countries, particularly in Norway. In 2020 battery-electric vehicles (BEV) made up more than 50% of all new cars sold in Norway (OFV 2021). Together with better batteries which increase the range for driving and a better infrastructure for charging, consumer preference has changed in a more and more positive direction towards electric cars. An extensive use of financial incentives has accelerated this rapid electrification of the car fleet in Norway. This illustrates how the interplay between different drivers may lead to disruptive changes in transport.

Scenarios for the Norwegian transport system towards 2050 point out many of the same drivers as mentioned above (KPMG 2018). Climate and environmental challenges will enforce regulations for decarbonisation of transport and promote use of zero-emission vehicles for both passenger and freight transport. Until now hydrogen has been lagging behind as an energy carrier but this may change in the years to come. The Norwegian hydrogen strategy, launched in 2020, emphasises the use of hydrogen for clean transport, particularly in the maritime sector and for heavy duty road transport. (Langeland et al 2021). New vehicle and fuel technologies (electrification) and new business models for mobility (shared mobility) together with digitalisation and automatization (ICT, ITS and AI), are supposed to result in a modal shift for both passenger and freight transport, and thereby lay the foundation for disruptive changes and a transition to a more efficient and sustainable transport system.

2.3 Pathways of transport transitions

There are several possible pathways for transformation of the transport system. This is described in detail in the literature of socio-technical systems (ST) and the multi-level perspective (MLP) respectively (Marletto 2014, Geels 2012). This kind of transition literature focuses on how and why existing systems endure and re-produce; what mechanisms destabilise them and allow for successful experiments and new pathways. Transitions are long-term processes and the shift from a car-based mobility regime to a less car-centred and decarbonised mobility system may take several decades and most probably will follow non-linear processes (Hussani and Scholz 2017).

The MLP-approach argues that transitions come about through interacting processes within and between three analytical levels – niches, socio-technical regimes and an exogenous socio-technical landscape. Structural changes often start as radical innovations or experiments in niches, i.e. in micro level space where radical novelties emerge, and the novelties can be a new practice or a new technology (Geels 2002, Geels and Raven 2006, Geels and Schot 2007, Geels et al 2012). Within the field of mobility studies, companies that are currently initiating shared mobility services (car sharing, MaaS) or new forms of urban logistics (crowd shipping, new solutions for home deliveries) represent such niches. Niches develop outside of regimes and regimes often function as barriers to niche innovations. Regimes are primarily a set of rules and practices of well-established private and public regime actors such as transport companies and transport authorities. Transition also take place on regime level but then often without fundamentally changing the regime, i.e. by producing incremental innovations which intend to sustain the existing regime. The role of niches for bringing about path-breaking (radical) innovations is emphasised in transition literature (Geels 2012, Smith and Raven 2012). Regimes represent stability and lock-in, whereas pressure from the socio-technical landscape (globalisation, macro-economic trends and policies, climate change) put pressures on systems and established practices and stimulate niche innovations.

Geels and Schot (2007) identify four different transition pathways which differ in terms of landscape pressure and level of niche development. *The Transformation* pathway characterises incremental changes and occurs when there is moderate pressure from the landscape and when niche innovations are not sufficiently developed. *The Reconfiguration* pathway is a result of massive landscape pressure and adoption of more developed niche innovations which gradually changes the existing regime into a new regime architecture. *The Substitution* pathway occurs when there is enormous landscape pressure and when niche innovations are fully matured, and the result is a radical change of the existing regime. *The De-alignment/re-alignment* pathway occurs when there is hugely disruptive landscape pressure at a time when several pre-mature niche innovations exist simultaneously. This pathway is characterised by experimentation, competition and learning before a certain niche innovation becomes dominant and results in a restructuring (re-alignment) of the old regime into a new regime.

The Norwegian National Transport Plan (St.meld 33, 2017) suggests several pathways for obtaining a low-carbon mobility system. Measures include 1) support of technological innovation of vehicles, fuels and infrastructure (EVs, hydrogen, charging stations etc.), 2) encouraging modal shifts from private car use to walking, cycling and public transport for passenger transport and a shift from prevailing car-based road transport to green logistics (EVs, cargo cycles etc.) for urban freight transport, 3) implement efficient forms of traffic management and driving behaviour (ITS) and, 4) integrate spatial planning with transport planning for obtaining sustainable urban mobility (Hickman et al 2013). Regarding transitions in urban mobility in Norway so far, one can primarily trace elements of the two first transition pathways which include incremental and gradual changes. This, however, holds true for most countries. The dominant automobile regime reacts on landscape pressure related to sustainability concerns and climate change, and on niche experiments related to technological and social innovations by gradually adapting to production of electric vehicles and biofuels and, take part in complementary social alternatives such as car sharing. The global car industry mainly follows a "green car" pathway based on technological innovations whereas transport authorities and planners aim at optimising traffic flow, infrastructure and regulations. So far, this has primarily contributed to sustain and enhance lock-in into an established auto-mobility regime, without making any explicit transformations in it (Geels et al 2012). However, with digitalisation and technological innovations becoming ever more important for achieving the goals of smart and green transport and, increasing landscape pressure (climate change) combined with more mature niche innovations (technological and social), this may spur transition processes in urban transport and mobility, both at levels of behavioural changes and policy-making.

3 Digitalisation and technology trends

Digitalisation has been an accelerating megatrend for decades, with far reaching ramifications across all sectors of society. An all-encompassing listing of trends within digitalisation would be far beyond the scope of this report. Instead we will briefly touch upon a number of salient dimensions applicable to urban mobility.

Digitalisation has been at the forefront of mobility of people and goods for quite some time. Information standards have paved the way to a well-integrated global air transport system and digital freight information standards have come a long way since the nineteen eighties. While many early landmark innovations concerned long distances and global supply chains, city scope mobility has increasingly become a focus for the digitalisation of mobility.

Digitalisation is the motor of the ongoing 'servitization' of the automotive industry that is developing at breakneck speed. Various design patterns of digital services and platforms are being developed and incumbent firms are currently positioning themselves in a changing business landscape.

Many prominent vehicle manufacturers, often called 'OEMs', have pursued servitization of vehicles and transport. OEMs are constantly looking for means to servitize the car-platform and use their installed base of connected vehicles as a leverage. As an example, since 2014 several OEMs (e.g. GM, Volvo, Audi) are pursuing car boot delivery services where packages can be delivered to cars rather than homes during office hours. Currently they seek partnerships with specific logistics partners, but it remains to be seen if and how these business models will scale.

The same challenge is being tackled by a number of firms by installing smart locks at customers' homes. Amazon In-Home Delivery tracks deliveries, unlocks doors and records the delivery using cameras. The Swedish Glue Lock provides a similar service, but aims to become a logistics provider neutral platform player instead of applying a vast vertically integrated value chain like Amazon.

This accelerating development has not passed governments and authorities by. Indeed, most countries now have detailed plans for the further digitalisation of the transport sector. Indeed, the European Union has implemented directives stipulating that novel digital services and infrastructure be introduced to improve safety, sustainability and mobility within the EU. The private sector, ranging from vehicle manufacturers to novel mobility service operators, is also highly active in developing digitalised services and infrastructure pertaining to the transport sector.

In the following sections, we introduce numerous key areas of digitalisation trends currently affecting the transport sector: Policies and initiatives, data, data sharing in the freight industry, analytics and digital platforms and ecosystems.

We will then describe several illustrative digital platform initiatives in the transportation and mobility industries. Finally, we will discuss the current state of vehicle automation.

3.1 Policies and initiatives

This section is intended to provide a brief overview of recent activities regarding transportation digitalisation from a policy and regulative perspective with a focus on the European region – more specifically, the directives on 'intelligent transportation systems', ITS, and the so called 'open data directive'.

ITS is a very wide and growing array of data driven functions and services to facilitate the optimal usage of transport infrastructure. It includes roadside equipment of various types, centralized multimodal traffic management technologies, mobile navigation and traffic information services, and mobility management suites to mention but a few.

The European union has long since put emphasis on the development of ITS services to improve the free movement of people and goods within the union and associated states. As a means to ensure progress and cross EU harmonization, a ITS directive (EU Directive 2010/40/EU (7 Juli 2010)) was developed by the commission, and is now national law via a delegated act. In it a number of key services are specified and these are expected to be implemented by member states.

The national Norwegian strategy for utilizing ITS in the transport sector is stated in the National Transport Plan. It has a 12-year horizon and is renewed every four years. The current plan was adopted by the national parliament (Storting) in June 2017 and applies from 2018 to 2029. Though primarily a plan for development of transport infrastructures, new technologies and transport services including ITS and automated and cooperative transport, has been given high attention.

The ITS directive has not been without controversy. Perhaps the most widely debated and disputed service of all has been the pan-European automatic emergency service, 'eCall'. This service mandates a telematics box be installed in cars set up to automatically call a designated national emergency service in case of a collision. From its early concept developments, several automotive actors voiced concerns that it was over-specified technically and threatened to nullify investments already made by a number of car manufacturers to a similar effect. Negotiations with the car industry were wrought with conflicts of interest and progress slow. Beyond the necessary telematics unit, it is also necessary to implement a conformant call centre function in all EU countries. This has also proven to be problematic resulting in a slow process in several countries. In addition, there was concern over the privacy implications of having all vehicles traceable. Ultimately, after some almost 20 years in the making, most issues were ironed out and implementation is now underway with pilots in several countries, Norway included. Another part of the directive causing similar concerns is the provision of safety related vehicle data free of charge to citizens. Here there were initially diverging views on what data to share, in what format and how the costs should be allocated. While legislating technology implementation is a controversial route, it is not without proponents outside the legislative bodies. A positive effect mentioned by many is a jump in telematics capabilities across the market as a result of the introduction of the standardized European in-car emergency system eCall[3].

While the open data directive (Commission 2019) is a far more generic piece of policy, its ramifications affects all forms of digital service innovation, transport and mobility included. While the EU has promoted commercial and public reuse of publicly funded data for some time, the current directive includes the latest modifications to promote digital innovation in all sectors, including transport and mobility. As opposed to e.g. the section on the provision of safety related traffic data, the open data directive is one sided – it places

[3] https://www.tu-auto.com/pan-european-ecall-boon-or-bust-part-ii/

demands on public authorities to facilitate in particular SMEs' use of data in digital innovation. Earlier versions allowed public data owners to charge more than the marginal cost for their data and in some instances private public monopolies were created as a result of public outsourcing and procurement. It is anticipated that more resources will need to be spent on public digital infrastructure to fulfill the ambitions of the directive. In particular this includes the development of application programming interfaces (APIs) that enable third party service developers to access data as well as well-designed lightweight access processes and quality level assurances to be made by public authorities.

In keeping with EU regulations, Norway has a national access point (NAP) for transportation related data hosted at https://transportportal.atlas.vegvesen.no/en/gen/about/ that caters to the ITS directive and a portal for more generic public data at https://data.norge.no/ . While there will still be upfront development costs to public authorities, it is thought that increased tax revenue from new services developed as a result of improved access to data will outweigh the initial costs by far.

3.2 Data

Centre stage of digitalisation is data, and the transport sector is no exception. The growth of data and its value has been characterized as the key driver of the digital economy and phenomena such as ongoing proliferation of AI depends on it. While adoption rates of telematics services have been around 20% for some time (Dharani et al. 2018), the automotive sector is now poised for an accelerated development. Most activities involving companies, authorities or citizens can produce digital data if a device or application can be used to capture it. Needless to say, not all activities provide equally important data. However, it may be of great use for someone else, or could increase in value if combined with data from somewhere else. From an innovation perspective, any piece of useful data can be viewed as a highly malleable complimentary asset (Roseman et al. 2011) forming an essential component of a digitalized service.

From an economic perspective data has a number of defining features in comparison to other resources (MIT, 2016). First, data is *non-rivalrous*. This means that, in principle, any data can be used by any number of applications or algorithms simultaneously. In contrast, an unspecified amount of money can only be invested in one venture at a time. Second, data is *non-fungible* which means that as opposed to money, certain data cannot be substituted for another one due to the uniqueness of each data point. Third, data is considered to be an *experience good*: its utility is not obvious until analyzing it. Before any utility can be acquired from such an analysis, however, a chain of activities with uncertain outcomes are required. On the one hand, derived information post analysis might be useless. On the other hand, it might be valuable, but the applications and algorithms cannot extract and structure the information for various reasons. The notion of *data readiness* (Lawrence 2017) has been coined to capture the actual value of data for a given application and gives a more detailed account of such challenges. It is pragmatically suggested that data readiness could be viewed as in progressive stages in three "bands". Band C is about challenges with the accessibility of a data set: whether it really is being recorded, the format in which it's being recorded, privacy or legal constraints on the accessibility of the recorded data, access limitations due to topology (e.g. when the data is distributed across a number of devices or embedded components). Band B is about the faithfulness of the data: Is what is recorded matching what is purported to be recorded? How are missing values handled, what is their encoding? What is the noise characterization (for sensors) or for manual data are there data entry errors? Are any scientific units correctly formulated? Band A is about data in context, the appropriateness of a given data set to answer a particular question or to be subject to a particular analysis. The context must be defined. A task could be "Use the data to predict a user preference" or "Use this data to prove the efficacy of a drug". From an analytics point of view, data is only considered useful at the most refined stage of band A.

As a final observation, data tends to increase the amount of data by implication (Yoo et al. 2010). Data analyses, data interpretations, and data-driven algorithms tend to increase the total amount of data over time. Dynamic pricing algorithms, for a ridesharing service for instance, that adapt pricing to changes in demand, improve from previously gathered data. The more data about demand changes available, the better the fine-tuning of the algorithm.

3.3 Data and freight

Data sharing in the logistics industry is on the one hand ubiquitous and a foundation on which globalized trade rests. Keystone 3PL actors integrate theirs partners in vast information networks spanning the globe sending and receiving updates on transhipments and informing planning and authorities. On the other hand, for reasons of competition among firms, information sharing beyond the customary business networks is notoriously difficult proposition in an information-driven business such as logistics. Additionally, consistent supply chain transparency remains difficult even within such networks.

There are numerous standardized 'ontologies' for various parts of the freight industry. Some are driven by governments or the UN whereas others are private consortia or a combination of both. Whereas such standards are critical to enable efficient digital exchanges within supply chains, paper documents remain a vital part of transactions with supply chain partners and authorities. A large amount of research networks, non-government and government bodies around the globe strive to further digital freight standards. The EU-funded project Fed-e-rated is a current example of an attempt at designing and diffusing new logistics information standards to remedy this[4].

More directly associated with urban logistics, there are several ongoing attempts to reduce empty space in trucks delivering goods in cities and thus reducing the amount of driven vehicle kilometres per ton of goods delivered by sharing information. While many cities have employed two-tiered crossdocking hubs as a means to lower the amount of poorly utilized freight trucks in the streets, such initiatives have been plagued by a lack of sustainable incentives. This often leads to difficulties in prioritizing freights in need of crossdocking and leaving already optimally planned deliveries. The project SMOOTh is an attempt at making more finetuned decisions in crossdocking utilizing a collaborative system of systems [5]. To be successful, this approach requires extensive data sharing among competitors, and likely added incentives from associated policy development by the city or real estate actors.

While new approaches to logistics and data sharing are constantly being tested in living labs across the globe, extensive research into data- and analytics-driven innovations has still not lead to any substantial differences in current business practices (Sternberg and Norrman 2017). Entrenched business models and high perceived risks of data sharing are among the

[4] http://www.federatedplatforms.eu/

[5] https://www.volvogroup.se/sv-se/news/2019/nov/volvo-reduces-transports-using-a-digitalized-system.html

main barriers to adopting more open decentralized ways of coupling freight and logistics providers across supply chains (Sternberg and Andersson 2014).

While logistics and telematics services directed at car owners might seem separate niches, the multi-contextual nature of data reuse and digital innovation leads to new types of connections between previously unrelated industries. Indeed, while direct logistics information sharing initiatives frequently run in to problems delivering results, novel cross industrial partnerships seem more dynamic currently. An interesting niche where this is happening is home deliveries. First, OEMs are constantly looking for means to servitize the car-platform. Since 2014 several OEMs (GM, Volvo, Audi) are pursuing car trunk delivery services where packages can be delivered to cars rather than homes during office hours. Currently they seek partnerships with specific logistics partners, but it remains to be seen if and how these business models will scale. Second, the same type of problem is being tackled by a number of firms by installing smart locks at customers' homes. Amazon In-Home Delivery tracks deliveries, unlocks doors and records the delivery using cameras. The Swedish Glue Lock provides a similar service, but aims to become a logistics provider neutral platform player instead of applying a vast vertically integrated value chain like Amazon.

3.4 Analytics

Although data is regarded as a highly valuable commodity, its utility is not realized until when data is used to analyse a phenomenon of importance to someone. Analytics can be described as a combination of one or more of descriptive, predictive and prescriptive analytics activities (cf. Hartmann et al. 2014). As an example, various types of traffic information can be analysed in several ways to gain different types of progressively more advanced capabilities. A *descriptive* analysis would aspire to accurately determine and describe the current state of the traffic system. This is a key activity with all actors as a main purpose of all traffic management is generating concurrent 'situational awareness' of the current state of the traffic system. A *predictive* analysis would attempt to accurately forecast a future state of the traffic system. This ranges from interpretations of effects of planned changes such as road works to advanced queue detection analysis. Finally, *prescriptive* analytics seeks to accurately gauge the optimal action to take in each traffic situation. This ranges from adaptive route calculations for the individual drivers to a potential system-wide optimization of all partaking vehicles and passengers. Note that the term "prescriptive" is not necessarily to be understood as a forced action, although from the point of view of a TMC, this level of analytics could be coupled to traffic control measures of various kinds, such as geofencing mechanisms or roadside equipment. From the point of a navigation service provider, showing users the optimal route is the key offering and showing a better route than the competition is important.

Even though an advanced algorithm has been executed successfully and delivered a result, caution is frequently merited as to the applicability of that result. In what has become known as 'algorithmic bias', a number of interpretational fallacies of data-driven algorithmic decision making can be listed, including commercial, political and racial implication. The role of social media in fermenting a polarized political landscape is perhaps the most apparent current issue (Epstein and Robertson 2015). While the mere implementation of an AI-driven decision process may indicate fairness and objectivity, the end result can be the opposite unless care is taken to avoid such issues. While the mere implementation of an AI-driven decision process may indicate fairness and objectivity in itself, the end result can be the opposite unless care is taken to avoid it. Current means of mitigating algorithmic bias include technological developments (Bellamy et al. 2018) as well as variants on the 'human-in-the-loop' safety measure, but the complexity involved makes avoiding unintended bias a difficult task.

Precisely what makes digitalisation such a powerful vessel of innovation (multi-contextual re-use of data and code) also makes it difficult to understand complex chains of third party code and data that form most advanced applications and platforms today.

Regardless of the type of analysis performed, data access and analytics capabilities are highly interdependent and they frequently join forces as two main building blocks of digital platforms (Gregory et al. 2020).

3.5 Digital Platforms and ecosystems

In most conceptualizations of data driven innovation, three related concepts play important roles: Networks, platforms and ecosystems. The transport sector is no exception. Ranging from digitalized automotive modular vehicle platforms to data driven information service platforms, platforms and their surrounding ecosystems are key to the development of new services and offerings to businesses, authorities and citizens alike. The rise of digital platform companies has led to the emergence of new types of competition in many sectors, including transportation.

Platform based newcomers tend to outcompete established firms. Well known examples in the transportation and logistics sectors include how Amazon created substantial challenges for bookstores and how Uber challenges local taxi companies. The power of so called 'network effects' in two-sided markets (Parker and Van Alstyne 2005; Rochet and Tirole 2003) is likely a key factor in this development.

A network is a collection of interconnected entities (Eisenmann et al. 2006). These can be individuals or collectives, e.g. organizations. According to extant theory, a network's value is a function of its size (Eisenmann et al. 2008; Katz and Shapiro 1986). On a general note, a direct 'network effect' implies that the more firms are actively adopting new standards the more valuable the network using them becomes for other firms. If firms profit from collaborating with the network, they will create affirmatory feedback effects and thus, make the network more attractive to others which in turn increases the network's size and benefits.

However, this only explains part of the power of platform-based innovation. Using a central node, different "sides" of a network can mutually benefit from the size and characteristics of the other side (Boudreau and Jeppesen 2015; Rochet and Tirole 2003). This is generally referred to as 'indirect network effects'. For example, travelers value access to a big global network of drivers, while drivers benefit from access to a large customer base. This type of mutual dependence promotes the emergence of platforms, typically digital, as intermediaries seek opportunities to facilitate or rationalize and scale transactions among the users—individuals or firms—of a network (Eisenmann et al. 2006; Rochet and Tirole 2003).

Such platforms can be conceptualized as interfaces between other artefacts. They are often embodied in products, services, and/or technologies. As illustrated above, they mediate transactions between two or more sides, for example buyers and sellers or app developers and users (Evans 2003; Gawer and Cusumano 2002; Rysman 2009).

An important key feature of *digital* platforms is its architecture (Yoo et al. 2010). As opposed to a modular physical product architecture, on the platform level, modern digital architectures are 'layered' (Adomavicius et al. 2008). This untangles components and allows for a highly malleable combination and recombination of the data held within. Essentially, this is key to the highly 'multi-contextual' nature of data driven innovation (Lindgren et al. 2008) in which various actor groups see varying utilities in the same type of data.

Just as data can be viewed as complementary assets and part of services, platforms can also function as building blocks for products or services developed by others (Gawer and Henderson 2007). In this context, 'complements' are products and services that are built on a platform by 'complementors', and that enhance the value of a core good to a network via indirect network effects, such that the value of the core good to adopters is greater in tandem with the complement than without it (Gawer 2009). *Complementor*s are thus independent providers of complementary products to mutual customers (Boudreau and Jeppesen 2015).

As a final level of aggregation, the broad term '*ecosystem'* has been frequently used to describe a community of interacting organizations who co-evolve their capabilities and roles, most often aligning themselves to one or more central 'keystone' companies (Iansiti and Levien 2004). '*Digital platform ecosystems'* thus refers to a platform as well as its network of complementors that produce complements in the form of data or services to enhance the perceived value of the platform. From this perspective, platforms provide value via a common architecture, the conceptual specification of interfaces that allows an ecosystem to be partitioned into a relatively stable platform and a much more volatile complementary set of modules, and governs the interactions among these different components (Baldwin and Woodard 2009). Similarly*, standards* define the technical specifications of the platform and ensure compatibility among architectural components. Dominant platform actors play a significant role in the formation of standards and can often be seen as de facto industry standards once the platform has achieved a critical mass of adopters (Hanseth et al. 2006). However, seeing as data is inherently multi-contextual, digital resources are continually recombined forming new value-streams including services of an ever increasing variety between organizations (Henfridsson et al. 2018).

Data driven innovation is commonly an effort spanning several actors of various kinds, and there is a wide range of organizing patterns in data sharing. These include private business models as described above as well as open collaborative or crowd based approaches to collecting, hosting and analyzing data (Boudreau and Jeppesen 2015; Janssen et al. 2017). A comprehensive taxonomy of such often public private way of organizing data driven innovation was developed by Susha et al. (2017). It is intended to both analyse existing collaborations and inform the creation of new ones. It includes six dimensions related to data sharing and eight dimensions related to data use, each with multiple choices, clearly indicating the highly varying nature of digital collaboration.

This description of data, analytics, networks, platforms and ecosystems is highly relevant to understand the current digitalisation of the transport sector. To illustrate some such variations of data collaborations in the transport domain, four examples are included; an open city wide platform, a nationwide public private data warehouse, a two-sided telematics data platform, and a citizen mobility management focused traffic management platform.

3.5.1 Open data in the city - CIP

The City Innovation Platform (CIP) is a set of B2G open source software components developed by Dutch firm Civity, designed to manage data and spur digital innovation in a city. It is intended as a facilitating layer connecting service providers to open data in an efficient manner.

A Data Market, to make all types of data available, according to licensing and pricing models and access rights determined by the provider of the data. In the Data Market's catalogue, data requests are accessed via standardized APIs (with associated tools).

The Data Management Framework is the core of the City Innovation Platform. Here, the collection, processing and storage of data (if necessary) is regulated. Much attention is paid to data quality, common data models and tools for the storage of open, linked and big data.

While CIP conforms to a B2G business model, providing authorities with a means to expose open data for innovation, they also pursue crowdsource data acquisition development, e.g. reporting services and crowd-sourced NOX-analysis suggesting a very wide scope of business activities. Civity and CIP has been very active on the EU-project scene and part of Swedish EU-research efforts.

3.5.2 National Data Warehouse for traffic information - NDW

The Nationale Databank Wegverkeersgegevens (the National Data Warehouse for traffic information, NDW) has procured comprehensive sets of traffic data from several sources. Through the Dutch national data warehouse for road traffic information nine public authorities maintain a shared database of road traffic information. The mutual collaboration among these public authorities, as well as their contacts and contracts with the private sector, have resulted in extensive high-quality traffic data with a high level of geographical coverage.

In 2014, NDW entered into a framework agreement with eleven private companies for the purchase of real-time traffic information. This provides a way for NDW to issue tenders that are completely customized according to the needs of the particular road authority. Since the public authorities have formed an alliance, they can use the economies of scale to buy at lower prices. The NDW partners can also decide to arrange for collecting the data themselves and then having it entered into the NDW database.

The NDW performs several data driven key activities with a focus on data acquisition, processing and aggregation but also analytics, distribution and visualization. Examples of the latter is a viewer to present the traffic data, and user-friendly reporting software to transform the data stored in the historical database into tables, maps and graphs. A crucial capability is data quality monitoring to ensure that data acquired is fit for purpose depending on its intended use in e.g. policy making or traffic management. 24/7 monitoring is coupled to a set of agreed procedures involving sources and there is a service desk managing malfunction reporting and support needs.

In terms of systems architecture, it is supplied and distributed among a number of private sector organizations all contracted by NDW. The high-quality information afforded by the aggregation of so many sources makes NDW a near full spectrum traffic information provider to public and private actors alike. Data is available as open data, meaning that it is available to third parties for reuse in their applications. For parties that require more services, NDW offers an Agreement on Mutual Data Provision and Services. Parties involved make record of mutual conformation to data and service deliveries to one another.

Beyond Business model activities, NDW also participates in National and international standardization agreements needed for the smooth exchange of information between various systems. NDW coordinates this aspect with other parties, participates in decision-making, and also contributes substantially to the development of standards. Once a new standard has to be introduced, NDW directs this process.

3.5.3 Traffic Management as a Service - TMaaS

The concept of 'Traffic Management as a service' is a new take on mobility management. It was developed in the city of Ghent using a combination of EU and regional national funding as a response to the lack of support for multi-modal traffic planning in the current automotive dominated landscape. It aims to promote alternative modes of mobility such as cycling or novel forms of micro mobility by facilitating planning for the citizens as well as on the citywide level.

While the emergence of advanced traffic management has been centred on big cities, many small and medium-sized cities around the world is also increasingly in need of improved traffic management. Historically, this has not been feasible, as building separate, traditional traffic management centers for all these cities is probably not the most feasible solution. As a response to this perceived need, the Traffic Management as a Service (TMaaS) project is developing a lightweight cloud-based platform that offers citizens and local government's situational awareness focusing on multimodal mobility.

The TMaaS team's ultimate goal is to build an on-demand modular solution, where users can build a customized tool by subscribing services, enabling a double sided multi modal mobility market. Pilots have been performed in Ghent and end-user research has been carried out into what information citizens need and how they prefer to view it. A key feature is an individualized citizen dashboard that they can adapt to their preferences and where they can follow-up the mobility related items of interest to them. While the dashboard design principle demands some degree of end user adaptation and there is a two-sided platform connecting city and public transport with citizens, the TMaaS initiative is first and foremost a lightweight end-to-end service approach targeting the same type of B2G market as traditional TMC-installations. Main activities include everything from data acquisition and aggregation to analytics. Having said this, it is important to note that this is a project that is yet to be finalized and that many issues are still to be resolved.

3.5.4 The Extended Vehicle concept and 'neutral server'

The automotive telematics sector has for some time been defined by a tug of war between the European Commission, third party service developers and vehicle manufacturers. From the Commission's perspective, the growth of the telematics based service sector is hampered by a bewildering variation of vehicle data formats and access terms among automotive OEMs. This sentiment is generally shared by third party service developers who need data access to innovate their own services. OEMs on the other hand point to safety and security problems related to allowing open access to vehicles and could lose important future service revenue if access to vehicle data was made more open.

The neutral server initiative, sponsored by the European Automobile Manufacturers' Association (ACEA), is a recent joint effort to make automotive data available to third-party service providers in a safe and secure manner, without requiring those third parties to sign a contract directly with each automotive manufacturer. The neutral server initiative was announced in late 2016 and received critical support from the European Union, automotive OEMs, and other automotive industry stakeholders such as insurance companies, energy providers, and automotive maintenance services.

On a similar note, ACEA also manages the FMS standard interface family. This is a set of information standards with which to gain access to data from vehicle on-board systems. Standards includes trucks and buses from a number of OEMs.

This type of platform ecosystem is still a novel phenomenon and it is currently far from certain how it will develop over the coming years. As an example of platform actor in this niche, Otonomo is an Israeli telematics company that does not focus on end to end user services, but rather to build a two sided B2B market based on attracting both several OEMs and their car data as well as service developers who would otherwise struggle to develop services with enough coverage. In a strict sense, Otonomo might not be targeting logistics or mobility services, but their business model, building on the ACEA open server concept, merits inclusion as an example of data driven business models that does not target analytics activities. Rather Otonomo strives to perfect data acquisition processing and aggregation to become a one-stop supplier of telematics data. The company has announced association with numerous major car brands and is seeking to include more to increase the indirect network effects of its offering.

3.5.5 Geofencing

Geofencing and 'UVARS' are a strong current trend in which telematics and policy and regulations are meshed for various purposes. Generally, geofencing allows a system to observe and act upon a moving object in space according to a set of regulations for that space. The technology has been available for quite some time and ISO has produced a reference standard for the implementation of road traffic monitoring (ISO 15638-1). There are also existing implementations. The Australian Intelligent Access program for very heavy road transports has been a proven success, albeit mostly covering non-urban settings. This system is both monitoring and enforcing regulations for these vehicles issuing automated tickets when detecting speeding or deviations from designated road segments (TCA 2018). IAP has been tested in applied research projects in Sweden within the area of high capacity vehicles (HCT).

As the market is becoming saturated by connected vehicles, geofencing has become increasingly feasible. While the IAP only concerns automating rules compliance, issuing fines for transgressions of designated corridors and speeding for very heavy trucks, there have been recent pilot tests in e.g. Gothenburg where public transport Volvo buses were automatically reduced in speed over a sensitive bridge. There is currently standardization work ongoing at CEN building on pilot test experiences in e.g. a pilot performed in Oslo together with Volvo Cars recently[6] (Arnesen et al. 2020).

The EU funded Reveal project[7] is currently exploring the opportunities and challenges of using geofencing to manage traffic in cities. Several cities are currently examining the potential of digital systems for intelligent access control via three types of adoption mechanisms. First, cities could use terms for services in their own procurement to force geofencing technology and regulation into use that way. A second option is to couple special permits for certain types of transports to the use of geofencing surveillance. A final option is to enforce a zone across certain segments or all users of the road infrastructure.

Several nations have started Geofencing initiatives. The Swedish Transport Administration is currently involved in a Swedish program to introduce Gefoencing in Sweden together with industry and research organizations. On a European level, the CEDR-project FALCON has developed a European 'smart infrastructure access policy' (SIAP).

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[6] The GeoSum project

[7] https://urbanaccessregulations.eu/public-authorities/reveal-project

3.6 Automation

Automated driving has attracted tremendous amounts of funding and talent during the last few years. It is a fastmoving field. Much of this section uses a recent state of the art report (Habibovic and Chen, 2021) from RISE (research institutes of Sweden) listing some of the most widely accepted constructs and current limitations. While early promises of swift progress have gained a somewhat more modest tone as challenges multiplied, development is still strong. While the developments in the car industry have been more visible in mainstream media, several trials of automated heavy vehicles are currently underway. As a prominent example, Swedish Einride is producing autonomous electrical trucks that are now being tested in several cases, including grocery transports to stores from warehouses. However, there are still both technological and regulatory hurdles to overcome before widespread adoption can take place. Heavy vehicles have been highly automated for mining operations for some time. All modes of transportation are being touched by automation, including shipping as exemplified by the new Norwegian vessel *Bastø Fosen VI*.

While using drones to deliver goods have been generating interest and capital for some time, it is currently not employed in numbers beyond pilot and small niche markets. Safety regulations remain a challenge for a technology still in its infancy and tests are mostly made using very small drones flying low so as to limit the risks, but also limiting its potential considerably.

As an example, the current food delivery trials by Uber Eats can carry meals for up two people for a roundtrip range of 12 miles. The drone will stay below 400 feet to comply with drone regulations. Uber has an airspace management system, 'elevate cloud systems' to track the drone and notify the driver when the order is ready to be picked up. Uber plans to use the driver to take over the delivery process once the drone has reached a drop-off point with the overall aim to deliver meals faster by using the technology to bypass obstacles such as traffic or bad weather.

Several organizations have proposed automation classification schemes. A widespread scheme concerns the automotive sector and is developed by the Society of Automotive Engineers (SAE) (SAE International, 2018). Since a vehicle can contain ADS of different automation levels used in different contexts, an operational design domain (ODD) refers to the conditions under which the ADS operates.

The SAE scheme has five levels, ranging from Level 0 (fully manual) to Level 5 (fully automated), see table 3.1. On Levels 0 – 3 a human driver is in the vehicle and either drives or is prepared to take over the driving task when the system requests it. Vehicles in the lower levels of automation (up to Level 3) are found in several types of mass-produced vehicles today (e.g., Adaptive Cruise Control (ACC), Lane Departure Warning (LDW), Lane Keeping Support (LKS), and Blind Spot Detection (BSD)). Level 3 automation is currently under development and is a widely debated topic due to on the one hand requiring a human driver responsible for the driving, while at the same time as ADS takes care of the driving allowing drivers to focus on other activities.

In Levels 4 – 5, the vehicle can also handle exceptional situations, negating the need of human drivers. However, most likely for some time a vehicle with automated functions at the higher levels may also be able to drive manually. The difference between Levels 4 and 5 is that Level 4 vehicles can only drive in certain traffic situations or in certain areas, while Level 5 vehicles are meant to handle all situations and environments that a physical driver can handle. In practice, Level 4 is referred to as highly automated driving, while Level 5 is fully automated driving.

Table 3.1: Automation levels as defined by the SAE standard J3016.

<table>
<tr><th></th><th>Level 0</th><th>Level 1</th><th>Level 2</th><th>Level 3</th><th>Level 4</th><th>Level 5</th></tr>
<tr><td rowspan="2">What does the human in the driver's seat have to do?</td><td colspan="3">You are driving whenever these support features are engaged — even if your feet are off the pedals and you are not steering</td><td colspan="3">You are not driving when these automated driving features are engaged — even if you are seated in "the driver's seat"</td></tr>
<tr><td colspan="3">You must constantly supervise these support features; you must steer, brake or accelerate as needed to maintain safety</td><td>When the feature request, <u>you must drive</u></td><td colspan="2">These automated driving features will not require you to take over driving</td></tr>
<tr><td>What do these features do?</td><td>These features are limited to provide warnings and momentary assistance</td><td>These features provide steering OR brake/acceleration support to the driver</td><td>These features provide steering AND brake/acceleration support to the driver</td><td colspan="2">These features can drive the vehicle under limited conditions and will not operate unless all required conditions are met</td><td>This feature can drive the vehicle under all conditions</td></tr>
</table>

Source: Habibovic and Chen 2021, based on (SAE International, 2019).

Automated driving is enabled by advanced software, powerful data processing units, detailed maps, and an array of sensors that together create a 360-degree living map of the traffic environment around the vehicle. To reach a high level of robustness and redundancy, several sensors are used (e.g., Waymo's 5th generation of automated diving system, 'Waymo Driver', incorporates 5 lidars, 4 radars and 29 cameras (Jeyachandran, 2020)). This poses integration challenges for manufacturers' and drives' ADS cost (between $50,000 and $250,000 for a road vehicle (Herger, 2020)). The expectation is, however, that the cost will decrease significantly with mass-production.

Machine learning (ML) and artificial intelligence (AI) are key enablers for automated driving. Algorithms rely on "learning" from reality and large pilots are underway on public roads to expose algorithms to as many varied traffic situations as possible. The ability to capture "edge cases" is seen as a major prerequisite for safe operation of AVs (Koopman and Wagner, 2017). There is no doubt that proving safety of ADS is one of the most difficult tasks (Nidhi Kalra and Paddock, 2016).

Most AVs still require a safety driver in the vehicle to warrant safety, due to a combination of ADS limitations and regulatory constraints. To remove the driver, stakeholders are considering teleoperations technology and human remote control of the vehicles if necessary. Ideally, a remote operator would be able to control and monitor several vehicles at the time, and thereby improve cost-efficiency. With this demand, several new stakeholders have emerged offering remote control technology and services (e.g., Phantom Auto, Voysys).

Automated driving systems under development

It is possible to distinguish four broad types of ADS (corresponding to Level 3 and 4) currently in development for use on public roads and that are expected to become mainstream within 5-10 years. Most forecasts agree that launch of these ADS is likely to occur at the earliest in 2022/2023.

- **Automated shuttles and taxis** addressing first- and last-mile trips are expected to revolutionize passenger mobility. They are mainly piloted in urban areas, but there are also a few examples of pilots in rural settings (e.g., in Japan and Sweden). The pilots commonly involve a few vehicles and take place in well-defined areas, at low speeds and with a safety driver on-board. In 2018, both automated shuttles and taxis were commercialized for the first time; the shuttles were integrated into regular public transport in a residential area outside Stockholm (Sweden), while Waymo started offering commercial taxi services in Phoenix. Recently, a few stakeholders got permission to pilot their services without a safety driver on-board. Norway is actually in the forefront when it comes to self-driving buses, pilots have been tested in several cities and towns (Statens vegvesen 2021).

- **Automated goods delivery vehicles** address the first- and last-mile urban delivery, between hubs or the final delivery destination. Various designs are being developed such as sidewalk delivery robots, automated delivery pods and automated cars. The latter are being developed by e.g., Waymo, Ford, and General Motors, similar to conventional delivery vehicles. Sidewalk delivery robots are created by e.g., Starship Technologies, Kiwi and Amazon. Typically, they are electric, carry one parcel at the time, travel on sidewalks at speeds up to 5-10 km/h. Electric automated delivery pods are being developed by e.g., Nuro and Neolix. They are somewhat larger than delivery robots, can deliver several parcels at the time, travel at a slightly higher speed (10-20 km/h) and use both local roads and cyclist paths. Larger delivery pods are also being developed by e.g., Einride. They are typically operating in non-crowded, pre-mapped areas and require remote monitoring and involve a limited number of vehicles.

- **Automated truck platooning on highways** has been under development for several years and is anticipated to improve efficiency of freight transport in terms of reduced fuel consumption (4% for the platoon leader, 10% for the followers) and road utilization. It is a system that enables automated vehicles to drive with very short inter-vehicular distances as ‘road trains’ or ‘platoons’ via ‘connected braking’ between trucks, enabled by vehicle-to-vehicle communication. Current commercially available platooning systems are designed to operate only on multi-lane, divided, limited access highways and involve two vehicles only, both with drivers. Platoon size is expected to grow and also in the future, only the first vehicle in the platoon will require a driver. Key stakeholders in the area include Volvo, MAN, Scania, Peloton, and Locomotion.

- **Automated driving on highways** both for passenger and freight vehicles are underway. These vehicles will retain manual controls allowing human drivers to remove their hands from the steering wheel and under certain conditions take their eyes off from the road for longer periods of time. A key distinguishing characteristic is whether the driver must remain alert and ready to take control if the system is unable to execute the driving task (Level 3), or not (Level 4). Initially, such systems are expected to be used only for specific conditions on specific highways.

Though much of the public debate on automation has focused on vehicle systems specifically, many evolutionary automated safety features rely on digital connectivity with surrounding systems. Such advanced 'V2X' applications rely on sensor data sharing, collective perception, and cooperative driving (Chen and Englund, 2016). The Car to Car Communication Consortium (C2C-CC)[8] summarizes the advanced V2X application as 'Day 2' and 'Day 3+' applications. Day 2 services require improved cooperative awareness, sensor information sharing, collective perception, and improved infrastructure support. Example of such services are overtaking warning, advanced intersection collision warning, motorcycle protection, cooperative adaptive cruise control (CACC), long term roadworks warning and special vehicle prioritization. Day 3 services require e.g., trajectory/manoeuvre sharing, and coordination/negotiation. Example services include advanced CACC (e.g., lane change), target driving area reservation, traffic light info optimizations with V2I, transition of control notification, cooperative merging, cooperative lane change, cooperative overtaking, and cooperative transition of control.

To summarize, the rapidly developing areas of connectivity and automation are moving towards an integrated approach. This has led to numerous new services not possible with only automation or connectivity. In addition, the rapid development of artificial intelligence, is moving the field into cooperative driving where vehicles themselves are able to coordinate locally to solve complex scenarios.

Key benefits, challenges and development trends

Connected automated driving concepts now also interact closely with electric vehicles and new shared mobility concepts, forming major trends of future mobility. Though many benefits are emerging with CAVs, challenges remain and call for technology advancement, business development, innovation, regulatory changes as well as holistic system of system thinking and inclusive design (Figure 3.1).

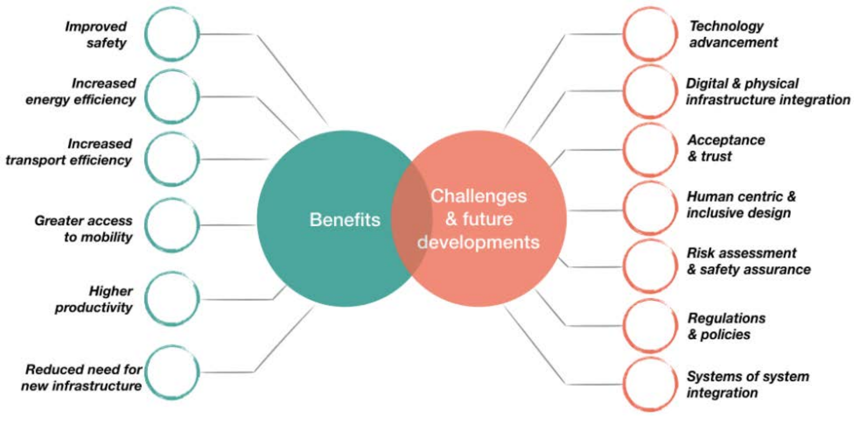

Figure 3.1: Key anticipated benefits and challenges of connected automated vehicles. (forthcoming 2021).

8 https://www.car-2-car.org/

3.6.1 Key benefits of CAV

Improved safety: Some favorable impacts on safety and environment have already been proven (HLDI 2019; Leslie et al. 2019). By eliminating driver, CAVs with higher automation levels are anticipated to improve safety even more and eliminate accidents caused by e.g., distraction, driving under influence and speeding.

Improved transport efficiency: Lower levels of automation have small effects on transport efficiency; mostly related to reduction in accident related congestions. CAVs with higher level of automation and connectivity could be integrated into an automated transport system, which helps reducing the environmental impact by smoothing the traffic flow (Papadoulis, Quddus and Imprialou, 2019).

Greater access to mobility: By enabling flexible, on-demand, and driverless transport, CAVs could improve quality of life and productivity of elderly as well as people with e.g., visual impairments (Owens *et al.*, 2019).

Higher productivity: As opposed to driving, commuting in a high level CAV can be productive time. On the commercial side, transportation companies already suffering from a serious driver shortage (e.g., mining, long-haul and home delivery) will be able to operate their businesses with fewer drivers.

Reduced need for new infrastructure: By enabling vehicles to travel closer to each other, CAVs could increase highway capacity. Being able to park much closer, the usage of existing infrastructure can be improved and needs for new parking areas can be reduced.

3.6.2 Key challenges and development trends

Overcoming technical limitations: Both automation and connectivity need improvement. For highly automated vehicles, continuous sensor technology advancement including new sensors, sensor fusion, positioning and on-board computation remain challenging. Similarly, connectivity with high reliability and low latency needs to tightly integrate with ADS for large scale testing and validation.

Digital and physical infrastructure: It is generally assumed that CAVs should be able to deal with existing roads without significant changes in the infrastructure. On the other hand, it is also agreed that close cooperation between CAVs and infrastructure is key for a safe and efficient transport system. Incorporating physical and digital infrastructure with CAVs will form another major development trend.

General acceptance and trust: CAVs will have to gain trust and societal acceptance. They need to safely, efficiently and seamlessly interact with other entities in the traffic system. The interaction between CAVs and conventional vehicles as well as vulnerable road users such as bicyclists and pedestrians remains an open research question. External vehicle interfaces (eHMI) have been proposed for such purposes (Habibovic *et al.*, 2018; Dey *et al.*, 2020), however, their role is yet to be explored.

Human centric and inclusive design: The interaction between humans and technology is crucial to automated driving and remains challenging. While development of CAVs has attracted significant research on human aspects from the driver and passenger perspective, it fails to address the special consideration of certain groups such as elderly and individuals with impairments. To ensure that CAVs and corresponding mobility services serve all people, stakeholders need to truly embrace a 'whole journey' mindset using the universal design from early development phases (Habibovic, Andersson and Englund, 2019).

New safety aspects: Early implementation of CAVs will be in environments where machine-based and human road users coexist. Considering unpredictability of such traffic situations, collisions might be inevitable in a foreseeable future. This may be addressed by traffic separation, such as proposed by NUMO with dedicated road network for CAVs (Chen *et al.*, 2018). It may also be approached with in-depth understanding of behaviors and interactions. Digital safety and security will become very important for managing deficiencies in the software controlling the CAV, missing or incorrect map data or sensor data, and cyber-security challenges. Currently, several relevant standards are under development (e.g., UL 4600, ISO 214448 SOTIF).

Regulations and policies: Mainstream testing and adoption of CAVs requires significant policy and regulatory changes to govern the design, construction, and performance of these vehicles. Governments around the world have developed, or are developing, regulatory frameworks and protocols for testing (and in some cases for deployment) of CAVs on public roads. The major challenge is that the rules vary widely between the countries (and states), making it difficult for manufacturers to navigate the regulatory landscape. Changing international regulations is an extensive process that may take years, if not decades. Among the key challenges are risk assessment (i.e., how safe is safe enough?), type approval, liability, licensing, training and insurance.

Transport system of systems: Transport systems include many stakeholders and components, where CAV and its corresponding stakeholders represent the major parties. With increasing connectivity for vehicles and infrastructure, emerging service innovation and collaboration, the transport system is transforming from many siloed systems into a system of systems (SoS) with independent yet interconnected and dependent systems. Introducing CAV in the system, may thus have a significant effect on the entire traffic system and its function in society. RISE and its partners have proposed NUMO[9] – New Urban Mobility (Chen et al 2018), which is a fully electrified, connected and automated transport system. Such an automated system requires holistic design and engineering with consideration of the technologies, humans, the society, and a continuous system evolution.

3.7 Concluding remarks

Whereas digitalisation of mobility and freight has been ongoing for decades, the sector is currently on the verge of several fundamental shifts as a result of recent digital innovations. In Europe, new policies on ITS are being developed and introduced to EU member countries. While some remain contested, it is clear that lawmakers are intent on influencing how traffic related information is to be configured and disseminated in the future.

The sharing of data across organizational borders is frequently a challenging prospect and transport is no exception. Novel innovations that include information sharing has been proposed and some are currently in use, but as of yet, the majority of the transport sector has not adopted such services.

As is the case across societies, the role of data is paramount to these new proposed innovations and emerging new digital platforms. Ecosystems in public as well as private domains are rapidly becoming increasingly important part of such developments.

Automated and connected vehicles are slowly merging into connected automated vehicles (CAVs). Such vehicles, in combination with other parallel trends such as artificial intelligence, electrification and shared economy, hold the potential for a safer, more efficient, accessible, equal and inclusive mobility. However, due to current limitations of technological capability as well as trust, security, safety and regulations, many challenges remain for fully reaching the benefits of CAV.

[9] http://bit.ly/numo-urban-mobility

4 Social trends

The transport system is strongly affected by global megatrends such as urbanisation, ageing societies and digitalisation (Loos et al 2020). An increasingly larger share of the global population lives in cities and the population is also getting older. Changes in urban and demographic structures lead in the next round to changes in transport demand. Growth in urban population usually increases movements of passengers and freight, and urbanization often implies longer travel distances.

Digitalisation plays an important role in meeting new transport demand and it also affects the working life and consumer preferences which is reflected in the recent years of growth in e-work and e-commerce. In sum, the intersecting trends of urbanisation, an ageing population and digitalisation affect both passenger and freight transport, and this chapter focuses on possible impacts of these trends on such demands.

4.1 Urbanisation

Urbanisation is a global trend, and it creates several challenges for the transport system. Today more people globally live in urban areas than in rural areas, approximately 55 per cent of the world's population lives in urban areas. In 1950, 30 per cent of the world's population was living in urban areas, and projections for the future predicts that 68 per cent of the world's population will be residing in urban areas in 2050 (UN, 2019, Ritchie & Roser 2018). The share of Europeans living in urban areas is expected to increase between now and 2050 from 74 to 84per cent (Coosemans et al 2016). In Norway, the share of the population living in urban areas is about 82 per cent (SSB 2020). Urban space has become the dominant geography, and transport movements occur increasingly in an urban context in most countries.

Urbanisation may affect the transport system in several ways. It can lead to increased demand for public transport and to higher walking and bicycling shares in the inner city. However, whether transport demand in aggregate will increase or decrease is unclear. In order to illustrate how ongoing urbanisation can affect the demand for passenger transport in Norway we will look into the travel pattern for the three largest cities in Norway, compared to the cities and their hinterland (city-regions) and to the general travel pattern in Norway.

As can be seen from figure 4.1 the travel pattern in the large cities deviates clearly from the travel pattern in the city regions/Hinterland. A substantially larger share in the city centres are walking or biking or using public transport than in the Hinterland The car is the primary means of transport in the Hinterland and the share who travel by car is higher there than the national average. When in addition considering the distance travelled (average daily travel in km), we can see that the inhabitants in the Hinterland travel more than the average in Norway, see figure 4.2. When cities grow as a result of urbanisation, the strongest growth takes place in the urban fringe zones and not in the inner city. This implies that a large part of the expected urban growth will come in the Hinterland, and consequently lead to more driving and associated problems related to emissions, congestions and urban land-use. Electrification of vehicles may reduce emissions problems in the cities but not land-use problems.

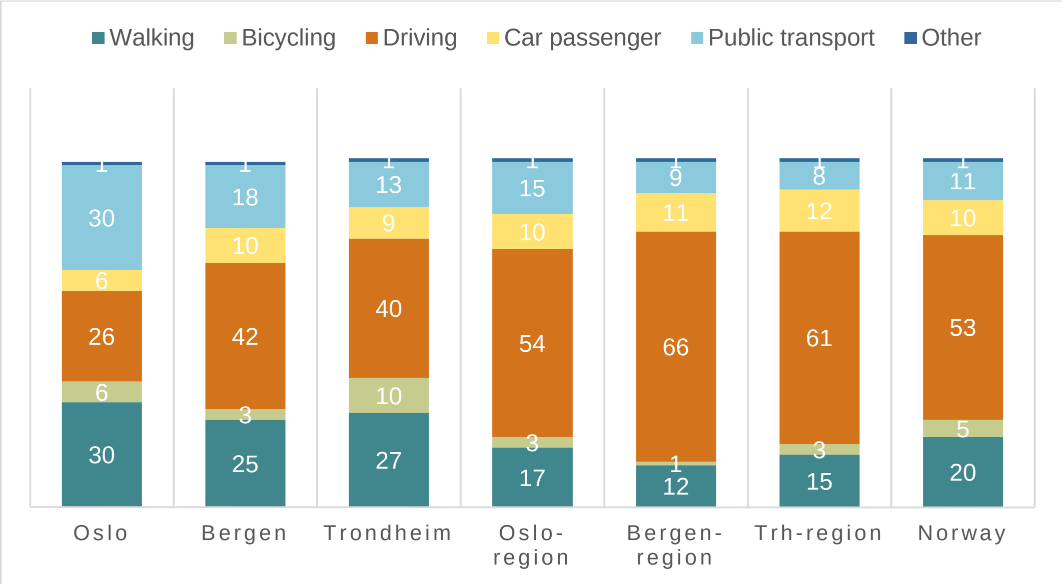

Figure 4.1: Mode of transport in the three largest Norwegian cities, city regions and the country. Per cent. Source: Norwegian National Travel Survey 2018-19 (Grue et al. 2021).

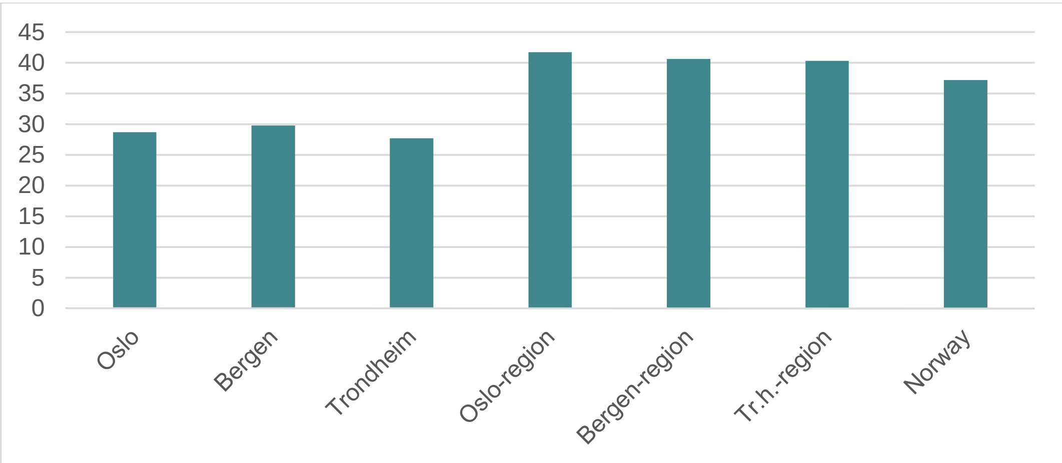

Figure 4.2: Daily travel by distance in km (air travels excluded), largest cities and city regions. Source: Norwegian National Travel Survey 2018-19 (Grue et al. 2021).

If the current travel pattern persists in the coming years, this implies that continued urbanisation will leads to more driving (travel in km). In addition, this will cause external effects (congestion etc.) as the traffic already is critically large in cities and their hinterlands. Coosemans et al. (2016) summarise the problems of urbanisation and transport in the following manner:

"Growing and extending cities lead to the emerging concept of city-regions, which combines several spatial scales and transport modes. In the context of an artificial land cover increase by 3.4% in Europe between 2000 and 2006, the 50-years lasting car based urban sprawl is more and more seen as an issue by urban and regional planners because of the associated externalities (land consumption, energy, traffic congestion) with proposed alternatives like urban intensification, compact development, Transit Oriented Development (TOD) and, to some extent, smart cities. Regarding urban logistics, it should be mentioned that freight is an important traffic component in cities (10 to 15% of vehicle equivalent miles), load factors for delivery vehicles in cities are very low (e.g. 38% for vans in London) and urban freight is responsible for 25% of urban transport related CO2 emissions and 30 to 50% of other transport related pollutants."

The concept of smart city, also referred by Coosemans (op. cit.) has been introduced as a possible solution to address the challenges arising from the strong growth of urbanisation and population. Smart cities use digital technology to support city operations related to transport and land-use. The smart city concept integrates information and communication technology (ICT) and several electronic devices (sensors etc.) in order to optimise urban transportation. The concept includes connected cars, intelligent infrastructure and smart traffic management (Silva et al 2018).

The smart city-approach may help cities to make urban transportation more efficient and safe but it is uncertain if it will resolve transport problems related to growing urbanisation. Continued urbanisation is expected to have several different effects on the transport system. It will lead to increased demand for public transport and to higher walking and bicycling shares in the inner city, but it will probably also result in more driving and increased traffic if the trend with stronger growth in the urban fringe zones continues. Whether transport demand in aggregate increases or decreases is dependent upon the how urbanisation trends develop and on how cities develop. The latter is dependent of their policies for city-planning, land-use and transport.

4.2 Demographical change

Demographic changes and demographic composition both influence transport. More people means more transport, both passenger and freight transport. However, the trend with an ageing society is increasingly important for the transport demand and for the mode of transport which is required. In many European cities, elderly people use public transport more frequently than younger people. Where the additional population may live and work is also an important determinant of travel mode choice. If housing and jobs are located on previous developed land (brownfield sites) it will generate more demand for public transport. If it takes place outside existing settlements (greenfield sites) it will generate more car-based transport (Metz 2012).

Internationally, the main current and future demographic trends are aging society and migration. According to Coosemans et al (2016) the aging issue have the strongest implications for the organisation of transport systems. They phrase it like this:

"*The percentage of Europeans aged over 65 is projected to rise from 16% in 2010 to 29% by 2060. The European population aged over 80 is set to rise from 4.1% in 2010 to 11.5% in 2060. Europe's population is also growing, with the EU population set to increase by 18 million people by 2050. The older European population of the future will have different transport requirements, and current transport and mobility enablers need to adapt to meet these challenges".*

The population in Norway also increases, partly due to immigration and partly because of extended life expectancy. The large cohorts born in the years just after the World War II are now in their 70-ties, and this "wave of elderly" will increase the need for transport and transport services. At the same time, todays elderly has higher income, better health, and a larger share of them have their own car, compared to elderly people some years back. This may reduce their demand for public transport but increase their car-based transport.

This can be illustrated by showing the share of daily travels by age and mode, and by age and travel distance in Norway, see figure 4.3 and figure 4.4. Except for the youngest age-cohorts, the share of daily travels by mode is remarkably stable over age groups. The number of kilometres travelled is high in all age groups over 35 years, except for the oldest. Persons in the oldest group travel at average only half the distance compared with the "young retired" at 67-74 years.

It is interesting to take a closer look at travels for the group 67 to 74 years of age. A few still take trips related to work, but the majority in this group is retired. However, their travel activity is still high; measured in number of kilometres travelled it is actually just as high as for the age group 34-44 years.

Persons between 67-74 years are born in the post-war period, which constitute the beginning of the wave of the elderly. In 2020 it was 75 years since the end of the second world war, and historically large numbers of childbirths took place in the next few years following the war. Therefore, the age group 75+ years will grow in the coming years and these elderly persons will probably have a different travel pattern than earlier cohorts. Several of them both have a driver license and a car, and they will probably be in a better health condition when getting older. All this indicates that there will be more elderly car drivers in the traffic in the years to come.

I addition, as more age groups with significant travel experiences and high expectations of an active and mobile life enter the oldest age cohorts, the demand for mobility will increase. This may expose the transport system for a different kind of pressure than before. More demanding customers will influence the planning and facilitation of the transport system in a way that makes it possible for the large group of elderly to travel, although their physical capacity to move may be reduced.

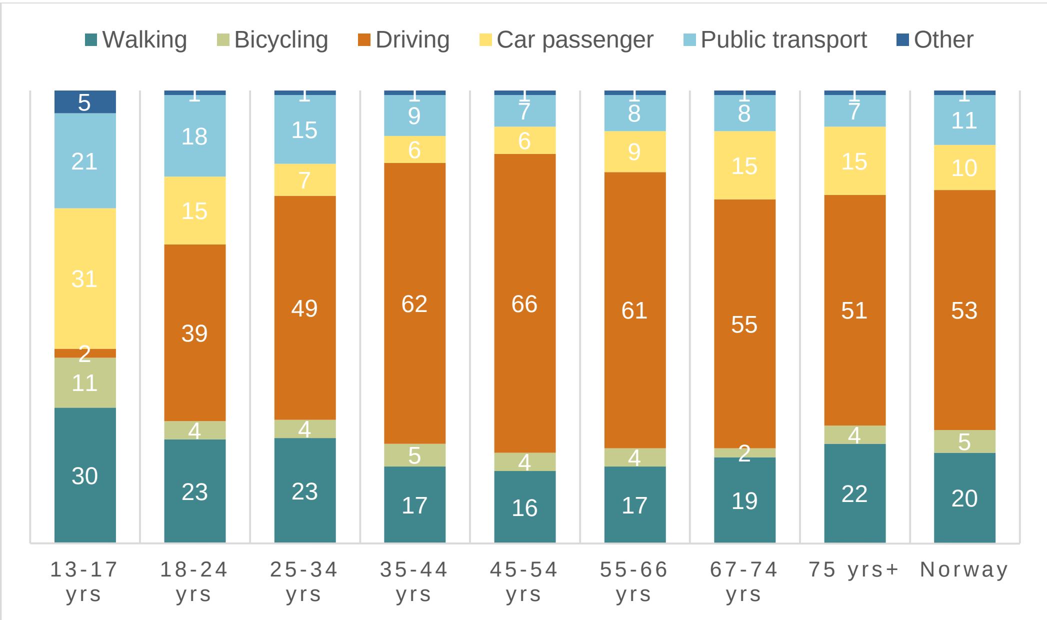

Figure 4.3: Mode of transport in by age. Per cent.
Source: Norwegian National Travel Survey 2018-19 (Grue et al 2021).

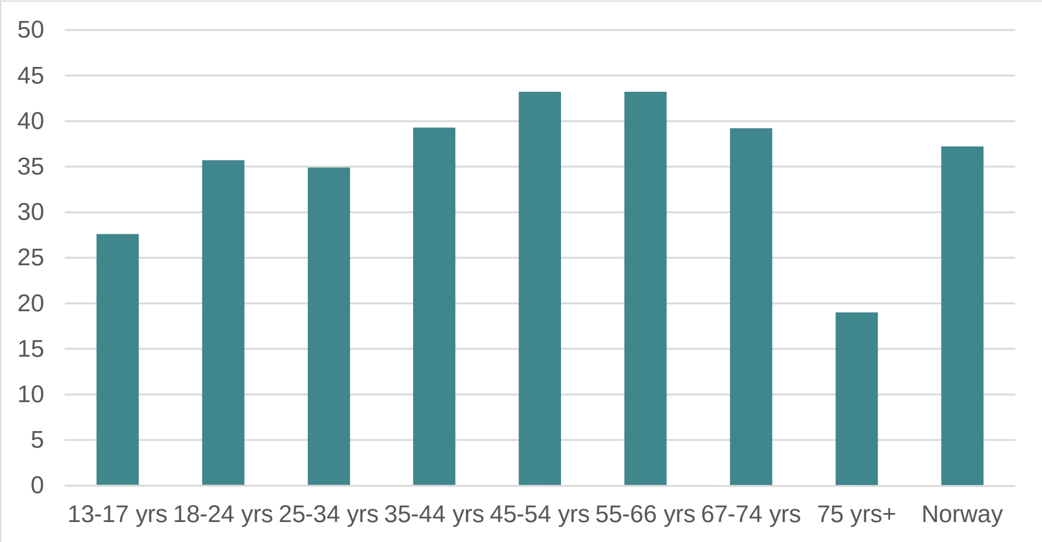

Figure 4.4: Daily travel by distance in km (air travels excluded) by age.
Source: Norwegian National Travel Survey 2018-19 (Grue et al 2021).

Loos et al (2020) discuss how smart transport may enhance older people's mobility by the use of digital technologies to improve age-friendly transport. Smart transport may increase the ability to move and thereby strengthen social and civic participation and access to community and health services.

At the same time as there is an increase in the elderly-population, there are large cohorts born in the late 1980-ies and 1990-ies that now are in the phase of entering the labour force and establishing families. These age groups will probably strengthen the trends of urbanisation referred to in section 4.1. Many will probably settle down in the hinterland of the city-regions in order to find more spacious and cheaper houses, or to live in places which they regard as more friendly to upbringing of children. This may cause more car-based urban transportation.

Smart urban transport, therefore must respond to different urban transport demands generated from both urbanisation and population trends. It must coordinate both urban freight and passenger flows by use of digital technologies.

4.3 Changes in work, industries and consumer preferences

Digitalisation affects jobs to a greater of lesser extent in all sectors, and particularly the organisation of work in many service markets. ICT investments lead to job losses in some sectors while creating jobs in others (IFT 2017). Digital transformation of markets and work is often driven by online platforms which facilitate interaction and transactions. *E-commerce* matches demand and supply of goods, and all kinds of services and information are delivered and exchanged by platforms through *e-work* and *e-communication* (Nof 2007).

There has been a very strong growth in online platforms in several service markets the past years, cf. chapter 3. Such platforms match demand and supply efficiently and they lower transaction costs. Platform services range from services delivered physically (accommodation, transportation, handyman or personal services) to digital services primarily delivered by the internet (financial trading and professional services). Strong growth of work in platform service markets may also change the organisation of work, from standard to non-standard work, i.e. work on a temporary or irregular basis, often part-time and frequently in combination with other activities and income sources (IFT

2017). Messenger (2019) operates with three generations of telework which have developed since the seventies and until today: home office, mobile office and virtual office. The first-generation of telework focuses mainly on one mode of work: *the home office* where the workplaces in or close to the employees' homes are remote, cheap and ecological, but also stationary. The second generation of telework is characterised by *the mobile office* where employees not only work at their home office, but could perform their work from many places, such as home, cafes, libraries on so forth. The third generation of telework is characterised by *the virtual office* which is accessible anywhere at any time, as this represents a seamless flexibility of the mode of work and of working time.

Increased use of teleworking and e-commerce may lead to changes in consumer behaviour and to changes in demand for passenger and freight transport. Intuitively one would expect that increased use of telework and home-offices should reduce the demand for passenger transport, and that extended use of e-commerce should increase demand for freight transport. However, the relation between ICT and transport is not that simple. It may take several forms, such as (Kos-Labedowics and Urbanek 2016):

- substitution – reduction of demand for transport, by means of telecommunication,
- enhancement – telecommunication may directly stimulate the demand for transport,
- operational efficiency – telecommunication rationalizes travelling by increasing the efficiency and effectiveness of transport system,
- indirectly, over a long term – e.g. telecommunication may influence planned land development, which in turn will influence travelling.

Complex relations between ICT and transport and between new technology and human behaviour make it difficult to estimate both substitution and enhancement effects. Applications of telecommunication which are assumed to be a substitution of transport are for instance: telecommuting, teleconferencing, teleshopping, telebanking, tele-entertainment, tele-education, tele-medicine, tele-justice. These are mostly services based on digital delivery where human interaction is less needed, whereas the growth in platform services based on physical delivery (both professional and personal services) may just as well enhance demand for both passenger and freight transport.

4.3.1 Telework and passenger transport

Several studies have focused on how ICT could reduce passenger transport demand, but how ICT could stimulate transport demand seems to be even more complicated to estimate than substitution effects. Kos-Labedowics and Urbanek (2016) refer to Mokhtarian (1990) who suggest three possible effects in short, medium and long terms:

- short term and direct ones – consisting of stimulating the demand for travel, through:
    - easier access to information about people, places, and events, which may result in willingness to visit/meet;
    - wide adoption of mobile telecommunications – equipping vehicles with communication devices may discourage from route optimization, car-sharing, or use of public transport;
    - interactive passenger information systems, which make journey planning easier;
    - extended possibilities for work during travels
- medium term and indirect ones – the time saved thanks to using telecommunication may be utilized for other journeys;

- long term ones – the above-mentioned possibility of introducing changes in public land development plans and in private location strategies, which may in the future increase the share of single journeys or the overall number of journeys made.

Telework enables employees to work from a distance, from a home-office or at other locations such as cafés or vehicles. This has the potential to reduce unnecessary work-related travel, particularly the daily commuting (Hynes 2016). Studies indicate that working from home only (full-day telework), decreases the daily commuting and increases the likelihood of avoiding peak-hours travel. However, there is no reduction in daily travel time for employees who carry out their work both at home and at the office (part-day telework) (Stiles & Smart 2020). Telework may also increase the demand for travel because teleworkers use the saved time to make additional trips, for instance to go shopping (Petterson et al 2018). Such rebound effects may increase the number of shopping trips and the total passenger mileage. In Norway shopping trips account for 28 % of all travels and 60 % of these travels are carried out by car (NTS 2019). If such trips are stimulated by telework, this may harm the climate and the environment. Finally, telecommuting may also affect housing location and thereby transport demand because the distance to work may become less important. If teleworkers have less daily commuting they may choose to settle down in more remote areas and become more car-dependent (Moeckel 2016).

The Covid19 pandemic has led to an unplanned and massive growth in working from home. Studies from USA show that about half of the workforce now work from home (Bartik et al 2020, Brynjolfsson et al 2020). The pandemic affects all sectors of the economy but some sectors and some occupations seem to be more suitable for telework than others. Home working and extensive use of ITC tools are easier to implement in high-tech sectors and for high-skilled employees than for low-skilled workers who often must work from physical locations. Younger people also adapt more easily to home work than older people. We do not know if and how the pandemic will lead to a permanent shift towards more home working and less commuting in the future, but it is not inconceivable. This comprehensive experiment may lead to changes in industrial structures, organisation of work and employee attitudes (Kramer & Kramer 2020), and it may be a tipping point for home working. However, how this may affect the demand for transport in the next round is not easy to predict.

4.3.2 E-commerce and freight transport

The rapid growth of the Internet has led to a significant increase in e-commerce the past years (Nisar and Prabhakar 2017). Due to better prices, larger selection, convenience, and time savings e-commerce is one of the fastest growing marketing channels for different kinds of products and services for consumers (Schröder et al 2016, Verhoef et al., 2015; Savelsbergh and Van Woensel, 2016; Hübner et al., 2016). E-commerce can be divided into five business types: business-to-business (B2B), business-to-consumer (B2C), business-to-government (B2G), consumer-to-consumer (C2C), and mobile commerce (Chen et al 2018). Online retailing, typically, must assemble (i) small orders from (ii) a large assortment under (iii) great time pressure and must flexibly adjust order fulfilment processes to (iv) varying workloads. This requires specific warehousing systems (Boysen et al 2019) and very efficient logistics service providers for handling outsourced e-commerce logistics orders (Leung et al 2017).

E-commerce has augmented the importance of freight transportation but exactly how it will affect freight transport and logistics is not quite clear (Cardenes et al 2017). It can both increase and decrease the amount of travel and it can alter the travel patterns of individuals in different ways; online retailing can be a complement to or it can be a substitute to traditional retailing (Friederiszick and Głowicka 2015). However, several studies point out that fast and flexible deliveries, home deliveries and growth in return deliveries (reverse logistics), will lead to increasing freight volume in residential area. This may produce negative effects like congestion, noise and environmental concern from increased traffic. In their studies on e-commerce Savelsberg & van Woensel's (2016) and Petterson et al (2018) claim that transport of goods to consumers' homes rather than to retail stores will increase the number of freight movements because the size of the deliveries will typically be small, and the relative increase in the number of freight movements will be even larger. Urban areas with high population densities are particularly exposed to negative effects of increasing freight volume from e-commerce.

To summarise: Recent research on e-commerce, freight transport and urban logistics, and telecommuting and passenger transport, indicate that there are complex relations between digitalisation and transport. Digitalisation may create new forms of work and change markets and industries, and this will undoubtedly have impacts on demand for both passenger and freight transport. However, there is no simple answer to whether increased use of ICT in work and industries will contribute to a substitution of transport or enhance transport demand. Some trends indicate a reduction in demand, whereas other points to an increase in transport demand.

5 Climate and environmental trends

5.1 Introduction

Climate and environmental challenges will enforce regulations for decarbonisation of transport and promote use of zero-emission vehicles for both passenger and freight transport. New vehicle and fuel technologies (electrification) and new business models for mobility (shared mobility) together with digitalisation and automatization (ICT and ITS), are supposed to result in a modal shift for both passenger and freight transport. Thereby, this may lay the foundation for disruptive changes and a transition to a more efficient and sustainable transport system.

Climate change problems are related to transport in two different ways. Transport has a huge impact on global climate and local environment through GHG emissions, air pollution etc., but the transport system and its infrastructure are at the same time heavily exposed to climate change through natural disasters and hazards (extreme weather, temperature variability etc.). Therefore, transport both contribute to climate change and it suffers from it. In both cases, mitigation and adaptation measures are required in order to bring about a sustainable transport system. New vehicle and fuel technologies are important for solving the climate emergency but likewise important are social and digital transport innovations, such as shared mobility and ITS, for decarbonising the transport system and contribute to a shift to cleaner and more sustainable modes of mobility (IFT 2019).

This chapter will focus particularly on measures and disruptive transport innovation in which digitalisation plays an important role.

5.2 Transport and exposures to climate change

The transport system, and particularly the road transport system, is vital for people's daily mobility and for freight transportation. However, climate change has increased the vulnerability of the transport systems and it makes a transition to sustainable transport more urgent because transport not only contribute to climate change but also because it suffers severely from the consequences of climate change. Therefore, climate change is a driver for sustainable transport in a double sense.

The transportation system faces both what Markolf et al (2019) label direct and indirect vulnerabilities or "pathways of disruption". The main focus is often on direct physical impacts of climate change such as extreme weather events (flooding, landslide, heat waves etc.) on the transport system (washout of bridges, blocked roads etc.), or on direct non-physical impacts on human health and travel behaviour. However, indirect vulnerabilities due to increased complexities within and interconnections between the transport system and other critical infrastructure, is likewise important. The transport system is closely interlinked to, for instance, the electricity system and the ICT-system both which can be exposed to extreme weather events. Power failure may lead to disruption in transport and communication systems, and a breakdown in the ICT-system will disrupt the traffic management system, real-time traffic and so forth. The use of Intelligent Transport

Systems (ITS) is important to avoid traffic congestion and to foster the use of intermodal transport (road, rail and waterways); but extensive use of ITS may also increase the vulnerability of the transport system.

The need for making the transport system more robust and resilient by mitigation and adaptation measures has increased considerably as a consequence of climate change. In addition to improving critical infrastructure, an extensive research effort is taking place for developing new and innovative vehicle technologies, advanced engine management systems and efficient vehicle powertrains. The use of biofuel in transport is increasing, not only of the first generation (vegetable oil, biodiesel, bio-alcohols and biogas from sugar plants, crops or animal fats etc.), but also of the second (biofuels from biomass, non-food crops including wood), third (biodegradable fuels from algae) and fourth generations which include electro-fuels and solar fuels (Aro 2016). Consumer information targeting less car driving and more use of public transport, and non-motorized modes such as walking and biking, is also more common.

5.3 Digitalisation and decarbonisation of transport

Transforming transport is one of the biggest challenges for climate and environment for all countries. The demand for mobility of people and goods have increased rapidly in the past decades, and the transport sector relies heavily on fossil fuels, which is detrimental to both the global climate and the local environment (Langeland et al 2018). In order to reduce GHG emission in the transport sector, The Norwegian government has launched several measures in the governmental report Transport 21 (Transport 21):

- increase the use of zero-emission technology and biofuel
- from 2025 all new passenger cars and light vans should be zero emissions vehicles
- zero emissions ferries, use of biofuel in planes and develop electric planes
- facilitate the use of intelligent traffic systems, autonomous driving, shared mobility (measures that include digitalisation)

In addition to transport GHG emissions, transport-related environmental pressures (air pollution, biodiversity fragmentation, traffic congestion, inefficient use of urban space and noise) also constitute important drivers for more sustainable transport. New societal and technological advances (innovations) have been introduced in recent years (shared mobility, mobile applications, mobility platforms). Such transport innovations are usually based on digital technologies (enabling technologies) and they are assumed to bring about a more sustainable transport or green mobility (se chapter 3 for elaboration of digital technology trends).

The pressure from climate change and other environmental trends for decarbonising transport can be divided into two main pathways – green cars and less cars (Geels 2012). The first pathway implies cleaner cars (electric vehicles, use of biofuel etc.) that will reduce GHG emissions but not necessarily reduce driving or change the transport system. Cleaner cars may even boost driving because reduced emissions can make it more attractive to use a car. Extended use of digital technology on the other hand may lead to less cars and less driving if it is combined with proper legislation and change of attitudes related to sustainable transport. Digital technologies may encourage the uptake of shared mobility and connected and autonomous vehicles and improve public transport. This may have a substitution effect and reduce transport demand. Table 5.1 shows possible mitigation measures and disruptive developments for decarbonisation of transport that include digitalisation (IFT 2019):

Table 5.1: Current and high ambition scenario specifications for urban transport.

Potentially disruptive Developments	Sector	Current ambition	High ambition
Shared mobility (MaaS)	Urban passenger	2050, 20% of travellers	2050, 50% of travellers
Electronic road pricing	Passenger and freight		
Autonomous vehicles	Passenger and freight	Continuation of current levels uptake	
Teleworking	Urban passenger	2-20% of trips are affected by 2050, dependent on region	3-25% of trips are affected by 2050, dependent on region
E-commerce	Freight	Slight increase in urban freight demand (5% in more developed regions by 2050)	
3-D printing	Freight	No change from current uptake	

Source: IFT Transport Outlook, table 3.1.

Transport-related climate and environmental trends may lead to deep changes in the transport systems in the years to come. Several factors could disrupt the current transport system and digital technologies will certainly play an important role in these issues.

6 Concluding remarks

Different megatrends seem to be driving a set of radical innovations in the transport sector. First and foremost are digitalisation and technology trends, which may cause several potentially disruptive developments within both passenger and freight transport in the years to come. Digitalisation has been at the forefront of mobility development for quite some time and it is the motor of the ongoing 'servitization' of the automotive industry. Key words related to digitalisation are digital platforms, shared mobility and mobility as a service (MaaS), e-logistics, intelligent transportation system (ITS) and connected automated vehicles (CAV). Particularly connected automated vehicles, in combination with other parallel trends such as artificial intelligence, electrification and the sharing economy, hold the potential for a safer, more efficient, accessible, equal and inclusive mobility. However, due to current limitations of technological capability as well as trust, security, safety and regulations, many challenges remain for fully reaching the benefits of CAV.

Secondly, social trends related to urbanisation and demographic shifts, changes in labour markets and consumer preferences will have impacts on the demand for personal mobility and freight transport in the coming years. Urbanisation can lead to increased demand for public transport, more walking and bicycling in the inner city but also to increased car-based transport in the larger city-regions. An ageing society may also affect both the transport demand and the mode of transport. The "wave of elderly" will increase the need for transport and transport services in general, but today's elderly will probably have a different travel pattern than earlier cohorts. Increased use of teleworking and e-commerce may also lead to changes in consumer behaviour and to changes in demand for both passenger and freight transport. However, complex relations between ICT and transport and between new technology and human behaviour makes it difficult to estimate possible impacts on transport demand both on short and long terms.

Finally, climate change and environmental trends will also influence future transport demand. The transportation system faces both direct physical impacts (extreme weather events) and indirect vulnerabilities due to increased complexities within and interconnections between the transport system and other critical infrastructure (electricity and ICT systems). The need for making the transport system more robust and resilient has increased considerably because of climate change. New societal and technological advances based on digital technologies have been introduced in recent years (shared mobility, mobile applications, mobility platforms) in order to bring about a more sustainable transport system.

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