SELF-DRIVING CARS

– the technology behind and the way forward

Teknologirådet

SELF-DRIVING CARS

THE TECHNOLOGY BEHIND AND THE WAY FORWARD

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FOREWORD

The Norwegian government has made it possible to test self-driving cars on Norwegian roads. The first applications have already been granted and public testing will shortly begin. The development towards self-driving vehicles on the road will provide many new opportunities for society, but also new challenges. Driving may become safer and more accessible for all, and the time spent inside a car may then be used to relax or work. With electrification, operating costs may become considerably lower, resulting in a private chauffeur experience for the price of a bus ticket. Such a development may also mean increased road congestion and a need for higher traffic capacity.

This report is the first in a project by The Norwegian Board of Technology on Automated transport. It provides an overview of the technology, analyses the time frame and need for new infrastructure, and highlights challenges concerning safety, responsibility and privacy. In the next report, we will look closer at how organisation and urban planning may be affected by digitalisation and self-driving vehicles.

The project's expert group consists of the following members:

- Rikke Amilde Seehuus, researcher at Forsvarets forskningsinstitutt (FFI) ("The Norwegian Defence Research Establishment")
- Jørgen Aarhaug, researcher at Transportøkonomisk institutt (TØI) ("Institute of Transport Economics")
- Lone-Eirin Lervåg, researcher at SINTEF Teknologi og samfunn ("SINTEF Technology and Society")
- Håvard Haarstad, professor of social geography and sustainable urban development at the University of Bergen (UiB) and member of the Norwegian Board of Technology
- Geir Malmedal, manager of the political department at the Norwegian Automobile Federation (NAF)
- Erling Dokk Holm, associate professor at the Institute for Marketing, Economy and Innovation, Kristiansand University College

The Norwegian Board of Technology's project managers Joakim Valevatn and Adele Flakke Johannessen are responsible for leading this report, and I want to extend a warm thanks to them and the expert group for their great work.

Tore Tennøe
Director, the Norwegian Board of Technology

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ABSTRACT

Just few years ago, developing self-driving vehicles was impossible, but now they are being tested all over the world. Several car manufacturers and technology developers estimate to have self-driving services ready for the market in 2021. Initially, it will be automated taxis and minibuses we see, whilst it will take time before we see privately owned self-driving vehicles ready for the market.

The Norwegian government has been very proactive, and testing of self-driving vehicles on public roads will begin in 2018. Self-driving vehicles can give better traffic flow and increase road safety. Additionally, the technology may pave the way for new possibilities in urban planning if parking spaces are freed up for other uses and congestion is reduced.

HOW DOES THE CAR DRIVE ITSELF?

In order to drive themselves, self-driving cars are fitted with sensors, powerful computers and artificial intelligence. A self-driving car must be able to manage the same tasks that a human carries out whilst driving. The hardware needed for a self-driving car to work is getting cheaper and more compact

Even though self-driving cars are ready to be tested on roads, there is still more development needed before they are completely ready to be deployed in regular traffic:

- Weather conditions and driving: In Norway, driving during winter can be challenging, but improvements in the sensors and artificial intelligence are likely to solve these challenges.

- Edge cases: The majority of what occurs in traffic follows predictable rules, and is relatively simple for a computer to carry out. But the vehicles must also learn to manage more uncommon events. Further testing and advanced software is needed for this.

WHEN WILL THEY TAKE OVER THE ROADS?

The development of self-driving vehicles can be separated into three categories: Self-driving private cars, robo-taxis and automated public transport.

To begin with, slow-moving minibuses in urban traffic or on predetermined routes will be made automated, which may be ready this year. During the next 5 years, we can expect the technology to facilitate self-driving taxis in some urban areas. The technology for entirely self-driving private cars are still a significant step away, but partial automation may occur over time.

How quickly the various types of vehicles will impact traffic depends on technological development, political decisions and societal changes. For example, the expansion of robo-taxis may be affected by competition policy and mobility pricing, whilst the expansion of self-driving private cars may be determined by how far the regulations allow it grow.

EFFECT ON INFRASTRUCTURE

Automated vehicles may affect the need for investment in infrastructure in two main ways:

- **Capacity:** If cars are able to drive closer together, an increase in traffic can be supported without the need to build extra roads. On the other hand, increased access and lower prices may lead to a demand for increased road capacity.
- **Specifications:** Automated vehicles may demand new standards for how infrastructure is built, either in the form of communication technology along the roads, or physical changes such as boarding and alighting points.

The greatest changes will most likely be behavioural changes as a result of the technology: That is, there may be either more cars on the roads due to an increased demand for private driving, or fewer cars on the roads as a result of carsharing and carpooling.

SAFETY, RESPONSIBILITY AND PRIVACY

The potential safety advantage of self-driving cars is based on the estimate that around 90% of today's traffic accidents are caused by human error. Humans are known to fall asleep behind the wheel, drive under the influence of alcohol/drugs, use mobile phones whilst driving or do other things instead of focusing on the road. Self-driving cars will allow passengers to both text and relax without putting anyone at risk. At the same time, new challenges arise when the line between humans and machines is blurred. Especially concerning partial automation, where we see a need for the authorities to take action in order to maintain good road safety.

Automated vehicles may also create challenges to privacy: The vehicles utilise cameras and extremely detailed maps in order to navigate their surroundings. This means that the companies who provide the vehicles can collect and store a great deal of information about people and properties outside of the vehicles. Automated vehicles will also be able to collect a great deal of information about people's travel habits.

THE WAY FORWARD

Norwegian authorities have facilitated development by approving legislation regarding the testing of self-driving cars. When automated vehicles are allowed on the roads with regular traffic, it is important to take political measures to ensure that there are no negative consequences with regard to safety, privacy and traffic flow. The technology is one step ahead of the regulations. Therefore, it is important that correct conditions for the development are put in place now. Based on the technology as described in this report, we believe there is a need for policy design in the following areas (for a more detailed description and justification, see chapter "The way forward"):

Work on Norwegian legislation must start now
Many of the laws and standards for vehicles are developed internationally, but there is also a need for the Norwegian laws to be updated. In order for automated vehicles to be used on the roads as more than a test project, the expert group believes it is vital that the work on new legislation begins now.

The responsibility between humans and machines must be clarified
The "Testing of Automated Vehicles Act" requires that a person assuming responsibility for the test must be appointed. By a general law, the responsibility

must be divided in a different manner and the expert group recommends that the various levels of automation should be taken into account.

Self-driving cars must not discriminate

Unlike humans, who will react instinctively in order to avoid a sudden accident, computers, in theory, are able to make a rational decision. This requires ethical decisions to be made before any accident occurs. This can be particularly controversial in cases where the vehicle must choose between the safety of passengers in the vehicle and those outside.

Our recommendation is that ethical guidelines for how automated vehicles should act in traffic should be established. This is important in order to ensure transparency and predictability for all road users. A paramount ethical principle should be that the vehicles must not be able to be programmed to discriminate between people based on their age, gender or other aspects.

Remote control of vehicles must be limited

If unexpected situations arise that the vehicle's software cannot solve, it may be necessary for a human to take over control of the vehicle via remote access. But the possibility of controlling a vehicle remotely could potentially have major consequences in the event of a cyber-attack.

The expert group recommends that the opportunity to control a vehicle via remote access is regulated. In order to reduce possible consequences, the speed of vehicles that are remote controlled should be limited so that they cannot cause significant harm.

Use of automated vehicles should only occur in approved and specially designed areas

We recommend that automated vehicles are only permitted on routes and in areas that are pre-approved by the road authorities for this type of use. Since the risk increases in mixed traffic, other road users should be made aware that the roads are being shared with automated vehicles, for example, with the help of road signs.

Partial automation must be regulated better

The Norwegian Board of Technology's expert group recommends that systems for partially automated vehicles should be better regulated than they currently are. In practice, these systems fall outside of today's legislations, since the driver is responsible when testing occurs. New regulations should differentiate between technology that supports the driver and technology that pacifies the driver to the extent that it is difficult to take control over the vehicle at short notice.

Self-driving cars should not be used as rolling surveillance cameras

Automated vehicles utilise a number of cameras in order to drive on the roads. Over time, if the technology is embraced by many, fleets of automated vehicles will make up massive networks of cameras that could be used for surveillance.

Therefore, we recommend that Norwegian authorities pay particular attention to how information from sensors and cameras on automated vehicles are to be processed and stored.

Travel on Norwegian roads must still be possible without the need to be continuously tracked

A self-driving car will know where it is located at any point in time and will most likely also be able to retain a part of its own location history. This means that a great deal of information about how passengers travel may become accessible.

It should always be possible to drive in private mode, where the car does not use any more information about us than what is necessary to deliver a safe journey. It is therefore necessary to establish clear guidelines for who owns the data, how it will be stored and how it will be processed after the user has provided a voluntary and informed consent.

Take control of 3D maps

Extremely detailed maps are an advantage to the proper functioning of a self-driving car. Large, private companies such as Google, Apple, Tesla, Baidu, collect this data and currently, have no obligation to share this with the public.

The expert group believes that Norwegian authorities should take an active role in managing the mapping data for automated vehicles. It should be a condition, in order to use Norwegian roads, that the companies share information that may benefit the community. For security reasons, the authorities should consider how much of this information should be available to the public.

INTRODUCTION

The post-war period saw the car change how and where we live. Now, it may do so again.

In Norway, private cars have been widely available since 1960. In that period, the car has contributed to significant changes in society. The car is Norway's most important means of transport and a necessity for the functioning of everyday life for many people. Simultaneously, it also brings disadvantages in the form of accidents, pollution and lost time.

New leaps in technology mean that now, it is possible to think anew about how we organise traffic:

- **Electrification** reduces CO2 emissions from driving
- **Digitalisation** and communication vehicles may provide better traffic organisation with the help of fleet management and new business models for carsharing
- **Self-driving cars** may make driving safer and provide better navigation for many

RACE FOR THE ROADS

Not long ago, it was considered a technological impossibility, but now, there is a competition between traditional car manufacturers and new technology companies to place self-driving cars on the roads. Traditional car manufacturers such as Ford, Volvo and Mercedes aim to have their own products on the market between 2020–2025.[1] At the same time, they are competing with technology companies like Waymo, the Chinese company Baidu and Uber.

Rapid technological development now means that self-driving cars are becoming part of the transport system. In addition to new types of vehicles, digitalisation is also changing how the transport system is organised.

MASSIVE OPPORTUNITIES

Self-driving cars may provide great gains to society once the technology is ready for the roads:

- **Better accessibility:** Adults who do not have a driver's license, children, the blind and people with disabilities may be given the opportunity to drive a car. This may make access to transport more fair than it is today.
- **The environment:** Digitalisation provides an opportunity for better traffic coordination. If more people are carsharing with electric cars, it spells good news for the environment.
- **Improved road safety:** Over 90% of all traffic accidents are caused by human error.[2] In Norway, over 100 people die in traffic accidents each year. If the technology becomes safer to use than human drivers, it may be possible to reduce this number to 0 in Norway.
- **Time and money saved:** Taxis and public transport may become cheaper if driver costs disappear. Due to digitalisation, the supply of these transport services could be better adapted to individual needs.

[1] Driverless Car Market Watch (2018)
[2] US Department of Transport (2018)

Additionally, the time spent driving yourself around could be used on other things.

- **Improved use of space:** Automated vehicles may reduce the amount of parking spaces needed in towns. This could be beneficial if these spaces are then used for more profitable goals.

TRAFFIC OBJECTIVES

In the National Transport Plan 2018-2029 (NTP), investments of over 1000 billion NOK are planned for improving traffic accessibility, the environment and road safety in Norway.[3]

Good mobility is a prerequisite for a modern society. The facilitation of transport so that it can operate in an effective and predictable manner is vital for a well-functioning society. The Norwegian government wishes to ensure high-quality accessibility and universally designed travel links, and make journey planning easier with better information tools.[4]

Due to expected population growth and a focus on greenhouse gas emissions, the Storting ("Parliament of Norway") has declared a goal that in the largest towns, private car use shall not grow from 2016 to 2030. The goal is to increase the growth of passenger transport in urban areas via public transport, cycling and walking. As it stands, it seems that towns will have trouble reaching this objective.[5]

Since the 1970s, long-term and purposeful road safety work has been conducted in Norway. But still, over 100 people die in traffic accidents each year.[6] The Norwegian governments main objective regarding transport safety is to reduce the number of transport accidents to zero (the "zero vision"). The zero vision – "a vision of a transport system that does not lead to one single loss of life or serious injury" – was adopted by the Storting in connection with the National Transport Plan 2002–2011 and is maintained in all subsequent National Transport Plans, as well as in the annual state budgets.[7][8]

[3] Meld. St. 33 (2017)
[4] Meld. St. 33 (2017)
[5] Statens vegvesen (2018)
[6] Statistisk sentralbyrå (2017)
[7] Statens vegvesen (2010)
[8] Meld. St. 33 (2017)

HOW FAR DOWN THE ROAD ARE WE?

In January this year, the law on testing automated vehicles on public roads came into force. By allowing the testing of self-driving cars, the government is facilitating technological development.

Automated vehicles and digitalisation may be a decisive factor in achieving the main objectives in the NTP, but the development may also work against them. Eventually, automated vehicles may replace many jobs. The digitalisation of transport also means there is an increased danger of cyber attacks or technical errors. And cheaper and more available transport may lead to a drastic increase in crowds of traffic.

In order to achieve the objectives it is therefore important that politicians and decision makers understand the technology, and get a picture of when and in which form it comes.

In later publications, we will look closer at how organisation and urban planning may be affected by digitalisation and self-driving vehicles.

STRUCTURE OF THE REPORT

Chapter 2, “How does the car drive itself?”, describes what automated vehicles are and how they work.

In chapter 3, “When will self-driving cars take over the roads”, we have divided the development into three stages: private cars, taxis and public transport. For each of the stages, we demonstrate possible consequences and ways in which politics can affect the development.

In chapter 4, “Safety, responsibility and privacy”, we look at, among other factors, data security, the risk of Norwegian roads being surveilled, and challenges that arise when responsibility is shared between humans and machines.

In the final chapter, “The way forward”, we look at some of the political questions that the technology may ask of us, and provide recommendations about safety, responsibility and data policies regarding self-driving cars.

HOW DOES THE CAR DRIVE ITSELF?

Self-driving cars were a pipe dream 15 years ago. Now, they are driving on roads all over the world. Great leaps in technology and artificial intelligence have made this possible.

In 2004, the United States Department of Defense announced The DARPA Grand Challenge: a competition to build a self-driving car able to drive a 240km (150 miles) route in the Mojave Desert region of the United States. The car that travelled the furthest distance along the road only drove 12km (7 miles). The following year, five teams completed the route, and the winner owed its success to new methods of machine learning.

The DARPA-winner continued the technological development as a Google project, which now has become a separate company called Waymo. In November, 2017, Waymo's self-driving cars were advanced enough to function in normal traffic and without the need of a safety driver behind the wheel in Phoenix, Arizona. Soon, Waymo will begin to offer taxi services in several American cities.[9]

[9] Waymo.com

THE TECHNOLOGY BEHIND SELF-DRIVING CARS

In order to drive themselves, self-driving cars are fitted with sensors, powerful computers and artificial intelligence. A self-driving car must be able to manage the same tasks that a human carries out whilst driving:

- **Know where it is:** With the help of sensors and satellite navigation, the car is able to position itself in the road and where it is located on the map.
- **Understand its surroundings:** Machine vision is utilised in order to view and interpret the surroundings, such as reading signs or distinguishing between pedestrians and cyclists. In addition, laser and radar sensors are used in order to judge the distance between the car and objects both on and off the road.
- **Make decisions in traffic:** A self-driving car must be programmed to follow traffic regulations, choose the best route from A to B and how to interact with other road users.
- **Manoeuvre:** Once the car knows where it is and where it needs to go, this information must be turned into instructions for the car on how to accelerate and steer.

MACHINE LEARNING AND ARTIFICIAL INTELLIGENCE

A large number of tasks that a car must perform can be programmed in advance, such as traffic regulations or commands for how common traffic events should be handled. However, since a great deal of what happens on the road are unique events, it is impossible to program everything beforehand. Therefore, methods of machine learning and artificial intelligence are also employed to enable the cars to drive:

- **Image recognition:** It is difficult to program rules for how a camera should differentiate between various objects on the road. Therefore, millions of example images are used to train the computer to differentiate between cyclists, children and pedestrians.
- **Behaviour:** Machine learning can also be used to learn what the car should do in different situations. Instead of explicitly programming traffic regulations and the like, these can be learnt from recordings of cars driven by humans. The recordings contain both what the sensors

see and what action the driver took. Recordings from millions of kilometres driven are necessary in order for the car to be able to learn what it should do in the majority of road situations. [10]

- **Simulation:** Traffic scenarios can be recreated in digital surroundings, where they can be tested repeatedly until the computer discovers the best solution to the problem, much like a video game.[11]

One challenge of using methods of machine learning is that it can be difficult or even impossible to understand what the computer has actually learnt. This makes it difficult to guarantee how computers will handle new situations and requires a great deal of empirical testing. This will be problematic if an accident occurs and cannot be explained afterwards. At the same time, some tasks are virtually impossible or extremely impractical to solve without machine learning, such as recognising objects on the road.

SENSORS AND INTERPRETATION OF SENSOR DATA

A self-driving car uses a number of different sensors in order to orient itself and view the outside world:

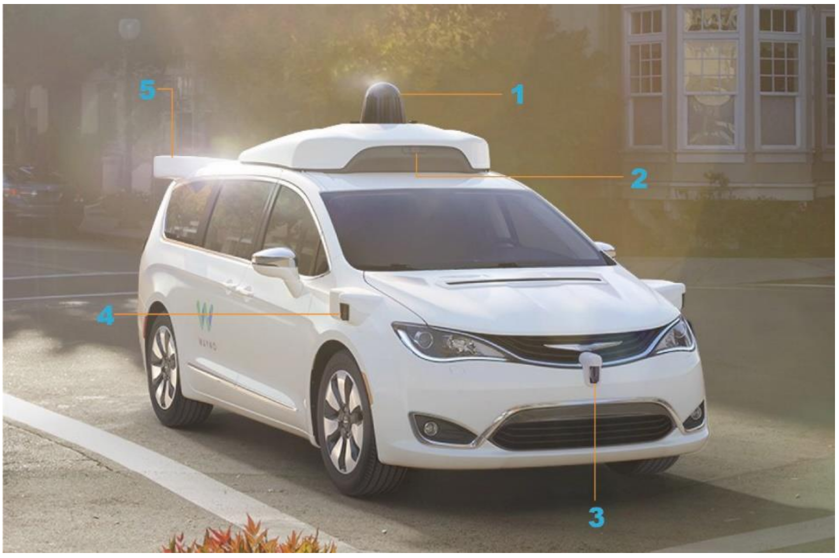

Image: Waymo

[10] Nvidia (2017)
[11] The Atlantic (2017)

1. **Lidar** is a laser surveying method that provides a detailed and three-dimensional image of the surroundings. This type of sensor is extremely precise but is very expensive and struggles in poor weather conditions.
2. **Camera** and image recognition identifies signs and objects on the road. Cameras are very cheap and provide detailed information but do not function well in the dark and are unable to precisely measure distances.
3. **Radar** detects moving objects and measures distances. It functions in all weather conditions but provide little detail.
4. **Inertial measurement units** are used to measure the whereabouts and speed of the car. This is used to measure how the car moves.
5. **GPS** is used to determine the position of the vehicle. Since GPS signals can be unstable, the car also has additional systems that allow it to measure its exact position at all times. For example, it will be able to orient itself to a pre-made map, as well as by measuring motion.

The vehicle uses powerful computers and advanced software in order to interpret the information from the sensors. *Sensor fusion* consists of combining information from several different types of sensors, so that you get the most detailed image possible. Utilising several different types of sensor ensures *redundancy,* so that the car can continue to drive even if one of the sensors is disrupted or falls out.

Tesla bets on camera vision

For the vast majority self-driving car prototypes, a lidar sensor is vital in order for the car to be able to get an accurate enough picture of its surroundings in order to drive safely.

The electric car manufacturer Tesla is an exception, and currently sells cars which they claim are equipped with all the hardware needed in order to make them completely autonomous.[12] Thus, they are gambling on camera vision and radar being enough. To achieve this, they need to develop artificial intelligence that works well enough so that they can upgrade cars with new software when it becomes available.[13]

If Tesla manages to develop completely autonomous cars without the need of lidar sensors, it will mean that self-driving cars will become much cheaper to produce, making them an average household possession. Some experts disagree as to whether completely autonomous vehicles are possible without the use of lidar.[14]

MORE POWERFUL AND MORE COMPACT HARDWARE

The hardware needed for a self-driving car to work is getting cheaper and cheaper and more compact all the time. Sensor systems that were previously the size of a coffee table attached to the roof of the car can now be integrated into mirrors, grilles and on the roof. The transition to electric propulsion means that cars are becoming easier to construct.[15] A computer with the power equivalent to 150 laptops can now be produced the size of a shoe box that fits into the glove compartment.[16]

HD MAPS

A self-driving car needs a model of the outside world in order to orient itself. In principle, this could be a simple digital 2D map, similar to those used on a smart phone. If the car is to only orient itself using a simple map, it has to use a great deal of computing power to understand and map the surroundings.

Therefore, it is common to use high-definition maps (HD). These are three-dimensional maps with a lot of information about the roads the car is to drive on. These are created by manually driven cars driving along the routes that need to be mapped. Self-driving cars can then be used to continuously update the maps.

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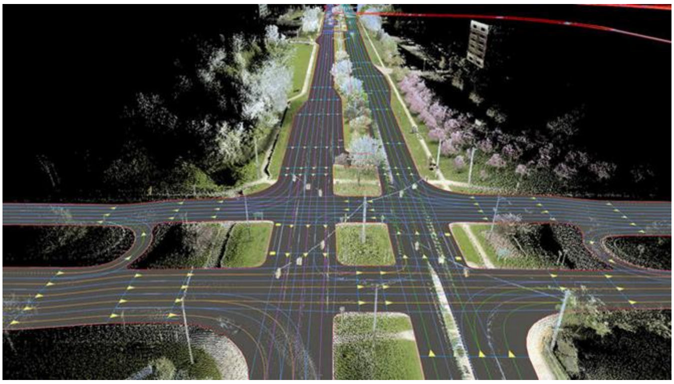
[12] Tesla (2018)
[13] The Verge (2018)
[14] The Verge (2018)
[15] Jenssen G. D. (2017, p. 197)
[16] Electrek (2017)

By using extremely detailed HD maps, the cars can concentrate their computing power on making quick decisions on the road.[17]

By having access to extremely detailed maps, a car can orient itself without the need of GPS. The map can also contain information that is not visible, for example, what the ground looks like under the asphalt using radar. This way, the car can orient itself even if the view ahead is poor.



Detailed: *A HD map contains information about the roads, the terrain and features in the surroundings which means the car can orient itself with ease. (Image: Here.com)*

[17] Seif, Hu (2016)

China forbids foreign HD maps[18]

A HD map has centimetre-level accuracy. According to Chinese law, public maps are not permitted to be more precise than 50 metres. Neither are they allowed to contain information on the heights of bridges and other types of infrastructure. Information on geographical data such as elevation and coordinates are also not allowed to be included on public maps. Due to this type of regulation, it is impossible to produce public maps for automated vehicles that comply with the legislation.

For this reason, no foreign companies are allowed to conduct mapping surveys for self-driving cars within China. This also includes cooperation between Chinese and foreign companies, as well as foreign investments related to mapping technology.

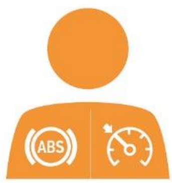
Chinese businesses wishing to conduct electronic mapping require a separate license in order to do so. Thus far, 14 businesses have received a license for this. It is still unclear how today's strict regulations will affect the opportunities that Chinese companies have to produce HD maps for automated vehicles.

LEVELS: FROM MANUAL TO AUTOMATED DRIVING

It is common to classify grades of automation from level 0 to level 5 according to the standards set by SAE International. The levels signify to what extent the vehicle is automated and who is responsible for keeping the car driving along the road:[19]

[18] China Law Insight (2018)
[19] Nhtsa.com

Level 0 – no automation:
The driver has complete control at all times, and no system is used to intervene.



Level 1 – driver-assistance:
The driver has complete control of the steering or speed, whilst one of the functions is automated. Such as adaptive cruise control.

Level 2 – partial automation:
Steering and speed are automated under certain conditions, but the driver must always be ready to take control.

Level 3 – conditional automation:
Steering and speed are automated under certain conditions, and the driver is warned in good time to take control when it is needed.

Level 4 – high automation:
The car has complete control of the steering and speed under certain conditions. This may be applicable within a limited geographical area, for example.

Level 5 – complete automation:
The car has complete control at all times, and under all conditions.

In accordance with the Road Traffic Act, the driver must always pay close attention to the road. Tesla's Autopilot is considered a level 2 on the SAE scale, since the version currently being tested requires the driver to focus on the road at all times. A change in legislation will be needed for using this function without paying attention while it is engaged.

The completely autonomous taxis and minibuses that exist are level 4, since they only operate within well-mapped and predefined areas.[20] It may take a long time before level 5 technology is ready, since this will require the car to be able to drive everywhere regardless of how well the road is mapped or signposted.

CARS THAT ARE ABLE TO COMMUNICATE

Cooperative Intelligent Transport Systems (C-ITS[21]) denotes transport technology that is communicative and cooperative. This can mean that the cars are able to communicate with each other (V2V – vehicle to vehicle) or with the infrastructure (V2I – vehicle to infrastructure). The aim of C-ITS is to promote safety, efficiency and better environment.[22] For example, a car may receive a warning if there is an animal in the middle of the road and a car further up the road slams its brakes, or if there are other traffic problems ahead.

Some experts point out that it is more important to develop smart vehicles rather than construct smart roads. By this, they mean that vehicles should be able to manage the roads by themselves, instead of being dependent on communication with specialised infrastructure along the roads. This would reduce the need for investments in new infrastructure.[23]

Within the European Commission's strategy for C-ITS, it is recommended that all automated vehicles should communicate with each other and infrastructure. Exactly which infrastructure this refers to is still uncertain, but existing mobile networks and the 5G network will most likely cover a some of the necessary communications (e.g. the remote control of vehicles).[24]

[20] Jenssen G. D. (2017, p. 198)
[21] EU (2018) (C-ITS = connected intelligent transport systems)
[22] Sintef.no
[23] Lipson & Kurman (2016, p. 1450)
[24] European Comission (2017, 20 September, p. 16 & p. 98)

REMAINING TECHNOLOGICAL CHALLENGES

Even though self-driving cars are ready to be tested on roads, there is still more development needed before they are completely ready to be deployed in traffic. There are two challenges that pose a particular problem for automated vehicles:

WEATHER CONDITIONS AND DRIVING

During the winter in Norway, driving conditions are extremely challenging. This also goes for vehicles with human drivers. Self-driving cars are primarily tested and developed in areas with nice and clear weather conditions. In snow, rain and ice, the cars have problems with vision and manoeuvrability. Developers are working on solving these problems. Ford has developed a car with camera vision that can orient itself by following different features on the road when the road signs are covered with snow.[25] Lidar sensors have particular problems with precipitation, but researchers have developed algorithms that can distinguish noises from precipitation.[26] Waymo has come a long way in using artificial intelligence to clearly identify the road when weather and driving conditions are poor.[27]

The radar sensors that detect objects in motion are not affected by precipitation. Experiments have also been made with ground penetrating radar sensors, which are able to recognise where the car is located based on distinctive “fingerprints” under the asphalt. This means that it may be possible for cars to know where they are on the roads, even when the view ahead is poor.[28]

In Norway, researchers at the Norwegian Defence Research Establishment (FFI) are developing vehicles that are able to function in winter conditions.[29] By synchronising information from several types of sensors, an automated vehicle is able to function in difficult weather conditions. If you also compare this information with a map, you can improve the vehicle’s vision even more.

[25] Wired (2016a)
[26] Quarts (2016, 14 March)
[27] Dolgov, D. (2018, 8 May)
[28] MIT (2016)
[29] FFI (2016)

Winter testing

Waymo begins testing in winter conditions
In October, Waymo announced that they will begin testing self-driving cars on roads in winter conditions. The testing will take place in the state of Michigan where in 2016, Google built a development centre of 53,000 square metres. It is also here that most of the United States car industry is situated, and where the weather has many similarities with the Norwegian winter conditions; snow, ice, slush and rain.[30]

Development and testing of ITS ("Intelligent Transport Systems") solutions on demanding winter roads
Through the research and development project Borealis, a 40km (24 miles) long road along the E8 in Skibotndalen is transforming into a national testing laboratory for new technology. Here, Statens vegvesen ("The Norwegian Public Roads Administration") is testing and developing Intelligent Transport Systems (ITS). Real-time information on weather conditions, driving conditions and traffic accidents, automatic scanning of vehicle brakes and warnings of animals or other hindrances in the middle of the road are all examples of ITS technology.[31] The project also aims to test self-driving cars. These tests will take place at a separate test facility and within a limited time period.

EXCEPTIONAL CIRCUMSTANCES

The majority of what occurs in traffic follows predictable rules, and is relatively simple for a computer to carry out. However, during a car journey, every driver is exposed to unpredictable events that require improvisation. It is almost impossible to pre-program all possible traffic situations, which means that the development of automated technology takes a long time. Exceptional circumstances (also called "edge cases") can be divided into two categories:

Identification of objects: The car must be able to distinguish between objects that must be taken into account and which objects are unimportant to the driving of the vehicle. Even if methods of image recognition are getting better, situations can still arise where the computer does not manage to identify an object. A computer can be trained to classify what a human looks like. If a person, for example, is carrying a box or is wheeling a bicycle. the car's systems may not be able to realise that this is also a human.

Unpredictable behaviour: The car must be able to function and interact with humans. This means that it must be able to anticipate how a cyclist or child will act on the road, and take action accordingly. In addition, there may be cars that

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[31] Krafcik, J. (2017)
[31] Statens vegvesen (2017)

are incorrectly parked or roadworks blocking the way that the car has not been pre-programmed to handle.

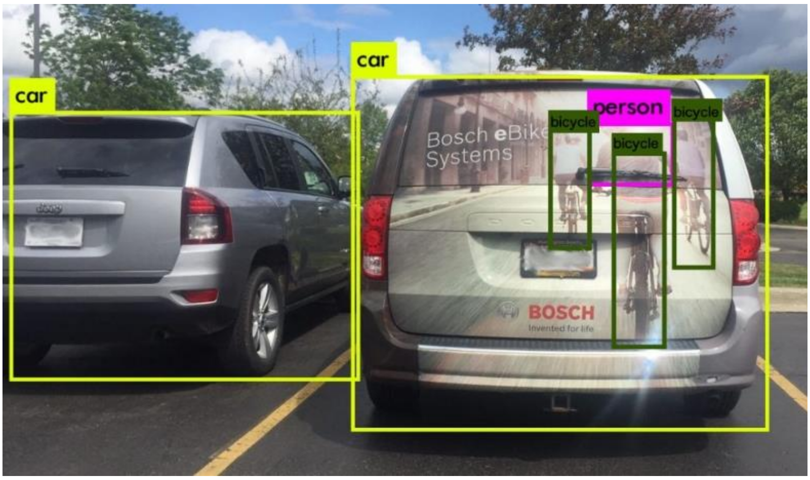

Image recognition is not perfect: *The camera on this car identifies a picture of cyclists on a different car as cyclists on the road. By using several types of sensor that also take distance into account, this kind of misunderstanding can be avoided.*[32] *(Image: Cognata.com)*

[32] Technology Review (2017)

Practice makes perfect

Since its foundation in 2009, Waymo (previously Google) has covered 6.4 million kilometres with testing. Additionally, they created 4 billion kilometres of virtual road simulations in 2017 alone. The goal is to train the cars to be able to handle all of the unpredictable situations that can occur on the roads. One advantage of self-driving cars is that when one car learns something new, the knowledge can be shared with the entire fleet.

Many companies have built separate towns to test self-driving cars. Waymo has created a full-scale town called Castle[33], whilst Ford[34] and Uber[35] have produced their own towns called Mcity and Almono. The towns have roads, roundabouts and traffic lights, where dummies, humans and manually driven cars expose the automated vehicles to unexpected situations.

Waymo has also created a separate digital environment called "Carcraft" (named after the video game "World of Warcraft"), where the cars are tested on digital copies of the towns and cities that they are to be deployed in. Here, 25,000 virtual cars can drive at once, and the same situation can be simulated more than 100,000 times a day in order to find the optimal way to manage it. Over 20,000 different traffic situations have been first tested in Castle and then recreated digitally in order to teach the computer how to handle them. Even more scenarios have been collected from driving on public roads.

THESE TYPES OF VEHICLES WILL SOON BE ON THE ROADS

Automated technology can be used for vehicles with many different functions - everything from taxis to small delivery robots and gigantic industrial loaders. Below is an overview of a number of vehicles that are currently in use or being tested:

PASSENGER TRANSPORT

- **Private cars:** In August 2015, all Tesla models were upgraded with a trial version of Autopilot which means that the car can drive itself on roads and motorways.[36] Completely autonomous private cars may exist in the long run, but it seems that it is a long way off before they can be bought on the market.

33 The Atlantic (2017)
34 Ford (2015)
39 The Drive (2017)
36 Tesla.com

- **Self-driving taxis:** Waymo has begun testing automated taxis within urban areas of Arizona. These are vehicles seating 6-8 people and can be ordered via a smart phone.[37] A number of other companies are developing similar concepts, such as Ford, Baidu and Uber.
- **Minibuses:** Small automated buses seating 10-12 passengers can be used as feeder bus services to larger public transport lines, or as flexible bus services in cities. This type of vehicle has been tested and developed in Europe in connection with the project CityMobil2.[38] In the Swiss town of Sion, such a bus has been tested among regular traffic and in pedestrian areas since 2016, with no human injuries to date.[39] These buses have also been tested in Norway, and Ruter (the public transport authority in Oslo and Akershus) plans to test a fleet of them integrated with the public transport system from 2019-2021.[40]

FREIGHT TRANSPORT

- **Lorries:** Interconnected convoys of lorries may mean that several trucks can be guided by one driver. This can save on shipping costs.
- **Shipping and delivery in towns:** Automated technology may reduce delivery costs in towns. This can be done via small robots that drive on the pavement or bicycle path, or via larger vans.

COMMERCIAL VEHICLES

- **Defence:** The Norwegian Defence Research Establishment (FFI) is developing automated vehicles that can be used in connection with security at military bases.[41] This type of vehicle must learn to navigate and choose routes in all types of weather and terrain.
- **Aviation:** In 2018, the Norwegian airport operator Avinor began to test driverless snow ploughs that will keep runways free of snow.[42]
- **Industry:** In Australia, since 2015, automated loaders have been used to haul minerals from mines. These weigh over 400 tonnes and reduces operating costs by 15%.[43]

[41] Waymo.com
[38] http://www.citymobil2.eu/en/
[39] Postbus (2017)
[40] It-avisen (2018)
[41] Ffi (2016)
[42] Avinor (2018)
[43] Quartz (2016)

WHEN WILL SELF-DRIVING CARS TAKE OVER THE ROADS?

In 2018, the law allowed for automated vehicles to be tested on Norwegian roads, and they will be able to affect traffic during the coming years. It may take a long time before private cars are completely autonomous, but taxis and buses in urban areas will be available much quicker.

The car was invented in 1886, but it did not become the dominant mode of transport in the United States until around 1930. In Norway, private car ownership first took off in 1960 after the car rationing regulation was abolished. In 1950, there were 65,000 private cars in Norway and by 1965, the number had risen to 465,000.[44] In 1975, there were close to 1 million private cars in Norway and in 2018, the number was at 2.7 million.

The time frame from the car being invented to becoming the dominating form of transport was a process with interactions between demand, political facilitation and economic growth. Before the car arrived, the streets were divided between trams, pedestrians and horses. At first, the car was seen as an undesirable foreign item or a toy without purpose, and not as a separate means of transport

[44] Statens vegvesen

for use in the town. It took many decades of negotiation before the car gained the right of way on the streets.[45]

Another important factor for the popularity of the car was the emergence of the suburbs. At the beginning of the 1900s, living in the centre of town gained a lower status. The towns were dangerous and full of horse manure. New residential areas and investment in roads meant that housing could be more spread out. This contributed to the strengthening of the car's value and usefulness.

THREE DIRECTIONS FOR AUTOMATED TRANSPORT

The transition from today's car-based society to extensive use of automated technology is potentially equally revolutionary. The speed of a possible transition to automated vehicles will depend on how the technological development continues. Social factors will also play a role, such as user acceptance, spatial and transport planning - and not least how politicians regulate and facilitate the use of new types of vehicle.

Three directions of development will occur parallel to each other, but are affected by different technological, societal and political factors:

1: New public transport
Automated technology is integrated into public transport and urban planning

Now – 5 years
How will the future transport systems be financed?

2: Self-driving taxis
New taxi services and shipping within limited urban areas

3 – 5 years
Who will have permission to deliver transport services in the city?

3: Self-driving private cars
Gradual transition from manual driving to advanced driver-assistance and autonomy

10 – 20 years
When will private persons be allowed to use self-driving cars?

45 Geels (2005)

NEW PUBLIC TRANSPORT

Already, a number of prototypes of small self-driving minibuses exist. The vehicles that are currently being tested are slow-moving and work best in well-mapped areas and preferably on predefined routes. In the long run, we will see vehicles that are more flexible and can drive faster. New digital platforms for coordinating transport services and the sharing economy contribute to the change in public transport.

MAY HAVE LARGE IMPACT IN URBAN AREAS

Small minibuses can be ordered via a mobile app and provides a more flexible bus service. This may be useful to use in connection with high capacity bus and train routes, and cover the first and last kilometres that might be the cause of people choosing to use a car rather than public transport. Once driver costs disappear, it may become more economically viable to use this type of transport.

Models made for Helsinki and Lisbon have shown that shared minibuses and cars combined with public transport are able to cover most of the journeys that occur in cities and largely eliminate the need for private cars.[46]

WHAT AFFECTS THE DEVELOPMENT:

- Competition with private car use: In order to achieve the significant advantages that a system of shared minibuses and taxis offer, the public transport system will have to be competitive with private cars. This may require both improved digital transport services as well as limits to private car use.
- Residential and transport planning: How sparsely or densely populated an area is, and the access to public transport, affects the need for people to use private cars in their everyday life.

[46] International Transport Forum (2017)

Testing of automated minibuses with differing objectives

User acceptance with Kolumbus in Stavanger
The mobility provider service Kolumbus wants to test automated buses on a route between existing bus routes and 4000 workplaces at Forus in Stavanger. The pilot itself will strengthen existing public transport services by offering transport for the first and last part of the commute (1.3km each way). [47] The pilot has been approved by the Directorate of Public Roads and started testing in the summer of 2018.[48]

Urban development with Ruter in Oslo
In April 2017, Ruter stated that they wished to invest in between 10–50 automated buses, which would form part of a provident and comprehensive public transport service in the Oslo area.[49] Recently, Ruter signed a contract with the company COWI, that will put together a transport model for the Oslo municipality and Ruter's future investments in automated and alternative transport.[50]

Business development in Kongsberg
Kongsberg Innovasjon is working on the development of a testing space for automated vehicles. The team is joined by the company Applied Autonomy, who will develop and deliver support systems for this mode of transport of the future.[51] They have applied to test automated buses on a route through the town and down to Kongsberg Technology Park.[52]

The goal is to collect experiences from automated vehicles on the road, with a particular focus on the Nordic climate. It aims to have the first commercial automated bus on the roads by spring 2018. It is partnered with Kongsberg municipality and the Norwegian Public Roads Administration. The enterprise is also a trial venture in an EU collaborative project.

Research for successful implementation
The research project SmartFeeder, which is owned by the Norwegian Railway Directorate and led by SINTEF, studies the early testing of automated minibuses in order to establish a knowledge of user requirements and effects, as well as provide recommendations that ensure a smooth and successful implementation within the Norwegian transport system.[53]

ROBO-TAXIS IN CITIES

Complete autonomy is easier to achieve within a well-mapped area where the car has been sufficiently tested and trained. Therefore, the first, completely self-

[47] Kolumbus (2018)
[48] Sola kommune (2018)
[49] Aftenposten (2017)
[50] Ruter (2018)
[51] Kongsberg innovasjon (2017)
[52] Kongsberg innovasjon (2018)
[53] Sintef (2018)

driving cars will be used within fixed geographical areas or on a predefined route.

Since the technology is still expensive, it is most likely that this type of car will not be owned by individual people, rather, people will buy individual journeys. This will most likely occur in cities and urban areas where the market is large enough for this type of service to be profitable.

Fleet operators will also have the greatest incentives to invest in this technology, since they have the most to gain in the form of reduced labour costs. Driver wages and social welfare costs amount to approximately 60% of the price for a taxi ride.[54] Thus, taxis may become more competitively priced in relation to privately owned cars or public transport.

FEWER CARS, BUT MORE DRIVING

Carsharing combined with personal transport becoming more accessible may lead to the motor pool shrinking at the same time as people are driving more cars. The consultancy firm PWC calculates that as much as 40% of all driven kilometres in European urban areas may take place in shared and automated cars by 2030. Based on this development, it estimates that the total number of driven passenger kilometres may increase by 23%, whilst the number of vehicles in Europe may decrease from 280 million to 200 million.[55] 10 Norwegian towns have an aim that private car traffic in 2030 should not exceed the level of traffic in 2016. This can be achieved by, among other things, more people sharing cars.

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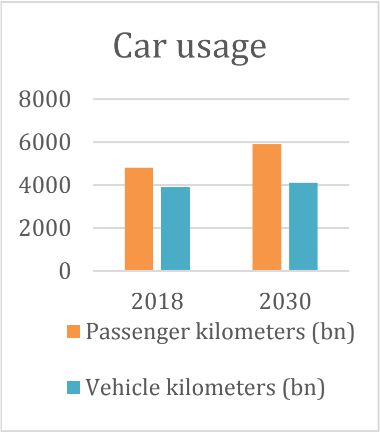
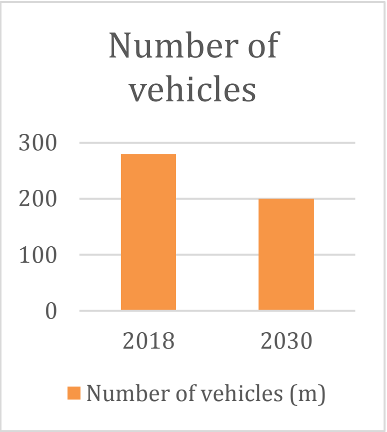
[54] Transportøkonomisk institutt (2013, p. 10)
[55] PwC (2017)





The graph above illustrates how an increasing demand for transport can be covered by a smaller car park if the vehicles are shared. The numbers are gathered from a calculation done by PwC for the entire EU region.

WHAT AFFECTS THE DEVELOPMENT?

- **The legislation:** Currently, you have to apply for permission to use automated vehicles on Norwegian roads. Significant growth in automated taxi services implies that a new legislation concerning the general operation of self-driving cars will be implemented.
- **Competition with existing businesses:** Robo-taxis will eventually come into direct competition with existing taxi services. Initially, this type of service will most likely be supplied by foreign companies such as Uber, Baidu and Waymo. Politicians will have to decide whether these companies shall be allowed to compete with Norwegian taxi drivers.
- **Mobility pricing:** Fewer vehicles on the road may mean that the state receives a lower revenue from car-related taxes. Simultaneously, digitalisation may make it easier to regulate what each individual vehicle needs to pay in order to use the roads. In order to avoid extra traffic as a result of empty vehicles, it may be beneficial, for example, to set a price according to how many people are in the car.
- **The machine replaces the human:** Automated taxi services depend on the technology becoming sophisticated enough for the cars to be able to collect and deliver passengers and park completely on their own. However, automated technology does not replace the service function

provided by a taxi driver. This may still be important for many people, for example, users of assisted transport.

SELF-DRIVING PRIVATE CARS

It still seems a long way off before we will see fully autonomous cars for sale to private persons. The technology needs to function in all types of weather conditions and on all roads. In addition, the sensors and hardware must be cheap enough to be mass-produced.

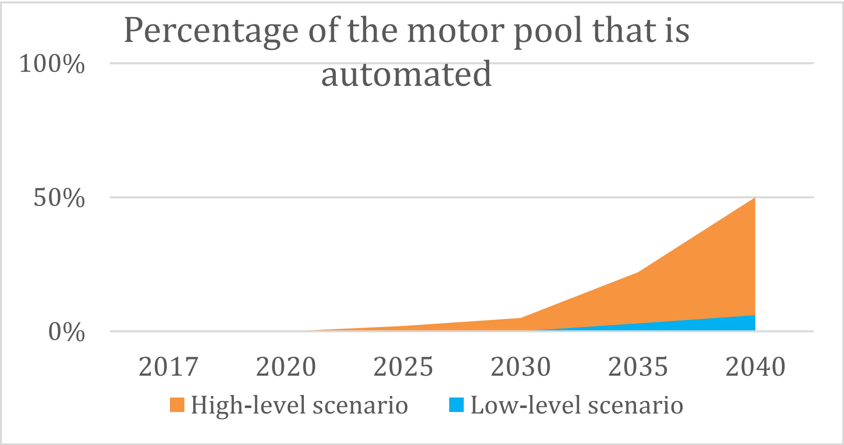
In 2017, Volvo planned to allow 100 private persons test out cars with level 3 automation outside of Gothenburg, but has now pushed this testing back until 2021, since the technology was not ready in time.[56]

Tesla claims that all their cars are equipped with technology that allows them to be upgraded to achieve complete autonomy.[57] In order for this to work, the company gambles that it will manage to develop sufficient artificial intelligence so that camera technology can replace the need for the sensors that the majority of other developers of automated technology utilise.

IT WILL TAKE TIME BEFORE LARGE SECTIONS OF THE MOTOR POOL ARE AUTOMATED.

The motor pool in Norway is on average, about ten years old.[58] Therefore, it will take time from new technology becoming available to when it can be used by the entire motor pool. The graph below shows two growth curves for the private car market. With a very rapid development, around 50% of the motor pool can have automated features equivalent to SAE levels 3-5 by 2040. With a slower development, the number may be closer to 5% by 2040. In such a high-level scenario, a very rapid growth in the percentage of self-driving cars sold is expected from 2020.

[56] The Verge (2017)
[57] Tesla.com
[58] SSB (2017)



WHAT AFFECTS THE DEVELOPMENT?

- **Safety and regulations:** Currently, only use of automation equivalent to SAE level 3 and higher is permitted for testing. The speed of the development depends on when and to what extent private persons are allowed to own and use this technology.
- **User acceptance and demand:** In order for people to want to pay extra for self-driving cars instead of manually driven cars, both their usefulness and safety must be more clearly demonstrated. Serious accidents may diminish user acceptance.

EFFECT ON INFRASTRUCTURE

Automated vehicles may affect how much road is needed as well as how the roads must be built. The authorities should take this into account when they plan future investments.

In the National Transport Plan, the technical service life of a road is estimated to be 40 years (70 years for train tracks).[59] This means that the profitability of an investment in a road completed by 2030, must take into account the need for such a road up until 2070.

It is difficult to plan investments so far ahead. Technology is one of the factors that will provide the greatest change in the need for investments in infrastructure. In addition to automated vehicles, other types of transport technology such as drones, automated ships and electric bicycles will also provide changes to the future need for roads and railways. Social changes such as population growth and housing patterns may also affect how people travel.

Automated vehicles may affect the need for investment in infrastructure in two main ways:

- **Capacity:** If cars are able to drive closer together and utilize the roads more efficiently, an increase in traffic can be supported without the

[59] Meld. St. 33 (2016–2017, p. 82)

need to build extra road capacity. On the other hand, increased access and lower prices will lead to a demand for increased road capacity.

- **Specifications:** Automated vehicles may demand new standards for how infrastructure is built, either in the form of communication technology along the roads, or physical changes such as pick-up and drop-off points.

INCREASED CAPACITY, BUT ALSO HIGHER DEMAND

Several concepts have shown promising opportunities for automated vehicles to provide a more efficient traffic flow: If vehicles are communicating with each other, they can merge continuously at traffic lights so that queues are reduced.[60] Experiments are also being conducted with fleet management and so-called "platooning", where communicating cars can drive much closer together along the motorway.[61]

Modelling indicates that a high percentage of automated vehicles may provide significant increases in capacity. A study made for the British Department of Transport estimates that 100 % of automated vehicles may provide an increase in capacity of 67% on the motorway.[62] A different model shows that the capacity may be increased by as much as 80 % on the motorway, and up to 40% on urban roads.[63]

In slow-moving urban traffic, automated vehicles can help improve traffic flow, and therefore shorten journey times. This is because automated vehicles can maintain a more even distance and speed, and avoid variable driving and unnecessary stopping. This level of efficiency can also be achieved by manually driven vehicles equipped with automatic intelligent speed adaptation in slow-moving traffic. [64]

[60] Senseable.com
[61] Wikipedia
[62] gov.uk (2017, p.24)
[63] Friedrich (2016)
[64] technologyreview.com (2017)

CAPACITY CHALLENGES GREATEST IN URBAN AREAS

The largest investments in the National Transport Plan are for road projects between towns. Investments in these types of roads are made with increasing accessibility in mind. The greatest challenges regarding capacity in Norway is on roads in urban areas during rush hour.[65] To the extent investments are made to increase road capacity, new technology may make this redundant in a 40-year perspective.

Even though automated vehicles may help improve capacity utilisation, the net effect of the technology may result in an increased capacity usage. Induced traffic is a concept used in transport research to show that as a rule, increased road capacity increases demand for driving, and thereby increased traffic.[66] Similarly, improved capacity utilisation by means of automated vehicles may lead to increased driving.

SEVERAL FACTORS ARE RESPONSIBLE FOR INCREASED TRAFFIC

An overview report from the Institute of Transport Economics shows that automated vehicles and associated technologies trigger several factors that are responsible for increased congestion:

Increased traffic[67]	**Decreased traffic**
• More people are able to drive cars: Old and young people alike, without the need for a license • May lead to empty cars driving in the streets • The disadvantages of driving are reduced since passengers can spend time in the car doing other things • May lead to increased urban sprawl since people can	• The cars can drive closer together and use less space on the roads • Traffic flow may be improved since the cars are automated and can communicate with each other[68] • Cars can be shared by many people or used as public transport support

[65] Meld. St. 33 (2016–2017, p. 59)
[66] Transportøkonomisk institutt (2017a)
[67] Transportøkonomisk institutt (2017b)
[68] gov.uk (2017)

endure longer commutes to and from work • Taxis may become much cheaper	

THE INFRASTRUCTURE CAN BE UPGRADED IN THE LONG RUN

A completely new infrastructure is not necessarily required in order for self-driving cars to work. Self-driving cars are developed to work in regular traffic and on common roads. This is extremely technologically demanding to achieve, but it also means that there will not be the need for completely new types of roads once the technology is ready.

Good roads, with clear markings and road signs will always be an advantage, whether it is a computer or a human driving the car. Additionally, the introduction of automated vehicles can be helped by certain changes:

- **Physical changes:** There may be a need for new pick-up and drop-off points for automated taxis and buses. In addition, it is thought that emergency stations where a self-driving car can stop safely may be necessary along motorways.
- **Digital infrastructure:** If the cars are to communicate with each other and the road (C-ITS), it will be necessary to install transmitters and sensors along the roadside. However, self-driving cars are not necessarily dependent on continuous network access in order to function. It is possible to produce self-driving cars that work without an internet connection, which may also be an advantage when considering the risk of cyber attacks. However, there will always be a need for internet access along the roads for entertainment and communication purposes.

Automated vehicles will be rolled out in progressively larger areas. It may be advantageous to use the testing to assess in the long run what new requirements may be needed for the building of infrastructure.

SAFETY, RESPONSIBILITY AND PRIVACY

Traffic is being digitalised and the car is becoming a part of the Internet of Things. We leave more digital traces along the road, the risk of cyber attacks increases and responsibility is divided between humans and machines. This should be considered when we plan future transport systems and the implementation of automated vehicles.

The potential safety advantage of self-driving cars is based on the estimate that around 90% of today's traffic accidents are caused by human error.[69] Humans are known to fall asleep behind the wheel, drive under the influence of alcohol/drugs, use mobile phones whilst driving or do other things instead of focusing on the road. Self-driving cars will allow passengers to both text and relax without putting anyone at risk. At the same time, new challenges arise when the line between humans and machines is blurred.

Although self-driving cars are technically ready for the roads, there is still a great deal left to be done before they can be deployed. Currently, there is no permanent legislation for automated vehicles, neither are there any guidelines for ethical assessments that must be made when pre-programming the car's response to different situations, whilst also using machine learning.

[69] Jenssen G.D. (2017)

Self-driving cars are almost here and we must put road safety, cyber safety, privacy and ethical challenges on the agenda.

LAW ON TESTING AUTOMATED VEHICLES ON NORWEGIAN ROADS

In Norway, the “Testing of Automated Vehicles Act”[70] came into force on 1 January, 2018. This act permits the testing of automated vehicles in regular traffic, in certain cases without the presence of a responsible driver in the vehicle. The objective of the law is “to uncover what effects automated vehicles may have on road safety, efficiency in traffic flow, mobility and the environment.”

> *“Automated vehicle refers to a vehicle that is equipped with a technical system that automatically drives the vehicle and has control over the driving. Automated vehicles include vehicles where a driver is able to transfer the driving to the technical system that automatically drives the vehicles, and vehicles that are built to drive without the need of a driver.”*[71]

A company or individual who wishes to test automated vehicles must apply for permission to carry out a test project for a limited period of time. The Road Traffic Act will normally not permit the use of self-driving cars, since it requires that the driver must always pay close attention to the road.[72] Therefore, in the long run, changes in the Road Traffic Act will be required in order for self-driving cars to be permitted.

Currently, it is the Directorate of Public Roads that can provide permission to test automated vehicles. The Directorate will approve applications and check that the tests are carried out according to current regulations and the permit that is given.

[70] Lov om utprøving av selvkjørende kjøretøy (2017)
[71] Lov om utprøving av selvkjørende kjør
etøy (2017, §2)
[72] Lov om vegtrafikk (1965, §6)

The first fatal accident

In March, 2018, a pedestrian was run over by one of Uber's self-driving cars and died as a result of her injuries. This was the first fatal accident caused by a self-driving car and led to several companies pausing their tests.

The accident occurred because the car's automated system did not react to the woman who came walking out of a dark area in the middle of the road. The sensors identified the woman, but the software did not regard her as an obstruction that it needed to stop for[73]. The safety driver did not have enough time to take over control of the vehicle and so the Uber accident came to pass[74]. The governor of Arizona, who had previously been supportive of the testing, banned Uber from testing after the accident. Uber halted the test driving in several states, including Arizona, but even if the company wanted to resume the test driving in Arizona, the governor's decision would prevent it.[75]

The accident has raised questions on whether the US has not been restrictive enough regarding the testing of self-driving cars.[76] Work is currently underway in Washington DC[77] on a law that will provide federal safety standards for testing automated vehicles. The idea behind the law was to simplify the regulatory framework in order to promote innovation, but in light of the accident, there will likely be restrictions added to the regulations.

Such events can potentially halt work on self-driving cars. Attitudes of the general population towards the technology, and any political regulations, will greatly depend on the results of the investigation. In this regard, the media may also play a significant role in affecting public opinion.

Uber agreed to a settlement with the family of the victim.[78]

ADVANCED DRIVER-ASSISTANCE CREATES CHALLENGES

New technologies in automated vehicles and infrastructure is expected to contribute significantly to a reduction in deaths and serious injury. However, technological development also leads to new challenges, such as increasing distractions to the driver.[79]

Cars with advanced driver-assistance equivalent to level 3 are beginning to enter the private car market. For periods of time, a level 3 car can drive completely

[73] Arstechnica (2018)
[74] Wired (2018a)
[75] NRK (2018)
[76] Economist (2018)
[77] House of Representatives (2017; 25 July)
[78] The Independent (2018)
[79] St. Meld. 33

automated, for example, on motorways or country roads. However, the system also requires the driver to assume control if the road situation changes, for example, when driving into a town or urban area.

Tesla has already launched a trial version of its product Autopilot, but other companies such as Volvo[80] and Mercedes[81] also have plans to launch this type of function. Tesla's Autopilot requires the driver to pay constant attention to the road.

It is important to emphasise that advanced driver-assistance systems are not the same as a self-driving car. They are therefore not covered by the testing legislation but by the Road Traffic Act. When using this function, the driver is responsible for paying close attention to the road at all times and taking control of the driving if needed. This relates to the regulation in the Road Traffic Act which states that the driver must have control of the vehicle at all times.[82]

PUSHING THE LIMITS

Many people use advanced driver-assistance systems to do other things such as looking at their phones or sleeping. Two fatal accidents have been recorded in the US where the driver handed over control to Tesla's Autopilot. During the first accident in 2016, the driver was warned several times to take control of the vehicle before the car collided with a lorry.[83] In the second incident, the driver did not have his hands on the wheel for 6 seconds before the car collided into the central reservation barrier.[84]

A report on the accident in 2016 from the American National Highway Traffic Safety Administration, NHTSA, determined that Tesla's Autopilot was not to blame for the accident, and that Tesla's safety system, however, leads to safer traffic .[85]

In the latest update to Tesla's Autopilot, a safety measure has been implemented that means the driver can only take his/her hands off the wheel for a certain period of time. If this time is exceeded, the car will get off the road and come to a stop. But it does not seem to deter people who want to stretch the

[80] Volvocars.com
[81] Mercedes-benz.com
[82] Vegtrafikkloven (1965, § 3)
[83] Wired (2016)
[84] The Guardian (2018)
[85] NHTSA, 2017

limits of automated driving. Tips can be found online on how you can trick the system into believing you still have your hands on the wheel.

Image retrieved from: ca.pressfrom.com[86]

HUMANS AND MACHINES

Driver-assistance systems are becoming more and more advanced every day, and we are seeing a transition from the technology supporting the driver to the driver supporting the technology. At the same time, the door has already been opened for the testing of self-driving cars on Norwegian roads this year. The flow of traffic will consequently become a blending of both manually driven and self-driving cars, up until the technology is ready for all vehicles to be able to drive themselves. This will create new challenges for the driver in terms of relating to new technologies, interacting with automated vehicles and not least, the switching between automated and manual driving. [87]

The driver's understanding of the traffic flow and situation, when the car's driving is automated, is much lower than when the driver steers the car himself/herself. [88] Studies made with car simulators show that drivers need 15-40 seconds from when they are given a warning to when they have control of the automated vehicle.[89] This phenomenon is well-known in the aviation industry, where some

[86] Press from (2018)
[87] Trafikkforum (2018)
[88] Financial Times (2018)
[89] Merat et. al. (2014)

accidents have occurred when the pilot had put too much trust in the computer's control of the aeroplane.[90]

As driver-assistance systems improve, the driver feels more confident and turns his/her attention to other activities (talking with passengers, controlling the music or looking at his/her phone). It can be easy to put too much trust in the system. This may be problematic for passenger and road safety, as it can be difficult to take over control of the vehicle after having had your mind and sight on things other than the road for a long time.[91]

MACHINES MAY BE SAFER THAN DRIVERS

The security of the car currently depends on the driving ability of each individual driver and support from various driver-assistance systems (such as ABS, cruise control etc.). Self-driving cars will only rely on the computer's systems and capacity. Depending on the degree of automation, technical systems will replace humans' perceptions, experiences, judgements and capacity to react whilst driving. Both the potential safety benefits and the risks of increasing the degree of car automation will vary depending on the various strengths and weaknesses of humans and machines.

Machines, for example, may have problems with reacting to unknown situations and anticipating the movements of a child. By comparison, humans can be inattentive and misjudge distance and speed, and the human eye can only see a limited area. However, the technology has a limited perception compared with humans. Therefore, a self-driving car must be equipped with several different sensors and trained through millions of simulations.

Cyber-attacks and sensor manipulation will be a genuine problem when using self-driving cars, and it important to think of security throughout the entire building of the system.

[90] Endsley (2016)
[91] Jenssen G. D. (2017, p. 198)

HACKING

Hacking is already a threat on today's roads. All cars with "smart" systems are vulnerable in the first place. With the likes of wifi, mobile phones, bluetooth, digital radio, apps, media files imported over USB, remote diagnostics, telematics etc., there are now even more points of entry for a cyber-attack.[92]

In 2015, two American researchers demonstrated how, by accessing the entertainment system in a Jeep, they could take control of the car via the Internet.[93] The result was dramatic: First, the hackers took control of the air conditioning, windscreen wipers and stereo system. Then they turned off the engine so that the car stopped by itself. The driver was not able to control this, and could not even use the brakes.

Several car manufacturers withdrew and updated the software of millions of cars after this flaw was demonstrated[94] and in July, 2016, General Motors expressed that protecting cars against cyber-attacks has to be a public security issue.[95]

When various types of vehicle become automated, in addition to their regular systems, they will also have more sensors and cameras. If self-driving cars or buses are to be coordinated as a service, they must also be online, which makes the device more vulnerable.

Waymo has chosen to keep cars offline in order to protect them from hacking, amongst other things.[96] By storing all map information locally, a self-driving car can, in principle, function fully offline, without having to send and receive signals from the outside world that tell it where it is located.

Encrypted communication and authorisation may be a solution to secure the vehicles against unauthorised commands.

SENSOR MANIPULATION

Self-driving cars utilise machine learning models for image recognition in order to manoeuvre on the roads. Sensor manipulation can make the vehicle crash, trick the device into driving somewhere else or misrepresent reality. Some variants of sensor manipulation may be to provide fake GPS, lidar or radar signals,

[92] NHTSA (2016, October)
[93] IOActive (2015)
[94] MIT Technology Review (2017)
[95] MIT Technology Review (2016)
[96] Financial Times (2017)

or falsify reflecting signals. The cars can also be tricked with a type of optic illusion to cause mistakes. By adding noise to images that are not seen with the naked eye, machine learning models can be tricked into classifying images incorrectly. For example, an image of a panda has been classified as an ape by adding unseen noise to the image. Images with such a noise can be printed on plain paper and still manage to deceive the algorithms. [97]

Such attacks can have just as dramatic consequences as physical hacking of the system. Algorithms can also be taught to interpret images of traffic sign errors by adding such noises, for example, interpret a speed limit sign showing 50kmph (30mph) as 150kmph (90mph). If you print the false image and paste it onto a regular traffic sign, automated vehicles will not realise it is fake, and therefore, drive at 150kmph instead of 50kmph. It is also possible for hackers to use cheap equipment that can trick lidar into believing that there are people or other vehicles on the road, but in reality, are just false echoes. [98]

Sensor manipulation can be avoided by using methods that handle unexpected sensor values and by seeing the context of information from several sensors.

THE CAR AS A MORAL AGENT

There are many choices to be made when the car's reaction to various situations have to be pre-programmed. Self-driving cars must comply with laws, regulations and human values. The cars will have to drive in mixed traffic with various groups of vehicles. They will face ethical dilemmas that they must be pre-programmed to handle.

A widely discussed question is what a self-driving car will do if it is exposed to an unavoidable accident where it must choose between two different outcomes. For example, it may be that the car must choose between running over two elderly people or two young people, or choosing between hitting a casual pedestrian or driving over a cliff, thus killing the passenger.

[97] Teknologirådet (2018)

[98] Spectrum (2015)

In a normal car accident, the injury is most often accidental, while in the case of self-driving cars, the choice must seemingly be made in advance. Therefore, the question of what ethical guidelines the car should follow arises.

Ethical guidelines in Germany

In Germany, the authorities have adopted 20 ethical rules for automated traffic. [99] The rules imply, among other things, that humans should always be protected before animals or possessions. If the car is in a situation where people may be injured, the software is not allowed to discriminate between people based on characteristics such as age, gender, or physical and mental conditions.

A self-driving car will not drive over the speed limit, be distracted by a mobile phone, or drive under the influence of alcohol/drugs. It will always maintain a safe distance between other cars on the motorway and not park illegally. Even if accidents are to occur, it is more likely that they will happen due to technical or human error, without any moral dilemmas concerned. However, it may still be useful to have a framework for ethical rules and responsibility like they have done in Germany, since this may provide a more predictable situation for all that are involved.

[99] Bmvi (2017)

The trolley problem

The trolley problem is an abstract, ethical dilemma, where you see a runaway trolley about to run over five people lying tied-up on the tracks. On a parallel track, lies one other person tied-up. By using a lever, you can send the trolley over to the other track, and save five people. At the same time, you will then have actively intervened and taken the life of the other person. Is it right to actively intervene and therefore, involve yourself in the accident in order to save the most amount of lives possible? There are many different variants of this problem. For example, in one variant, you have to choose whether to push someone off of a footbridge in order to stop the trolley before it hits the five bound people. The outcome would be the same, but the intervention would be more active.[100]

In a study made by Princeton University, test subjects were asked to put themselves in the position of facing these dilemmas whilst they were connected to a brain scanner. The results showed that the test subjects thought it was much more difficult to physically push a person in front of the trolley than to use a lever.[101]

MIT Moral Machine[102]

Researchers at Massachusetts Institute of Technology (MIT) have developed a website where you can face the dilemmas that a self-driving car may be exposed to. A video game allows you to choose between two different outcomes. For example, would you prefer to save the life of a homeless person who crossed the road during a red light, or two elderly passengers in the car? Or how about two athletes who stood in the way of a car with three criminal passengers?

THE THOUGHT EXPERIMENT IS TROUBLESOME IN PRACTICE.

The thought that a self-driving car will make these types of decisions on the road can be terrifying and unpleasant both for the people on the road and those sitting in the self-driving cars. A spokesperson for Mercedes was criticised for claiming that the car manufacturer would always prioritise the life of the person in the car before other road users.[103] This made many people fear that Mercedes would release dangerous cars onto the road.

It would be problematic if those programming the cars made ethical choices that would affect society. Theoretically, it may be possible for cars with facial recognition to be able to make decisions based on who is on the roads. However,

[100] Store Norske Leksikon (2017)
[101] Princeton (2001)
[102] http://moralmachine.mit.edu/
[103] Fortune (2016)

this is far from being technologically possible, and would most likely never be done due to privacy issues.

Critics[104] [105] of the ethical dilemma highlight that the following issue is immediate: Self-driving cars must be introduced in a way so that they create safer roads than we have today. This implies, first and foremost, that cars are not put on the roads without being sure what their abilities are to handle difficult situations.

RESPONSIBILITY

Even though one of the arguments for self-driving cars is improved safety, accidents will still occur. Who will be legally responsible when a self-driving car causes an accident?

According to the Norwegian legislation regarding the testing of self-driving cars, the application and authorisation for testing should designate a physical person who is responsible for the testing being carried out in accordance with current regulations and under the stipulated conditions. In particular, they should ensure that the safety measures are taken where the test is carried out with automated vehicles without a responsible driver.

It is also assumed that vehicles used for testing are insured according to current laws, and that those conducting the tests consider appropriate insurance agreements for the relevant vehicles in collaboration with insurance companies.[106]

NEW DISTRIBUTION OF RESPONSIBILITY

According to our analyses, we will shortly witness a number of automated vehicles within public transport and taxis, yet it will take a little longer before we see privately owned self-driving cars on the roads. This will cause a completely new flow of traffic and the role of the driver will be changed. Who is responsible if an accident occurs when the car has switched from manual to automated driving, the driver or the manufacturer? And will the car have the same status as a

[104] The Atlantic (2018)
[105] Johansson & Nilsson (2016)
[106] Forskrift om utprøving av selvkjørende motorvogn (2017, §5)

driver at some point? In other countries, the discussion on responsibility has already begun.

In Germany, it was decided that the manufacturers are chiefly responsible during the testing of self-driving cars and that there must always be a person ready to take over control.[107] It was further expanded that the driver has two tasks. Always be ready to take over the driving when the system sends a warning. The driver should also be ready to take over the driving if he or she realises that the system is no longer functional. This means that the driver is responsible for only using automated driving where permitted. The regulations do not provide an answer to how the responsibility should be distributed if the vehicle can only be driven automatically and not manually. [108]

In the US, it was decided that at level 4-5 (where the system can drive completely without a human driver present), the system can be defined as the driver.[109]However, it is up to each individual state to define the responsibility of the various levels outside of this. In California, responsibility is split between the driver and automatic system during automated driving. This means that during automated driving (level 3-5), the manufacturer is responsible for the vehicle following traffic regulations. In Tennessee, the system can be considered the driver during automated driving. However, at level 3, the driver is always responsible for the vehicle following the traffic regulations, even during automated driving. At level 4-5, the manufacturer is responsible during automated driving.

The various regulations have a common feature in that they all begin at which level of automation the car has. If self-driving cars are to go on the market in Norway, this discussion must be debated right now.

SURVEILLANCE ON NORWEGIAN ROADS

For a long time, we have been able to keep our information to a minimum when we have been driving, and we have had the freedom to travel anonymously. This is about to change. If the cars are connected together, large amounts of data will be exchanged. This may restrict the opportunities to travel anonymously. From

[107] Bmvi (2017)
[108] SOU (2018, p. 546-547)
[109] NHTSA (2016)

leaving traces periodically, such as when we pass a tollbooth, the new technology will potentially enable a continuous line to be traced after us.

It may be an important principle to distinguish between what data is necessary to collect in order to travel safely, versus information that is valuable to sell to third parties. Additionally, you can distinguish between information the car collects from its surroundings and what information is collected about the passenger.

DATA FROM THE OUTSIDE WORLD

Self-driving cars will gather information on everything that occurs around them. Self-driving cars and cars with advanced driver-assistance systems, like Tesla, must use cameras to orient themselves. A great deal of information must be saved if an accident occurs for insurance claims or investigations. Some taxis already utilise video surveillance for security reasons; robo-taxis will also be able to surveil both the passengers and their surroundings in order to protect themselves.[110]

In the Testing of Automated Vehicles Act, the images from the cameras are not considered as "continuous surveillance", nor are they covered by the surveillance regulations in the Personal Data Act. However, a camera on a bus or car on a fixed route may be considered as surveillance.[111] In China, foreign companies are not allowed to test or develop self-driving cars, in fear that detailed mapping and image recording may be used for espionage.[112]

PASSENGER DATA

According to Gartner, 30% of user interfacing with technology in 2018 can occur via a voice recognition platform, such as Amazon's virtual assistant Alexa, for example.[113] Nvidia and Volkswagen are working together on the possibility of sending commands via hand movements and voice recognition, as well as using facial recognition in order to unlock the car.[114] In the approved testing law, it is specified that audio recording will not be allowed inside the vehicle, unless it is applied for and everyone involved in the audio recording has provided their written consent.[115]

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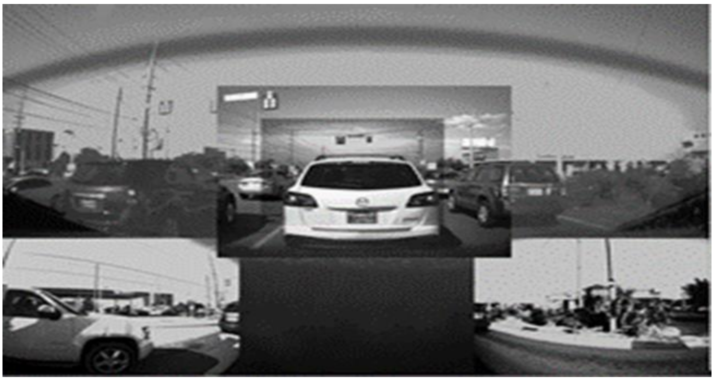
[110] The Economist (2018)
[111] Samferdselsdepartementet (2017, 16 June)
[112] Financial Times (2017)
[113] https://su.org/tech-scouting-August/
[114] Nvidia (2018)
[115] Stortinget (2017, §12, p. 4)

Tesla has approximately 80,000 cameras on Norwegian roads

Tesla models sold from August 2016 are equipped with 8 cameras, a number of sensors and a powerful computer. The cameras film in all directions.[116]

In May, 2017, Tesla updated their user conditions so that they can collect short video clips from the cameras in order to train the software to recognise road markings, signs and develop the Autopilot function.[117] The company stresses that it will be possible to deactivate the video clips and that the videos will not be connected to the vehicle's identification number. Neither will it be possible to search for videos connected to a specific vehicle. However, a great deal of information on and around the roads will be collected.[118]

Currently, there are approximately 10,000 such Tesla models in Norway. This means that around 80,000 Tesla cameras already exist on Norwegian roads.[119]



The Tesla camera: *These are images collected from the different Tesla cameras. The cameras redirect images in black-and-white. They are able to send high-definition colour images, but black-and-white images are quicker to process.* [120]

[116] Tesla.com
[117] Electrek (2017, 6 May)
[118] Tesla.com
[119] Our own calculations based on the number of Registered Tesla models found in Norway after September 2016 http://teslastats.no/
[120] Electrek (2017, 16 May)

THE WAY FORWARD

Self-driving cars will be put on the roads over the next few years. The technology may make the roads easier to navigate, provide safer traffic and offer more efficient and attractive transport services. However, certain measures are required so that the introduction of automated vehicles does not negatively affect road safety, privacy and traffic flow.

NEED FOR POLITICS

There has been a massive leap in technology during recent years, and automated vehicles have gone from being a pipe dream to being driven on roads all over the world. Many of the regulations concerning vehicles occur at an international level, but laws regarding the testing of automated vehicles have been created at a national level. Norway has facilitated the development and adopted a testing legislation that came into power on 1 January, 2018. Several applications have already been approved and we will see automated vehicles on Norwegian roads this year.

Self-driving cars and the digitalisation of the transport system have the potential to provide the population with increased mobility and better quality with regard to the transport system, but we still have a limited knowledge and experience of the technology. Therefore, it is positive that the Norwegian authorities are actively facilitating the testing and evaluation of automated vehicles. This will help make informed and beneficial decisions regarding the transport system, and at the same time, may contribute to strengthening the Norwegian industry in this field.

The first tests on public roads in Norway will be with slow-moving minibuses on relatively restricted stretches of the road. In the long run, more advanced vehicles may become available. In the US, several companies have already begun testing completely autonomous taxis on urban roads. This type of vehicle may be ready for the market in Norway too, perhaps in the next 3-5 years.

When the technology reaches this level, it will seriously be able to affect traffic. Even though it may take time before large sections of the motor pool becomes automated, we will have a mixed traffic flow and all types of road users must be able to relate to the new vehicles.

The technology is one step ahead of the regulations. Therefore, it is important that correct conditions for the development are put in place now. Based on the technology as described in this report, we believe there is a need for policy design in the following areas:

- **Responsibility and safety:** In order for the vehicles to be used more extensively, a general regulation for automated vehicles is needed, where responsibility is clearly defined.
- **Partial automation:** Testing of partially automated vehicles is already occurring, but falls outside current legislation. Therefore, it needs to be better regulated than it is today.
- **Privacy, data and digital maps:** A policy must be developed for the handling of data collected and used by automated vehicles. This concerns privacy, national security and competition.

RESPONSIBILITY AND SAFETY

According to the Road Traffic Act, there must be a driver who has full control of the vehicle. Norway is also bound by the UN's laws regarding vehicles, which state that a driver should always be in control of the vehicle.[121] Automated

[121] Unece (1968)

vehicles without a driver behind the wheel are forbidden according to these definitions.

Therefore, automated vehicles can only be used in testing projects where individual exceptions are made to the Road Traffic Act. Norway was quick to adopt a testing legislation, which enabled automated vehicles to be used on public roads already this year.

In order to move from testing to general use, new laws are needed. These laws should clearly define who is responsible in the event of an accident and how the vehicle reacts to ethical challenges. The possibility of remote control of vehicles should be limited, and standards for which roads can be used by automated vehicles should be defined.

WORK ON NORWEGIAN LEGISLATION MUST START NOW

When a legislation regarding the general use of automated vehicles is developed, it will be necessary for it to be internationally concordant, so that vehicles are able to cross borders. Norway has signed the Amsterdam Declaration[122], which stipulates that the European countries will develop a harmonised legislation for automated and connected vehicles. A number of standards regarding vehicles are all regulated internationally through the UN.[123]

Although a great deal of the regulatory work occurs at an international level, it will still be necessary to make changes to the Norwegian legislation. The expert group recommends that work on a new legislation begins now.

THE RESPONSIBILITY BETWEEN HUMANS AND MACHINES MUST BE CLARIFIED

The "Testing of Automated Vehicles Act" requires that a person assuming responsibility for the test must be appointed. By a general law, the responsibility must be divided in a different manner and take into account the various levels of automation.

Different countries have differing practices for how you should regulate responsibility in the event of an accident. However, the common consensus seems to be that the driver is responsible up to level 2, and that the manufacturers of the automated vehicles are responsible at full automation at level 4 and 5. For level

[122] EU (2016, 14 April)
[123] https://www.unece.org/trans/main/wp29/introduction.html

3, where there is a switch between manual and automated driving, there is significant disunity. In some US states, the driver is always responsible, whilst in other states, it is the supplier who is responsible if an accident occurs when the vehicle is automated at level 3.[124]

The Norwegian Board of Technology's expert group suggest a revision to the Road Traffic Act where the distribution of responsibility would be based on the level of automation. Up to and including level 2, the driver should always be responsible. At level 3, where automation is permitted on certain stretches of the road, the driver should have the same responsibility as he/she does at level 0-2, however, the driver should also have an overall responsibility for ensuring that automated control is only activated in permitted areas and stretches of the road. When the automated control is switched on, it is recommended that the road authorities or the supplier of the automated system are responsible. Who is ultimately responsible here, should depend on whether the accident occurred due to a road/infrastructure failure or due to a system error. At level 4 and 5, the passenger is free from responsibility. The responsibility is defined in the same way as it is for automated control at level 3.

[124] SOU 2018:16

	Level	The expert group recommends the following distribution of responsibility
	**Level 0 – no automation:** The driver has complete control at all times, and no system is used to intervene.	The driver is responsible at all times
	**Level 1 – driver-assistance:** The driver has complete control of the steering or speed, whilst one of the functions is automated. Such as adaptive cruise control.	The driver is responsible at all times
	**Level 2 – partial automation:** Steering and speed are automated under certain conditions, but the driver must always be ready to take control.	The driver is responsible at all times
	**Level 3 – conditional automation:** Steering and speed are automated under certain conditions, and the driver is warned in good time to take control when it is warranted.	During manual control: The driver is responsible at all times. During automated control: The road authorities are responsible if an accident occurs due to a road/infrastructure failure that they have approved for automated vehicles. If the accident occurs due to a system error, the supplier of the automated system is responsible. The driver has an overall responsibility for ensuring that automated control is only activated in permitted areas and stretches of the road
	**Level 4 – high automation:** The car has complete control of the steering and speed under certain conditions. This may be applicable within a limited geographical area, for example.	The road authorities are responsible if an accident occurs due to a road/infrastructure failure that they have approved for automated vehicles. If the accident occurs due to a system error, the supplier of the automated system is responsible.
	**Level 5 – complete automation**: The car has complete control at all times, and under all conditions.[125]	The road authorities are responsible if an accident occurs due to a road/infrastructure failure that they have approved for automated vehicles. If the accident occurs due to a system error, the supplier of the automated system is responsible.

SELF-DRIVING CARS MUST NOT DISCRIMINATE

Unlike humans, who will react instinctively in order to avoid a sudden accident, computers, in theory, are able to make a rational decision. Situations come to mind where the system of the automated vehicle must choose between two different outcomes that may harm people either inside or outside of the vehicle. The way the system is pre-programmed will decide which outcome the computer chooses.

Situations like this, where the computer must make such a calculated assessment, will be relatively uncommon. It is more likely that accidents will occur due to a technical error, where the vehicle does not make an ethical choice at all.

However, in order for the technology to be accepted by society, it may be important to establish certain foundational principles in advance for what ethics the automated vehicles will follow. Transparency about how the vehicles are programmed to handle accidents may provide better predictability for road users and suppliers of the technology. A particularly controversial and challenging topic for an ethical framework will be to what extent the vehicle is programmed to prioritise the lives and health of the passengers as opposed to those outside the vehicle.

In Germany, an ethical framework has been created, which, among other things, states that vehicles must not discriminate people based on age, gender or other aspects in the event of an unavoidable accident.[126]

We recommend that ethical guidelines be established in Norway too for how automated vehicles should act in traffic. A paramount ethical principle should be that the vehicles must not be able to be programmed to discriminate between people based on their age, gender or other aspects. Here, it will be important to clarify how the vehicles will prioritise the safety of the passengers and those outside the vehicle.

REMOTE CONTROL OF VEHICLES MUST BE LIMITED

An automated vehicle does not need to be connected to a network in order to work, but for use in traffic, it would be an advantage. For example, the vehicles

[125] Jenssen G. D. (2017, p. 199)
[126] Bmvi (2017)

will need to be able to receive bookings for trips and warnings about traffic and incidents on the road.

It may also be necessary to remote control the vehicle in the event of unexpected incidents on the road that the vehicle is not programmed to handle, such as road works. The Norwegian company Applied Autonomy is working on the development of a control centre where one person can administer a fleet of automated vehicles.[127] Similar companies also exist in the US.[128]

The possibility of controlling a vehicle remotely could potentially have major consequences in the event of a cyber attack. Therefore, we recommend that the opportunity to control a vehicle via remote access is regulated. In order to reduce possible consequences, the speed of vehicles that are remote controlled should be limited in such a way so that they cannot cause significant harm.

USE OF AUTOMATED VEHICLES SHOULD ONLY OCCUR ON APPROVED AND SPECIALLY DESIGNED ROUTES

Automated vehicles are being developed in order to work on today's roads and together with pedestrians and manually driven vehicles. Therefore, it will not be necessary to build completely new roads in order to use the technology. However, the roads will still need to be of a good standard. There may also be a need for some modifications such as digital signs, or pick-up and drop-off points.

We recommend that automated vehicles are only permitted on routes and in areas that are quality assured and approved by the road authorities for this type of use. The risk increases in mixed traffic and so other road users should be made aware that the roads are being shared with automated vehicles, for example, with the help of road signs.

PARTIAL AUTOMATION

Features of partial automation already exist on the market. These types of systems allow the driver to periodically transfer the control to the vehicle. Tesla's

[127] https://www.appliedautonomy.no/
[128] Wired (2018b)

product Autopilot is one example, but companies like Volvo[129], Mercedes[130], Cadillac[131] and Audi[132] are developing similar features.

Partial automation can be classified as either level 2 or 3 within SAE's classification of automated vehicles from 0 – 5. The levels describe both the degree of automation and the distribution of responsibility between humans and machines. Systems at level 2 are considered as advanced driver-assistance, where parts of the control are left to the vehicle, but the driver must always pay close attention to the road, and be ready to take control of the driving at all times. At level 3, the control and responsibility for paying attention to the road is left to the vehicle, and the driver is warned when he/she needs to take control.

Advanced driver-assistance[133] is primarily used to improve the existing abilities of the driver by providing blind spot warnings, adaptive cruise control, collision warnings and automatic braking. Some types of advanced driver-assistance aims to improve safety, whilst partial automation systems are primarily marketed for the purpose of comfort.

When many driving tasks are automated, it is difficult to maintain your concentration. Experiments and research so far indicates that partial automation can be dangerous, since it is difficult for people to actively pay attention to the road for a long time without actively taking part in the driving.[134]

PARTIAL AUTOMATION MUST BE REGULATED BETTER

The Road Traffic Act states that the driver of the car must always have complete control of the vehicle.[135] Thus, use of automated functions at level 3 is not legal according to the Road Traffic Act. When partial automation is tested today, there is a prerequisite that the driver must pay close attention to the road and be ready to take control of the driving at all times, just like at level 2.

ITE, an international organisation for transport engineers, recommends that advanced driver-assistance systems that improve safety should be used in all

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[129] https://www.volvocars.com/intl/buy/explore/intellisafe/autonomous-driving/drive-me
[130] https://www.mercedes-benz.com/en/mercedes-benz/innovation/with-intelligent-drive-more-comfort-in-road-traffic/
[131] http://www.cadillac.com/world-of-cadillac/innovation/super-cruise
[132] https://www.audi.com/en/innovation/piloteddriving/piloted_driving.html
[133] Often known as ADAS (Advanced driver-assistance systems)
[134] Endsley (2016)
[135] Vegtrafikkloven (1965, §6)

new cars. However, they warn against partial automation at level 2 and 3, since it has still not been sufficiently proved that this improves road safety. The organisation recommends that development focuses on level 4.[136]

The Norwegian Board of Technology's expert group recommends that systems for partially automated vehicles be better regulated than they currently are. In practice, these systems fall outside of today's legislations, since the driver is responsible when testing occurs. New regulations should differentiate between technology that supports the driver and technology that supports the vehicle's automated features that pacify the driver to the extent that it is difficult to take over control of the vehicle at short notice. In addition, it is important to develop standards that ensure similar experiences of the systems coming from the various suppliers.

PRIVACY, DATA AND DIGITAL MAPS

Automated vehicles can be regarded as rolling computers. They have many types of sensors that are able to collect large amounts of data from the outside world. It will be advantageous to have extremely detailed maps with 3D scans of the surroundings to help navigation.

An automated vehicle often utilises many cameras to orient itself, which means that they will register information about people within the surroundings. It is also likely that the vehicles will register information about the passengers within the vehicles.

The new privacy laws in Europe (GDPR) will lead the way for how data management and privacy are regulated in Norway. However, it is important that Norwegian authorities are aware of how much data automated vehicles have the potential to collect. This concerns privacy, managing the digital infrastructure and national security.

SELF-DRIVING CARS SHOULD NOT BE USED AS ROLLING SURVEILLANCE CAMERAS

More than 10,000 Tesla models equipped with eight cameras have already been sold. This means that approximately 80,000 cameras are regularly recording

[136] Institute of Transport Engineers 2018

video clips of Norwegian roads, which are used to develop automated driving technology.

In the proposition of the "Testing of Automated Vehicles Act", it is stated that cameras fixed to a vehicle will not be considered as "continuous personal surveillance", unless it is on a fixed route.[137] A self-driving taxi driving as a hired vehicle is considered, according to this definition, as continuous surveillance. Over time, if the technology is embraced by many, fleets of automated vehicles will make up massive networks of surveillance cameras.

We recommend that Norwegian authorities pay particular attention to how information from sensors and cameras on automated vehicles are to be processed and stored. Important principles in this context are data minimisation and purpose limitation. Collected data should never be used for anything other than controlling the vehicle and developing the technology in order to avoid data being used for other purposes. Nor must the data be stored longer than needed for any investigation of a traffic accident where the vehicle in question has been involved.

TRAVEL ON NORWEGIAN ROADS MUST STILL BE POSSIBLE WITHOUT THE NEED TO BE CONTINUOUSLY TRACKED

A self-driving car will know where it is located at any point in time and will most likely also be able to retain a part of its own location history. From leaving traces periodically, such as when we pass a tollbooth, a continuous line will be traced after us. This data may be of interest to many parties: manufacturers, insurance agencies, public authorities and third parties.

Online, we have practically entered a business model where our personal data has become a currency that can be bought and sold. Should the surveillance economy also join us on our travels?

It should always be possible to drive in private mode, where the car does not use any more information about us than what is necessary in order to deliver a safe journey.

At the same time, we can see that proper use and the sharing of data will benefit customers, manufacturers and public authorities. It is therefore necessary to establish clear guidelines for who owns the data, how it will be stored and where

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[137] Prop. 152 L: p. 14

applicable, how it will be processed after the user has provided a voluntary and informed consent.

TAKE CONTROL OF 3D MAPS

Extremely detailed maps are an advantage to the proper functioning of a self-driving car. These maps have centimetre-level accuracy. The maps consist of several layers with an increasing level of detailed information: A basic layer of information on where the roads are. A layer of information on speed limits, road signs, traffic lights, pedestrian crossings etc. Followed by a layer of images and three-dimensional models of the surroundings. Large, private companies such as Google, Apple, Tesla, Baidu, collect this data and currently, have no obligation to share this with the public.

Having the best map will be a competitive advantage, and several companies are competing for a market that may be extremely valuable in the future. The company with the highest amount of vehicles on the roads will have the most up-to-date maps, and therefore, also have the safest vehicles. This may create monopolised mapping systems.

The Norwegian Mapping Authority and the Norwegian Public Roads Administration are working on making the data on Norwegian roads available via, among others, The National Road Data Bank and Geonorge (the national website for map data and other location information in Norway). These services are used as a foundation for developing mapping services such as Google Maps, OpenStreetMaps and a number of other products. The Norwegian Mapping Authority and the Norwegian Public Roads Administration are also working on point cloud maps that will be openly available to the public, and which may be of significant use for developing maps for automated vehicles.

Automated vehicles will eventually be updating their own maps continuously and collect a great deal of information on how the roads change due to road works or weather conditions.

Regarding emergency preparedness, it may be a disadvantage if foreign companies own the most updated and detailed information about Norwegian roads. Yet when considering road safety and competition, it will be an advantage if all automated vehicles have access to the same information.

The expert group believes that Norwegian authorities should take an active role in managing the mapping data for automated vehicles. It should be a condition, in order to use Norwegian roads, that the companies share information that may benefit the community. For security reasons, the authorities should consider how much of this information should be available to the public.

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