REPORT
Ref. no. TSG 2014-1316
08 2014
ISBN

Autonomous driving

Pilot study

Road and Rail Department
Traffic and infrastructure unit

This report is available on the Swedish Transport Agency website at www.transportstyrelsen.se

Ref. no./Designation	TSG 2014-1316
ISBN	
Author	Björn Arrias, law Anna-Lena Elmqvist, licenses Anna Ferner Skymning, technology and vehicles Peter Larsson, marketing, quality and strategy Jonas Malmstig, law Annacarin Mörsell, traffic and infrastructure Niclas Nilsson, traffic and infrastructure Henrik Olars, communication Olof Stenlund, licenses Yvonne Wärnfeldt, technology and vehicles Per Öhgren, traffic and infrastructure
Month Year	08 2014

Foreword

The investigation has been implemented as an internal assignment at the Swedish Transport Agency. The objective has been to create data, knowledge and strategy for ongoing work.

Contents

Summary

The development of self-driving vehicles is taking place at a rapid pace, and systems which – under certain conditions – support a higher degree of automation will soon be ready for market launch. This development may have a radical effect on the entire road traffic system and its function in society. This is a complex system which could probably impact upon community and urban planning, settlement patterns, travel patterns and travel habits, traffic volume, car ownership forms, etc.

The working group has come to the conclusion that there is nothing in the road traffic legislation to directly prevent the use of self-driving vehicles in the road transport system. Current road traffic rules are based on driver responsibility for driving the vehicle. For fully self-driving vehicles, where there may perhaps be no driver at all, the division of liability and concept of liability need to be developed so that there can be said to be someone who is responsible for each journey.

Vehicle legislation is controlled by the EU and UNECE. There are currently no requirements guaranteeing an identified level of safety for vehicles' self-driving functions. In the opinion of the working group, regulations will be needed which guarantee a sufficiently high level of road safety for vehicles with a higher degree of automation so as not to impede the market launch. The working group is of the opinion that these vehicles will be technically ready for launch on the market in around 2020.

Current legislation provides scope for test operations in real traffic using vehicles with a higher degree of automation. The road traffic legislation does not present an obstacle, and if the vehicles fail to meet the technical requirements the Swedish Transport Agency has the opportunity to grant exceptions for this enterprise.

Not much is known about the difficulties of the future systems and any risks they may involve, and so at present the working group perceives no need to change regulation of the driving test or vehicle requirements for the driving test. The same is applicable to any need for development in driver training.

The working group has devised a number of proposals for ongoing work in order to enhance the Swedish Transport Agency's knowledge and opportunity to influence developments. These involve – among other things – actively monitoring testing operations in order to enhance knowledge of how national and international regulations need to be developed and to continue and intensify efforts within the EU and UNECE, based on a collective Swedish target for the field of autonomous driving.

1 Introduction

1.1 Background

The development of self-driving vehicles is taking place at a rapid pace, and systems which – under certain conditions – support autonomous driving will soon be ready for market launch. However, as things stand at present there is no clear structure to development. Different stakeholders with access to different policy instruments often operate independently. It may be easy to believe that the challenge is primarily technical in nature, such as ensuring the reliability of these systems. However, today's road traffic system is very complex, with interaction among its various elements which is often difficult to predict and control. This means that development in the field may have a radical effect on the entire road traffic system and its function in society. Thus this development will probably also impact at an overall societal level in respect of community and urban planning, settlement patterns, travel patterns and travel habits, traffic volume, car ownership forms, etc.

The structure of the technical solutions in future is very much uncertain. Much of this uncertainty comes about on account of the fact that development towards autonomous driving is dependent upon the complexity of the system in which the technology will operate. For example, the technology has to be adapted to human criteria and restrictions and the infrastructure may need to be adapted to vehicle technology. To create a foundation from which to understand and deal with any risks, companies such as Google, Mercedes and Volvo Car Corporation all intend to test and evaluate self-driving vehicles on public roads.

Therefore, the major challenge facing society involves ensuring that developments towards autonomous driving move in the right direction, i.e. help to achieve transport policy targets, but other societal objectives as well, while at the same time not hampering innovation and development. It is also clear that no one stakeholder can control this development alone, and interaction will be needed among a large number of stakeholders in order to achieve the targets as efficiently as possible. This may lead to the roles and policy instruments of various authorities having to be adapted in accordance with the above reasoning.

1.2 Purpose

The purpose of the working group is to identify whether and how legislation needs to be modified in order to permit partly or fully automated driving, and if so which legislation; and to prepare the way prior to the trials to commence in 2015.

In the longer term, the aim is to permit introduction of fully or partly automated driving on roads in 2016.

Another aim is to form a basis for a strategy for the ongoing work of the Swedish Transport Agency.

This proposal has constituted a partial basis for the shared government assignment for the Swedish Transport Administration and the Swedish Transport Agency, involving review of the national ITS action plan for which a final report was submitted on 5 May 2014.

1.3 Limitations

The working group will not propose legislative amendments, but solely identify any need for such amendments.

1.4 Method and implementation

The investigation has been conducted with broad representation from a range of different units within the Swedish Transport Agency and is largely based on research and situation analysis, as well as discussion with external stakeholders. Hence no references are stated.

A study of the literature[1] has taken place, with a view to:

- enhancing the Swedish Transport Agency's knowledge on the safety effects of different degrees of handover of driver control to technical systems, primarily in respect of automation of longer driving sequences with a view to relieving strain on the driver, and
- creating a foundation from which to understand and deal with any risks inherent in the technology which the Drive Me project intends to test and evaluate on public roads.

A number of conferences have been held with various stakeholders with a view to creating an overall perspective, finding forms of cooperation and acquiring a knowledge of how other stakeholders are working in the field.

- A workshop has been held with a view to highlighting the views of various stakeholders in respect of development and discussing what is needed in order to achieve effective development in the field. External participation from Folksam, Scania and Volvo Car Corporation.
- Participation in the Drive Me project, which is a partnership involving the Swedish Transport Administration, the Swedish

[1] See Appendix 13 Literature study, Autonomous driving – HF/MTO.

Transport Agency, the City of Gothenburg, Lindholmen Science Park and Volvo Car Corporation.

- A conference has been held with representatives of the Swedish Prosecution Authority (Development Centre Malmö), primarily for discussion of issues relating to criminal liability in connection with autonomous driving.
- A teleconference has been held with the Swedish Work Environment Authority, and contact has been made with the Swedish Insurance Federation.
- Internal authority interviews have been held with representatives of railways and aviation.

Alongside this, representatives of from the Swedish Transport Agency together with the Ministry of Enterprise, Energy and Communications, the Swedish Transport Administration and representatives of the automotive industry and academia have participated in seminars and conferences in Washington D.C. involving American authorities and organisations. The Swedish Transport Agency has established contact with the Department of Motor Vehicles (DMV), a state authority in California which is also working with the issue. California's aim is to be able to offer the opportunity for self-driving vehicles to use the road network by 1 January 2015.

Otherwise, participants in the investigation have provided information internally in respect of the assignment during a special day held for the road and rail department.

The working group has also received information from Lindholmen Science Park concerning the implementation of a project which is working on an R&I agenda for the field.

1.5 Definitions and terms

During the investigation work, a need has emerged for definitions for terms which otherwise remain undefined in national or international legislation.

The description of the assignment uses the term "autonomous driving". Other terms for phenomena which are partly the same are also used in the industry and the mass media. Certain terms focus on the driving of the vehicle, such as "automated driving", while other terms are used to describe a type of vehicle which has been equipped with technology which allows the vehicle to operate in traffic without the driver actively controlling it, such as "autonomous vehicles" or "self-driving vehicles". The working group has chosen to use the terms "self-driving vehicles" and "autonomous driving".

These terms are not defined in the Swedish vehicle or road traffic legislation, nor are they defined in – for example – the Vienna Convention on Road Traffic, dated 8 November 1968 (known as the Vienna Convention), or in Community legislation.

The working group has opted to relate to the levels of automation devised by the American National Highway Traffic Safety Administration (NHTSA). Below is a somewhat simplified description of these[2]:

Level 0 – No automation
The driver has full control over the primary vehicle controls (brakes, steering, acceleration/drive) and is himself responsible for driving the vehicle safely. Vehicles with a certain level of driver aids or comfort systems which which do not have the option of controlling steering, brakes or acceleration would still be classified as "level 0 vehicles". Systems which merely provide warnings and systems which provide automation of secondary controls such as windscreen wipers, direction indicators, etc. can be referred to by way of example.

Level 1 - Function-specific automation
Automation at this level involves one or more specific control functions. If several functions are automated, they operate independently of one another. The driver has overall control and is himself responsible for ensuring that the vehicle is driven safely. A certain degree of control over primary controls (such as cruise control, automatic braking and assistance to remain within lanes) can be handed over, but there are no combined, integrated systems which interact so that the driver does not have to physically engage in driving and can let go of the steering wheel and take his foot off the brake and accelerator pedals all at the same time.

Level 2 - Function-combined automation
This level includes automation of at least two primary functions which have to work together to relieve strain on the driver. The driver is still responsible for driving the vehicle safely and is expected to remain constantly alert so that he can react at short notice. The different here compared with level 1 is that an automated drive mode is enabled here under the specific operating conditions for which the system was developed. This relieves strain on the driver in that he does not have to physically control the vehicle. One example of a level 2 vehicle is one in which adaptive cruise control (ACC) works in combination with lane assist.

Level 3 – Limited autonomous driving
Vehicles at this level of automation make it possible for the driver to hand

[2]http://www.nhtsa.gov/About+NHTSA/Press+Releases/U.S.+Department+of+Transportation+Releases+Policy+on+Automated+Vehicle+Development.

over all control over all safety-critical functions under certain traffic or environmental conditions. However, the driver must be available to control the systems, and there must be a convenient transitional period within which the driver can resume control. One example is when the system can no longer be operated without driver control – e.g. when passing roadworks – and when the system signals to the driver that he should resume driving. The big difference between levels 2 and 3 is that the driver of a level 3 vehicle is not expected to constantly monitor the road during driving.

Level 4 – Fully autonomous driving
The vehicle is designed to execute all safety-critical driver tasks and monitor road conditions throughout the entire journey. The driver is not expected to be available to control the vehicle at any point during the journey. A design of this type requires the driver to enter a destination or road description. This also includes vehicles without passengers or drivers. Driving safety rests entirely upon the vehicle's automated system.

2 External factors

The intention of this chapter is to provide a brief introduction to the field of autonomous driving as the working group perceives it at present. Which primary stakeholders are driving development, and where are the decisions influencing this development being made? What is the role of the authorities, and in which forums is the Swedish Transport Agency currently active? What research is ongoing, and what knowledge will we need for the future?

2.1 Stakeholders

2.1.1 The automotive industry

As stated in the introduction, the rate of development for technical solutions in and associated with the vehicles is very high. It may also be stated that technological development is extremely interesting to the existing automotive industry as a whole. Research and testing are taking place in parallel, and more or less all the major car manufacturers have reported over the past year that they are developing more or less advanced systems with a view to enhancing levels of car automation. In simplified terms, the situation could be described as a form of "arms race", an important factor in the individual vehicle manufacturers' abilities to meet the future needs of the market.

The role played by the vehicle manufacturers' international trade organisation, Organisation Internationale des Constructeurs (OICA, the International Organisation of Motor Vehicle Manufacturers), is harder to assess at this stage of development. They are representing competing companies that are preparing for a new field, so it is conceivable that *this* in itself is a challenge to be dealt with.

The European Automobile Manufacturers Association (ACEA) and BIL Sweden are also important representatives for the automotive industry.

2.1.2 "The new innovators"

What is known as the Google Self-driving Car is a very good example of new stakeholders driving development towards self-driving cars. There are other examples, too, and it is telling that a number of these new stakeholders are resident in the telecoms and/or IT industry in one way or another. Another example is the Australian car sharing company GoGet, which together with the University of New South Wales has embarked upon a partnership to develop a self-driving car. Another example is the American technology company Cybernet Systems, which is planning to develop fully automated trucks and fully automated road vehicles which operate even in bad weather.[3]

2.1.3 Academia

Advanced research is a must if self-driving cars are to become reality on our roads. It is also very clear that universities and research institutes are already heavily involved in the development which is taking place. (See ongoing research and research requirements in section 2.5 in this chapter.)

2.1.4 Legislative bodies and authorities

The European Union
The EU has legislative power and is the stakeholder responsible for establishing Community provisions in ordinances and directives in this field as well, with the exception of many of the aspects relating to road traffic rules and infrastructure design in a more physical sense. When it comes to preparing technical requirements for vehicles, this work has been delegated to the international United Nation Economic Commission for Europe (UNECE), based in Geneva. When provisions in the form of regulations have been devised, these will be sent back to the EU for regular decision-making. Alongside its role as a legislator, the EU is also initiating and financing extensive research in which the field of autonomous driving is deemed to be on the increase. (See chapter 2.5.)

UNECE
UNECE has a range of Working Parties (WPs) in the field of road transport, but in this context WP 1 and WP 29 are of relevance. WP 1 deals with the field of road safety at a more general level and works with matters such as the Vienna Convention on Road Traffic, which includes provisions for vehicles and drivers in international traffic. A contracting party must also ensure that national road traffic legislation reflects the provisions of the Convention in all material respects.

WP 29 is working on technical requirements for vehicles, and its work is being carried out by six different workgroups. Advanced driver assistance systems are being handled by the Working Party on Brakes and Running Gear (GRRF). Issues relating to regulation of advanced driver assistance systems have just started to emerge.

The Swedish Transport Agency, the Swedish Transport Administration and the municipalities
The Swedish Transport Agency holds regulatory responsibility and is heavily involved in the developments and negotiations taking place in the field within UNECE. The authority is also participating, in a similar way, in

[3] This paragraph is based on regular newsletters received from Swedish ICT.

the elements being handled by the EU, but it could be stated in this regard that the issue has not been brought to the fore there in the same way as at UNECE.

The Swedish Transport Administration and the municipalities are central stakeholders in the ongoing work on account of their roles as infrastructure owners, not least as regards the future design of infrastructure with regard to autonomous driving.

On a national level, both the Swedish Transport Agency and the Swedish Transport Administration are participating in Volvo Car Corporation's ongoing Drive Me project, test operations in which the aim is to study the social benefits of autonomous driving in respect of punctuality, capacity, robustness, usability, safety, environment and health, as well as urban development. This project is being run by Volvo Car Corporation, and the City of Gothenburg and Lindholmen Science Park are other project participants. This project began in the spring of 2014, and plans are afoot to commence the actual testing stage in Gothenburg within the next few years. The Swedish Transport Agency is currently preparing targets for project participation so as to gather knowledge of its own from the tests.

NHTSA
NHTSA is an authority subordinate to the American Department of Transportation. The authority is responsible for matters such as reducing deaths, injuries and financial losses as a consequence of accidents involving motor vehicles. To achieve this, it establishes and maintains safety standards and provides consumer information on this. It also carries out research into driver behaviour and road safety. (See chapter 2.5.)

NHTSA is also taking part in several of the workgroups within WP 29 (see above).

2.1.5 Different roles, perspectives and levels of maturity

It can clearly be stated that politicians, authorities and decision-making bodies, either individually or jointly, are not the ones who are progressing the development of autonomous vehicles. That said, it is very clear that companies have high levels of both innovation and motivation. Again, we can state that companies outside the traditional automotive industry are involved in that the field cannot be restricted to pure vehicle development. In general, it could be stated that politicians, authorities and other regulation-setting bodies in both the EU and the rest of the world are playing a rather cautious and more contemplative role so far; with the exception of a number of states in the USA, headed by California, where the authority is actively working to introduce a state regulation with a view to accelerating work to be able to introduce these vehicles to the roads.

There is no clear-cut view of the opinions of individual countries on the societal benefits of autonomous driving. How will this development contribute towards societal benefits, and which benefits would it provide? In the USA, there is much emphasis on the benefits involved in the fact that the technology will permit more efficient use of the road traffic environment as the technology will allow cars to be "packed more tightly". The capacity-increasing effect is also being emphasised in Sweden, but here the primary discussion relates to societal benefits in the form of greater road safety as the technology will correct human errors. There are also important environmental gains to be had as a result of greater energy efficiency due to platooning/road trains, for example, or in purely general terms as a result of smoother driving.

As mentioned in the paragraph above, in the opinion of the working group the EU has maintained something of a low profile to date in the field of autonomous driving. If Sweden is to be involved and help with the required development, it is therefore extremely important for the Swedish Transport Agency to immediately enhance its knowledge of and participation in the EU forum which is dealing with these issues.

To conclude, it may be stated that we have identified, within the scope of the authority's regular work within UNECE (WP 1 and WP 29), clear differences in how development should be approached on the part of the various authorities. One very clear example indicating how far apart the various countries are in respect of central standpoints is the discussion which took place some time ago as part of UNECE WP 1, concerning the liability of the driver (Article 8 in the Vienna Convention). Another issue which will probably present a stumbling block involves the conditions that have to be in place for vehicles to be launched on the market, i.e. the need for regulation. What requirements have to be specified? When should they be specified, and is this possible – or even desirable – within the scope of the approval system used for cars at present?

2.2 Vehicle development

Vehicles fitted with systems for limited automated driving can already be found on our roads, and development in respect of vehicles is progressing at a tremendous pace. Below are some examples of systems which are available and what future vehicles can be expected to have in the short term and the slightly longer term.

2.2.1 The current situation – what is available on the market?

The systems available on the market at present assist the driver with driving. The driver is expected to maintain control over the vehicle at all times. These systems largely include systems which manage steering (lateral) or acceleration and braking (longitudinal), which is equivalent to level 1 in the NHTSA scheme. However, systems are starting to be introduced which can combine these functions and hence belong to level 2.

Examples of system on the market

System	Function	Estimated NHTSA level
Automatic Emergency Brake System (AEBS)	Automatic **emergency brake** system, normally **warns** first, then **brakes** to prevent collision or reduce the consequences of collision	1
Lane Keep Assist (LKAS)	An assistance system which warns and then intervenes by **countersteering** if the driver leaves a lane.	1
Active parking assist	The driver activates the system, accelerates and brakes, the system **steers** the vehicle into position.	1
Adaptive cruise control and driving in heavy traffic	Maintains the correct distance to the vehicle in front. **accelerate/brake**	1
Adaptive Cruise Control with steering assistance (adaptive cruise control supplemented with an autonomous steering function)	Maintains the correct distance to the vehicle in front and keeps the car in the middle of the lane (straight and slightly curved roads). **accelerate/brake/steer**	2

2.2.2 Up to 2020 – what can we expect to see on the market?

More and more combined systems will be introduced which can handle steering, acceleration and braking. Several vehicle manufacturers and other stakeholders have announced that they will be producing self-driving cars and launching them on the market from late 2020. These will probably be vehicles which can handle the entire task of driving under certain conditions, e.g. on the right type of road and under certain weather conditions, i.e. level 3 in accordance with NHTSA's classification. The driver activates the system and can leave the task of driving entirely to the vehicle. However, the driver must be present and capable to taking over driving within a reasonable time when so requested by the car. Driverless parking systems can also be anticipated. The car will then be able to locate a parking space and park itself. During this period, it should also be technically possible to introduce some form of what is known as platooning, where vehicles are electronically linked and travel in close formation. The main aim of platooning for heavy goods vehicles is to reduce energy consumption as air resistance is reduced for the "tailgating" vehicles.

2.2.3 In the longer term

The technology for driving vehicles with no driver intervention at all currently exists, as has been demonstrated by Google through its trials in the USA. But when will these vehicles be ready to launch on the market? That is unclear. Some technology companies reckon they will be ready to launch such vehicles in the early 2020s, while other stakeholders predict that this will not happen until 2025. And what will happen with car ownership in respect of level 4 self-driving vehicles, compared with today's ownership structures? There is a lot of discussion on car pools, taxis and similar transport services using self-driving vehicles.

2.3 ITS – Intelligent Transport Systems and Services

ITS is currently a *system concept* relating to the use of information and communications technology within the entire field of transport. It largely involves systems, but perhaps even more so *services*, requiring interaction between telecommunications, electronics, information technology, traffic technology and traffic infrastructure.

As regards road traffic, ITS may involve increasing accessibility and safety, but it may also relate to technology helping to reduce environmental impact. The chances of increasing compliance with targets on roads with the aid of ITS appear to be very good as there is untapped potential in respect of road traffic compared with airborne, waterborne or trackbound traffic, where implementation of ITS has made more progress. To be able to benefit fully from these systems, collective standards are required which ensure that communications will work.

2.3.1 ITS, cooperative systems and vehicles

Cooperative systems (C-ITS) are ITS systems based on wireless communication; vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I) and infrastructure-to-infrastructure (I2I). An initial basic set of standards for C-ITS has been compiled by the standardisation bodies ETSI and CEN on behalf of the EU Commission. These standards will make it possible for vehicles of different makes to communicate with one another and with the infrastructure. The organisations are continuing their work and will produce a further set of standards.

As self-driving vehicles need to know what external conditions are like and what is happening out there in real time, wireless communication (V2V and V2I) is an important piece of the puzzle in the development of self-driving vehicles, too. However, the need for information will probably vary depending on factors such as the degree of automation, the road traffic environment and the vehicle manufacturer's choice of technical solution.

2.4 Other traffic types

2.4.1 Aviation

Experience is available from other types of traffic which have implemented advanced technology and automation in their designs, and comparisons can be drawn with these. Aviation has many years of experience of autonomous system usage in the form of autopilot systems. Many of these experiences can also be applied to other traffic types, e.g. cars/vehicles on roads, even though there are major differences between traffic types. Automation and the interaction between man and system are the common factor.

Classic problems linked with the introduction of automatic functions are as follows:

- Automation will not necessarily resolve the most difficult elements, but will leave them to the driver.
- When you rely on technical aids, your own skills will diminish over time[4].

This is something which also emerges from the research and experiences cited in respect of automation in the field of aviation, along with experience indicating that automation has helped to make flying safer and faster. Early arguments in respect of greater safety in aviation stated that pilots were regarded as the primary cause of accidents, which led to automation of everything that could be automated, and perhaps not always things which ought to have been automated.

According to EASA[5], commercial aviation resulted in no deaths within the EU last year. Flight safety officers and pilots state that computerisation of technology on board aircraft has made a major contribution to this improvement in safety.
The introduction of automation has helped to relieve the strain on the pilot during various flight phases, and there are also systems which help to ensure more stable approaches and safer landings. Automation has also reduced the pilot's physical workload, and not having to fly the aircraft manually frees up time for other tasks. However, experience shows that the mental workload has not been reduced to the same extent; rather, it has increased. Automation reduces the mental workload when cruising at altitude, but during more demanding situations it does not facilitate matters to the same extent. Instead, it increases the load. This can take place during flight phases in which the workload is already high, such as on approach and landing. This development has also added a high level of complexity, which means

[4] Stig Franzén, Professor of man-machine interaction at Chalmers University of Technology, Gothenburg.
[5] The European Aviation Safety Agency.

that pilots need tools to be able to handle the aircraft safely. There are lots of different parameters to be monitored with technically advanced systems, and mistakes have been shifted. In other words, the complexity of automation has helped to bring about new human errors. Difficulties with understanding the logic behind the behaviour of automation, so making it more difficult for pilots to predict what automation will do next, is one example.[6]

Early research into the potential effects of automation on how pilots operate has shown, among other things, risks resulting from an increased level of automation.[7] This assumption is based on the fact that pilots no longer physically fly aircraft, and the fact that we humans are normally not very good at monitoring complex systems which often work well. Automation is considered to have taken over many of the control and monitoring functions on board aircraft. It is argued that automation has contributed to higher levels of boredom and complacency, often known as "automation complacency", and that greater automation hence presents a risk. Further risks mentioned involve the erosion of skills and proficiency and loss of situational awareness in space and time. In various accident investigations, the risks above are sometimes specified as being direct or indirect causes of the occurrence of accidents or incidents. Measures then tend to be at individual level, i.e. pilots receive supplementary training, procedures are rewritten, etc.

Conclusions drawn through earlier research indicate the importance of taking into account the Human Factors/Man-Technology-Organisation (HF/MTO) perspective when developing and implementing automation in the cockpit so as avoid the risk of isolating the pilot from the systems. Investigations of accidents occurring within organisations in which advanced automation and high-tech systems are used on a daily basis have also indicated causal factors such as inadequate interfaces (interaction) between man and technology.[8] The human errors in these accidents were consequences of factors such as poor design, inadequate procedures and insufficient training.

One important conclusion is that human error or impaired human performance is often induced by factors which can be avoided by taking into account the individual's criteria and restrictions at an early design stage.

Air traffic

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[6] See Dekker, S. W. & Hollnagel, E. (1999). *Coping with Computers in the Cockpit.* Aldershot, UK: Ashgate Publishing.
[7] Wiener, E. L. & Curry, R. E. (1980). Flight Deck Automation: Promises and Problems. *Ergonomics,* 23, 1995-1011.
[8] Including The Challenger space shuttle, the nuclear accident in Chernobyl (see ICAO, Human Factors Training Manual, 1998). The air accident in Nagoya, Japan involving an Airbus 300 (see Aircraft Accident Investigation Commission: Ministry of Transport, Japan, 1994).

Aircraft which can be operated with a relatively high degree of automation have been used for air traffic purposes for a long time. Aircraft which can be operated unmanned are also used, under various names. Such aircraft are sometimes termed drones.
The Swedish Civil Aviation Act (2010:500) includes certain basic provisions stating the conditions under which aviation may take place on Swedish territory. Provisions relating to this are also specified in EU ordinances. The Swedish Civil Aviation Act includes an authorisation for the Government or the authority which the Government decides may issue regulations concerning aviation traffic, what must otherwise be observed in the case of aviation in order to avoid accidents and inconvenience, flight paths which aircraft must follow on Swedish territory, limitations in the use of airspace in connection with such flight paths, and flights which cross the country's borders. Pursuant to this authorisation, the Government has announced the Swedish Civil Aviation Ordinance (2010:770) and authorised the Swedish Transport Agency in Chap. 8(1) to, following consultations with the Swedish Armed Forces, issue regulations on aviation traffic rules, among other things. The traffic rules shall correspond in the main to the traffic rules adopted by the International Civil Aviation Organization (ICAO)[9] (the international traffic rules). Hence aviation is also subject to international conventions.

To an extent, the power to set standards differs between aviation traffic and on-road and off-road traffic. The Swedish Transport Agency has no authorisation to issue regulations on traffic rules on-road and off-road, but merely has the opportunity to grant exceptions to certain provisions in regulations issued by other authorities.

The Swedish Transport Agency has issued the Swedish Transport Agency's regulations (TSFS 2010:145) and general recommendations on traffic rules for aviation, pursuant to the authorisation in the Swedish Civil Aviation Ordinance. The regulations, like the Swedish Road Traffic Ordinance, include general consideration principles which state that an aircraft must not be operated in a negligent or reckless manner which presents a risk to the lives or property of others, as well as provisions on evasive action.

The design, manufacture, modification, maintenance and operation of unmanned civilian aircraft are regulated in Sweden via the Swedish Transport Agency's regulations (TSFS 2009:88) on unmanned aircraft – UAS. The Swedish Transport Agency's regulations and general recommendations (TSFS 2010:145) on aviation traffic rules are applicable to flying unmanned aircraft, unless prescribed otherwise in the Swedish Transport Agency's regulations on unmanned aircraft – UAS.

[9] The International Civil Aviation Organization, a UN body.

It is worth noting in this context that even unmanned aircraft are considered to have a pilot. Thus they are not fully autonomous, but have an operator who would be able to control the aircraft. The Swedish Transport Agency's regulations include demands on the pilot even for unmanned aircraft certified for flight and control out of sight of the pilot. The pilot must maintain constant control over the aircraft such that the function and status of the aircraft can be monitored constantly. Moreover, the pilot must have the option in all situations of exerting control by issuing commands to the aircraft. Every UAS must be equipped with a built-in failsafe system which can interrupt the flight if the normal communication or control functions fail.

Thus an initial comparison with aviation traffic indicates that there are both technical requirements and traffic rules for a particular type of aircraft. Development has advanced further, but for aircraft popularly known as drones there are demands on the pilot, even if the pilot is not aboard the aircraft.

2.4.2 Railways[10]

Demands on the signal systems used on the railways can essentially be described as extremely stringent. Since the introduction of the ATC signal safety system in the 1980s, there has thus generally been very little public tolerance for any safety deviations. This is because a signal fault on a railway track could have devastating consequences for both individuals and society in general. Quite simply, a major accident must not be allowed to occur as a result of one or more systems failing.

Unlike the approval system used in the automotive industry, where the respective systems are tested against a minimum requirement level which is regulated in established EU directives and ECE regulations, railways work on the basis of an international standard[11] when systems are to be approved. The standard per se includes general methods for development of safe technical systems without including actual design requirements. Nor is this standard specifically aimed at railway systems. However, in practice the approval authorities use application standards[12] which are prepared specifically to suit railways.

The role of the approval authority in this type of approval system, then, is to assess the manufacturer's and other railway stakeholders' choice of safety level, as well as their ability to meet the required level of safety. In slightly simplified terms, it could be stated that the authority approves the system on

[10] This text is built on internal interviews with officers dealing with signal system approvals.
[11] International Electrotechnical Commission EC 1998 61508.
[12] CENELEC EN 50126:1999, EN 50128:2011, EN 50129:2003.

the basis of the manufacturer's methods and risk management capabilities, instead of stating – as with roads – that the system meets requirement levels established in advance. For the authority, it is then a matter of being able to assess the reasonableness of the level of safety provided by the system by studying the methodology for the risk analyses carried out. This includes assessing both expertise and conclusions concerning.

The term Tolerable Hazard Rate (THR) is central to this context. This involves defining and working on the basis of an intended risk acceptance, i.e. designing the level of safety for the system on the basis of the concept of how frequently safety deviations can be tolerated. European countries operate from slightly different starting points when carrying out these risk acceptance analyses, but in practice this may mean, for example, that a manufacturer has to be able to demonstrate that a new, untried system is ideally a little better than an existing system but at least every bit as good as it. This may also mean that the manufacturer can demonstrate that it has undertaken all measures which are financially feasible for a reasonable risk acceptance. For instance, this may involve having duplicate or even triplicate systems to guarantee functionality.

To conclude, it may be noted that there are basic differences between road traffic and trackbound traffic which complicate the chances of drawing direct parallels for the management and approval of advanced technical systems. Despite these varying conditions, it should nevertheless be of interest to the Swedish Transport Agency to continue to study how the track side of things, with its historically stringent safety requirements, has long opted to leave to manufacturers, rail companies and infrastructure administrators the task of describing how to ensure a level of safety acceptable to society for the technical systems present in both vehicles and infrastructure.

2.5 Research and development

2.5.1 Europe

While North American research in this field has largely focused on automated road systems, European research has departed from this field in order to develop vehicles for the existing infrastructure. Examples of such research include SARTRE (platooning), HAVEit and CityMobil. Most of these projects have focused on practical resolution of the implementation of hardware and software, e.g. to ensure that cameras and sensors work and that the infrastructure needed is in place. Unfortunately, there has been very little research into how humans could interact with this technology. What is known about human interaction with automated vehicles is largely based on the things we know from research in aviation and process control/process regulation. This type of research provides valuable experience, but driving is not the same as flying and when designing self-driving vehicles, overlooking the driver is significantly more vulnerable. However, there is research which deals with the significance of the transition between automation and manual driving, e.g. CityMobil and HAVEit and "intelligent copilot" MIT.[13]

Research which takes into account the full consequences of autonomous driving is not as extensive as the research focusing on lane management and speed control systems individually, not as a system. The studies that exist indicate two underlying design philosophies: automated driving and driving support systems. Results from a number of studies, which deal with earlier research in other fields, believe that the philosophy for automated driving may delay driver reactions in the event of incidents in which the driver must intervene and take over control from the automation system. Understanding how to organise/manage the transfer or sharing of control between system and driver, particularly in the case of critical incidents, presents a central challenge.

Today's vehicles are able to carry out ever-increasing numbers of basic driving tasks, because vehicles with several degrees of automation are available. Examples of advanced assistance systems which the driver to maintain control over the vehicle, ADAS, include park assist, lane management, adaptive cruise control, collision warning, speed adjustment, warnings at bends and blind spot warnings. Incorporating all these systems in a vehicle could involve giving the systems more control over the vehicle than the driver has.

Use of communication equipment in a manner hazardous to traffic has been investigated by the Swedish Transport Agency as part of a a Government commission[14]. This proposes an action plan for development of a collective platform for various stakeholders.

Results from the first major European project involving field studies (euroFOT) were presented in June 2012. This project involves 28 partners, including the major car manufacturers. Data was collected over four years in order to acquire knowledge about interaction between drivers with ADAS. The results showed that these systems are accepted among European drivers and generally improve driving. They reduce the number of accidents, increase driving safety and comfort and help to improve fuel efficiency. The advantages of ADAS are encouraging manufacturers to include more ADAS functions in vehicles.

[13] (Anderson, Karumanchi & Iagnemma, 2012).
[14] N2013/4869/TE.

Besides the increasing number of ADAS functions in vehicles, there is also an increase in the use of sensors and wireless communication in vehicles, permitting communication between vehicles and perhaps also communication between vehicles and other road users such as bicycles, motorcycles or pedestrians.

2.5.2 USA - NHTSA

In the USA, NHTSA has devised a research plan concerning the safety perspective for self-driving vehicles[15]. They have identified three important research fields as described below.

Human Factors - NHTSA's aim is to develop requirements for the interface between driver and vehicle so that the switch between automatic and manual driving can be made safely. This research will focus on level 2 and 3 vehicles, and the need for driver skills will also be evaluated. Recommendations concerning the interface between driver and vehicle will be one of the end products of the research programme. The first phase of the programme should be complete in 2015.

Electronic Control Systems Safety – As safety-critical electronic system are central elements in all control systems in vehicles, it may be necessary to develop requirements to ensure their reliability and *security*. NHTSA is well aware of the fact that standards exist in the field and of how important these are as regards the development of safety-critical systems, and so there will be focus on the development of functional safety requirements and requirements for reliability within certain areas. Moreover, research has been initiated into cybersafety linked with in-car systems, with the aim of being able to set up an initial set of requirements. It is thought that the first research phase will be completed in 2016. After this, NHTSA should be able to determine what further standards are needed for the safety-critical systems.

System Performance Requirements - Research must be carried out in order to support the development of potential technical requirements for automated vehicle systems. It is thought that this work will involve analysis of levels 2 – 4 with a view to producing functional descriptions of the systems. These descriptions will then be used to identify possible scenarios and analyse them with a view to using them to develop appropriate safety requirements. The first research phase is planned for completion is 2016 and will be based on results from the above research fields.

[15] Preliminary Statement of Policy Concerning Automated Vehicles.

2.5.3 Research requirements for the future

Viktoria Swedish ICT has carried out an extensive review of the literature in respect of research and development relating to autonomous driving and self-driving vehicles. This review shows that various stakeholders, such as the automotive industry, subcontractors, universities, colleges, etc. are involved in the development of technology for self-driving vehicles. This development is intensive and ongoing throughout much of the world. The next step for many vehicle manufacturers is to introduce systems which permit limited autonomous driving, level 3, which involves – among other things – autonomous driving in queues and on motorways (longitudinal and lateral control of the vehicle) and automated parking. Driving in road trains, known as platooning, is another field with which the truck industry is working. There is also a certain amount of albeit limited research which focuses on fully autonomous driving, level 4.

The review of the literature identifies the following challenges for research and development in future:

Data management and data analysis - One important prerequisite for self-driving vehicles is the ability to manage and analyse data from sensors in the vehicle. This is nothing new for the automotive industry and researchers, but the large volume of data generated by a large number of sensors in the vehicle presents a challenge.

The issue of liability - The issue of liability is central to autonomous driving. When the vehicle takes over control from the driver to an ever-increasing extent so that the driver can focus his attention on other things, the issue of liability must start to be analysed and discussed in earnest. This issue is discussed in greater detail in chapter 5 in this investigation.

Reliability - A major challenge for vehicles being driven autonomously in certain traffic situations is that it is necessary to be able to predict when the vehicle is about to no longer be able to deal with the traffic situation and provide enough time for the driver to take over control and familiarise himself with the traffic situation, which is often complex.

This is affected to a great extent by the sensors and the ability of the system to predict the outcome of a complex situation. However, it also involves the way in which people adapt their behaviour to the technical systems in the vehicle.

Communication (V2X) - There is currently limited knowledge on what levels of communication have to be achieved between vehicles (V2V) and between vehicle and infrastructure (V2I) in order to optimise the effect of self-driving vehicles.

Human factors - The ongoing development towards transferring driver control to technical systems in the vehicle to an ever-increasing extent will affect the role of the driver and hence his behaviour to a great extent. Viktoria Swedish ICT's review of research and development in the field does, however, indicate that handing over control will take place gradually and so that the driver will continue to play a significant part in driving even in the immediate future.

However, the extent to which drivers will adapt to autonomous driving over time and the manner in which this will happen is unclear. Before we have entirely driverless vehicles, safety will be dependent on the combined performance of the driver and the technical systems. Research focusing on how humans adapt their behaviour to the technology in both the short and the long term will therefore be crucial to development in the field.

Autonomous driving in mixed traffic - From a technical perspective, vehicles can be driven fully autonomously, level 4, on lit sections in a controlled traffic environment. But how such fully automated vehicles or partly automated vehicles, level 3, will be able to operate in all traffic situations and weather conditions will present a major challenge for development work in future.

Evaluation methods - There is a need to develop methods to evaluate the effects of self-driving vehicles at different levels. This may, for example, involve looking at the effects these will have on community planning, accessibility for various groups in society, road safety, the environment, etc.

3 Policy instruments

The road transport system is open and complex. Moreover, this is a system which is constantly changing, and many external factors/conditions affect the function and safety of the system. No one party can control the whole picture, or the safety of the system. There is a series of models in order to achieve safety, and these are built up so that the components of significance are linked together with requirements for performance and mutual relationships. In this way, safety can only be created if vehicles, roads, speeds and road users all meet requirements at the same time. If the road is safe, the vehicle is safe and the driver remains within the framework for the system, most deaths and serious injuries can be avoided. The challenge in this regard is to establish all the properties which will eventually generate a safe road transport system which is also efficient and sustainable in the long term. Thus safe road traffic can be expressed schematically as a function of a safe road user, a safe road/street, a safe vehicle and a safe speed.

3.1 General information on policy instruments

Various policy instruments are used so that the transport policy target can be achieved. The following policy instruments are some of the most important ones used in order to meet the targets:

- Statutory regulations
- Practice in licensing and supervision
- Negotiations and agreements
- Financial policy instruments
- Infrastructure planning, physical planning and traffic planning
- Procurement
- Target and performance management by authorities
- Research, development and analyses
- Information and opinion formation

The most important regulations are provided by the legislation decided upon by the Riksdag (Swedish parliament) and
the Government, as well as the enforcement and implementing regulations decided upon by the authorities according to authorisation by the Government. These also include EU legislation which is normally incorporated in national legislation. Supervision to ensure compliance with various rules is another important task. However, one policy instrument does not rule out others, and in order to achieve the targets combinations of different policy instruments must be tested with a view to ensuring that they support one another.
It should be emphasised that the policy instruments also have to be adapted to changes in external factors so that they do not lose their steering effect. They often have to be combined in different ways and over time in order to achieve the maximum possible effect. This is particularly applicable to areas undergoing rapid development. Regulation and supervision are not always the most efficient policy instruments.

The choice of policy instruments and the combination of these should therefore be based on meticulous analyses of which mechanisms lead to a high level of implementation and compliance with targets relating to both transport policy and economic policy.

3.1.1 Policy instruments in respect of vehicles

So how can society ensure that development is moving in the right direction as regards technology for different degrees of autonomous driving? To be able to answer this question, we need to understand what it is that controls vehicle manufacturers' development.

Of course, what the vehicle manufacturers offer is based mainly on what their customers demand. In turn, this demand is controlled by a number of factors which include consumer information such as the independent crash testing programme, Euro NCAP, and financial incentives such as tax rebates and premium setting. However, car manufacturers' own product development and marketing are another important factor. They often develop and market technology which customers may not ask for in many cases. Of course, the aim of this is to increase the added value given to customers.

Many major research and development projects are also being carried out within the EU, for example. These are often co-financed by the industry and the authorities. Such projects result in new applications which the vehicle manufacturers then develop and market in order to add value for customers. Such research, particularly with emphasis on the evaluation of effects, also affects legislation.

It is important to view all of these factors as a whole in order to create a "toolkit" comprising different tools which can be combined in different ways in order to create and encourage development.

International legislation on vehicles does of course also influence which systems manufacturers are installing in vehicles, as well as system performance. Legislation defines a minimum requirement level which vehicles have to achieve in order to be marketed.

3.1.2 Legislation as policy instruments

Of course, international legislation also greatly affects which systems car manufacturers install in vehicles. As stated above, the traditional way of steering and regulating the road transport system is often based on regulation of performance and permitted variations in the same among the individual components in the system (road user, vehicle, road). This approach is also applicable to the field of vehicles to a great extent. Such regulation defines a minimum requirement level which vehicles have to achieve in order to be marketed. Regulation is also a prerequisite for trading vehicles between countries – harmonised provisions create a common market for vehicles which helps to ensure that the vehicle manufacturers are competing on equal terms. Thus the legislation does not drive safety development.

That said, however, factors such as Euro NCAP, which grades cars on the basis of their safety properties, have been highly significant to the development of safety since the mid-1990s. This development has been "market-based" and would not have been possible had just vehicle legislation been used as a policy instrument. That said, regulation in the automotive field plays an important part in guaranteeing safety properties and safety equipment which are not demanded or offered on a market, as well as defining a minimum level which is applicable to all vehicle manufacturers. The latter also means that competitive conditions are the same for all.

However, with this traditional approach there is an obvious risk of rapid technical development being inhibited by the protracted legislative process required in order to agree on the detailed requirements for testing and approval which often result. Once the regulations come into force, there is a risk that the technology regulated has already undergone further development. The detailed criteria, in combination with the time-consuming legislative process, therefore means that legislation is not a flexible instrument for steering technical development. One possible way of circumventing this problem is to define more function- or target-oriented safety requirements for the technology in question, which means that there are different ways of achieving the requirements. This does not lock opportunities for development. A procedure of this kind will require vehicle manufacturers to indicate to a greater extent how they have proceeded in order to meet the requirements. The job of the authorities will then be to assess whether this has been done in a systematic and reliable manner. However, it is important to point out that an approach of this type requires international coordination. As things stand at present, the international regulatory process type approval system are firmly established in the more traditional approach.

Sometimes, financial incentives, consumer information and other market-influencing policy instruments will not be enough for the introduction of safety technology with plenty of potential. The automotive industry is probably of the opinion that in these cases, customers will receive no added value if the technology is introduced voluntarily. Alcolocks are one example of such safety technology. In such cases, probably the only way of implementing them is to make them compulsory. If safety technology is partially introduced in the relevant vehicle category, e.g. with only certain manufacturers perceiving added value for customers or with information and financial incentives leading to certain vehicle manufacturers opting to introduce the technology, legislation is probably still an effective tool for extending the technology across the market while creating equal competitive conditions for all manufacturers.

4 Current legal situation

4.1 Road traffic legislation

4.1.1 Conventions

Sweden, like most countries in Europe, has ratified the UN's Vienna Convention on Road Traffic, dated 8 November 1968. As a result of this ratification, Sweden has undertaken to follow the Convention under international low. However, the Convention is not directly applicable as a Swedish law; instead, authorities and courts exercise their power in accordance with the provisions of the national legislation. The Riksdag and Government are responsible for ensuring that Sweden meets its obligations under international law. Sweden has chosen to adapt the legislation via what is known as the transformation method, primarily transferring provisions in the Convention to the Swedish Road Traffic Ordinance (1998:1276) in the main. Sweden has also ratified the UN's Vienna Convention on Road Signs and Signals, dated 8 November 1968, and implemented this in provisions in the Swedish Road Signs Ordinance (2007:90) and regulations pursuant to this. Unlike vehicle legislation, therefore, road traffic legislation largely does not originate from provisions in community law.

These conventions describe an international system for road traffic rules, road signs and instructions for traffic. The aim of both conventions is to make things easier for road users moving across national borders by making the rules, markings and instructions for road traffic more or less the same regardless of the country in which road users are located. Thus Sweden has used these conventions to affiliate to the international system for road traffic rules which is applied in most countries.

There are certain opportunities to make decisions on deviating rules in fields which are not regulated in the conventions. When devising new road traffic rules, the provisions of the conventions and any limitations defined by the convention on national legislation must be taken into account. Such decisions also require assessment of whether the intended change is consistent with Sweden's international undertakings.

Pursuant to the Act (1975:88) with authorisation to issue regulations on traffic, transportation and communications, the Government has issued the Swedish Road Traffic Ordinance and with it delegated to municipalities and county administrative boards the power to issue special road traffic rules both on-road and off-road. The Government has also used the Swedish Road Signs Ordinance to issue provisions concerning on-road and off-road traffic, as well as provisions concerning instructions for traffic and markings on-road and off-road.

4.1.2 Swedish Road Traffic Ordinance (1998:1276)

The Swedish Road Traffic Ordinance includes provisions for on-road and off-road traffic. In Sweden, requirements for the driving of vehicles and other road traffic rules can be found in the Swedish Road Traffic Ordinance and regulations issued pursuant to this.

General provisions

The ordinance include provisions with specific demands on drivers, indicating how vehicles may or may not be driven under certain situations, and also provisions which can be described as general duty of care. Examples of specific requirements include requirements indicating which lane is to be used, requirements stating that vehicles must not be driven under certain conditions and that the driver must indicate when changing lanes. Examples of general duty of care include general requirements defined for the driver concerning adaptation of speed and driving style. The ordinance also includes authorisations for municipalities and administration authorities to issue regulations with special road traffic rules. The ordinance also includes authorisation to issue regulations concerning exceptions to the ordinance, as well as liability provisions.

Special road traffic rules for a specific road or section of road, or for all roads within a certain area or for an area or track off-road are issued via local traffic regulations. Special road traffic rules via local traffic regulations must normally be marked out.

Chapter 10(1) of the Swedish Road Traffic Ordinance states that special road traffic rules may be issued via local traffic regulations in respect of matters such as speed limits, prohibition of stopping and parking vehicles, a specific area being used for lanes for public transport, restriction to smaller widths, etc.

Chapter 10(2) states that certain regulations with special road traffic rules may relate to

1. a specific group of road users,
2. a specific vehicle type or specific vehicle types, or
3. vehicles with loads of a specific nature.

Essentially, it can be stated that the municipalities issue regulations within densely populated areas, while the county administrative boards issue regulations outside such areas.

Lanes or carriageways for certain vehicles

Public roads, according to the Swedish Roads Act (1971:948), are open to public traffic, and therefore it must essentially be possible for all kinds of vehicles to use them. Roads are divided into different carriageways and lanes, depending on traffic. Some carriageways are essentially designed for certain types of traffic, such as cycle paths or cycle lanes, while others can be used by all kinds of vehicles. Special road traffic rules via local traffic regulations can then restrict traffic on carriageways and in lanes in different ways. The option of defining certain carriageways or lanes for specific traffic is limited with the current legislation.

The current legislation provides few opportunities to regulate special lanes or carriageways for certain vehicles, apart from motorways and arterial roads. Special road traffic rules stating that certain lanes may only be used by public transport, mopeds and bicycles can be issued via local traffic regulations. Such local traffic regulations are indicated using road sign D10 *mandatory lane or carriageway for public transport, etc*.

Road sign D10, *mandatory lane or carriageway for public transport, etc*., was introduced via the Swedish Road Signs Ordinance. Ministry memorandum (Dsk 1976:4) Proposal for a new road sign ordinance (1978:1001), explained that the sign had been adopted by the European Conference of Ministers of Transport and that the Conference of Ministers of Transport had submitted to the UN Economic Commission for Europe a proposal stating that a sign of this type should be incorporated in the Convention on Road Signs and Signals. New provisions on the road sign used to separate lanes for public transport, etc. from other lanes in Article 26 of the Convention on Road Signs and Signals came into force on 1 November 1995. In December, a workgroup operating under the Nordic Road Safety Council submitted a report to the Road Safety Council which included proposals on how the revised Vienna Convention could be incorporated into the Nordic road traffic statutes. The report stated that the workgroup agreed that it was necessary to be restrictive when it came to permitting other traffic to use public transport lanes.

The Swedish Transport Agency's opinion such as the one expressed against this background in the appeal cases on which the authority and the former Swedish Road Administration made decisions, is that the road user categories which may conceivably be allowed to use public transport lanes, besides the ones specified in the Swedish Road Traffic Ordinance, should be those which complement public transport. The vehicles used by road user categories should also be easy to differentiate from the other elements of general traffic. Taxis are one example of traffic which complements public transport. The vehicles used in this traffic differ from other traffic in that they bear special registration plates for taxis.

The special road sign for public transport indicates the boundary for the lane for public transport, etc. and another lane. This sign must only be implemented if the lane has no time limit[16]. There are already calls to allow certain vehicles to use the public transport lane, such as heavy goods vehicles or motorcycles. There are also calls to allow separate lanes for certain other vehicles which are currently not regulated in the road traffic legislation, or to allow them to use the public transport lane, such as green cars, electric cars or hybrids, cars carrying at least one passenger, etc.

Provisions concerning driver liability

In this context, it may be worth mentioning that Article 8 of the Convention on Road Traffic includes requirements stating that every vehicle or vehicle combination must have a driver and that the driver must be capable of controlling his vehicle at all times. There is no corresponding provision in the Swedish Road Traffic Ordinance, but the provisions are based on the notion that there is, in some way, someone driving the vehicle.

The Swedish Road Traffic Ordinance demands that road users must take the action required in respect of the circumstances in order to avoid road traffic accidents. It is also stated that vehicles must not be driven by anyone who us unable to drive the vehicle safely on account of illness or fatigue or when under the influence of alcohol or other stimulants or anaesthetic substances. Thus the provisions make demands in respect of the driving of vehicles, and so they have to be understood as meaning that someone is driving the vehicle, and that this person is the one who should take care and be able to accept liability for the propulsion of the vehicle. Essentially, it is also the driver of the vehicle who can be held criminally responsible in accordance with the Swedish Road Traffic Ordinance and the Swedish Road Traffic Offences Act (1951:649). The legislature is based on the fact that there may be someone other than the party actually driving the vehicle who should be considered to be the driver in the legal sense, and that this person does not need to be in the vehicle being driven. This is applicable in the case of driving practice and driving lessons, in accordance with Chapter 4 of the Swedish Driving Licence Act (1998:488) and Chapter 4 of the Swedish Driving Licence Ordinance (1998:980), where the person supervising the driving is considered to be the driver.

One prerequisite for allocating liability in accordance with the Swedish Road Traffic Ordinance and the Swedish Road Traffic Offences Act is whether the driver is deliberately or negligently breaching the provisions of the Swedish Road Traffic Ordinance.

4.1.3 Swedish Road Signs Ordinance (2007:90)

The Swedish Road Signs Ordinance includes provisions on instructions for traffic and markings on-road and off-road by means of road signs, traffic

[16] See the Swedish Transport Agency's regulations (TSFS 2012:171) on road markings.

signals and road markings, etc. The ordinance specifies requirements stating that road signs and other arrangements must be designed and positioned and in a condition which allows road users to see them in time and understand them. Requirements are also specified for the design and colouring of these.

In the Swedish Road Signs Ordinance, the Government has delegated to municipalities, the State road maintenance authority, etc. liability for ensuring that arrangements and signs for traffic are set up, removed, maintained and implemented to the extent specified for each location.

4.2 Vehicle legislation

Approval of vehicles is required for vehicle manufacturers or importers to be able to sell and register cars, trucks, buses and trailers within the EU. This is stipulated via EU framework directive 2007/46/EC[17]. The rules for approval are harmonised within the EU, and in some instances are even global. The purpose of the EU-wide provisions on vehicles is to create an internal market within the Community and aims to ensure a high level of road safety, health protection, environmental protection, energy efficiency and protection against unauthorised use. In other words, the EU regulates which requirements have to be met. However, the more detailed technical provisions are mainly prepared within UNECE (WP 29) and can be found in the UNECE regulations to which the EU legislation refers.

4.2.1 Do the regulations impeded self-driving vehicles?

The current regulations largely involve guaranteeing the performance of vital functions, such as ensuring that vehicle brakes provide sufficient retardation. Driver assistance systems, which help the driver with the task of driving, are available in approved cars at present. As regards complex electronic systems which affect steering or brakes, these are covered by certain provisions via UNECE regulations 79 and 13 respectively, even though the function itself is not regulated. The requirements include fault strategies and the fact that the manufacturer has to demonstrate how it has ensured that the systems will not adversely affect basic functions. Brakes must provide sufficient retardation even if the vehicle is fitted with an emergency brake system or a system for driving in heavy traffic.

To date, therefore, the driver has controlled the vehicle using different assistance systems. Now that developments are allowing the vehicle to manage the entire task of driving, the regulations face new challenges. If the regulations and vehicle approval are to ensure that vehicles can be driven

[17] European Parliament and Council directive 2007/46/EC dated 5 September 2007 concerning the establishment of a framework for the approval of motor vehicles and trailers for these vehicles, and of systems, components and separate technical units designed for such vehicles.

safely without driver supervision, a number of new questions will probably have to be asked; for example

- whether the vehicle acquires sufficient data,
- whether the vehicle has a satisfactory way of making decisions on control,
- whether the performance of the systems is sufficient,
- whether data security and system robustness are sufficient, and
- whether interaction between vehicle and human works when handing back the task of driving, level 3, for example.

In other words, there are no provisions which guarantee a minimum level of safety for the self-driving function. Without this regulation, would manufacturers dare to market self-driving vehicles? Would the testing body type approval authority pass such vehicles? Would society accept such vehicles? In the opinion of the working group, the lack of rules will probably impede the introduction of self-driving vehicles of level 3 automation or higher.

4.2.2 Exceptions for testing

As stated previously, the EU determines which requirements vehicles must meet by means of framework directive 2007/46/EC. However, there is a certain amount of scope to allow member states to permit exceptions. The EU's provisions are primarily implemented in the Swedish Vehicle Ordinance (2009:211), and the Swedish Transport Agency has the opportunity to make decisions on exceptions from requirements via authorisation in Chapter 8(18). Exceptions may only be permitted under certain conditions, e.g. if they do not risk road safety. This authorisation can be utilised to make decisions on matters concerning vehicles for use for testing purposes.

4.3 Driver competence

4.3.1 Basic requirements

At present, a class B driving licence without condition codes is entitled to drive cars and light goods vehicles regardless of which various technical assistance systems and aids the car has, such as park assist, cruise control or automatic transmission. That said, different technical assistance systems may affect the assessment of the driver's skills during the driving test.

Requirements for the awarding of driving licences are regulated in:

- EU directives,

- the Swedish Driving Licence Act (1998:448),
- the Swedish Driving Licence Ordinance (1998:980), and
- the Swedish Transport Agency's regulations.

The requirements specified for vehicles used during driving tests are regulated in EU directives and the Swedish Transport Agency's regulations. The Swedish Transport Agency's regulations on driver testing specify that the examiner may decide whether use of technical assistance systems is to be limited if necessary for any part of the driving test. For instance, a decision may be made not to permit the use of park assist when testing the candidate's ability to manoeuvre the vehicle.

As things stand at present, there is perceived to be no need to re-regulate the driving test or vehicle requirements during driving tests. The Swedish Transport Administration's driving test maintains a positive view of new technology and has not yet encountered any major problems with assistance systems for the driver when marking driving tests. It is often apparent when the assistance system takes over, and this indicates to the examiner that there are shortcomings in the driver's abilities.
However, to ensure that the skills required to be awarded a driving licence are still in place, it is important for the authorities to monitor technical development and see whether future assistance systems will present a problem for driving tests in years to come.

Nor is there perceived to be any acute need to re-regulate driver training on account of technical assistance systems. At the moment, the content of driver training is largely steered by the requirements of the driving test. And requirements for mandatory, two-part risk training are compensated for by things which are not possible or are difficult to measure by testing[18]. Risk training must ensure that all drivers receive training on the most important areas from a road safety standpoint. One element in the risk training syllabus involves allowing the student to experience and recognise the advantages, limitations and risks involved with different technical systems.

There are certain concerns that drivers may find it difficult to operate the technical assistance systems, and that there may therefore be a need for special training or tests. At present, however, we know little about the difficulties of the future systems and any risks they may involve. This is why it is too early to draw conclusions about whether further requirements should be specified for training, beyond the elements currently included in driver training. In this regard, too, it is important for the Swedish Transport

[18] See Chapter 3(4 a) of the Swedish Driving Licence Act. This requirement is applicable to class A1, A2, A or B.

Agency to monitor developments and analyses any incidents involving vehicles which have this type of new technology.

Other notions from an authorisation perspective is whether it would be possible to extend the field in the future with conditional driving licences. At present, for instance, drivers are required to do their driving tests in vehicles with manual transmission. People are permitted to do their tests in automatic vehicles, but their driving licences are then restricted and are only valid for vehicles with automatic transmission, condition code 78[19]. If new condition codes are conceivable for the future, it could – in theory – be possible to use different levels of autonomous driving during driving tests. After such tests, driving licences could be restricted using conditions which state that drivers can only operate vehicles fitted with the same aids. In the future, this could pave the way for elderly or disabled people to retain their driving licences for longer, as long as they use aids.

Condition codes for driving licences are regulated by EU directives and are the same for all member states. However, it is possible to create national codes which are applicable within one country only. Work is currently in progress within the EU on revising the condition codes so that they are less focused on technology and describe the driver's needs to a greater extent. Here, too, it is important for the Swedish Transport Agency to monitor developments and continue to participate in international workgroups in respect of driver licensing. The Swedish Transport Agency is also part of the CIECA (International Commission for Driver Testing), where vehicles' technical assistance systems will be discussed in respect of driver testing.

4.3.2 Skills versus automation

How requirements for driver skills for self-driving vehicles are to be regarded is largely dependent on the level of automation in question; i.e. it depends on whether the vehicle is driven completely independently, or partly or completely without driver intervention.

Level 1 - Function-specific automation
Level 1 automation, e.g. cruise control, electronic stability control, etc. is common on newer cars nowadays, but it does not replace vigilance on the part of the driver or take responsibility for driving the vehicle. Nor is it considered to influence the chances of assessing driver skills during driving tests. Nor can it be said to be particularly difficult to operate for people who already hold driving licences.

Level 2 - Function-combined automation
With level 2 automation, the driver can decline active control in certain

[19] See Swedish Transport Agency regulations (TSFS 2012:60) on driving licence structure and content.

specific driving situations. For instance, it is possible for drivers to drive with no hands on the steering wheel while lifting their feet away from the pedals. However, the driver is still responsible for monitoring the road and driving the vehicle safely. The driver is expected to remain alert at all times and be able to react at short notice. Therefore, just as with level 1 it is necessary for the driver to have the full skills needed to pass a driving test in order to use vehicles with this level of automation. Using these systems would affect opportunities to assess driver skills during driving tests. Therefore this type of system could be permitted in driving tests, but only very sparingly. It is conceivable that certain skills are required in order to determine when these systems can be enabled and disabled, but as things stand at present they are not thought to present any particular difficulties for anyone who already has a driving licence.

Level 3 – Limited autonomous driving
Level 3 vehicles make it possible for the driver to hand over all control of all safety-critical functions under certain road or environmental conditions, and to rely on the vehicle under these conditions to monitor any changes requiring control to be returned to the driver. The big difference between levels 2 and 3 is that at level 3, the vehicle is designed so that the driver is not expected to constantly monitor the road during driving. However, the driver must be available for periodic checks and be able to resume driving safely. Using these systems would also affect opportunities to assess driver skills during driving tests. Therefore it would hardly be possible to permit this type of system in driving tests. It is conceivable that certain skills are required in order to determine when these systems can be enabled and disabled, but as things stand at present they are not thought to present any particular difficulties for anyone who already has a driving licence.

Level 4 – Fully autonomous driving
Level 4 vehicles must be designed to execute all safety-critical driver tasks and monitor road conditions throughout an entire journey. A design of this kind assumes that the user enters a destination or road description, but the driver is not expected to be available to control the vehicle during the journey. Driving safety rests entirely upon the vehicle's automated system.

Of course, level 4 vehicles may not be used in driving tests. The issue of authorisation differs at this level compared with the lower levels as these vehicles are permitted to operate without supervision by a driver. Any requirements for driving licences, certificates or training for owners of level 4 vehicles are dependent on how the forms for this type of driving are to be controlled and regulated, and how responsibility for driving is viewed. To summarise: the Swedish Transport Agency is therefore of the opinion, as things stand at present, that it is too early to determine what authorisation requirements for level 4 would be appropriate. However, this discussion should be resumed when more progress has been made on the issue of liability.

5 Problems inventory with analysis

5.1 Complexity and systems approach

The road traffic system is open and complex. Moreover, this is a system which is constantly changing, and many external factors/conditions affect its function and safety. No one party can control the whole picture, or the development of the system. The major challenge for society is to encourage and steer the development of the road traffic system without introducing unnecessary barriers which inhibit development and innovation.

Technical systems for different degrees of autonomous driving are currently being developed at a tremendous pace. Different vehicle manufacturers are competing to be at the forefront of development. Therefore, there is no clear structure in this regard at present. The structure of the technical solutions in future is also very much uncertain. Much of the uncertainty in respect of development towards autonomous driving is due to the complexity of the system in which the technology is to operate.

The following are a few examples of this complexity:

- Technical systems in the vehicle must be developed so that they interact with humans (HMI, Human Factors).
- technical systems in the infrastructure must be developed so that they interact with the vehicle systems (e.g. magnetic loops in the road)
- communication technology must be developed in order to facilitate interaction between the systems (V2V, V2I, etc.)
- humans and technology in the entire system must be capable of interacting and operating in fast traffic situations which are difficult to predict
- in many instances, the technology must surpass human performance

Therefore, it is impossible to indicate in detail how the technology for autonomous driving will develop, and so it will be difficult for society to steer this development unilaterally. Therefore, the major challenge facing society involves ensuring that developments towards autonomous driving move in the right direction, i.e. help to achieve transport policy targets, while at the same time not hampering innovation and development.

As regards steering and controlling safety in complex sociotechnical systems, research in the field of other safety-critical systems provides indications of how the issue should be approached in respect of autonomous driving. In such systems, a systems theory approach is regarded as an effective way of understanding and dealing with the risks more appropriately.

Systems theory is an approach which began to be developed in the 1930s as a reaction to the difficulties in understanding and explaining the properties of social, sociotechnical and biological systems (complex systems) on the basis of the properties of the individual components in the system (known as analytical reductionism). Instead, the system's properties are a result of interaction between the individual components in the system.

From a safety standpoint, this means – for instance – that an accident can rarely be explained by the "breakdown" of an individual component in the complex system. Every component in such a system, including humans, often has a prescribed or permitted variation in performance. Even if all incorporated components remain within these limits, complex and unforeseen interactions between these may lead to accidents in and damage to the system. A further consequence of this is that the safety of a complex system cannot be optimised by optimising the performance of the incorporated components.

However, the traditional way of steering and regulating the road transport system has involved regulating performance and permitted variations in the same among the individual components in the system (road user, vehicle, road). An approach of this kind means that the people formulating or standing responsible for the system, often authorities, are working on the basis of an idealised model of how the system is structured and intended to function and how humans in the system have to behave in order to achieve an optimum level of safety. The regulations are then developed on the basis of this idealised model. This assumes that the people responsible for the formulation and regulation of a complex system can predict all possible and impossible interactions between the components in the system. Of course, this becomes a lot more complicated, not to mention impossible, when the complexity of the system increases and which components will be developed and hence need to be regulated is uncertain. This is why regulation, if it must exist at all, must be implemented at system level in the form of functional requirements for system performance. One example of this is what is known as the lane-keeping system for vehicles. By making demands of system performance – e.g. stating that the system must keep the vehicle within a lane on certain types of road – this may pave the way for vehicle or systems manufacturers to start cooperating with infrastructure managers in order to identify a system solution, i.e. a combination of technical solutions in both vehicle and infrastructure.

There is a series of models in order to achieve safety in complex systems, and these are built up so that the components of significance are linked together with requirements for performance and mutual relationships. For the road traffic system, this means that safety can only be created if vehicles, roads, speeds and road users all meet requirements at the same time. If the road is safe, the vehicle is safe and the driver remains within the framework for the system, most deaths and serious injuries can be avoided. The challenge in this regard is to establish all the properties which will eventually generate a safe road transport system which is also efficient and sustainable in the long term.

One conclusion that can be drawn from the above analysis is that society's role and tools need to be discussed and, where necessary, reassessed.

A discussion is taking place on the role of society as legislators in respect of nuclear power, for instance. In this regard, there is a view that society must switch from "governing" to "governance", the latter involving creating coordination between different stakeholders in society. This differs from "governing", which is a deliberate initiative for steering and controlling various social sectors, often by means of micromanagement. "Governance" instead involves society setting general targets, paving the way to allow different stakeholders to work together and communicate, share resources, follow up results, etc.

5.2 Benefits of autonomous driving

Autonomous driving is deemed to have a major effect on helping to meet transport policy targets.

Traffic safety
Increased road safety is emphasised in these reasonings, for the most part. However, to date we have not been made aware of any studies which systematically define in greater detail the road safety potential of systems for the various levels of autonomous driving. Rather, this assessment appears to be based on statements and general reasoning from the automotive industry and other stakeholders rather than well-substantiated studies. It is important to emphasise that it is difficult to calculate in theory the actual safety effect of different systems as it is difficult to assess how humans will interact with them. This may take place in an often unpredicted way and change over time, known as behavioural adaptation. However, it is clear that there is great confidence among many elements of society that autonomous driving will markedly improve road safety and that this can be achieved by reducing the risk of collisions.

Accessibility
Self-driving vehicles may enhance accessibility for various categories of people who cannot or are not allowed to drive vehicles due to various physical impairments, e.g. the elderly and disabled. This is particularly true

of level 4 vehicles. However, level 3 vehicles may also mean that people who are currently borderline when it comes to meeting the requirements for a driving licence due to less serious impairments may be allowed to drive a vehicle.

This increase in accessibility will help enhance personal independence, reduce social isolation and improve accessibility to important social functions for these people.

Congestion
Autonomous driving is also deemed to offer plenty of potential when it comes to congestion. Among other things, capacity may be increased by allowing vehicles to drive faster and more closely together. Studies exist which indicate a fivefold increase in capacity on certain road types when vehicles are driven autonomously in road trains (known as platooning). Further, self-driving vehicles can brake and accelerate more smoothly, leading to a more even traffic flow and hence greater capacity and less congestion.

As the number of road traffic accidents is expected to fall on account of autonomous driving, it it thought that congestion will be reduced as a result. However, there is a risk of autonomous driving potentially increasing traffic volume. As people will be able to do other things while they "drive" and fuel and insurance costs are expected to come down, it is thought that the attractiveness of the road traffic system, and hence traffic volume, may increase. This risks increasing congestion on our roads.

Fuel consumption and alternative fuels
It is thought that self-driving vehicles could reduce fuel consumption overall. This is because driving will be smoother, with less braking and acceleration and reduced congestion, at least as regards level 3 and 4 vehicles. Furthermore, the development of self-driving vehicles will primarily focus on avoiding collisions. This is why the need for equipment and designs for a high level of impact safety will be reduced. Thus it will be able to make vehicles lighter, which will reduce fuel consumption.

The reduction in weight will also facilitate the introduction of vehicles which run on electricity or other alternative fuels. The range of such vehicles will then increase, which should lead to greater interest in them.

Energy consumption and emissions
Autonomous driving may result in a reduction in the cost of running a car. First and foremost, this involves direct costs such as fuel and insurance costs. It is thought that the latter costs will be reduced as there will be a reduction in the number of road traffic accidents. Indirect costs may also be reduced as people will be able to use their time in the car to work, for

example. All in all, this may lead to an increase in the attractiveness of the road traffic system, with increased traffic volume as a consequence. The net effect this will have on energy consumption and emissions road traffic will therefore be dependent on the extent to which the traffic volume increases and how energy-efficient vehicles can be made to be.

Utilisation of land
It is thought that level 3 and 4 autonomous driving will lead to more efficient utilisation of land. Commuting distances may increase as people will be able to work while they drive, for example, and it is thought that the cost of fuel and insurance will be reduced. Hence people will be able to live in less densely populated areas outside the cities. Furthermore, the need for parking spaces in town and city centres may be reduced as level 4 autonomous driverless vehicles can drop off passengers in the centre and then park on their own in parking spaces outside the town or city centre.

In Sweden, a discussion is currently taking place on whether it would be possible to build narrower lanes for self-driving vehicles, resulting in reduced utilisation of land.

5.3 Autonomous driving and human factors

One of the most central issues with regard to vehicle automation is who bears liability when travelling in a self-driving vehicle. The importance of continuing to work with HF/MTO cannot be underestimated; no matter how advanced the systems we produce, individuals will always perform one or more central roles in the success of such systems. Designers should not assume that automation can replace drivers entirely without problems. Nor is it possible to assume that drivers can safely adapt to the limitations of automation. Therefore, designers should also take into account the role of humans in vehicles with a high level of automation and the support needed by the driver if he is to be regarded as responsible for control of the vehicle.

One way of balancing authority and responsibility is to support the job of the driver, rather than automating it. There are systems/automation designed to allow the driver to maintain control over the vehicle as much as possible, rather than controlling the vehicle or warning the driver in the event of an immediate risk of accidents. There are results which show that automation can be more effective if it allows the driver to be part of this control.

There are studies/research leaning towards wanting to maintain the driver's control by sharing responsibility between the driver and the automation. Attempts are being made to minimise the problems of returning control to the driver when automation fails by focusing on shared control. In the case of shared control, the driver has manual control over the vehicle but receives repeated support from the automation. This should ensure that the driver is involved in the task and not merely monitoring the system, which may lead to a delayed response when the driver has to intervene in unforeseen situations. [20]

The studies arguing in respect of the importance of shared targets between the driver and vehicle automation reckon that humans are influenced by/react to technology in a social manner, similar to the way in which humans react to other humans. As the technology becomes more sophisticated and humanised, particularly voice-based interaction, credibility and other social reactions may become even more critical. Another important aspect is how drivers of ordinary vehicles will react to vehicles with a high level of automation.

It is also important to consider how best to integrate vehicle automation. Some people advocate designing vehicle automation from the ground up by means of a continuous process instead of gradually building up an ever-increasing degree of automation on the basis of existing systems. Research from automation in aviation indicates that systems built up in small steps can lead to complicated interaction and confusion, even among trained pilots.

Although it may perhaps be difficult to imagine handing over control to a self-driving vehicle, a survey[21] based on responses from 1 500 people from ten countries has shown that 57 per cent of respondents would consider travelling in a self-driving car. If we consider the results country by country, we can see that 95 per cent of respondents in Brazil would trust self-driving cars, and in India and China the corresponding figures are 85 per cent and 70 per cent respectively. In Japan, 28 per cent of respondents would consider travelling in a self-driving vehicle; this is the lowest figure. The figure for the USA is 60 per cent, which is just above average. [22]

Vehicle automation will probably change the role of the driver, particularly as drivers adapt to automation over time. Driving safety is becoming more dependent on a combination of human and automation performance, and successful design will depend on recognising and supporting the new role of the driver. As in other fields, increased road safety/driving safety is dependent on interaction between humans and automation. Any successful design will be dependent on recognition and support in the new role assigned to the driver in controlled/managed cars.

The development towards higher levels of autonomous driving will greatly affect the transport system, in many ways positively. This development will

[20] Mulder et al.
[21] Study carried out by Cisco among world consumers.
[22] http://robotnyheter.se/tag/autonoma-bilar/.

take place gradually, and there are major challenges in respect of how automation/technology is to be designed, given human factors and restrictions.

5.4 Inventory of problems in the road traffic legislation

There is a relatively widespread view in the world that the issue of liability is central and must be dealt with so as not to hinder development in the field. The Convention on Road Traffic, known as the Vienna Convention, is often cited as one of the biggest obstacles to autonomous driving. However, there are different types of liability, and it is extremely important to clarify these and analyse them individually.

5.4.1 Will road traffic legislation hinder implementation of automated driving?

Given the information in section 4.1 concerning road traffic legislation, the working group has found that the national legislation on on-road and off-road traffic via the Swedish Road Traffic Ordinance includes nothing which would hinder the implementation of automated driving. In any case, this ought to be applicable as long as there is someone in or outside the vehicle who can control the vehicle in some way. In such instances, this person should be regarded as the driver.

At the same time, it must be observed that the present legislation is not adapted to a situation where automation is so far-reaching that the vehicle is designed to perform all safety-critical driver tasks and monitor road conditions throughout an entire journey and the driver's presence is not required, level 4. A design of this kind assumes that the driver will input a destination or road description, but the driver is not expected to be available in order to control the vehicle at any point during the journey. Driving safety rests entirely upon the vehicle's automated system. Under such conditions, with current legislation there will probably be no designated driver who can follow the road traffic rules and be held responsible for any infringements of the law.

5.4.2 Provisions concerning criminal liability for drivers

In a number of instances, the rules specifying liability for crimes indicate a number of specific demands on the person seemed to be the offender; this person has to have a specific quality or a certain task to perform. This is also true of the road traffic legislation. The following rules on liability are examples of this:

- The Swedish Road Traffic Offences Act, Section 1 (negligence in traffic) requires the offender to be a "road user",

- Sections 3–4 of the same Act (driving without a licence and drink driving) state that the offender is the person "driving" a vehicle,
- Chapter 4(3–6) of the Swedish Road Traffic Ordinance indicates that the offender is the "driver", and
- Chapter 9(5) of the Ordinance (2004:865) on driving and rest times, tachographs, etc. indicates that the offender is the "driver". Other rules on liability in the same ordinance state that liability rests with a "member of the vehicle crew".

In current road traffic legislation, the driver is often the person designated as the offender. The courts, which normally considers issues relating to criminal liability, have to assess whether a specific individual can be regarded as a driver. One reasonable assumption is that the assessment will require, as a minimum, that the person in question should have been able to influence or intervene in the motion of the vehicle. If this is not the case, this person cannot be convicted of a crime. However, for people to rely on the vehicle's systems and hand over control to these, one basic prerequisite should be that they are approved for such use.

To be convicted of a crime, the offence also has to have been committed deliberately or negligently. Nowadays, the definition of a crime indicates directly whether negligence is sufficient to indicate liability.

In traffic situations, statutory provisions such as the Penal Code can also be applied, in addition to the rules on liability in the road traffic legislation. One example which can be cited is Chapter 3(7–8) of the Penal Code, which relates to guilt when it comes to causing injury or the death of another person. These rules state that anyone who causes injury to or the death of another person on account of negligence can be convicted. The term "offender" in this respect is not attributable to the person having a specific property, such as being the driver of a vehicle. Instead, the requirement is for someone to have been negligent in certain respects, for this person to have done – or failed to have done – something which involved a clear deviation from the desirable action. Furthermore, for criminal liability there has to have been a clear link between this negligence (the action) and the effect.

There are already technical aids which largely automate certain elements of driving. Anti-lock brakes, electronic stability control and traction control and advanced cruise control are all examples of technical aids of this kind. These systems influence and, to an extent, take over the driver's options for influencing how the vehicle is driven without having been deemed to alter responsibility when it comes to following the rules and criteria for criminal liability.

If these systems stop working while driving and the vehicle consequently causes an accident or breaches a road traffic rule, the question is whether the driver can be considered to have acted negligently. Only the courts are able to determine the extent of the driver's liability and duty of care. There is a lot to indicate that with a higher level of automation, more instances will be beyond the control of the responsible driver, which in turn means that drivers will be found guilty of negligence in fewer instances than is currently the case, provided that the driver manages the vehicle systems in accordance with the instructions and that these systems are approved.

There are examples in criminal law whereby criminal liability, known as strict liability, can be ascribed to a specific individual entirely irrespective of intent or negligence. One example is this is when the publisher of a journal is considered liable for everything published. For such liability, the legislature has to expressly state this. There should be situations in which it is particularly important from a public standpoint to be able to single out a person as being criminally liable in any one situation.

5.4.3 Conditions for transferring driver liability to someone else

As specified above, it is less likely for a driver managing an approved system in accordance with instructions to be punished for infringements of the law resulting from a vehicle with a high level of automation failing and causing an accident. One issue arising in this regard is whether society nevertheless wants to hold someone else liable for the driving of the vehicle, such as the manufacturer or the owner, particularly when it comes to road traffic accidents resulting in injuries. This is primarily a political issue of a legal-philosophical nature which we cannot and should not decide on as things stand at present.

The issue of liability in the event of traffic offences for anyone other than the driver has been investigated in the *Investigation on owner liability in the case of traffic offences* (SOU 2005:86). The job of the investigator involved examining the legal criteria for introducing some form of liability for the vehicle owner when his or her vehicle is used by someone else when breaking the speed limit or committing other traffic offences which can be monitored and detected by means of automatic systems. The results of the investigation have been reproduced in detail in Transport Working group report 2005/06:TU13.

According to the investigation, introduction of owner liability could lead to conflicts between various basic principles of criminal law, such as the principles of legality, conformity and fault. Citizens must have the ability and opportunity to comply with the law and hence be able to predict how their actions could lead to action in criminal law, and in which situations. Further, identical cases must be dealt with in the same way. Introduction of owner liability with the assistance of an automatic system may result in deviation from this principle. In the case of a speeding offence detected by means of traditional traffic monitoring by a police officer, the driver can probably be identified easily, while the vehicle's owner must bear liability for a speeding offence detected by means of an automatic system. If a rule is introduced which is applied directly due to the fact that a certain monitoring method has been used in the case in question, this involves deviation from this principle. For criminal liability, the action also has to have taken place deliberately or through negligence, so it may possibly be difficult to claim that the owner acted deliberately or negligently if someone else was driving.

The investigation also analysed how the sanction relates to extended owner liability. Penal sanctions are mainly used for offences which society considers to be particularly reprehensible. Breaking the speed limit is a criminalised action. Infringing the law on speed limits and similar rules are punished by means of fines. If the infringement is serious, the driving licence may also be rescinded. Any such action thus assumes criminal behaviour. Breaking the speed limit, in combination with other crimes, may lead to the driver being deemed guilty of negligence or gross negligence in traffic.

The investigation cannot be applied fully to the issues of driver liability arising when vehicles are largely automated. However, this is some measure of the complexity of the issue, and deviations from a number of basic principles of criminal law are required if it is to be possible to assign driver liability to any person other than the person deemed to be driving the vehicle.

Criminal liability for a physical person at the manufacturer's company is hardly a viable approach. Rather, it would be possible to consider extended liability other than criminal liability, such as product safety liability. The Swedish Product Safety Act (2004:451)[23] aims to ensure that goods and services provided to consumers are safe and do not present any risk to human health and safety during normal or reasonably predictable use and service life. Anyone providing a product which is not safe can be banned by the supervisory authority from providing the prohibited product. Financial penalties may also be imposed on anyone providing a product which is not safe.

The issue of transferring different types of liability is, as touched upon earlier, a matter of the political willingness there is in this field to change the legislation. The contact which the working group has had with the automotive industry shows that there is no uniform opinion on which

[23] Cf. European Parliament and Council Directive 2001/95/EC dated 3 December 2001 concerning general product safety, as amended by European Parliament and Council Ordinance (EC) no. 596/2009.

development is desired as regards liability, and it is highly likely that there is currently no clear opinion among elected politicians.

There is a relatively widespread opinion which states that the Vienna Convention on Road Traffic regulates the driver's criminal liability. However, this is not correct as the Convention is aimed at contracting parties (nations) and not directly at individuals or legal entities, and so it has no criminal provisions. A contracting party must then ensure that national road traffic legislation reflects the provisions of the Convention in all material respects. Liability and criminal provisions are established in the legislation. Thus these provisions vary from country to country, and the Swedish Transport Agency is not aware of any form of international harmonisation in the field. Of course, this affects the automotive industry's chances of developing and marketing self-driving vehicles.

5.4.4 Conditions for special road traffic rules and markings for self-driving vehicles on-road and off-road

With the current legislation, in the opinion of the working group is it not possible for county administrative boards or municipalities to issue special road traffic rules via local traffic regulations specific to self-driving vehicles, regardless of the level of automation.

There are three reasons for this.

1. There is no legal definition of what a self-driving vehicle is as regards vehicle type.

2. There are no special road signs and other arrangements in accordance with the Swedish Road Signs Ordinance in order to mark out a regulation for self-driving vehicles. However, supplementary board T22, *text*, could provide supplementary instructions. In theory, this board could be used occasionally together with a road sign in order to explain in words what rules do or do not apply to self-driving vehicles.

3. According to Chapter 2(2) of the Swedish Local Government Act (1991:900), municipalities must treat their members the same unless are objective reasons for doing otherwise. Because of this provision, municipalities in general are unable to formulate local traffic regulations so that they give certain members who own, drive or are driven in self-driving vehicles benefits or disadvantages not applied to other members, unless there are objective reasons for doing otherwise.

Requirements for roads, lanes or carriageways for self-driving vehicles
For a self-driving vehicle to be able to drive and the driver to be able to devote himself at the same time to things other than the task of monitoring or driving, stringent demands are made of the vehicle's ability to read the

infrastructure, road signs, instructions and the road users on or adjacent to the road. This in turn leads to the infrastructure, road signs and instructions having to be in sufficiently good condition for self-driving vehicles to be capable of reading the information, processing it and then making the right decisions. If special demands were to need to be placed on the Swedish Transport Administration, the municipalities and the owners of individual roads, stating that certain roads for autonomous driving had to be of a certain design or equipped in a certain way, the Swedish Transport Agency can probably issue more detailed regulations on this. For the foreseeable future, roads and infrastructure will look the same as they do at present. It will probably not be possible to implement any extensive changes to the road network; the technical equipment, its design and solutions in cars must be adapted to the infrastructure available.

As far as the Swedish Transport Agency is aware at present, the automotive industry has not expressed any special requirements concerning the design of the road environment for self-driving vehicles to work. Nor is it likely for the infrastructure to be adaptable to comply with all technology from different manufacturers. If the infrastructure has to be changed, this change should be such that it suits all self-driving vehicles, not just some of them.

As regards road signs and other arrangements in accordance with the Swedish Road Signs Ordinance, they will provide instructions to traffic and must be in a condition which allows them to be seen in good time and understood by road users. The municipality, the state road maintenance authority or the individual road owners will be responsible for ensuring that this is done. If the technical systems in self-driving vehicles will be dependent on clear, readily visible road signs and road markings, etc. the road owners will bear a great deal of responsibility.

As regards parts of the infrastructure other than those regulated in the Swedish Road Signs Ordinance, trials are in progress using magnets in the carriageway, and as far as the Swedish Transport Agency is aware the results from these trials have been good.

Special lanes or carriageways for self-driving vehicles

One of the benefits emphasised in connection with self-driving vehicles is the opportunity to mark out narrower lanes. Current lanes are marked out with certain dimensions, which in practice means a bit more space for cars in each lane and less for buses and trucks. As self-driving vehicles are expected to be able to centre themselves on lanes, discussions are taking place as to whether future lanes for self-driving vehicles could be marked out so that they are narrow than the present lanes. However, they will still be designed and implemented so that there is little likelihood of accidents and that any accidents occurring will have limited consequences. In the case of autonomous cars, this may involve a lane width of as little as perhaps two metres between lines, and perhaps three metres of class II cars, buses and trucks. There are currently no provisions which expressly regulate how wide lane markings are to be spaced, but there is an indirect requirement which states that lanes must be wide enough for four-wheeled vehicles to use them, one after the other, if there are no markings.

That said, in the opinion of the working group it is not possible at present to introduce provisions concerning special lanes or carriageways just for self-driving vehicles, regardless of the level of self-driving, or to issue a special road sign for this. This is probably in contravention of the Convention on Road Signs and Signals. As a number of different countries will probably introduce self-driving cars, it is appropriate for the rules via convention provisions to be the same in every country.

Before regulations on special lanes or carriageways for self-driving vehicles are implemented, it will probably be necessary for self-driving vehicles to be defined in some way. What a self-driving vehicle is needs to be clarified so that it is possible to regulate special lanes for such vehicles. There are a number of questions to answer; should these vehicles be allowed to drive there even if the driver is doing the driving himself? Should other vehicles being operated by drivers or by drivers who have disabled the self-driving system be allowed to drive the vehicle in such lanes or on such carriageways?

If road maintenance authority wishes to notify road users of the fact that they are entering a section of road which is particularly suitable for autonomous driving, applicable provisions for markings in the Swedish Road Signs Ordinance may be applied for this purpose.

5.5 Problems inventory: vehicle legislation

5.5.1 The current situation

There are currently no requirements guaranteeing a minimum level of safety for vehicles' self-driving functions. There is nothing odd about this as vehicles in which the driver is permitted to hand over control over the vehicle are still at the development stage. These vehicles may perhaps be ready for market launch in around 2020. However, the working group is of the view that this lack of rules will impede the market launch of vehicles with a degree of automation equivalent to level 3 or above. Hence one of the pieces of the puzzle when it comes to making self-driving vehicles possible is the development of such regulations. The Swedish Transport Agency is of the opinion that this is the way ahead in order to achieve sufficient security and acceptance in society, both in Sweden and elsewhere. Specifying requirements would essentially serve two purposes: ensuring a minimum level of safety, and facilitating the vehicle trade. However, there is currently no clear picture of the structure of the future regulations.

Self-driving vehicles which will be present in traffic environment together with "ordinary vehicles" also need to have "ordinary" vehicle properties such as exhaust emission control, seatbelts, braking ability, etc. As things stand at present, therefore, there is no reason to focus on reviewing these rules. However, this will probably be necessary in future. If self-driving vehicles are not involved in collisions, for example, the need for well developed collision protection properties will disappear.

5.5.2 Challenges - legislation

To date, therefore, the driver has controlled the vehicle using different assistance systems. Now that development is heading towards something new, now that the car is becoming a robot that should be able to manage a complex environment, a range of different challenges are arising for the people who have to devise the legislation. The working group has identified the following:

Technology
The complexity in itself presents a challenge. Issues which have not been discussed to date through the vehicle legislation are becoming more important to safety, such as data management and data analysis, reliability and robustness, as well as communication with the outside (V2X). The legislature needs to relate to this. For level 3, successful interaction between vehicle and driver is a must.
Technology is developing at a rapid pace, which means that regulations are needed which can handle the fact that the technology is changing. The traditional way of regulating vehicles has been based on establishing requirement levels for separate systems which vehicles have to demonstrate that they meet. Essentially, this involves clearly established limits and test methods which are used for testing by independent testing organisations. An arrangement of this kind assumes that regulation can predict all possible and impossible interactions between components in the system. When the complexity increases and it is not certain which components will be developed and hence need to be regulated, an arrangement of this kind will be difficult to manage. In the case of the complex safety-critical systems required for autonomous driving, another approach is probably required. This will consider how the different specific systems are managed individually, but – not least – how they interact with one another.

It may then be appropriate to study how other enterprises guarantee the function of similar safety-critical systems At the same time, there may be properties which need to be formulated in a standardised manner in order to achieve safety and function. The regulations also need to be developed in consultation with the industry. Results from research need to be taken into account, and projects similar to "Drive Me" could provide important lessons to be learned.

Different attitudes
Another challenge facing the legislature is the attitudes of different countries, different people and different organisations towards self-driving vehicles. The criteria vary all over the world, and a broad range of perceptions is apparent in the forum in which the Swedish Transport Agency participates – should the legislation permit or prohibit these vehicles?

Who is dealing with the issue?
In the USA, there is a plan with a clear focus which involves devising requirements in standards and recommendations in order to ensure that self-driving vehicles can be driven safely. It will be clear within a few years how the regulations are intended to be structured there. As far as Sweden is concerned, the EU is the primary legislature in respect of things automotive. In the opinion of the working group, the work of the EU is currently at a strategically important initial stage, and so it is extremely important for the Swedish Transport Agency to work to increase the authority's as yet rather limited knowledge of how the EU intends to act in respect of future regulations. Vehicles are no longer a separate component in the transport system, and so several stakeholders should be involved in development of the regulations. One challenge is that who is initiating and controlling the focus of these new regulations is unclear to the Swedish Transport Agency. A number of Directorates General are involved within the EU Commission:

- *DG Enterprise*, which is usually the body which prepares proposals for requirements for vehicles. The Swedish Transport Agency does not know whether this directorate is carrying out any preparatory work. However, this is a forum with which the Swedish Transport Agency is used to working, but it does not go without saying that we know what is going on within the directorate.
- *DG Move*, which works with transport issues. They are dealing with the ITS Directive[24]. The Swedish Transport Agency has an expert who is very familiar with issues relating to the ITS Directive.
- *DG Connect*, which is responsible for communication issues.

[24] Directive 2010/40/EU.

The working group is also aware of a couple of networks, but it is not involved in the work of these networks.

- *ERTICO – ITS Europe*, which links together ITS stakeholders in Europe.
- *VRA – Vehicle and Road Automation* is working with the introduction of automated vehicles and related infrastructure.

On a more global level, we have the stakeholder UN:

- *UNECE/WP 29*, which devises technical provisions concerning vehicles in the UNECE regulations. The issue may perhaps be discussed within their ITS workgroup. However, the Swedish Transport Agency has a good insight into operations in this forum, and it has the opportunity to act within the associated workgroups.

Of course, the automotive industry and its subcontractors are important players with regard to how the issue is handled within the EU.

5.6 Compensation issues

When a claim arises as a consequence of traffic involving a motor vehicle, liability may also follow on from legislation other than the legislation applied by the Swedish Transport Agency in its business sector. Therefore, an introductory analysis has been carried out within the scope of the commission to find out what effect this could have on issues relating to terms of insurance and liability for claims when vehicle driving becomes ever more automated. However, the Swedish Transport Agency is not a central administrative authority in the field of insurance. The Swedish Financial Supervisory Authority is the authority which can issue more detailed regulations on insurance terms and the activities of insurance bodies, and which also supervises operations.

As far as liability for claims in general is concerned, Swedish law has something known as the Culpa Rule. "Culpa" can be translated as negligence. The Swedish Tort Liability Act (1972:207) includes elements such as "negligence" and "fault or neglect" to express the basic prerequisite so that a party causing a loss can be held liable. This can be said to constitute a primary rule for liability for claims. However, as can be seen in Chapter 1(1) of the Swedish Tort Liability Act, this act must not be applied unless specifically prescribed or occasioned by contracts or otherwise following on from rules on claims in contractual relationships.

Claims arising in road traffic are generally subject to special legislation, primarily in accordance with the Swedish Traffic Damage Act (1975:1410). The Swedish Traffic Damage Act includes provisions on requirements for motor vehicle liability insurance and compensation from motor vehicle liability insurance for claims resulting from the driving of motor vehicles, with certain exceptions as specified in the statute, such as – for example – motor vehicles designed to be operated by pedestrians and motor vehicles being used within enclosed areas.

Section 2 of the Swedish Traffic Damage Act states that motor vehicle liability insurance must be held for motor vehicles registered with the road traffic register which have not been deregistered, and for other motor vehicles used on the roads here in Sweden. The obligation to hold insurance must be met by the vehicle's owner in accordance with Section 2(2).

Thus the point is that motor vehicle liability insurance must be held, and that the obligation to take out insurance rests with the owner. These requirements are applicable irrespective of the vehicle's level of automation.

Another point of the Swedish Traffic Damage Act is that anyone suffering personal injury as a consequence of the operation of a motor vehicle will be entitled to compensation as a result of the accident; see Sections 10 and 11 of the Swedish Traffic Damage Act. Any compensation will be paid by the insurance policy, which means that the insurer which issued the motor vehicle liability insurance will be obliged to pay compensation.

Anyone suffering injury as a result of the operation of a motor vehicle may instead claim damages in accordance with the rules on this, even though this person can claim compensation as a result of the accident. Settling a claim by means of assessment in accordance with the Swedish Tort Liability Act is thus a purely civil action in which the obligation to pay compensation is assessed in a general court of law. However, most commonly any claims arising as a consequence of the operation of a motor vehicle should be settled via the motor vehicle liability insurance.

The entitlement to compensation as a basic principle for road traffic injuries is applicable to drivers and passengers, third parties or other parties (known as no fault insurance), irrespective of the circumstances. Compensation as a result of an accident is based on the motor vehicle liability insurance which must be held for the vehicle. The degree of automation in any aid systems for driving the vehicle should therefore be of no significance initially when it comes to determining whether compensation should be paid as a result of the accident. Compensation for property damage must initially be paid even if compensation for property damage as a result of an accident caused to the policyholder by his own vehicle is payable only if the vehicle was being used illegally by someone else. As regards the extent of compensation as a result of an accident and what compensation is to be paid for, Section 9 of the Swedish Traffic Damage Act indicates that provisions in Chapter 5 and

6(3) of the Swedish Tort Liability Act and the Act (1973:213) regarding Adjustment of Life Annuities Awarded in Tort must be applied.

As regards the size of premiums for motor vehicle liability insurance, there is a restriction rule in Section 2 of the Motor Vehicle Liability Insurance Ordinance (1976:359) which indicates that the premium must not be set to an amount higher than can reasonably be considered to correspond to the risk which the policy is intended to cover, plus necessary expenses. As regards supplementary insurance to the insurance required by the Swedish Traffic Damage Act – e.g. partial cover and fully comprehensive insurance, as they are known – this is not regulated in the Swedish Traffic Damage Act, but in the Swedish Insurance Contracts Act (2005:104) and in the insurance contract between the insurer and the policyholder. The issue of insurance terms is therefore largely a civil issue in which the insurer makes a risk assessment and determines a premium on the basis of this. In this context, it should be stated that any insurer which has been awarded a permit in accordance with the Swedish Insurance Companies Act (2010:2043) and hence is permitted to issue motor vehicle liability insurance is also liable, upon request, to issue motor vehicle liability insurance, see Section 5 of the Swedish Traffic Damage Act. Provisions concerning the obligation to contract for partial cover and fully comprehensive insurance can be found in the Swedish Insurance Contracts Act.

The effect this will have on the size of premiums is also difficult to predict until such vehicles are available on the market. As far as could be learned from contact with the insurance industry, companies have not yet reflected in any great detail on these issues, but they have stated that this is a development which they will be continuing to monitor.

It may possibly be said to be conceivable that the need to make different assessments between different policyholders will be reduced if traffic in general is driven using largely automated aid systems. It is difficult to predict what effect this will have on the extent of compensation until situations arise in which such claims have to be settled. If two vehicles are damaged in which neither of the drivers was actively monitoring the driving, the insurance companies will have to decide between themselves who is to bear the cost. Such issues can only be determined conclusively by a court of law.

5.7 Work environment legislation

The Swedish Road Traffic Ordinance includes provisions for on-road and off-road traffic. Only some of the provisions of the Swedish Road Traffic Ordinances are applicable on railway or industrial sites and in fenced-in competition areas or other similar fenced-in sites.

Development is taking place in which autonomous working machinery is starting to emerge. This machinery is largely operated on fenced-in sites. Legislation which is related to both road traffic rules and vehicle rules involves work environment issues for protecting the people who use such machines in their work.

However, the Swedish Transport Agency is not a central administrative authority in respect of the work environment. The Swedish Work Environment Authority is the authority which can issue more detailed regulations and supervise operations. Even so, there has been reason to carry out an introductory analysis of the relationship to work environment issues.

The Swedish Work Environment Act (1977:1160) includes rules on obligations for employers and other safety officers to prevent ill-health and accidents in the workplace. The work environment includes all factors and relationships in respect of work. The job of the Swedish Work Environment Authority is to ensure that the work environment meets the requirements defined in the Swedish Work Environment Act, which state that everyone must have a good work environment which allows them to develop. This is achieved by issuing legally binding regulations, inspecting places of work and distributing information.

European Parliament and Council Directive 2006/42/EC on machinery and amending Directive 95/16/EC, generally known as the Machine Directive, is enacted in Swedish legislation and includes – among other things – regulations which can be applied to "an assembly consisting of multiple parts or components where at least one of them is moving. It is or it should be equipped with a gear system that is not powered by a man or an animal. It is designed for a specific purpose". There are a number of exceptions to the application of the directive for vehicles regulated in accordance with other directives, etc. The Swedish Work Environment Authority exercises market control, and the rules are aimed at ensuring that machines are safe regardless of whether or not they are used on work sites. Third parties, animals and property must also be protected.

It has not been possible in this investigation to elaborate on the Swedish Work Environment Authority's authorisations and responsibilities in respect of the requirements defined in the Work Environment Act and how this may be affected by extended use of vehicles driven more or less autonomously. The Swedish Work Environment Authority has a comprehensive regulations which do not examine in detail how vehicles are driven, or in what manner. If the vehicle is safe to use and safe for employees inside and outside the vehicle, and if it meets the regulations specified by the Swedish Work Environment Authority, the vehicle can be used for work. Some of the provisions of the Swedish Road Traffic Ordinance are also applicable to self-driving vehicles used in businesses where work environment legislation is applicable, including within fenced-in sites. Regardless of what is stated in the road traffic rules, the Swedish Work Environment Authority has the option of issuing regulations and deciding upon general recommendations which specify more detailed requirements for the work environment. These regulations may relate to matters such as mental and physical stresses, hazardous substances or machinery. Examples of such regulations which could already affect vehicles driven more or less autonomously at places of work are the Swedish Work Environment Authority's regulations and general recommendations (AFS 2010:1) on rock and mine work and regulations (AFS 2006:4) on the use of work equipment. The development of autonomous motor vehicles, etc. will indicate whether further provisions are required in respect of the work environment.

6 Closing discussion with conclusions

Autonomous driving is a clear example of the complexity presented by development of a component in the road traffic system, in this instance the vehicle. The technology cannot be developed in isolation as it will have a major impact on the road traffic system and need to interact with humans, vehicles, infrastructure and society in order to have the maximum impact. Moreover, the technology is developing quickly and lots of different stakeholders are involved in or affected by the development. This complexity means it is impossible to predict development and steer it in detail. Moreover, detailed control risks hampering innovation and so reducing the potential for autonomous driving. This also means that development has to take place via a number of stakeholders acting in cooperation.

The complexity presents a challenge to the Swedish Transport Agency in a number of ways; the role to be played by the authority, the role to be held by regulation in order to support technical development, and how any such regulation should be formulated so as not to impede innovation, while also ensuring that the development contributes to the meeting of transport policy targets. In the opinion of the working group, we need to be more proactive and work as an active stakeholder in the development of self-driving vehicles.

Observing HF/MTO at an early stage of system manufacture and design is important in order to create opportunities for human performance and limitations in interaction with the automation. Driving safety is becoming more dependent on a combination of human and automation performance, and successful design will depend on recognising and supporting the new role of the driver. Vehicle automation will probably change the role of the driver, particularly as drivers adapt to automation over time.

The chances of increasing compliance with targets on roads with the aid of ITS appear to be very good as there is untapped potential in respect of road traffic compared with airborne, waterborne or trackbound traffic, where implementation of ITS has made more progress. To be able to benefit fully from these systems, collective standards are required which ensure that communications will work.

Vehicles with self-driving functions which support the driver in certain situations, levels 1-2, can already be seen on our roads. The driver is liable for any infringements of road traffic rules, the current rules on driver competence are relevant as the driver needs full driving skills and the vehicles can be approved. In around 2020, it is likely that the market will offer the first vehicles which, under certain conditions and in specific traffic environments, will be capable of performing the entire task of driving, level 3. The intention is for the driver to be able to do other things while the car drives, but the driver must still be in the driver's seat and be capable of intervening. There is no provision in the Swedish Road Traffic Ordinance or any other statute which expressly states that the driver must hold onto the steering wheel while driving the vehicle. The provisions of the Swedish Road Traffic Ordinance are instead based on the fact that the driver has control over the driving of the vehicle and is responsible for driving the vehicle in a satisfactory manner. The present regulations on driver competence are relevant as the driver must be able to drive the vehicle in all situations which the vehicle is unable to handle. As regards vehicles, the working group is of the opinion that the absence of EU rules for the self-driving function will complicate the introduction of level 3 vehicles. It is unclear as to when level 4 vehicles – where the vehicle manages the entire task of driving throughout the entire journey – can be expected to emerge onto the market and how they will be owned. It may be stated that the current provisions with respect to on-road and off-road traffic, based on the notion that the driver must have control over the vehicle, and requirements in respect of driver competence are not suited to future phenomena. The absence of rules for self-driving vehicles is one aspect which it it thought will impede the market launch.

Test operations
The working group is of the opinion that current legislation provides scope for test operations in real traffic using vehicles with a high degree of automation. The road traffic legislation does not present an obstacle, and if the vehicles fail to meet the technical requirements the Swedish Transport Agency has the opportunity to grant exceptions. There are vehicle manufacturers who currently have what are known as test dispensations. The test dispensation model could be used for exceptions for vehicles with different degrees of automation. Even testing parking options with vehicles without drivers is possible as they can be placed on an equal footing with other traffic where the driver is not sitting in the vehicle but still bears liability, e.g. unmanned aircraft.

The driver's responsibility to follow road traffic rules
The working group has come to the conclusion that there is nothing in the road traffic legislation to prevent the use of self-driving vehicles in the road transport system.
Current road traffic legislation is based on driver responsibility for driving the vehicle. As long as there is someone who can be considered to be a driver in or in connection with the vehicle, self-driving vehicles up to level 3 can be operated. Vehicles operating at levels 3 and 4 raise the issue of liability if anything happens.

When technical development continues in respect of traffic and roads, it will be entirely natural for the courts' opinions of driver liability in traffic to change. Greater vehicle automation will probably mean that ever-decreasing numbers of people will be found guilty of offences relating to accidents and infringements of the law involving vehicles. There will be a reduction in the number of instances in which people can meet requirements to be considered drivers will. It is likely that the courts will demand that people must have had, in some form, the opportunity to influence or intervene in the motion of the vehicle to be deemed to be driving it. Cases involving people being regarded as driving negligently will also become less common. The actual control exerted by people over vehicles will be reduced as automation increases.

Is it a problem for people to be viewed as criminally liable to a lesser extent when vehicles have been involved in accidents and infringements of the law? The technical development will result in a reduction of the risk of human error, thereby reducing the chances of people doing things which are now criminalised. This should be regarded as a positive development, but it is mainly a political issue of a legal-philosophical nature. Contact with representatives of the automotive industry has also failed to turn up any clear view of the issue. The issue of driver liability and whether or how this should be regulated is a national issue in the first instance. A national change in respect of this issue will probably have very little effect on corresponding legislation in other countries or sales of self-driving vehicles in these countries.

Although we do not want legislation to impede the development of autonomous driving in Sweden, we should avoid introducing provisions which cannot be used by other countries' drivers and vehicles, or which we have to reassess soon because technical development is progressing so quickly. The fact that road traffic rules in different countries have been aligned has been a success factor for all types of road transport for a long time. Therefore, the starting point is that the issue of special traffic regulations, special road signs and other arrangements for self-driving vehicles should be implemented internationally within UNECE.

Issues remain in respect of road traffic legislation and also as regards liability, which is essentially an issue for the law enforcement agencies to resolve. ***The working group is of the opinion that as things stand at present, we should continue to monitor the application of the law in the projects and investigations taking place in the field of autonomous driving both nationally and internationally.***

Vehicle legislation
There are currently no requirements guaranteeing an identified level of safety for vehicles' self-driving functions. In the opinion of the working group, regulations will be needed which guarantee a sufficiently high level of road safety for vehicles of level 3 or above so as not to impede the market launch. We are of the opinion that level 3 vehicles will be technically ready for launch on the market in around 2020 and onwards.

Vehicle legislation is largely controlled by the EU. If Sweden wishes to influence the direction, this should take place as part of the EU work. As things stand at present, the Swedish Transport Agency has limited knowledge of the EU's plans for the regulatory process in the field. Therefore, greater efforts are required on the part of the authority in order to actively exert an influence.

In the opinion of the working group, the regulations that will be needed require new approaches. The traditional way of regulating requirements in respect of vehicle characteristics and equipment has been based on establishing requirement levels to be met by vehicles. This will probably not be appropriate for more complex, safety-critical systems. In the opinion of the working group, the regulations that will be needed require new approaches. As part of this work, it may be interesting to study how other operations guarantee similar functions, such as approval of signal systems for railways. The Swedish Transport Agency needs to find out more about how the EU, other countries and industry view this.

Driver competence
The working group finds at present that there is no need to readjust the driving test or vehicle requirements for the driving test. The same is applicable to any need for development in driver training. At the moment, training is largely steered by the requirements of the driving test. That said, it is important to monitor and follow technical development among vehicles used for driving tests in Sweden and other countries in order to ensure that the knowledge requirements for the awarding of driving licences continue to be met.

At present we know little about the difficulties of the future systems and any risks they may involve. Therefore, it is too early to draw any conclusions as to whether further requirements should be specified for training beyond what is currently included in driver training for the awarding of class B driving licences. However, it is important for the Swedish Transport Agency to monitor developments and analyse any incidents involving vehicles which use this type of new technology.

Influence on social planning
Interaction between the planning of the transport system and social construction is a must if we are to be able to implement sustainable towns. ***A road transport system with a large proportion of autonomous vehicles will have a noticeable influence on social planning criteria.*** It is important in this regard to bear in mind the time perspective. Although we will not see a traffic system which includes a large number of automated vehicles for at least ten or so years, planning for this society should start, or at least start to be discussed, right now, given the natural slowness of social construction.

Digital infrastructure
There are currently no clear signals providing a response to the issue of the need for a digital infrastructure as a criterion for autonomous vehicles in the road traffic system. However, it can be stated that in their views of the future, vehicle manufacturers are anticipating a road transport system where road signs, etc. will not be needed. If such a scenario comes to pass, it can be stated that Sweden is a long way out in front from an international perspective. The Swedish Transport Agency bears responsibility for ensuring that all traffic regulations decided upon locally in Sweden are published on the special Svensk trafikföreskriftssamling (STFS, Swedish traffic regulation collection) website. However, the quality of the content is entirely dependency on the competence of the decision-making authorities and the necessary resources. Major shortcomings have been identified here, which is why this is an area which must be rectified if an autonomous system based on information on applicable road traffic rules being issued directly to cars is to be capable of functioning reliability. Similar systems involving traffic regulations announced digitally, as is the case with STFS, are not available in any other country as far as we are aware. As the demand for similar systems can be expected in other countries, Sweden should be involved at an early stage with international fora in order to attempt to influence the structure on the basis of our Swedish system.

Interaction among stakeholders
The working group has identified the fact that there is a pronounced need for interaction among the stakeholders influencing the development. No one stakeholder can control the whole picture, or the development of the system. The policy instruments available cannot be applied in isolation from one another as they can interact with one another when applied correctly and have a greater effect than optimising on the basis of one policy instrument at a time. Moreover, they have to be adapted to changes in external factors so that they do not lose their steering effect.

The choice of policy instruments and the combination of these should therefore be based on a good understanding of the mechanisms which affect development in the field. This requires developed working methods which help to enhance and encourage active interaction with involved stakeholders, with a view to sharing knowledge and providing feedback on one another's activities. Synergies may arise when stakeholders exchange information on different products and services: for example, work on national and international regulations and standards can be reprioritised and adapted as a result of these dialogues. The regulatory process and the objects of these rules stand to benefit hugely from exchanging views and discussing the effects of one another's activities.

In the long run, extended interaction should result in a collective Swedish target for the field of autonomous driving..

Need for research and new knowledge
The working group perceives a need for further knowledge and research even though research into vehicles with a high degree of automation is increasing, as is research covering the influence of the transition between automation and manual driving.

The interaction between human and technology is an important element of autonomous driving. Both research and previous experience indicate how important it is for this to work. Despite the fact that research into vehicles with a high degree of automation is increasing, as is research covering the influence of the transition between automation and manual driving, more knowledge and research are needed. Observing HF/MTO at an early stage of system manufacture and design is important in order to create opportunities for human performance and limitations in interaction with the automation.

How society will be affected and how this influence should be handled, e.g. how urban planning will be affected, how settlement patterns will change, how traffic volume will change, how vehicle ownership will change, etc. are other issues which need to be addressed.

6.1 Suggestions for further work

- Increase the Swedish Transport Agency's knowledge of how national and international regulations need to be developed by participating in or monitoring relevant testing. As things stand at present, this means active participation in Volvo Car Corporation's Drive Me project and monitoring the Royal Institute of Technology's work on buses for public transport purposes.

- Identify the fora and groupings within the EU and UNECE which prepare legislation in the field of self-driving vehicles and work together with the Ministry of Enterprise, Energy and Communications to determine how Sweden can best proceed so as to be able to influence the formulation of the legislation in the required direction.
- Enhance knowledge of how safety may be required in complex and safety-critical systems in order to meet the challenges arising as a result of ongoing development. This work will begin with internal authority work in which we will study various alternatives in respect of how these systems could be approved, by studying – among other things – how other operations are guaranteeing the function of similar systems.
- Monitor the development of autonomous driving from a wider perspective, particularly in the USA, via the network of contacts established at NHTSA and the transport authority DMV in California.
- Continue to examine the criteria/opportunities for trials involving level 4 cars on the public roads within a limited area
- Work for more in-depth interaction with the Ministry of Enterprise, Energy and Communications, other authorities, industry and academia in order to contribute to a national consensus, but also to identify and clarify the role of the Swedish Transport Agency in this work. Work to promote cooperation along the lines of the collective platform proposed as part of the Government commission, with a view to devising an action plan in respect of use of communication equipment in a manner hazardous to traffic.[25]
- Work to include autonomous driving as part of the systematic situation analysis and analysis of external factors developed at the road and rail department.
- Monitor the priority research fields identified by Viktoria Swedish ICT and identify whether the research being carried out meets the needs of the Swedish Transport Agency.
- Map the need for research in respect of autonomous driving as a basis for the Swedish Transport Agency's research strategy.

[25] N2013/4869/TE.