DIGITAL SYSTEMS
MOBILITY AND SYSTEMS

Photo: Volvo Buses

Self-certification of Autonomous Buses

Kristina Andersson, Håkan Burden and Susanne Stenberg

RISE Report 2021:19

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Abstract

Self-certification of autonomous buses

It will still be a few years before we will have autonomous buses driving city streets and squares without drivers. On the other hand, it should be possible to have autonomous buses in a depot at an early stage in order to ensure more efficient maintenance of the vehicles when they are not in service, while at the same time learning how to be part of future operations. Such buses would be type-approved for manual traffic (SAE level 0-2), but not approved for autonomous road operation (SAE level 4-5). During the span of a single day, the bus will therefore alternate between the regulations for enclosed (fenced depot) and non-enclosed (road) areas, between being autonomous and not autonomous.

The bus, which was previously a legal “static whole”, will now instead be tested based on two regulations depending on the environment it is in at any given time and level of autonomy. This is a completely new situation: that a bus is “dynamically divisible” from a regulatory perspective, which has significance in terms of who shall decide whether the vehicle is safe to use in a certain environment.

After analysing the challenges based on existing regulations, interviewing relevant authorities, arranging workshops with various stakeholders and meetings with experts in certification, our conclusion is that, in order to be considered safe in autonomous mode within the depot, the bus should be self-certified by means of CE marking according to the Machinery Directive[1]. This is the authors’ conclusion and not necessarily representative of the other parties involved in the project.

We predict that we will see more self-certification of autonomous vehicles in the future. Partly because there are such large international markets working in this way, such as in North America, and partly because it enables faster market introduction of dynamic vehicle concepts. With “dynamic vehicle concept” we mean vehicles that gain new areas of application by replacing the chassis or changing software settings and are thus converted from a bus to a truck or from a car to quadricycle. Maybe even several times a day.

Self-certification, however, will also increase the need for standardisation, both for processes and products. Processes may involve how a vehicle can be certified, particularly how the risk analysis should be carried out. In terms of products, standardised descriptions of the technology’s function will facilitate proprietary self-certification since operators know how to describe their own products, including how their certification should be structured based on the constituent certified components. Current regulations will also need to be updated if more vehicles are to be self-certified, such as the Machinery Directive.

Lastly, we would like to communicate the method used to reach our conclusions. The project has been carried out as a Policy Lab where we have brought together various stakeholders around a common challenge. This has enabled us to concretise both the challenge of autonomous vehicles within the enclosed area and our conclusions. The

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[1] Directive 2006/42/EC of the European Parliament and of the Council of 17 May 2006 on machinery, and amending Directive 95/16/EC

method selected has also given relevant authorities the opportunity to familiarise themselves with how they should relate to tomorrow's technology without having to present a view on how they will relate to a specific test or vehicle. In this way, Swedish authorities will be ready to adopt technical innovations once they are introduced to the market.

This report is structured so that Section 2 describes the current regulatory framework, particularly in terms of the distinction between the Machinery Directive and vehicle type-approval. Section 3 uses specific examples to describe business operations pertaining to autonomous buses in a depot. Section 4 presents the authors' conclusions based on how the regulations relate to the specific details obtained from the depot pilot. Section 5 presents the full picture by relating our conclusions to what is happening internationally and how the national ordinance on autonomous vehicle trials on roads corresponds to international trends. Lastly, in Section 6, we provide a summary of what we consider to be the most important issues for which further work should be carried out.

Key words: Type approved vehicles, enclosed areas, machinery directive, CE mark, Policy Lab, mobility, self-driving

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Foreword

Sweden has 17 strategic innovation programmes funded by the Swedish innovation agency Vinnova, Formas (a research council for sustainable development) and the Swedish Energy Agency. The overall task of the innovation programmes is to create "conditions for sustainable solutions to global societal challenges and increased international competitiveness"[2] in their respective areas.

Drive Sweden[3] is one of these programmes. Drive Sweden comprises members from academia, industry and society and is hosted at Lindholmen Science Park. Together, the members work on the challenges associated with the next generation of mobility systems for people and goods.

The following report constitutes one of three reports in the Drive Sweden Policy Lab project. The project is co-funded by Vinnova through Drive Sweden and by the Swedish Transport Administration. The project was run from October 2019 until December 2020 under the direction of RISE. The following entities also worked in the project:

- Applied Autonomy AS
- Boliden AB
- Combitech AB
- Easy Mile GmbH
- Einride AB
- Municipality of Gothenburg
- Keolis Sverige AB
- The Swedish Association of Road Transport Companies Västra Götaland
- The Swedish Transport Administration
- Veoneer Sweden AB

Keolis provided the case study which forms the basis of this report. Volvo Buses also contributed to the project through the company's collaboration in a parallel sister project and answered questions relating to the technology and bus operation in general. However, neither Keolis nor Volvo Buses participated in the work involved with examining current regulations. We also invited authorities and other operators to participate when deemed pertinent. We would like to take this opportunity to thank everyone who has been involved and provided opinions and expertise.

We wish to underscore that the views and standpoints in this report are the authors' alone. Other parties or representatives may have a different analysis and come to different conclusions.

The cover photo was taken by Volvo Buses, the photo at the end of the report was taken by Kristina Andersson.

Gothenburg, January 2021

Kristina Andersson, Håkan Burden and Susanne Stenberg

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[2] https://www.vinnova.se/en/m/strategic-innovation-programmes/
[3]https://www.drivesweden.net/en

1 Two Trends in Gothenburg

In terms of vehicle development, the legal requirements range from technology-specific solutions to functional requirements. An example of the former is UNECE vehicle categories and how they are reflected in the Swedish Vehicles Act (2002:574). On the other hand, the Swedish Ordinance (2017:309) on autonomous vehicle trials is a regulatory framework that does not pre-define approved technology solutions, but indicates instead that it is crucial to relate a particular technology to the environment in which it is to be used. Various technological solutions exist, and they pose different risks, which in turn presents the organisation running the trial with numerous different strategies to manage.

In parallel with the transition from regulations based on technology-specific solutions to regulations based on functional requirements, the perception of what constitutes a vehicle is beginning to change, from an autonomous and indivisible unit to a system that is dependent on surrounding systems, i.e. from a single system to a system of systems. At the same time, the general trend pertaining to digitalisation and virtualisation has allowed for vehicles to be reconfigured and gain completely new features by updating the software wirelessly, i.e. updating the logic of the system without replacing the hardware. The focus on vehicle electrification has also enabled new vehicle designs, which in turn can lead to vehicles that can be reconfigured by changing mechatronic components without visiting the workshop. An example of the latter is Scania's NXT concept,[4] which, by swapping the bodywork, can operate as both a bus and a truck.

In the Drive Sweden Policy Lab project, we have explored how an autonomous bus in a depot relates to both the trends and the existing regulations. The focus has been on the first trend: from regulations based on technology-specific solutions to regulations based on functional requirements. We revisit the second trend in Section 5, where we broaden the perspective and look both outwards and to the future. The work was carried out in four well-attended workshops and a series of work meetings. The workshops presented the challenge, the initial analysis was discussed and finally validated. The actual analysis of the challenge was carried out at the work meetings where the bus was analysed based on current regulations from the perspective of the authorities and companies alike. We also participated in a demonstration of the autonomous bus in the bus depot. Interviews were also conducted to supplement the work and gain a broader understanding.

From our work, we conclude that a bus, which is only autonomous[5] in the depot area, falls under the Machinery Directive[6] and that the onus is on the bus operator owning the depot to self-certify the vehicle as part of a compound machine, where charging infrastructure and control towers will be included. This means that the operator is also the responsible manufacturer of the compound machine. We also anticipate that self-certification will become an increasingly important process in the introduction of new technologies. This presents established operators in the Swedish automotive industry

[4]https://www.scania.com/uk/en/home/experience-scania/news-and-events/news/2019/06/taking-urban-transport-to-the-nxt-level-.html Published 10/06/2019

[5] When on the road, the bus is an SAE level 2 vehicle and is operated by a driver. Inside the depot, the bus becomes autonomous (SAE level 4) and is operated by an automated driving system.

[6] Directive 2006/42/EC of the European Parliament and of the Council of 17 May 2006 on machinery, and amending Directive 95/16/EC

with several challenges. One initial and central challenge involves the means of self-certification since operators are accustomed to working with a type-approval process for this category of vehicle. Furthermore, the ecosystem of operators around the technology also faces new challenges since they need to know what to certify, but also what form of self-certification must be applied to the constituent components.

It is likely that the transition to increased self-certification will also lead to further standardisation initiatives to simplify the harmonisation of different systems, as well as to analyses of the reciprocal impact between the system and the environment into which it is introduced and the people with whom the machine will operate.

2 Technology and function

We analysed the autonomous bus based on two different paradigms – regulations that define the technology-specific solutions considered safe in a type-approval (such as the Swedish Vehicles Act and the Swedish Vehicle Ordinance (2009:211)) and regulations that define functional requirements that must be met but which do not specify how (such as the Machinery Directive). This is because type-approved vehicles are actually machines, but for historical reasons they have their own regulations and are therefore not legally regarded as machines. Put simply, all type-approved vehicles meet the definition of being machines but are considered so "important" that they have their own space in which to operate (see Figure 1). There are vehicles, however, that have not been given their own specific regulations at EU level and are instead covered by the Machinery Directive, e.g. heavy-duty vehicles (so-called yellow goods). One challenge posed by autonomous vehicles is that these are not (yet) covered by the type-approval regulation, i.e. there is no type-approved autonomous bus.

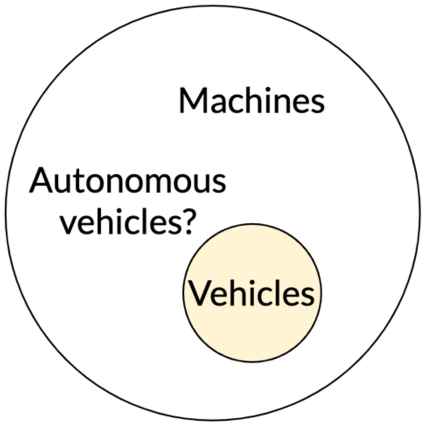

Figure 1: Relationship between machines, vehicles, and autonomous vehicles

2.1 Machines

According to Article 2 of the Machinery Directive, a machine is an assembly of different parts, at least one of which moves, with associated control systems and engine, which are joined for a specific application (Machinery Directive, 2006). If the power source in the system is directly applied human effort, it is not a machine. A hand-powered lawnmower is therefore not considered a machine, whereas a motorised lawnmower is. The term 'machine' also applies to a group of machines which are set up and controlled for a common purpose so that they function as one unit. A production line in a factory can thus be considered a machine where the components together have a common purpose and function as one unit.

In Sweden, machines are regulated by the EU Machinery Directive, supplemented by Swedish Work Environment Authority Regulation (AFS 2008:3) on machines.

2.1.1 Market surveillance

Monitoring of machinery is achieved by means of, for example, market surveillance. Market surveillance means that the responsible authority monitors products supplied on the market or put into service to ensure these comply with the applicable requirements. The purpose of monitoring is to ensure the safety, health and environment of citizens, and defective products may be subject to a ban on sales. If the product has very serious flaws, the relevant authority may decide to withdraw the product from the market. Market surveillance also aims to counteract competitive disadvantages between companies.

The requirements for market surveillance are stipulated by Regulation (EC) No 765/2008 of the European Parliament and of the Council of 9 July 2008 setting out the requirements for accreditation and market surveillance relating to the marketing of products, Swedish Regulation (2014:1039) on market surveillance and other related monitoring, the Swedish Product Safety Act (2004:451), the Swedish Product Safety Ordinance (2004:469) and sectoral legislation. Market surveillance takes on different forms in the EU Member States. What we describe in this report is based on the form in Sweden. It is therefore debatable whether our conclusions can be directly transposed to another Member State.

In Sweden, market surveillance is distributed across many authorities with different responsibilities, which in turn requires coordination. The Swedish Work Environment Authority is responsible for the sector pertaining to machinery, whereas the Swedish Transport Agency is responsible for vehicles on the road. An autonomous bus in a bus depot is a new challenge for vehicle manufacturers, the Swedish Work Environment Authority and the Swedish Transport Agency since an autonomous bus is not easily classifiable according to existing sectoral responsibilities.

2.1.2 CE marking

Many products are marked or labelled to provide consumers, authorities, etc. with valuable information about the product. Markings may be mandatory or voluntary. An example of a mandatory mark is the CE Marking, while the Nordic Swan ecolabel is voluntary.

The CE Marking is a product marking for certain products sold with the European Economic Area. The marking indicates that the product complies with EU requirements and can be sold freely within the EU. With the CE marking, a manufacturer certifies that the product complies with the legal requirements for safety, health, and the environment, along with other product characteristics.

The manufacturer is also responsible for ensuring that the product, which is intended to be sold on the EU market, has been designed, manufactured, and inspected in accordance with regulations. For most products, it is sufficient for the manufacturer to ensure that the product itself meets all the requirements, but for certain products considered particularly hazardous, the manufacturer is required to have the product inspected by an independent third-party, known as a notified body.

When the time comes for a manufacturer to CE mark a product, several steps must be followed:

1. The first thing the manufacturer does is identify the relevant applicable regulations. These may include EU directives and harmonised standards such as the Machinery Directive, but also other regulations, such as the Electromagnetic Field (EMF) Directive.
2. In the next step, the manufacturer must verify the product-specific requirements (in the Machinery Directive, Annex I, is particularly relevant).
3. Some products must be inspected by a third party and manufacturers cannot do so themselves (Annex IV of the Machinery Directive lists products that need to be inspected by a third party). The manufacturer is responsible for certifying that the product was inspected by a third party.
4. The manufacturer must then test the product and ensure that it complies with regulations.
5. The manufacturer must then create and store relevant technical documents (when CE marking according to the Machinery Directive, Annexes II and VII provide the details for this).
6. An EC Declaration of Conformity for the machine must be formulated (Annex VII A.b if we adhere to the Machinery Directive).
7. Lastly, the CE marking can be affixed to the product by the manufacturer.

Since there are two definitions of a machine (see Section 2.1 above), there are also two perspectives on how CE marking can be carried out:

1. Machine consisting of parts: the machine is an assembly of different parts, at least one of which moves, with associated control systems and engine; or
2. The machine consists of machines: a group of machines that are set up and controlled so that they function as one unit.

In both cases, the constituent components (parts or machines) of the machine that are certified share a common purpose as a machine. In both cases, the constituent components may be certified, perhaps according to the Machinery Directive, or not. It depends on what applies to those parts and whether they have been built for large-scale production or are unique to this machine. The latter could involve a production line where there is only one purpose-built machine, for instance a precision sheet metal bending machine for a particular bus model produced only in one factory. In this case, the precision bending machine does not need to be CE marked together with the other machines as a group of machines.

As described, CE marking is not specific to the Machinery Directive but constitutes a general process for self-certification where different regulations are applied depending on the type of product to be certified. Prerequisites for CE marking a product:

a. the product complies with basic requirements such as health, safety, function, and the environment; and

b. the prescribed inspection procedure has been followed.

Provisions on CE marking are stipulated in Regulation (EC) No 765/2008 of the European Parliament and of the Council of 9 July 2008 setting out the requirements for accreditation and market surveillance, the Swedish Accreditation and Conformity Assessment Act (2011:791), and in sectoral legislation.

2.2 Vehicles

Motor vehicles consist of several parts, are equipped with an engine and a control unit, and are manufactured for a specific purpose. Yet they are not considered machines. The Machinery Directive expressly states that several vehicle categories are exempt and subject to different regulations (Art. 1). The Swedish Vehicles Act regulates, inter alia, the verification of vehicles and related systems, components, and separate technical units (Chapter 1, Section 1). One means of verifying vehicles is by type-approval (Chapter 2) as opposed to individually approving each vehicle produced.

2.2.1 Vehicle categories

Some vehicles are considered "more important" than others for reasons including their high commercial value. They therefore have their own harmonised regulations on how they are to be designed to be considered safe. This facilitates trade across national borders. A type-approval can be national, i.e. it may only apply in Sweden, or international, such as within the EU. Essentially, type-approval for buses is negotiated within the United Nations Economic Commission for Europe (UNECE) under a type-approval directive from 1958, after which the EU then 'adopts' the regulation.

In the EU regulation, buses fall under the M2 and M3 categories depending on their size. A bus used for public transport is usually large enough to be classed as M3. Type-approval for an M3 vehicle means that, among other things, the bus must be marked in a certain way, there must be extensive documentation on the design of the vehicle and how it conforms to the approved type.[7]

All currently permitted vehicle types presuppose that the vehicle is driven manually, levels 0 to 2 on the SAE scale. The vehicle types therefore presuppose operation by a human driver who either has full continuous control over the basic safety-critical systems such as brakes and steering or that the driver continuously monitors the systems that are temporarily in control. The latter case concerns functionality such as adaptive cruise control or parking assistance. Autonomous vehicles, levels 3-5 on the SAE scale, allow the driver to relinquish control of the safety-critical systems under certain conditions (level 3) or allow the vehicle to assume full control in all traffic situations (level 5).

[7] Regulation No 107 of the United Nations Economic Commission for Europe (UN/ECE) Uniform rules for the type-approval of Category M2 or M3 vehicles as regards their general construction.

2.2.2 Swedish ordinance on autonomous vehicle trials

At present, no type-approvals for autonomous vehicles exist. However, there is a national regulation that stipulates how autonomous vehicles may be used on public roads in Sweden, namely Ordinance (2017:309) on autonomous vehicle trials. To have a trial approved by the Swedish Transport Agency, an application must be submitted for a trial with autonomous vehicles on public roads.

The application must include:

1. contact details of the applicant
2. the name, personal identity number or corporate identity number and address of the person or persons responsible for the trial
3. a description of how the trial will be managed and how responsibilities will be distributed within the operations
4. an overall description of the purpose and objectives of the trial
5. a description of the fully or semi-automated functions to be tested and evaluated in the trial
6. a description of how the trial will be carried out and evaluated
7. information about the geographical area and roads on which the trial is to be carried out
8. a risk assessment showing that the risks associated with the trial are managed to an acceptable level and that the trial will not cause any significant inconvenience in the surroundings
9. information about who owns the vehicles involved in the trial
10. a technical description of the vehicles involved in the trial
11. requirements for exemptions in accordance with Chapter 8, Section 18 in the Swedish Vehicle Ordinance (2009:211)
12. other information relevant to the trial

If the Swedish Transport Agency is not familiar with the vehicles to be used in the trials, it may be necessary to conduct tests prior to the vehicle leaving the factory (FAT, Factory Acceptance Tests) and/or on-site (SAT, Site Acceptance Test).

Type-approval presupposes that a bus has a steering wheel, but an autonomous bus does not necessarily have a steering wheel. In order to resolve the conflict that emerges from the separate requirements imposed by the Vehicles Act and the Vehicle Ordinance on how a vehicle must be designed in order to be considered safe to use, the Swedish Transport Agency grants exemptions from the rules in the Vehicle Ordinance on a section-by-section basis. However, the ordinance on autonomous vehicle trials only applies to autonomous vehicles to be operated on roads (Section 1). We will revisit this later in the report.

3 The autonomous bus depot

The distinction between vehicle and machine may seem theoretical, but it has arisen in practice in a specific case at Keolis' bus depot in Partille outside Gothenburg. There, the company is seeking to investigate the optimisation advantages afforded by automated operations based on autonomous buses. But are the autonomous buses vehicles or machines when they drive around the depot? We conclude the section by describing what we did to answer the question.

3.1 Keolis' bus depot in Partille

At Keolis' bus depot in Partille there are 116 buses, which makes it a medium-sized Swedish depot. All operations carried out in the bus depot are linked to public transport, i.e. no bus ordering services are provided. This means, for example, that the buses do not need to be equipped with a tachograph. In the region, Västtrafik procures public transport and the contracts run for 8-10 years. Västtrafik does not provide a depot as part of the procurement; rather, this is the responsibility of Keolis.[8] The bus depot has recently won a major tender and the business is secure for at least 10 years.

The bus depot is an R&D depot and was nominated Depot of the Year in 2019 regarding quality and product development. Västtrafik's regular customer surveys show that the bus depot is of a very high quality, partly because the buses are perceived as clean and the drivers are friendly.

The depot houses 350 bus drivers and 40 depot workers (20 mechanics and 20 service technicians), who work in three shifts. Operations essentially run around the clock, from 04:00 in the morning to 02:30 in the morning. Drivers are busiest in the mornings and evenings when people commute to and from work and school. Most of the depot workers start at 22:00 to prepare the buses for the next day.

3.2 Today's bus depot

In the morning, bus drivers arrive to begin their shift. They then have 8 minutes of "On time" during which they must register their driver's licence at a terminal to show that they are on-site, find their bus, perform a brief external inspection of the bus to ensure that nothing has happened to it during the night, check that the bus is sufficiently heated, boot up various systems (ticket system, the on-board computer that shows the next stop on the route, etc.), set their seat, hang up their jacket, etc. The drivers then take the bus on the roads.

In the evening, the buses will return to the depot. The bus drivers then have 3 minutes "Off time", i.e. they hand over the bus and log out of the systems.

At this point, the depot workers take responsibility for the bus. The first thing they do is perform a safety inspection of the bus. The safety inspection involves checking that all liquids are at the correct level, that there are no broken lamps, that the tyres are satisfactory, that the doors are working properly and whether there is any damage to the bodywork that needs to be repaired.

The safety inspection results in one of three decisions.

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[8] Different tenders are offered depending on whether or not a depot is included in the procurement.

1. The bus has damage that the workshop needs to repair during the evening/night. The bus is not approved for service and this is registered in the internal depot system.
2. The bus is dirty (for example, graffiti) and needs to be thoroughly cleaned during the night. The bus is not approved for service and this is registered in the internal depot system.
3. The bus does not require any further action, which means it is then certified and can be parked overnight.

In addition to safety inspection, every bus is cleaned inside. For example, the floors are mopped, and the seats are wiped down. The bus is also washed on the outside in a bus wash if necessary. At the depot in Partille, the safety inspection and cleaning are carried out in sequence: inspection and interior cleaning first followed by the exterior wash. The workshop manager decides in what order the vehicles should be seen to during the night and draws up a plan for this.

During the evening/night, the buses are transferred to the workshop. The mechanics have 6 minutes to get the bus to the workshop. These are the buses that did not pass the safety inspection and buses which have been scheduled for maintenance. When the work is complete, the mechanic certifies the bus and it can then be parked overnight. If necessary, the buses are scheduled for cleaning.

During the evening/night, the buses are collected for servicing/cleaning. The service technicians have 6 minutes to collect the bus. This is when, for example, graffiti needs to be washed off the bus, the seats need to be vacuumed or replaced, or advertisements need to be changed. When the work is complete, the service technician certifies the bus for road use and the bus can be parked overnight.

If the bus is parked outdoors at night, it is connected to a bus supply ramp.[9] The ramp enables electricity, heating, and compressed air, for example, to be connected to the bus. Work environment requirements state that when bus drivers starts their shift in the morning, the temperature at the driver's seat must be at least +5 °C for the work environment to be satisfactory.[10] At Keolis' bus depot in Partille, the buses are parked outdoors, but buses do park in halls indoors at other bus depots in Sweden.

At the depot are a number of systems/programs that keep track of different things. One system is used to schedule drivers and buses, another keeps track of scheduled servicing for the buses, and a third is used to report accidents or problems while the vehicle is in service.

3.3 Tomorrow's autonomous bus depot

Volvo Buses AB (hereinafter Volvo) is developing autonomous buses. Volvo's development of autonomous buses is not based on the principle of "everything everywhere at the same time" but rather on the gradual development of the technology, which is split up according to different needs linked to a particular environment. Later

[9] If there is no bus supply ramp or none is available, the bus must be started and warmed up, which means that empty buses are driven around on the road for about 20 minutes before being put into service.
[10] This follows from a government decision, 2003-09-05, N2003/7250/ARM.

down the line, the different parts can be connected into a whole. For example, trials are underway with automated bus stop approach/docking at for buses in road use. Furthermore, Volvo has also started to develop autonomous technology for buses at depots.

The premise of this project is that the bus is manually driven (SAE level 2) out on the road. In the depot, however, it is autonomous, corresponding to SAE level 4 (i.e. autonomous under certain conditions). It is also assumed that it is a fully electric bus, that is, it has no powertrains other than the electric one. The reason for the latter assumption is that this is the intention for operations in a depot.

In today's depot, when buses are not inside the depot building for work-related reasons, they are parked in designated areas outdoors. This means that personnel must go and collect/find and drop off the buses at different locations in the enclosed depot area. In a depot with autonomous buses, the vehicle drives itself to where it needs to be. The area of the depot in which the autonomous bus should be is determined by a control tower, which assigns a task to the buses and checks to ensure they are following instructions – the right bus should be in the right place at the right time. Since this is within the depot area, the vehicle does not travel at a higher speed than the pace of a pedestrian.

In the morning, the autonomous bus drives up to the bus driver, who then assumes control of the bus. The driver is still required to inspect the bus, boot up the systems, etc. but the time it takes to go and find the bus can be saved, an estimated 4 minutes. In the evening, when the bus returns to the depot, the bus driver hands over the bus to the control tower, which then decides what to do next (i.e. wait at the designated parking space or undergo the safety inspection).

During the safety inspection, the personnel will be in close contact with autonomous bus. This task cannot be automated. The same is true when it comes to servicing. However, all movements inside the depot area can be automated so that the bus drives itself between parking, pantograph (charging infrastructure), servicing and the workshop. The type of movement and when it will take place is managed by traffic control through the control tower.

Even in a bus depot with autonomous buses, snow clearing, road sanding, sweeping, etc. need to be carried out all year round. The same applies to the ability to handle an emergency. These are also issues that need to be considered in order to achieve the full potential of automation.

3.4 Potential benefits of an autonomous bus depot

We do not know what the future holds, so we can only speculate on what the benefits will be of having autonomous buses in a bus depot. In this context, one can speak about first- and second-order benefits. First-order benefits are those we can predict with our current knowledge about the technology. Second-order benefits are those we cannot presently predict since we do not yet fully understand how the technology can be utilised.

Automation is expected to reduce the risk of accidents. In this regard, it should be underscored that Keolis has not experienced a serious accident at the depot in Partille.

Today, the maximum speed limit at the depot for manual vehicles is 20 km/h. Autonomous buses can be restricted to driving at 5 km/h and, in theory, personnel would be able to walk away from an autonomous bus. A bus depot could also be designed so that people and autonomous vehicles in operation are not required to share the same space. But the safety benefits can be negated by new kinds of accidents. For example, the misuse or overestimation of the capabilities of the technology by personnel, or misjudgement or failure to heed safety precautions on the part of personnel when in a stressful situation.

There is also a risk of minor accidents at a depot, such as paintwork being scraped, or a side mirror being struck by a pole. Keolis estimates that the cost of vehicle damage should be reduced by SEK 500,000 annually if the human factor in terms of stress and negligence could be eliminated using an autonomous bus depot.

The use of autonomous buses presents new opportunities for the organisation of depots. Lessons can be learned from how warehouses manage logistics. If the control tower keeps track of the vehicles and their location, the operation can be optimised in a whole new way. Autonomous buses do not need to have predetermined locations for personnel to find them. Instead, they are issued with driving tasks by the computer and can essentially park wherever is most suitable in the depot at any given time. In addition, they can be parked closer together because the doors do not need to be opened. The autonomous buses will thus require less space in which to park. In Partille, the depot is rented on commercial terms, which means that if less space is needed for the depot, the costs could be reduced. Keolis estimates that the area could be reduced by 20-30%. This may also be positive for Partille Municipality since space can be made available and used for other businesses in a crowded town.

Having autonomous buses in the depot should also result in time savings. Instead of personnel having to collect the vehicle, the bus comes to them. Today, bus drivers have 8 minutes to collect their bus, but Keolis estimates that this could be reduced to 4 minutes. Servicing and workshop personnel currently have 6 minutes to collect the vehicle, and this could be reduced to 3 minutes. This should be considered in light of the fact that Keolis estimates there to be more than 100,000 individual vehicle movements per year at the depot.[11] The technology today is not yet mature enough for a bus to connect itself to the existing bus supply ramp for electricity, heating, ventilation, etc. As long as this remains a non-automated procedure, the degree of automation at the depot will be limited, and thus also the benefits. If something goes wrong, for example, if the bus does not come when commanded, personnel will have to traverse the platform to determine the fault, which can pose a risk to safety. Another risk associated with automation is that personnel get less exercise during the workday, which in the long run can lead to poorer employee health. The work environment and co-determination in the workplace are addressed in more detail in Appendix A below.

A fire in a bus depot can have very serious consequences for the community since it may mean that public transport cannot be provided, and there is a risk then that the public cannot to get to work, school, preschool, etc. It should be easier to fight a fire in a depot housing autonomous buses. In theory, autonomous buses (following a command from

[11] The time savings are even greater if autonomous vehicles are used in a mine. For example, it may take 40 minutes for an employee to collect a vehicle in a mine.

the control tower) could drive themselves away from the fire, form fire breaks, and evacuate the bus depot depending on what is deemed best in the circumstances. Emergency workers would not have to go near the buses either, which should mean a safer work environment for them, although a resulting challenge would be in finding safe parking spaces outside the depot (the autonomous buses in the depot are not approved for autonomous driving on roads). Fire and safety are addressed in more detail in Appendix B below.

What will ultimately determine whether any benefit can be achieved by having autonomous buses in a depot is the degree of reliability they will be able to offer in terms of on-time departures from the depot. If the current system of manually driven vehicles sees 99.5% of all buses departing the depot on time and in the right condition, the corresponding reliability of a system of autonomous buses cannot amount to 90%. Instead, autonomous buses must offer a degree of reliability exceeding 99.5%.

3.5 Legal challenges

It should be possible to factor in a proportion of the investments into autonomous buses by gaining automation benefits in the depot. But if you proceed from a single experiment with one bus on one occasion to daily operation, you need to understand which laws apply and which authorities to cooperate with. For example, it has been discussed that it would be easier to start the market introduction of autonomous vehicles in enclosed areas than on the roads, since there are fewer rules that the vehicle needs to take into account and the environment is less complex.

Autonomous buses in a depot are a new phenomenon primarily challenging the law in two fields. Firstly, there is a challenge in terms of regulations related to the environment in which the vehicle is used. The second challenge involves the hierarchical order of the regulations.

Traffic legislation in Sweden distinguishes between road/off-road and enclosed/non-enclosed areas (roads). In the case of the depot, off-road regulations are not applicable, so we shall focus on the difference between roads and enclosed areas. Within an enclosed area, many traffic rules do not apply that would otherwise apply out on the road. This approach also impacts the assessment concerning who shall determine whether a vehicle is safe to use. For vehicles to be used on the road, it is the Swedish Transport Agency, as a type-approval authority, that decides whether a vehicle is safe to use. This also applies to autonomous driving since the Swedish Transport Agency can, for example, grant permission for trial operations in accordance with Ordinance (2017:309) on autonomous vehicle trials. In the case of enclosed areas, there is no authority that grants approval for the use of a vehicle/machine, rather, it is the manufacturer/employer who determines whether the vehicle/machine meets the safety requirements and ensures this. This can be accomplished by means of CE marking in accordance with regulations in the Machinery Directive. The employer also has an obligation to ensure that the work environment is safe for employees, which is overseen by the Swedish Work Environment Authority. Within enclosed areas there is therefore no authority that grants permission for the use of an autonomous vehicle, but the onus is on the manufacturer/employer to decide whether the autonomous vehicle is safe to use. However, in the event of a workplace accident, the Swedish Work Environment Authority will investigate the incident.

In this case, the bus is manually driven out on the road and operates autonomously within the enclosed area. The bus thus corresponds to SAE level 2 on public roads and SAE level 4 within the enclosed area. Since it operates both on public roads and in an enclosed area, it alternates between two different regulations (see Table 1 below).

Occasionally, different regulations come into conflict with one another. There are therefore guidelines for determining which regulation takes precedence over another. For example, constitutions take precedence over laws, laws take precedence over ordinances, and ordinances take precedence over regulations. From a vehicle safety perspective, type-approval for road use has meant that the vehicle has thus also been considered safe to use in enclosed areas, i.e. when it comes to safety, the regulations for non-enclosed areas (roads) take precedence over regulations for enclosed areas. Furthermore, type-approved vehicles are explicitly exempted from the Machinery Directive.

	Road	Enclosed area
Manually driven	X	
Autonomous		X

Table 1: The regulations our bus alternates between over a single day.

Until now, bus manufacturers and bus operators have not had to think about the regulations for enclosed/non-enclosed areas from the perspective of safety. A bus is manually driven and type-approved for road use, which means that it has also been considered safe for use within an enclosed area. A bus manufacturer has therefore been able to focus solely on the regulations for non-enclosed areas. In this case, the regulations pertaining to type-approval. Since the bus is considered safe to use on the road, it is also safe to use within an enclosed area. Furthermore, bus operators have focused on creating a safe work environment given that the vehicles are safe according to their type-approval and thus are safe to use.

However, in the case of autonomous buses in a bus depot, the situation is different. The bus is still type approved for road traffic with a driver, but it is not type-approved for autonomous operation on the road (SAE level 4 or 5). This means that, during the span of a single day, the bus will alternate between the regulations for enclosed and non-enclosed areas. The bus, which was previously a legal “static whole”, will now instead be tested based on two regulations depending on the environment it is in at any given time and the level of autonomy. This is a completely new situation: that a bus is “dynamically divisible” from a regulatory perspective, which has significance in terms of who shall decide whether the vehicle is safe to use in a certain environment.

3.6 Method

Investigations into which regulations apply to a bus that can be considered autonomous under certain conditions (SAE level 4) but is always driven by a person on public roads (SAE level 2) were conducted in the project Drive Sweden Policy Lab (DSPL). Within

DSPL, two other paths of inquiry relating to data sharing were investigated, and the activities and conclusions resulting from this are communicated in separate reports. The project is described in more detail in Appendix C below.

In November 2019, Volvo held a demonstration of an autonomous bus in the bus depot.[12] Our work on the autonomous bus in the depot got properly underway with a two-day meeting in Gothenburg in November 2019. Keolis served as host on the first day, which gave us an opportunity to walk around the depot and familiarise ourselves with the different environments there. The meeting described the structure and intended benefits as well as how day-to-day operations could be optimised (refer to Sections 3.2-3.3). Besides for Keolis, representatives from Volvo, Combitech, Einride, the Swedish Work Environment Authority, Easymile, Chalmers University of Technology, the Swedish Association of Road Transport Companies, Boliden, AstaZero and RISE participated. It is worth noting that, although they attended the meeting, they were not necessarily there to represent their respective businesses, but to give their views on what was discussed and to listen to what others said.

The first meeting was followed by a series of diversely themed meetings during which RISE, Keolis, Volvo and Combitech more thoroughly analysed the technical aspects of an autonomous bus in a depot. In parallel, RISE and Combitech carried out further analyses to clarify which regulation took precedence and how it could be applied according to the technology and environment in which it would be used. We also spent time comparing different regulations and how they are applied in practice to gain a better idea of what self-certification means for the automotive and transport industries. These meetings were complemented by interviews with the Swedish Transport Agency and the Swedish Work Environment Authority.

The conclusions drawn from the series of meetings were then presented to the large group at a meeting in June 2020. Based on the discussion that took place, RISE formulated its conclusions and presented them partly as shorter feedback on the meeting via email, and partly through events for the project participants at two major meetings in September and December 2020.

The conclusions are the authors' own. What the conclusions would have been without the efforts of the other parties is difficult to determine since their expertise and insights played a vital role in advancing the work. At the same time, we wish to underscore that the conclusions of this report are our own and do not necessarily represent their analysis of the challenge or visions of the future.

4 Our conclusion: Autonomous buses shall be CE-marked

Our conclusion is that autonomous buses shall be CE marked in the depot. We also believe that it is most appropriate to CE mark autonomous buses on the basis that an autonomous bus is a machine in a group of machines. Furthermore, we believe that it is the bus operator who should carry out the CE marking because they are responsible for

[12] https://www.youtube.com/watch?v=gWr2wBNuf9g&t=13s

the work environment in the depot and they serve as the manufacturer of the compound machine. Such work would require the operator to have access to the technical documents requested in the certification process and the specifications according to which it was built (see Section 2.1.2). The same applies with respect to the control tower and the pantograph. Another way of looking at this is that parts of the depot should be CE marked pursuant to the Machinery Directive. A semi-automated depot is analogous to a machine. The relevant parts of the depot comprise a number of machines acting as a single unit with a common purpose (cf. a production line in a factory).

The vehicle manufacturer can therefore choose whether they wish to CE mark the autonomous bus. CE marking the bus as an individual machine can then be given lower priority since it is, in part, a type-approved vehicle. The work will then be to show how the type-approved vehicle – together with the new control system and associated components – constitutes a reasonably safe machine. We recognise that this can be a challenge for vehicle manufacturers as they will need both a type-approval process and a CE marking process for the same product, depending on whether the product is a vehicle or a machine at any given time. A question that needs to be answered involves which risk is managed during which process, because the same risk cannot be managed by two regulations simultaneously.

If the bus is already CE marked, the operator's work will be limited to showing how the certified machines in unison form a reasonably safe whole. The greater the number of certified machines, the easier the work will be. Who is required to CE mark what is also a matter of significance in the event there are autonomous buses from different manufacturers in the depot (coexistence).

Certification may be reviewed through market surveillance by the Swedish Work Environment Authority. This is not a requirement, but something decided by the Swedish Work Environment Authority. However, if an incident involving the autonomous bus occurs in the depot which impacts the work environment or product safety, market surveillance may become necessary. If the Swedish Work Environment Authority then finds that the certification does not conform to the evidence, it can result in both compensation pay-outs to the injured parties and the recall of the technology concerned.

The first time the bus is used on public roads following the installation of the autonomous system (but disabled when switching to manual operation), the Swedish Transport Agency will most likely want to carry out an inspection on the road use. The inspection is justified by the fact that the Swedish Transport Agency intends to ensure that, even if disabled, the autonomous system cannot affect the safety-critical systems on the bus. This kind of inspection of the bus would be carried out before the bus is approved for use on public roads, as opposed to the market surveillance of certification, which may be carried out after the technology has been put into service. Another question that needs to be answered is whether the type-approved bus with autonomous technology still meets the requirements for the initial type-approval or if the modifications have altered the bus to such an extent that it no longer conforms to the approved type.

5 Two trends in the future

In the preceding sections, we have focused on the trend that we are moving from regulations characterised by technology-specific solutions to regulations based on functional requirements. It is now time to revisit our second trend – electrification – and how it relates to the first trend by enabling new vehicle concepts in practice. But first, we will put what is happening in Partille in an international context.

5.1 Self-certification of vehicles from an international perspective

The EU single market is based on the free movement of services, people, capital, and goods. Achieving this requires harmonisation. The principle in the case of goods is that a product legally manufactured and marketed in a Member State in accordance with its fair and traditional rules, and with the manufacturing processes of that country, must be allowed onto the market of any other Member State. A principle of mutual recognition is, however, inadequate. The EU has therefore introduced regulatory frameworks for various goods in many areas where common safety and security levels are regulated. Since the rules are common, they are usually referred to as harmonised rules.

The EU has also resolved that essential safety requirements to be met by products are laid down in legal acts, while the technical details are stipulated in European standards referred to in EU legislation. These standards, so-called harmonised standards, are generally voluntary for manufacturers to follow. However, the standards become significant pursuant to the legal act because a product complying with such a harmonised standard is presumed to meet the mandatory safety requirements (until proven otherwise). The manufacturer may therefore choose not to comply with a specific standard but must be able to demonstrate in another way how the mandatory requirements of the legal act have been met, which entails an open system for technical testing and verification. The fact is that the standards themselves may differ depending on the product to which they are intended to apply.

Nowadays, the general rule is that the onus is on the manufacturer to certify that the product meets the requirements of the relevant legal acts, referred to as the Manufacturer's Declaration. There are exceptions, however. In some cases, it is presumed that the manufacturer entrusts an independent body (notified body) to adjudge whether the product meets the essential requirements prior to market introduction. Notified bodies are agencies which a Member State has deemed competent to carry out testing, inspection, or certification under a specific product act. Once the prescribed inspection has been carried out and the manufacturer has certified that the requirements have been met, the product is CE marked, if provided for, after which it may be introduced on the market. The role of authorities has been limited by this system to one of responsibility for legislation and to conducting market surveillance by means of market inspections to ensure compliance with regulations.

The Commission carried out a multi-year review of the new method with a view to utilising the experience gained from its application and improving and clarifying the regulatory framework. The review concerned, in particular, the regulations for technical testing and control, market surveillance and actionable measures relating to goods which do not comply with harmonised rules. In the non-harmonised area (i.e. the area for which the EU has not yet adopted common rules), the review covered procedures to be observed in the case of actionable measures relating to goods legally introduced on the market in another Member State.

Self-certification of vehicles is not a new phenomenon. Instead of UNECE approvals, the United States and Canada use the principle of self-certification in vehicle manufacturing.[13] Thus, approval by a government agency or authorised testing body is not required before the vehicle may be sold or otherwise introduced on the market. Since North America is not part of the EU, certification is not carried out pursuant to the Machinery Directive or any other EU directives, but according to federal regulations or even regulations at the state level.

The National Highway Traffic Safety Administration (NHTSA) in the United States is the federal agency responsible for road safety. Part of the NHTSA's work is to develop functional requirements that reduce the risk or impact of accidents. [14] Manufacturers need to self-certify that they satisfy the requirements, but they are free to choose the methods and tools used in the process. The NHTSA can then review compliance through its own testing methods. If the self-certification is shown to be erroneous, it may lead to compensation pay-outs and the recall of the vehicles concerned.

The trend relating to self-certification in North America recently led to a new move by the industry when some twenty vehicle manufacturers and suppliers presented a new roadmap for policy issues in the United States[15]. The objective is to encourage authorities to accelerate the establishment of policies that allow for large-scale testing and the introduction of autonomous vehicles. The roadmap spans 4 years and the following are included among the 14 recommendations:

1. Create a new vehicle class. This would allow a state to more effectively reform existing safety regulations pertaining to autonomous vehicles without impacting regulations for conventional vehicles operated by human drivers.
2. Embrace innovative regulatory approaches. To start with, the reform of existing regulations should be able to keep up with the current pace of technological advancement. Furthermore, the US Department of Transportation should allow vehicle manufacturers to provide technical documentation as evidence of the safety of their new vehicles. This will encourage the development of unique vehicles as well as the use of new safety assurance techniques, such as virtual testing with validated simulators.
3. Promote industry standards. Industry standards promote road safety and authorities should support the development of these standards and benefit from them.

[13] https://www.hsdl.org/?view&did=751039 Published 18 February 2014
[14] https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/ads_safety_principles_anprm_website_version.pdf Published 19 November 2020
[15] https://www.autosinnovate.org/posts/press-release/av-roadmap-invitation Published 18 November 2020

4. Build knowledge for safety assurance. Authorities should encourage the development of a safety assurance framework and monitor these developments in order to stay abreast of the latest advancements.

The industry's move was followed by a new announcement by the NHTSA in December 2020.[16] The NHTSA then concluded that self-certification is acceptable as a process for autonomous vehicles. To sum up, self-certification is the established process for the market introduction of reasonably safe, manually driven vehicles and will serve an equivalent function for autonomous vehicles in the North American market.

5.2 Is tomorrow's mobility self-certified?

To answer the question in this heading, we can start by comparing the CE marking process with the information the Swedish Transport Agency wants to see in applications for autonomous vehicles trials (Table 2).

CE marking (according to e.g. the Machinery Directive):	**Swedish Transport Agency list for applications for autonomous vehicle trials**
Presentation of the product including components Identify relevant directives and standards Present purchased parts	Technical description of the vehicles involved in the trial
Specify safety-critical components	Description of the fully or semi-automated functions to be tested and evaluated in the trial
Risk analysis	Risk assessment showing that risks associated with the trial are managed to an acceptable level
Testing and verification of conformity	Description of how the trial will be carried out and evaluated
Installation, user, and maintenance manuals	(The Swedish Transport Agency requires a report subsequent to the trial which describes how the trial went and what was learned)
The manufacturer guarantees safety	Details of the person responsible for the trial and how responsibility is distributed during the trial

Table 2: The CE marking process in relation to the information to be provided in applications for autonomous vehicle trials.

Because CE marking is geared towards marketable products, the requirements for documentation differ to those stipulated by the Swedish Transport Agency. Autonomous vehicle trials are often conducted in close cooperation between the parties that will use the technology. This means that there are different needs about manuals for the customer, and that the products may be in different phases of testing. The way information is shared between the parties and how it affects responsibility is therefore more flexible in the context of a trial. Moreover, the information is provided on a trial-by-trial basis, while mass-produced market products must have manuals.

[16] https://public-inspection.federalregister.gov/2020-28107.pdf published 21 December 2020

Despite the differences, there are also many similarities. The focus is on the interplay between people, technology, and the environment, as well as on how this combination can create or be exposed to risks and how those risks can be reasonably managed. There is also focus on the introducer of the technology. The Swedish Transport Agency adds on its website: "*In order to facilitate the application process, the Swedish Transport Agency has produced a number of supporting documents that can be used, but the applicant is completely free to rely on the documents and the information that is relevant for the handling of the case.*"[17]

With regard to the suitability of the Machinery Directive as a basis for the self-certification of autonomous vehicles, we believe that the Machinery Directive will need to be either updated or amended.[18] At present, UNECE vehicle categories are explicitly exempted from the Machinery Directive. Therefore, no information is provided on how to relate to the safety-critical functions of a manually driven vehicle. At the same time, there are vehicles that are CE marked today based on the Machinery Directive (heavy-duty vehicles), so the regulation can nonetheless be applied to vehicles. Other machines with safety-critical systems (such as saws) have their own appendix in which their specific requirements are addressed. There are also general appendices that would need to be reviewed, e.g. *"Additional basic health and safety requirements to prevent the specific hazards arising from the mobility of machinery"*. It is not unreasonable to assume that if self-certification based on the Machinery Directive and other directives becomes the model for autonomous vehicles, the relevant directives will then also be updated to cover those aspects.

Self-certification may also come about through the ongoing work within the UNECE forum WP.29. One of the forums tasks concerns vehicle regulations and, in the field of autonomous vehicles, functional requirements are a clear priority[19]. Work is also underway at EU level aimed at the type-approval of autonomous vehicles in the future (see e.g. EU regulations (EU) 2019/2144 and (EU) 2018/858). Self-certification will then be carried out according to the principle that it is incumbent on each technology developer to show how their particular system meets requirements (compare the steps *"Identify relevant directives and standards"* and *"Testing and verification of conformity"* in CE marking). Whether reviews by authorities will be carried out by means of approval prior to market introduction or through market surveillance and inspection remains to be seen.

With regard to self-certification, it is also interesting to speculate on how we know that tomorrow's vehicles will be reasonably safe. We mentioned at the start that we are seeing a trend where a vehicle is no longer a static and indivisible unit and that there is increasing expectation that vehicles will comprise several interchangeable physical components and also be configurable through software updates across the existing vehicle categories. However, this is challenging in relation to current regulations and standards since every vehicle has a unique Vehicle Identification Number (VIN). If, by

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[17] https://www.transportstyrelsen.se/en/road/Vehicles/self-driving-vehicles/ last updated 5 June 2018

[18] The Machinery Directive covers self-driving machines but may still need to be adapted if the distinction between a vehicle and a machine disappears. Doing so will ensure that the rules contained in the vehicle regulations will be included in the Machinery Directive going forward

[19] https://www.unece.org/fileadmin/DAM/trans/doc/2020/wp29grva/FDAV_Brochure.pdf published February 2020

changing the bodywork, a vehicle can alternate between being a truck and a bus (see Figure 3 below), the VIN will no longer be locked to a specific type but change type every time the bodywork is changed. Today, each change would require a re-registration by an inspection company (Swedish Vehicle Ordinance (2009:211)), which makes the idea impracticable.

The same reasoning in terms of changing the vehicle from a passenger car to a quadricycle applies to digital performance, thus limiting the top speed making it possible to drive the quadricycle with a moped driving licence from the age of 15. However, this also requires the vehicle to be re-registered by an inspection company.

If we instead start from self-certification, the onus would be on the party introducing the technology to ensure its safety. This would allow for dynamic vehicles without specifying the technical prerequisites for moving from one type to another.

Figure 3: Scania's NXT concept. It is possible to change the bodywork to obtain a new vehicle type (e.g. from a small truck to bus), but also to change an axle. Since the axle supports the engine, the performance of the vehicle can also be altered in this way. This raises the question: what exactly constitutes the vehicle? And what kind of vehicle is it?

5.3 Validity of the results

In Sweden there is a tradition of collaboration between industry, authorities, and academia, which provides a good basis for policy work because co-creation from several perspectives is a central part of the process. Investigating specific cases in research form and on that basis determining what is possible and desirable enriches policy work with data and grounds it in real-world activities, instead of general wishes or vague hopes. This allows work to be carried out similarly to the work within test beds and sandboxes, but without being limited by the time constraints inherent in research – insights and lessons learned are utilised by the respective party and can be further pursued both internally and through new collaborations.

At the same time, it is important to remember that the parties involved may have differing opinions or may not have settled on a position. This is particularly true of authorities whose role is to conduct reviews with respect to the other operators. They are and should be careful about promising a certain action in advance or providing answers that can be interpreted as advance confirmation in a specific case. The involvement of each authority may therefore also take different forms and vary according to the issue at hand and the specific conditions under which it is investigated. For this reason, it should not be assumed that this report reflects the opinion or analysis of the parties involved. To find out what each party thinks and believes, we recommend approaching them directly.

A weakness in the policy model concerns which parties are involved in the different projects. This affects the representativeness of the proposals put forth and one must be wary of presuming that one fully understands the whole picture or that other parties share the views of the project team. Proposals should therefore rather be a starting point for more detailed investigations or more comprehensive activities.

6 Conclusion

It has been said that it would be easier to begin using autonomous vehicles in enclosed areas than on the roads, since the environment is less complex and there are fewer traffic rules. Our report has shown that it may not be quite so simple, since autonomous buses in a depot engender new challenges that need to be addressed. For example, an autonomous bus needs to be CE marked because it does not fall under any of the exemptions in the Machinery Directive, and who is going to do that work? At the same time, it is also clear that an autonomous bus in a depot is part of a system of systems. Autonomous vehicles are not their own universe, but rather part of a planetary system. It is likely that future autonomous vehicles operating on the road will need to be incorporated into some sort of system. How and whether such a system could be CE marked is a question for later.

Another outcome of the project is that two administrators at different authorities have been given the opportunity to assess new technology and its use before it is used in day-to-day operations. In this way, they have been able to evaluate their own role and assignment in relation to the regulations they are enforce. In the specific case of a bus that is only autonomous in the enclosed area, the administrators with whom we have had contact at both the Swedish Transport Agency and the Swedish Work Environment Authority agree that the Swedish Work Environment Authority should serve as the supervisory authority. This analysis may be amended if the conditions for the conclusion are amended, for example, by updating or supplementing the Ordinance on autonomous vehicle trials so that there is also a regulation pertaining to enclosed areas. However, as things stand, the aforementioned authorities are prepared to apply existing regulations on the day the new technology reaches the market.

How a bus can actually be CE marked was not an issue addressed in the DSPL project. There are therefore a number of aspects to pursue further, such as which standards are relevant to employ and which standards should be further developed as a priority in order to facilitate CE marking to a greater extent, what documentation is needed and, not least of all, the relationship with the type-approval process. If it were possible to use artefacts developed for type-approval, a lot of time and effort could have been spared. Once work on CE marking begins, more details will become apparent, which will need to be analysed and addressed, so the list is far from complete. Identifying details and a concrete approach to the challenges by implementing CE marking for an autonomous bus are therefore on our to-do list.

Appendix A: The work environment and co-determination

Keolis, as an employer, has a responsibility for how the work environment in the bus depot is structured in relation to the employees. The purpose of the Swedish Work Environment Act (1977:1160) is to prevent occupational illness and accidents and to otherwise ensure a good work environment (Chapter 1, Section 1).

Chapter 2 stipulates the general requirements for how a work environment shall be structured. The provisions are general because the Swedish Work Environment Act constitutes a framework law in which other provisions in supplementary regulations can be enacted, e.g. the Swedish Work Environment Authority's regulations. It also has to do with the fact that the Swedish Work Environment Act must be practicable in many different workplaces. As per Section 1: Technologies, the organisation of work and the content of work must be designed in such a way that the employee is not subjected to physical strain or mental stress that may lead to illness or accidents. The work environment must also consider the technological developments in society. As per Section 2: Work must be planned and organised in such a way that it can be performed in a healthy and safe environment. Furthermore, Section 3 states that the premises in which work is performed must be designed and equipped so as to be suitable from a work environment perspective while Section 5 states that machinery, tools and other technical equipment must be constructed, positioned and used so as to provide adequate safeguards against illness and accidents.

Chapter 3 outlines the general obligations for the work environment, who is responsible for it and how far their obligations extends. The starting point is that employers and employees must cooperate to create a good work environment (Section 1a). However, the main responsibility for the work environment lies with the employer. The employer must take all necessary measures to prevent the employee from being exposed to illness or accidents (Section 2). Anything that can lead to illness or an accident must be changed or replaced to eliminate the risk of illness or an accident. If it is not possible to eliminate the risk, the employer must instead take measures to mitigate it.

The requirements on the employer are therefore very high, but the provisions of Chapter 3 shall apply in conjunction with, inter alia, the provision of Chapter 2, Section 1 on technological development (Chapter 3, Section 1). There is therefore a need for a *balance of interests* to be applied. This means that an overall assessment needs to be made on a case-by-case basis with respect to which of the requirements generally seem *reasonable* for the work in question. Efforts to improve the work environment must not be unreasonable in relation to the results achieved, e.g. based on a cost aspect (Prop. 1976/77:149 s 253f and Prop. 1993/94:186 s 23 ff.). The employer is obligated to inform the employee of the risks and how they can be avoided.

The employer always has ultimate responsibility for the work environment, but others may also have obligations. For example, the Act also imposes requirements on manufacturers or suppliers of machinery. As per Chapter 3, Section 8: Any person who manufactures, imports, transfers, or supplies a machine, tool, safety equipment or other technical equipment must ensure that the equipment offers adequate safeguards against illness and accidents. The fact that responsibility is shared does not lessen the employer's responsibility. The employer must ensure that machinery is maintained, and the employee handles the machinery in a safe manner (refer also to the section on market surveillance).

The Swedish Work Environment Authority is not responsible for the work environment, but monitors the work environment and checks, by means of inspections, to ensure that the employer complies with the legislation. As per Chapter 3, Section 2a: The employer must systematically plan, direct and monitor activities. This means that all employers shall engage in systematic work environment management pursuant to AFS 2001:1.[20] Systematic work environment management is based on the employer first carrying out a survey of the workplace, followed by a risk assessment. Thereafter, measures shall be taken to reduce risks. Lastly, a follow-up is to be carried out. Did it turn out as intended? Have risks been minimised or have new risks emerged? This work then results in a work environment/health and safety policy, e.g. road safety policy. Voluntary management systems are available like AFS 2001:1, such as standard ISO 45001, in accordance with which companies opt to be certified. Being certified as a company may be an important requirement during procurement, for example.

Work environment offences are governed by Chapter 3, Section 10 of the Swedish Criminal Code. Reports of offences are normally made to the police in connection with a workplace accident. Investigations are then conducted to determine the person(s) with safety responsibility at the workplace. The onus is on the prosecutor to prove which failures in the work environment management caused the accident. To secure a conviction, evidence must show, among other things, that the accident, with a high degree of probability, would not have occurred if the person(s) with safety responsibility had fulfilled their obligations in accordance with the law. Work environment offences may also incur financial penalties for the company.

Keolis works actively with occupational safety and health in the work environment by means of, for example, work environment inspections and safety inspections. Risk analyses are conducted regularly, such as when a timetable is changed, or new products/goods are purchased.

In our opinion, an operator and a bus manufacturer first need to reach consensus on who shall CE mark what in an autonomous bus depot (refer to our reasoning above with respect to CE marking). Once this is finalised, the bus operator needs to engage in systematic work environment management and establish a work environment policy as described above. During the project, different views have been expressed as to whether an autonomous bus depot will initially consist solely of autonomous buses or whether, during a transitional period, autonomous and SAE level 2 buses will occupy the same depot. We recognise that this is as an example of something that will have an impact on work environment management. For example, a situation may arise where a driver of a manual bus pushes past an autonomous bus (autonomous buses shall stop when obstructed).

[20] Supported by EC Directive (89/391/EEC).

Swedish Employment Act (1976:580) on Co-Determination in the Workplace contains rules on when an employer is required to negotiate with employee representatives along with provisions on collective agreements. If the employer is bound by collective agreements or the employees are unionised, the employer must negotiate with the union before deciding on important changes to the business, such as the introduction of new technology in a bus depot. The bus drivers in this case are unionised in the Swedish Municipal Workers' Union (Kommunal). In our opinion, the transition to an autonomous bus depot constitutes such an important change that needs to be negotiated with the union.

Appendix B: Societal security

Moving from manually driven buses in a bus depot to autonomous buses will pose completely new safety risks to society. For example, if an automated bus depot were to be rendered inoperable by a cyberattack, there is a risk of interruption to the vehicle supply for public transport. Society would be especially vulnerable if several bus depots across the country have the same flaw in their IT system and become inoperable at the same time.

The Swedish government established a national cybersecurity strategy in 2017. Among other things, it states that technological dependencies can be a risk factor in maintaining the security of society and that the risk of disruption to essential services thus increases. This involves, for instance, cyber threats/IT attacks by foreign powers, terrorists, and organised criminal networks. The safety and security of people in Sweden are contingent on, among other things, safe and reliable transport, which is an important function and necessary for society to function. The development has also meant that functions previously overseen by the State or municipalities are now administered by private operators, e.g. an outcome following a procurement. This means that private operators must also contribute to societal security and emergency preparedness by possessing IT systems with high operational reliability and high-level protection against increasingly sophisticated external attacks. There needs to be a resilience in society, i.e. society's ability to prevent, resist, manage and recover.

The NIS Directive is in force at EU level.[21] NIS stands for Network and Information Security. The EU directive is enacted in Swedish law through Swedish Act (2018:1174) on information security for essential services and digital services. The directive aims to strengthen security and enhance the security of supply in key sectors of society, including transport. Any party identifying as a provider of an essential service within the framework of the NIS Directive shall notify the relevant supervisory authority. For the transport sector, the Swedish Transport Agency serves as the supervisory authority. The law requires companies to work systematically and risk-based with information security and report incidents. The Swedish Civil Contingencies Agency has identified several providers of essential services in the transport sector. Chapter 4, Section 4 of MSBFS 2018:7 states that intelligent transport systems, such as eCall, fit this description. Autonomous bus depots are not on the list, but it is possible that, at some point in the future, the list will be amended to include them.

The NIS Directive is formed around the concept of essential services. In a broader context is the concept of "vital social functions", for which a national strategy was formulated in 2011 by the Swedish Civil Contingencies Agency.[22] In 2013, the Agency also developed an *Action Plan for the Protection of Vital Societal Functions & Critical Infrastructure*. The aim of the action plan is to concretise the strategy and achieve systematic security work for vital societal functions. The action plan is geared towards all those who own or

[21] Directive (EU) 2016/1148 of the European Parliament and of the Council of 6 July 2016 concerning measures for a high common level of security of network and information systems across the Union.

[22] MSB 2011 A Safer Society in a Changing World: national strategy for the protection of vital societal functions.

operate vital societal functions. The action plan identifies public transport as an example of a vital societal function in the transport sector. The strategy addresses three key principles for the work:

System perspective: The functionality of vital societal functions at local, regional, and national level must be guaranteed. This means that both public and private sector entities must be involved in the work and not only ensure their own activities, but also view them in relation to those of other entities, with whom they must engage in dialogue. A disruption can quickly propagate through the system because multiple entities are dependent on one another.

Measures before, during and after a disruption: In a crisis or emergency, the entire course of events should be considered. Achieving this objective requires systematic safety work.

Cover all threat and risk types: Risks are difficult to predict. It is therefore crucial that work on societal functionality is based on a wide threat and risk profile.

There are three elements to systematic safety work. These are:

Risk management: Risk assessment and vulnerability analysis constitute the basis for systematic safety work. This entails identifying, processing, evaluating, managing, and controlling risks, e.g. according to Standard ISO 31000.

Continuity management: This entails planning to be able to maintain vital societal functions regardless of the type of event, i.e. establish a contingency plan for operations to safeguard functionality despite the event, e.g. according to Standard ISO 22301. How will the operations function if the premises are destroyed, the staff cannot attend work due to illness, the electricity supply is disrupted and the buses cannot be charged, etc.? It requires compartmentalisation of operations, prioritising and then planning to ensure that operations can be maintained.

Managing various events: This necessitates capabilities to manage everything from minor incidents to serious crises.

The above points are not stipulated in any regulatory framework, but the intention instead is for them to become binding by, for example, being included in public procurement. In this way, emergency preparedness can be considered and become part of the procurement process.

Appendix C: Fire

A fire in a bus depot can have very serious consequences for the community since it may mean that public transport cannot be provided, and there is a risk then that the public cannot to get to work, school, preschool, etc. Keolis' bus depot in Hornsberg (Stockholm) was completely destroyed in a fire in 2018, but the buses survived because the fire started during the day (the buses had already left the depot when the fire broke out).

The destruction of a bus depot results in logistical problems. The buses need new parking spaces, bus drivers must make their way to the new areas in which the buses are parked, the buses must be warmed up by being driven instead of by means of a bus supply ramp, etc. If a fire occurs in a bus depot at night, there is a risk of many vehicles being destroyed at the same time, which in turn risks major disruption to public transport.

Autonomous electric buses in a depot will present new challenges and opportunities in terms of fire safety. The risk of a fire spreading will be greater since autonomous buses will park much closer together, which will also make firefighting efforts more difficult. At the same time, autonomous buses (following a command from the control tower) could in theory drive themselves away from the fire, form fire breaks, and evacuate the bus depot. Emergency workers would not have to go near the buses either, which should mean a safer work environment for them, especially when it concerns battery fires.

The likelihood of a fire breaking out in a bus depot is low but, if a fire does occur, it has major consequences. A bus operator therefore needs to work to ensure that the probability a fire breaking out remains low but must also take measures to mitigate the consequences of an accident occurring. As per Chapter 2, Section 2 of Act (2003:778) on Protection Against Accidents, it is the property owner or the holder of usufruct rights pertaining to the building who is, among other things, responsible for, to a reasonable extent, implementing requisite measures to prevent fire or limit damage and injury caused by fire. Here, "to a reasonable extent" means that the individual should not have to implement more extensive measures than what is justified according to risk and that the cost of any measure should be proportionate to the expected benefit. At the same time, what is considered to be reasonable may vary according to the area of use. The measures to be implemented pertain to both the technical (equipment) and organisational (training and information) (Prop. 2002/03:119 s 50ff).

The Swedish Civil Contingencies Agency divides an incident into five stages.

Prevent incidents: The first stage assumes that good preventive planning reduces the likelihood of an incident. In our case, this entails formulating a basis for safety design with respect to a future autonomous bus depot. It may also involve changing human behaviour in a future bus depot.

Implement damage-limitation measures: The second stage focuses on reducing the consequences of incidents by limiting damage and curtailing the course of an incident. This could involve designing the system to enable autonomous buses to evacuate themselves and ensuring that there is sufficient free space for this, etc.

Prepare emergency response efforts: Early intervention has a major impact on the course of an incident, since it lessens the severity of consequences. The individual is also responsible for saving their property and their life, and for initiating firefighting efforts using their own resources. Only when the individual is unable to cope with the situation does it become society's duty to intervene. This involves making best use of the time before emergency services reach the area.

Complete emergency response efforts: Emergency response efforts are completed in the fourth stage. In this stage, the emergency services carry out risk assessments, block off the area, etc.

Remedial actions: The last stage involves, for example, cleaning the area as well as evaluating and learning from the incident and how the incident unfolded.

During the project, we interviewed a team leader from the emergency services in Gothenburg in order to gain a better understanding of the challenges presented by an autonomous bus depot in terms of firefighting. A summary of the interview follows.

It is reasonable to start from the requirement that autonomous vehicles should be able to evacuate themselves in the future. An autonomous electric bus will have a higher value than today's buses, while it also a vehicle to be used in public transport (vital societal function). It is therefore important to incorporate fire safety at an early stage in the development of the technology.

A fire in a bus depot can take various forms, such as a bus catching fire while charging to 10 vehicles being set on fire at the same time (sabotage). It is therefore unlikely that AI in a control tower would be able to decide on how to handle the incident by starting an automatic alarm. A human must always be present able to take decisions on emergency response efforts, in other words, there will not be an automatic alarm that activates all the buses simultaneously for evacuation. Another significant aspect will be whether an autonomous bus depot is planned entirely from scratch based on fire safety or if, during a transitional period, there will be different levels of vehicles in an old depot (coexistence).

A fire in a bus does not require equally extensive action. A rule of thumb when it comes to a burning vehicle is that the damage will extend to at least four adjacent vehicles, i.e. four vehicles on each side. It is therefore prudent to first move these vehicles away from the burning bus to a new area approximately 100 metres away. Since this does not involve an excessive number of vehicles, it should be possible to move these to a different area in the depot.

In the event of sabotage involving multiple vehicles burning at the same time, a comprehensive emergency response will be required. The vehicles will probably have to be evacuated to a site outside the depot. This can be accomplished by having the emergency services, in concert with the police, demarcate a road outside the depot where the vehicles can be parked (in this regard, the fact that the autonomous vehicles are not approved for road use is of little consequence). In order to carry out such an evacuation, some preparatory work is required based on the technology of the buses, e.g. it may be necessary to film the route that the vehicles must follow during an evacuation. A number of alternative routes must also exist in order to take wind direction into account at the time of the fire. At the same time, emergency services must have a clear route into the depot. A narrow area of the depot will be at the entrance gate. It will not work if the autonomous buses evacuate the depot at the same time as the emergency services vehicles enter.

It should be possible for depot personnel to begin emergency response efforts and move the autonomous buses within the depot while waiting for the arrival of the emergency services. Once the emergency services arrive, that work may be suspended because the next steps must be planned and coordinated by consensus. Among other things, the emergency services will want to know what fuel the buses are using and will conduct on-site risk assessments. Emergency services will want to control which autonomous vehicles are to be evacuated to which location. For example, it must not be possible for an autonomous bus to drive over a fire hose, otherwise the fire hose may become damaged and hinder firefighting efforts. It will probably be too dangerous to have both in-service autonomous vehicles and people in the area; the autonomous vehicles and people need to be kept separate. It may be necessary to compartmentalise the risk area into different zones and control the evacuation accordingly.

Appendix D: Drive Sweden Policy Lab

Drive Sweden Policy Lab was initiated in 2019 by Drive Sweden as an initiative to support technology development projects within Drive Sweden's portfolio that had encountered regulatory challenges. The idea was for these projects to continue as planned, while the stakeholders in those projects, together with RISE, would investigate the policy aspects of a sister project, Drive Sweden Policy Lab (DSPL). As the name suggests, the activities would be carried out as a policy lab based on the experience of previous policy projects under the direction of Drive Sweden.[23]

The advantages afforded by this approach were that the original projects did not have to reallocate their budgets or change their planned activities within the project. At the same time, more of Drive Sweden's members could join the policy work if they recognised similar issues in their own operations. To facilitate such a solution, each policy issue became its own work package with its own budget within DSPL. Furthermore, we left the total budget open so that new work packages could be linked during the course of the project. The project form itself is thus a contribution from the project since it was a new way of organising projects to meet regulatory challenges in technology-focused development projects.

DSPL commenced with an introductory meeting in November 2019 and ran until December 2020. At the start we had two work packages, one linked to the CeViSS project (Cloud Enhanced Cooperative Traffic Safety Using Vehicle Sensor Data)[24] and one linked to Keolis and Volvo's trials with autonomous city buses.[25] [26]

For CeViSS, the focus was on how vehicle sensors can contribute data in the service of the public. In the work involved with this, we saw that there is an interest on the part of the authorities to procure vehicle data, but uncertainty regarding how this should be done. If the police are looking for a white Audi in Solna, vehicles nearby may very well have data on the vehicle based on different sensors. But the police would prefer not to make their search public in an open market. At the same time, there may be a need for historical data in the investigative work, and this is an aspect that will probably need to be pursued further. In this respect, technology providers would like to see a different business model from that which telecommunications operators have with the authorities. If there is no gain for them, developing the service will not be worthwhile.

For Keolis and Volvo, the question revolved around which regulations apply to an autonomous bus in a depot environment. Since the bus would only be autonomous in the depot but manually driven on public roads, the self-certification of the bus should be governed by the Swedish Work Environment Authority pursuant to the Machinery Directive instead of the Swedish Transport Agency reviewing it in relation to the ordinance on autonomous vehicle trials. In addition, we saw a general trend in that self-certification is becoming increasingly important in the automotive industry, both for managing autonomous functions and for new, dynamic vehicle concepts enabled by

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[23] https://www.drivesweden.net/en/projects-5/platt
[24] https://www.drivesweden.net/en/projects-5/ceviss-cloud-enhanced-cooperative-traffic-safety-using-vehicle-sensor-data
[25] https://www.drivesweden.net/en/news/unique-demonstration-autonomous-bus-0
[26] https://www.drivesweden.net/en/projects-5/autonomous-city-buses

continuous reconfiguration of the physical platform with safety-critical vehicle performance coming from different cloud services. The work has been presented to BIL Sweden and Volvo as well as the Committee for Technological Innovation and Ethics (Komet).

Work on the third work package commenced in autumn 2020 following a request from the Swedish Transport Administration. Contact was initiated by the Swedish Transport Administration subsequent to the Administration being assigned a government mandate to develop proposals for information exchange systems and open data for horizontal coordination in order to increase the utilisation of empty space in transport vehicles.[27] The assignment period is from 2018 to 2029 and, up to the present, has generated two reports, one of which was presented on 31 May 2019 and the other on 30 June 2020. The assignment is expected to lead to increased transport efficiency and reduced climate impact.

The question RISE was tasked to answer concerned the legal aspects related to horizontal data sharing in order to make transport in Sweden more efficient. We have seen that the issue is complex from a competitive perspective. We can also see that a number of initiatives focusing on data sharing exist, but they are struggling to gain momentum because the market is fragmented. On the other hand, several freight forwarders have worked to rationalise their market share, e.g. Schenker for delivery of packages, and we can see how IKEA and Green Cargo work together to enhance efficiency using rail transport.

The results of each work package can be obtained through the RISE report series from 2021.

[27] https://www.regeringen.se/regeringsuppdrag/2018/08/uppdrag-att-utarbeta-forslag-om-horisontella-samarbeten-och-oppna-data-for-okad-fyllnadsgrad/ published 28 August 2018


AUTONOMOUS VOLVO
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