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Regulatory governance in emerging technologies: The case of autonomous vehicles in Sweden and Norway

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ABSTRACT

Vehicle producers, universities, and technology companies, among others, are today involved in the development of autonomous vehicles (AVs). Ongoing in several countries are experimental activities in actual traffic situations. The legal conditions for autonomous vehicles, however, vary by country. A number of countries have introduced, or are considering introducing, rules for such activities. Some countries see autonomous vehicles as prohibited unless otherwise stated in the regulations, while other countries take exactly the opposite view, i.e., anything not explicitly prohibited is allowed. This paper introduces a regulatory governance perspective on autonomous vehicles. It describes how new regulatory standards are being shaped for emerging technologies in the transport sector using the case of autonomous vehicles in Sweden and Norway. The findings show how regulations are shaped by external pressures and that international conventions are influencing regulatory design. It also concludes that the final regulations hold some degree of flexibility but also that specific restrictions may be hindering advanced experiments. By introducing a theoretical perspective on regulatory governance of AVs, the paper contributes to a further understanding of how to analyse the shape of new regulation in the transport sector generally.

1. Introduction

The development of more or less autonomous vehicles (AVs) has been ongoing for many years. Already, thirty years ago, the EU-funded project Eureka Prometheus included elements for developing self-driving vehicles. Vehicle producers, universities, and technology companies, among others, are today involved in the development of autonomous vehicles. Ongoing in several countries are experimental activities in actual traffic situations. A number of countries have introduced, or are considering introducing, rules for such activities. The legal conditions for autonomous vehicles, however, vary by country. For example, in Finland, the testing of automated vehicles at all levels of automation is permitted as long as the test organisation gets the permit approved. The test vehicle requires a driver to be physically present, either inside the vehicle or able, if necessary, to steer the vehicle remotely. In France, the government has approved the testing of automated vehicles on public roads under the condition that a driver is in the vehicle and can at any time disable automated driving and take control of the vehicle. In Spain, no specific automated vehicle laws have been adopted. Spain does, however, have a favourable position compared to many other countries, since it has not ratified the 1968 UN Vienna Road Traffic Convention (SOU, 2018). The German government started plans for expanding the legal base to autonomous driving in 2016 (Kaltenhäuser, Werdich, Dandl, & Bogenberger, 2020). Hence, roles and responsibilities in terms of safely, liability, cybersecurity, privacy, infrastructure, etc., are discussed and evaluated on a governmental level.

This paper introduces a regulatory governance perspective on autonomous vehicles. It describes how new regulatory standards are being shaped for emerging technologies in the transport sector using the case of autonomous vehicles in Sweden and Norway.

Comparing regulations is important not only for policymakers but also for engineers who need to understand the implications of regulations for design requirements (Lee & Hess, 2020). Reports and academic studies covering regulatory aspects of autonomous vehicles are now emerging. Several policy reports provide descriptions of current legislation (see, for example, KPMG, 2019). Taeihagh and Lim's (2019) comparative study entails a comprehensive analysis of strategies which can be adopted to address risks in relation to autonomous vehicles and the regulative response of governments. There are also case study-specific papers describing developments on a country or state level (Barringer, 2013; Fagnant & Kockelman, 2015; Pinto, 2012). The

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discussion on regulating new technology has also been addressed by the Thredbo conferences (Aarhaug & Olsen, 2018; Mulley & Kronsell, 2018). There remains, however, a need for more research.

The paper makes two main contributions to existing studies. First, it provides a new understanding of regulatory governance in relation to autonomous vehicles. Previous studies have focused on how to regulate the central aspects of autonomous vehicles (e.g., safety, risks, cyber security, and insurance). This paper, however, provides new insight into the pre-conditions that affect regulation as well as the regulatory process itself. Second, by introducing a theoretical perspective to regulatory governance, the paper furthers understanding of how to study and analyse the shaping of new regulation in the transport sector generally.

The paper comprises six sections. Section 2 provides a description of methods and materials. Section 3 provides the theoretical framework related to regulatory governance. It introduces general theories of regulation as well as specific studies describing regulation of autonomous vehicles. Sections 4 and 5 are empirical sections; Section 4 provides an overview of the central international regulatory work, which has influenced the process in Sweden and Norway, and Section 5 describes regulatory governance processes in the two countries. The final section draws general conclusions.

2. Methods and materials

This study employed traditional legal research methods. To interpret the application of the regulations, preparatory work, case law, and legal literature were examined. First, the relevant sources of regulations in Norway and Sweden were identified. Then, the sources were analysed and interpreted in descending order of authority according to the hierarchy of law (Strömholm, 1996).

The empirical material, therefore, comes from multiple public sources consisting of national and international regulations and reports that underlie the regulations. In order to exemplify how this regulation works in practice, materials have also been selected that describe ongoing test projects in Sweden and Norway. To this end, public documents, websites, and newspaper articles were collected and analysed.

Since the paper focuses on regulation in a policy area that is rapidly changing, it was sometimes difficult to get an overview of the regulatory development on a national level. This is especially evident in Section 5.3, which describes test cases of autonomous vehicles and regulatory interpretations. New applications for testing autonomous vehicles are approved on a regular basis, leading to the continuous refinement of interpretations of the regulations. For example, a speed limitation might change from 12 km/h to 18 km/h as a result of new technological advancements and refinements in application. I therefore acknowledge that the paper might contain some information that is now obsolete.

3. Theory

This section consists of a sub-section, 3.1, which departs from general regulation theory and provides definitions of four modes of regulation as well as factors that affect regulatory design. Section 3.2 presents findings from published papers on autonomous vehicles and discusses those findings in relation to the design factors presented in Section 3.1.

3.1. Regulation and regulatory design

Regulations have been studied from many perspectives and therefore are subject to several definitions (Baldwin & Cave, 1999; Jordana & Levi-Faur, 2004). Regulation can be interpreted broadly, emphasising the social mechanism of control, or hold a narrower meaning in which regulation is defined as "a specific form of governance: a set of authoritative rules, some often accompanied by some administrative agency, for monitoring and enforcing compliance" (Jordana & Levi-Faur, 2004, p. 3).

A mix of regulatory modes may co-exist within a country (or other regulatory regimes—for example, the EU). A regulation may differ in relation to the obligatory nature it imposes on its addressees. It may also differ in the distribution of tasks across the tiers of governance and the level of discretion that actors are granted in the implementation process (Jordana & Levi-Faur, 2004). Combining the two dimensions, the four modes of regulatory intervention are presented as shown in Table 1.

Regulatory standards often hold detailed and obligatory rules, making it possible for the regulator to control the level of compliance. Hence, the level of discretion is low for the implementing actor.

New instruments are described as a 'bag of regulatory tools' with an aim of achieving behavioural change. The level of obligation is high, but the instruments are broad, and there is leeway in how compliance is to be achieved. Framework regulation is common in this regulatory mode; it provides decentralised levels of governmental authority to add regulatory substance in order to fit local and/or contextualised conditions.[1]

Self-regulation shifts the obligation and discretion towards private actors and away from governmental invention. Private actors within a sector or industry develop standards that apply to their setting (for example, different 'codes of conduct,' quality standards, etc.). For example, an industrial association may set rules and standards which are then compiled by associated firms.

Open method of coordination originates in the EU setting, emphasising benchmarks. Policy benchmarks are set by the EU, but member states can formulate regulations independently without threat of sanction. The EU provides a context which enables structures for cooperation and learning among national policymakers. The regulatory impact is mainly based on best practices; hence, both levels of obligation for a regulatory authority are low, and a wide range of policy strategies can be chosen to implement the regulatory policy (Jordana & Levi-Faur, 2004, pp. 220–221).

Table 1 presents four general modes of regulation based in two dimensions of regulatory invention: level of obligation and level of discretion.[2]

For a regulation to be effective, it must have a design that can meet the problems that are to be regulated (Hansson, 2011; Hansson & Holmgren, 2011). Jordana and Levi-Faur (2004, p. 230ff) bring forward four factors that need to be addressed in a regulatory process. Depending on how flexible these factors are, a regulation can be more or less open/flexible to meet innovation and new technological changes.

The first factor is *adjustment flexibility*. Adjustment is difficult with

Table 1
Modes of regulation.

	High level of obligation imposed by regulator or implementing actor/authority	Low level of obligation imposed by regulator or implementing actor/authority
High level of discretion for implementing actor/authority	New instruments: economic, communicative, framework regulation	Open method of coordination (OMC)
Low level of discretion for implementing actor/authority	Regulatory standards: substantive, procedural	Self-regulation in the shadow of the state

Source: Knill & Lenshow, in Jordana and Levi-Faur (2004, p. 220).

[1] Example of a framework law is the Swedish health legislation SFS, 2017, p. 30. It presents an obligation for society to provide care but does not give the patient any direct right to demand care in court.

[2] Table 1 was originally presented to describe modes of regulation in the EU, but it can be applied to regulatory approaches in general (see discussion in Jordana & Levi-Faur, 2004).

regulation that is based on legally binding directives such as regulatory standards. If a legislative framework is too detailed (or narrow), new innovative solutions/technology might require new legislation. This will slow scientific and technical development. Instead, a regulation that features a high adjustment flexibility allows a redesign of regulations in light of new technical innovations or new scientific findings.

The second factor is the possibility to *capture the problems* that are to be regulated. Generally, in order to achieve an effective regulatory design, the regulator needs information identifying the problems that are to be regulated. Strong interest groups may influence problem definitions as well as political conflicts within a governmental system. When it comes to new technology, the industry shaping the new technology is often the one that holds the most information. This gives the industry a degree of advantage over regulatory arrangements. Hence, there is a risk that regulatory rules will primarily serve industry interests. When analysing how to “capture the problem,” one must take account whether the regulatory design is shaped in light of the interest of the public at large or in the interest of the regulated group/industry. Problem capture can also be done by benchmarking, for example, comparing different countries' regulatory designs or adopting international policies/recommendations.

The third factor is *context responsiveness*, addressing whether the regulation is responsive to subnational and local problem constellations.[3] Having the leeway to adjust to regulatory requirements in light of distinctive problem constellations at the national, regional, or local level enhances the changes for effective regulation. However, too much discretion may jeopardise the overall objective of the regulation, making it ineffective.

The fourth factor is the *predictability of regulatory outcomes*. In order to predict potential regulatory outcomes, the regulator needs to have clear indicators and sound data upon which to make prognoses and model alternatives. This information, when it comes to new technology, is often unsecure since it involves unknown predictions of the future (Jordana & Levi-Faur, 2004).

3.2. Regulation in light of autonomous vehicles

The need for new regulation can be explained by conflicts within the regulatory framework or new political agreements (Baldwin & Cave, 1999; Hansson, Nerhagen, 2019; Jordana & Levi-Faur, 2004). Existing regulations may become obsolete, or there may be a lack flexibility to meet changing conditions in society. Autonomous vehicles are one such example in which new ideas have emerged based on scientific findings that challenge the status quo (Fagnant & Kockelman, 2015; Straub & Schaefer, 2019). Several studies have demonstrated that existing regulation is in conflict with further development of AVs (Béland, 2005; Mordue, Yeung, & Wu, 2020). Autonomous vehicle technologies represent a transfer of responsibility for driving from humans to machines/autonomous drivers. It is this transformation that is especially problematic when formulating autonomous vehicle regulation, because existing international laws and regulations are based on human drivers and hold no flexibility in terms of making allowances for autonomous driving (Li, Sui, Xiao, & Chahine, 2019). For example, in the US, it remains unclear how autonomous vehicles fit into existing legal frameworks (Brodsky, 2016; Danks & London, 2017). In the US, the current laws regulating autonomous vehicles are to a large extent decided by each state. This means that the legislative guidance varies from state to state. Fagnant and Kockelman's (2015) paper shows that Nevada's original legislation contained just 23 lines of definitions and broad guidance for its DMV, while California's covers six pages. The authors also compared AV government guidance and on-road testing rules in three countries: Australia, the US, and Germany. The paper shows there were significant differences regarding rules for driver presence. Only California does not require a human safety driver in the AV while testing (Fagnant & Kockelman, 2015, p. 176).

As presented in Section 3.1, interest groups can add pressure that leads to legislative changes. There are several examples in the literature that show why the industry drives the need for better standards or regulation in terms of autonomous vehicles. Without a consistent certification framework and standardized set of safety tests for acceptance, autonomous vehicle manufacturers may be faced with regulatory uncertainty and unnecessary overlap (Fagnant & Kockelman, 2015, p. 176). Brodsky (2016) argues that the state might have an interest in shaping regulation that simplifies central industries' work. For example, the author points to California as a “Google friendly state” and the Midwest, where “trucking” is an important part of the economy. In these states, the government can be reluctant to pass restricted autonomous vehicle laws (Brodsky, 2016, p. 876). Shladover and Nowakowski (2019) have a slightly different perspective, differentiating between interest groups that resist regulation and those that favour higher regulatory barriers. The first type includes interest groups representing companies that want to sell vehicle automation products and services, while the second type includes interest groups representing vulnerable road users and traffic safety (Shladover & Nowakowski, 2019). The latter can, for example, include some union groups who forecast a potential loss of employment in the event that AVs replace human drivers. There are also worries connected to social inequity, in the sense that the initial cost of AVs is likely to be high and only wealth consumers might be able to afford AVs as personal vehicles (Raj, Kumar, & Bansal, 2020).

Interest groups can apply pressure to initiate regulatory changes, but they can also be involved in shaping the actual regulation. Hence, the regulatory process can be more or less open. In an open process, there might be a collaboration or co-production between external actors (for example, industry associations, other interest groups, the public, etc.) and regulators throughout the process, while in a more closed process the discussions and work are primarily conducted within the governmental system (Lodge & Wegrich, 2012). There are several examples from the literature that show an open process (Marchau, Zmud, & Kalra, 2019).

A central discussion when it comes to regulating autonomous vehicles is how to deal with uncertainty. Hence, new regulation has to be shaped with limited knowledge of the outcome of future technology, as well as the outcome of the regulation that is shaped (Marchau et al., 2019; Straub & Schaefer, 2019). One way to deal with uncertainty is to limit the scope of autonomy in the technical systems so that the technology can be limited to use within existing regulatory structures. In terms of AVs, the responsibility would then remain within humans, and in this sense, the system's autonomy would be constrained. Alternately, it is possible to constrain the use of AVs by regularizing the environment. This strategy has, for example, been pursued for aerial vehicles/air traffic control systems (Danks & London, 2017). The work of Nowakowski, Shladover, Chan, and Tan (2015) and Shladover and Nowakowski (2019) on regulation of autonomous vehicles in California makes a distinction between *testing regulations* and *regulations for use by the general public*. Their work shows how regulation is divided into stages in order to meet future challenges. Hence, the first type of regulation makes it possible for testing in experimental environments. Then, in stage two, a general regulation for public use of autonomous vehicles is shaped (Shladover & Nowakowski, 2019). Shaping regulation in this way, which allows for testing/trials, is a recurring theme in the autonomous vehicle literature, and several case studies describe how this takes place in different countries. In a controlled setting, policy challenges are identified for the immediate use of test vehicles and for the long-term introduction and widespread use of AVs (Kyriakidis, Happee, & de Winter 2015; Lee & Hess, 2020; Mordue et al., 2020; Wang & Zhao, 2019).

[3] When it comes to international regulation (for example, the EU), the flexibility also lies in being responsive to different national regulations.

3.2.1. Linking general regulatory design factors to autonomous vehicles studies

The previous studies provide information on central problems and aspects addressed when shaping autonomous vehicle regulation. Table 2 tries to match that discussion to the general theory on design factors affecting a successful regulation.

4. International work and regulation

Section 4 describes some of the international regulations and standards central to the regulatory governance processes in Sweden and Norway (as well as in many other countries).

4.1. The UN, the Geneva Convention, and the Vienna Convention

The Geneva Convention and Vienna Convention are international agreements that list basic rules for road traffic, drivers, and vehicles. The EU, as well as Sweden and Norway, have ratified these conventions (United Nations, 2019). The Geneva Convention states that "'driver' means any person who drives a vehicle, including cycles, or guides draught, pack or saddle animals or herds or flocks on the road, or who is in actual physical control of the same …" (UN, 1950, Art. 4), that "every vehicle or combination of vehicles proceeding as a unit shall have a driver" (UN, 1950, Art. 8.1), and that "drivers shall at all times be able to control their vehicles or guide their animals …" (UN, 1950, Art 8.5). The Vienna Convention states that "every moving vehicle or combination of vehicles shall have a driver" (UN, 1969, Art. 8.1) and that "every driver shall possess the necessary physical and mental ability and be in a fit physical and mental condition to drive" (UN, 1969, Art. 8.3).

These paragraphs have been central to the discussion on allowing self-driving vehicles on public roads due to their definitions of 'driver.' The Vienna Convention, however, also states that:

> *Vehicle systems which influence the way vehicles are driven and are not in conformity with the aforementioned conditions of construction, fitting and utilization, shall be deemed to be in conformity … when such systems can be overridden or switched off by the driver* (UN, 1969, Art. 8.5 b).

This paragraph opens up the meaning of 'driver' to an interpretation that may allow a high level of automated driving as long as a driver can override or switch off the automated system. In 2016, changes were introduced to the convention that admitted some automated functions (SOU, 2018).

The United Nations Economic Commission for Europe (UNECE) is one of five United Nations regional commissions administered by the Economic and Social Council (ECOSOC). Since 2014, the UNECE's Sustainable Transport Division has provided a multilateral platform for the negotiation of international legal instruments (UNECE, 2019a). Within UNECE there are efforts to enable traffic of automated vehicles at higher levels than those permitted by the SAE definition (see, for example, UNECE, 2019b). Here, however, the organisation also stresses the need for a driver in each vehicle on the road (SOU, 2018).

Table 2
Design factors affecting a successful regulation applied to autonomous vehicle studies.

Regulatory design factors	Autonomous vehicle studies
Adjustment flexibility	Current regulation on autonomous vehicles in many countries shows an inflexibility in meeting new technological advancement, in particular how to deal with the shift of responsibility from human drivers to a non-human drivers.
Capture of problem	Open process in which different interest groups/ organisations are part of shaping and driving forward new regulatory standards.
Context responsiveness	Studies from the US have shown that there are no cohesive standards/regulations for autonomous vehicles. The context responsiveness is high in that sense; however, it brings uncertainty in terms of autonomous vehicle manufactures/ developers.
Predictability of outcomes	The autonomous vehicle literature brings forward several aspects of how uncertainty has been dealt with: • Restricting technological development by fitting it into existing regulatory structures (for example, requiring a human in the autonomous vehicle). • Controlling the environment by allowing testing/trials, which also capture potential policy challenges. • Shaping regulation in phases: regulating for trials and then regulating for open/public use.

4.2. The European Union

Sweden is a member of the European Union (EU), and Norway is associated with it through its membership in European Economic Area (EEA) agreements. Therefore, the EU's regulatory work is central to both countries.

The EU has a comprehensive set of rules that regulates traffic with today's technology. EU legislation, however, lacks a legal definition of 'driver' and 'driving.' Still, 'drivers' as a concept does appear in the Third Driving License Directive (EU, 2006; see also, discussion in SOU, 2018). Thus far, the EU has no regulatory framework in place for automated driving although extensive work related to it is currently underway—for example, within the High Level Group (HLG) GEAR 2030 (GEAR, 2017). Central in this context is the European Commission's paper "On the Road to Automated Mobility: An EU strategy for Mobility of the Future" (EU, 2018). In that paper, the Commission proposes "a comprehensive EU approach towards connected and automated mobility, setting out a clear, forward looking and ambitious European agenda" (EU, 2018). One of the aims of the agenda is to "ensure that EU legal and policy frameworks are ready to support the deployment of safe connected and automated mobility" (EU, 2018, p. 2). As part of the strategy, the Commission has published guidelines to ensure a harmonised approach for an exemption procedure for EU approval of automated vehicles (EU, 2019). Hence, the EU strives to harmonise legislation on the automation of vehicles among its member states.

The EU also has other work in progress that strives to enable the introduction of automated vehicles. These projects focus on promoting trials and cross-border tests of automated driving and connected vehicles on a larger scale. For example, there is work on common building blocks to the approval of trials so that member states can more easily accept or use one another's authorisations or approvals of particular activities. There is also ongoing work related to digitalisation and data-related issues (SOU, 2018). Twentynine European countries, including Sweden and Norway, have signed a Letter of Intent (Declaration of Amsterdam) to increase cooperation related to testing of automated road transport at cross-border test sites (EU, 2017).

4.3. SAE classification/levels of driving automation

The SAE levels of driving automation have become a standard when defining aspects of automation (SAE, 2018).[4] These definitions were first formulated by the industry, namely the Society of Automotive Engineers (SAE), which was later accepted by the US Department of Transportation and the National Highway Transportation Safety Administration (Raj et al., 2020) and is today widely accepted (SAE, 2018). In short, the SAE levels consist of a taxonomy in which different levels of driving automation are defined, ranging from no driving automation (level 0) to full driving automation (level 5) (SAE, 2019).

[4] The latest description of SAE levels (J3016TM "Levels of Driving Automation") can be downloaded at https://www.sae.org/standards/content/j3016_201806/.

5. The regulatory governance process of autonomous vehicles in Norway and Sweden

This section describes regulatory work on autonomous vehicles in Sweden and Norway, neighbouring countries in northern Europe. The two countries are similar in terms of culture and language, as well as the structure of their political systems. They have a long tradition of joint collaboration and, in many policy areas, regulation harmonised through Nordic agreements. A vast difference between the countries relevant to this paper is that, unlike Norway, Sweden has a long tradition of car production and a robust automobile industry. Norway, on the other hand, is the leading country in deploying private electrical vehicles (approximately 30% of new car sales in Norway are EVs) and has a history of working with automated solutions within the aquaculture industry.

5.1. The formal decision-making process

On November 12, 2015, the Swedish government authorised a special investigator to analyse what regulatory changes were needed in order to introduce driver-supporting technology and fully or partly self-driving vehicles on the road. The assignment included considering and submitting legislative proposals with the aim of creating better legal conditions for: a) trials of self-driving vehicles on public roads and b) the introduction of such vehicles on public roads. The deadline for Part A was set to April 1, 2016, and for Part B to November 28, 2017 (Swedish Government, 2015). The investigation for Part A (trials of self-driving vehicles) was presented in 2016 (SOU, 2016). The Swedish Data Inspectorate, however, had strong views regarding aspects of integrity in the proposal, and there have been delays in getting regulation in place (NyTeknik, 2017a). On March 7, 2018, a special investigator submitted Part 2, the final report on self-driving vehicles (SOU, 2018), to the Minister of Infrastructure, with a draft of a regulation prerequisite to the gradual introduction of automated vehicles. It was an extensive report—1298 pages in total (SOU, 2018).

On April 20, 2017, the Swedish government passed an ordinance[5] that allowed experiments with self-driving vehicles (SFS, 2017), with permission for such experiments to be granted by the Swedish Transport Agency. In September 2018, it also began to allow experiments with self-driving vehicles on public roads (Swedish Parliament, 2018). To date, however, no legislation has been enacted.

In Norway, it has been a much faster process of preparing for and passing legislation permitting experiments with self-driving vehicles on public roads. On January 6, 2016, the Norwegian government authorised the Norwegian Public Roads Administration to investigate and prepare possibilities for regulations that would allow for experiments with self-driving vehicles on public roads, with a deadline of April 2016 (SVV, 2016). A proposal for new legislation was sent to hearing in December 2016 (Norwegian Government, 2016).

On December 15, 2017, the Norwegian Parliament passed new legislation that allowed experiments with self-driving vehicles on public roads (Norwegian Parliament, 2017). This law permitted the responsible authority to make exceptions to existing laws[6] that had previously prevented the testing of self-driving vehicles (Lov, 2017). When designing this legislation, the government relied heavily on the Swedish report on self-driving vehicles (SOU, 2016). Norway, however, went further than Sweden in terms of the role of the driver, since the Norwegian legislation did not impose the requirements of having a driver physically in or outside the vehicle (TU, 2017).

It can be concluded that the regulatory decision-making process differed between the countries. First, Sweden had already started preparing for a new (or adapted) regulatory framework by 2015, while Norway began its work a year later. Second, the preparatory work for new legislation was much more extensive in Sweden, resulting in two reports totalling 1464 pages.[7] The Norwegian report was much shorter, only 46 pages. Third, Norway has adopted new legislation that allows experiments with self-driving vehicles on public roads. Sweden has an ordinance but no legislation in place.

5.1.1. Taking into account the international context

Both countries reference the Geneva and Vienna Conventions in their reports when discussing the design of a new regulation (SOU, 2018; SVV, 2016), in particular the rules related to the driver and the stipulation that the driver should have full control over the vehicle. It is this paragraph (8:1 and 8:5 in United Nations, 2019) that is considered a hindrance to allowing self-driving vehicles on public roads without a driver (automated vehicles at SAE levels 4–5). The reports also mention that ratifications have been made and describe some of UNECE's work (Norwegian Government, 2016; SOU, 2018). The Swedish report's discussion related to the Vienna Convention is much more extensive than the Norwegian one, pointing out that the Vienna Convention makes it "inappropriate to introduce national driver-specific rules" (SOU, 2018, p. 620). The report, however, also analyses the convention in relation to sanctions:

It can be noted that the Vienna Convention lacks sanctions against the parties to the agreement. If country A nationally interprets the convention in a way and country B interprets the convention in another, there is no international body that can decide which country is right or wrong about the interpretation, even if I the UNECE Secretariat that manages the Convention, has some views about the interpretation of this (SOU, 2018, p. 621, p. 621).

Hence, it is noted that there would be no sanctions if Sweden were to read the convention in a different way than it was written. The report also states, "It is possible to make an extensive national interpretation of the Vienna Convention to enable experiments and a careful introduction of fully automated driving." (SOU, 2018, p. 621). This is also the recommendation made by the special investigator (SOU, 2018).

Both countries address the current work within the EU. Sweden's report describes both legislation and other work—for example, GEAR 2030. The Norwegian report focuses mainly on legislation and concludes that "there is no explicit prohibition in legislation under the EEA Agreement for experimenting with self-driving vehicles" (Norwegian Government, 2016, p. 12). Both countries also point out that they have signed the Amsterdam Declaration (EU, 2017).

The reports also describe ongoing work in other countries. The Swedish report covers some countries within the EU, Asia, and Oceania, as well as some states in the USA.[8] The Norwegian report describes work in Sweden, Denmark, and Finland (all Nordic countries). Both reports conclude that there is ongoing work in facilitating and experimenting with self-driving vehicles in many countries. In principle, most countries face similar challenges, even though their methods of approaching these might differ. They also point out the importance of awareness of the changes made internationally and the need to consider them when shaping the national regulatory framework (see, for example, Norwegian Government, 2016, p. 20).

In Sweden, national factors in relation to economic development in Europe and on a global level are analysed. From this perspective, it is brought forward that the automobile industry is important for Sweden, and this position should be considered when formulating the regulation:

The possibility of conducting tests in Sweden is of great importance for the Swedish automobile industry and the Swedish business sector.

[5] An ordinance (Swedish: Förordning) is a lower degree of regulation than a law.

[6] Lov (1965); Lov (2002); Lov (2018).

[7] SOU (2016), p. 168 pages and SOU (2018), p. 1296 pages.

[8] Europe: Belgium, Denmark, Finland, France, Great Britain, Holland, Spain, Germany. USA: California, Michigan, Florida. Asia: Japan, China, Singapore. Oceania: New Zealand, Australia.

This should be taken into account when the regulation is designed (SOU, 2016, p. 31, p. 31).

Norway does not have an automobile industry. However, Ketil Solvik-Olsen, Minister of Transport and Communications, previously stated that Norway strove to be a good test region for self-driving vehicles, to which car producers could come to develop and try out autonomous cars (TU, 2017b):

We have received feedback from several American drone producers that they come to Norway to test their latest products because we have created flexible legislation. We want to have the same flexibility with self-driving cars (TU, 2017b).

5.2. Regulating autonomous vehicles

Due to the new legislation in Norway and the ordinance in Sweden, it is possible to do experiments with self-driving vehicles on public roads. The content of the regulations is similar in both countries. The Swedish report on self-driving vehicles (SOU, 2016) was also used in Norway when it formulated its legislation (TU, 2017b).

Both countries have similar procedures for obtaining permission to perform experiments. One must send in an application, which is then evaluated by a national agency (the Swedish Transport Agency and the Directorate of Public Roads at the Norwegian Public Roads Administration, respectively). In order to obtain a permit, the applicant must prove that they meet a number of requirements, including traffic safety, vehicle control, and emergency procedures (Lov, 2017; SFS, 2017). In Norway, the applicant must prove that he or she has control of the vehicle at all times; if the technology can handle all driving situations, there is no requirement for a person to sit behind the wheel (Lov, 2017; TU, 2017b).

Hence, the application must be in line with the regulation. Since the regulation covers technical and personal data as well as safety data, many factors must be taken into account. Many criteria must be met when drafting an application.

In addition to the formal aspects of the application, other considerations will increase the probability of a positive outcome. A consultant firm that presented its work for a municipality in Norway gave the following recommendations for those planning an experiment with self-driving buses:

- Do not compete with existing public transport routes.
- Make sure the traffic situation is simple.
  - No complicated traffic routes (avoid left turns, roundabouts, and crossing roads)
  - Preferably customised surroundings
- Ensure the application is in line with municipal plans and strategies.
- Hold the experiment in a location where it is possible to store and charge the bus at night.
- Ensure the bus can meet the capacity need and scale.
- Verify that the traffic route is in line with the criteria set forth in the legislation.
- Create value for the passengers.

(Presentation at a municipal meeting, May 16, 2019).

Hence, even though the regulation itself may be open to experiments with self-driving vehicles, procedural aspects related to time frames, traffic complexity, and technology may hinder the possibility of application approval. The final empirical section will show how practical experiments with self-driving vehicles are interacting with regulation by addressing some examples of experiments conducted in Sweden and Norway.

5.3. Regulation in practice

In Sweden, research organisations and the automobile industry play a central role in furthering new regulation. Most of this work is concentrated in the Gothenburg area—for example, Volvo and research-intense organisations such as the Chalmers University of Technology. DriveMe is a project conducted in collaboration with the Volvo Car Group, the Swedish Transport Administration, the Swedish Transport Agency, Lindholmen Science Park, and the City of Gothenburg. The aim of the project is to "study the benefits to society of autonomous driving and for Sweden and Volvo Cars to become a leader in sustainable mobility" (Testsite Sweden, 2019). The project began in 2014 with the plan of having pilot cars launched on the streets of Gothenburg by 2017. In total, it was planned to have 100 self-driving Volvo cars on public roads in Gothenburg (Lindholmen, 2013). The Swedish Transport Agency, however, stopped the parts of the project that involved self-driving cars, arguing that they:

Cannot legally authorise third parties. No one who does not work at Volvo Cars can take part in this project because then it becomes unclear about the responsibility if an accident should occur (NyTeknik, 2018).

The issue of responsibility was not clear. In September 2018, Volvo got permission to experiment with self-driving cars on public roads; the driver, however, was required to have a hand on the wheel all the times, and the car was not allowed to change lanes. Later, some limitations were modified and approved by the Swedish Transport Agency: the cars were allowed a maximum speed limit of 80 km/h, the steering wheel could be released completely, and the software was allowed to change lanes. The tests are still limited to a few major roads in Gothenburg and require a person physically in the car (Di, 2018).

In Sweden, there have also been experiments with self-driving buses. This work has also been done in collaboration with research organisations. The first pilot was conducted in the Stockholm area, in Kista, on January 24, 2018. It was a collaboration between the bus company Nobina Technology, Ericsson, the train operating company SJ, the Royal Institute of Technology (KTH), the real estate company Klövern, Urban ICT Arena, and the city of Stockholm. Buses were allowed to operate on a 1.5 km route and transport 12 passengers (six seated). The speed was set to a maximum of 20 km/h. A person had to be in or outside the vehicle (Nobina, 2018). The person did not have to be a licensed bus driver; rather, it could be another person that had the ability to take control of the vehicle. The experiment was successful, and in October 2018, the project was expanded to self-driving buses on public roads in Stockholm (Järfälla). The buses were allowed a speed limit of 12 km/h and 11 passengers (SVT, 2018). In May 2018, experiments with self-driving buses were done in Gothenburg (the Chalmers-Johannesberg area). Those buses had similar regulations to those in Kista; 11 passengers were allowed, and the maximum speed was 20 km/h (Rise, 2018).

Despite having such legislation in place, there has been little interest in Norway in experiments with self-driving vehicles. By March 2019, the Norwegian Road Directorate had received only eight applications for projects involving them. Five applications were accepted, four of which concerned self-driving minibuses in customised surroundings. No application met the requirements for driving in normal traffic. None of the buses had cameras in use to support the automation and therefore could not read signs or road markings or perceive dangerous situations (SVV, 2019).

In Norway, the first experiment with self-driving buses was conducted in Stavanger. It was organised by Kolumbus (the public transport operator in Rogaland County), Forus PRT (a company that develops and operates autonomous transport for municipalities), and Forus Næringspark (a large business organisation comprising around 2500 companies). The project began in January 2017 and was implemented in several phases. In the first phase, the driverless bus ran in a closed test area on Forus property. A year later, legislation was passed which allowed testing of self-driving vehicles on public roads, and on June 12, 2018, the first bus was allowed to drive on a 1.2 km route. The Norwegian Road Directorate gave the project permission for the bus to travel at a maximum of 12 km/h with a maximum of six passengers (even though the bus is registered for twice that number) (Kolumbus, 2018).

On May 20, 2019, experiments with self-driving buses began in Oslo. These buses are part of the public transport service in the Oslo area and are a collaboration between Ruter (the public transport operator in Oslo), the Norwegian Public Roads Administration, and the City Environment Agency of Oslo. In this project, the buses are allowed to drive in normal traffic with a speed limit of 18 km/h and a maximum of 11 riders (10 passengers and one service person) (Ruter, 2019).

This section shows that the regulations in both countries have elements of flexibility. This is illustrated by the fact that the regulatory bodies have changed their decisions regarding what is allowed in the experiments based on the technology at hand. For example, one project may be allowed to have a speed limit of 12 km/h while another is permitted 18 km/h. There are also examples in which the same project (in this case DriveMe) is granted more leeway over time when the new technology shows that it is meeting the standards set in the regulations. The section also shows differences between Norway and Sweden in terms of who is driving the implementation of the regulation. In Sweden, there is a concentration of research organisations, the automobile industry, and public authorities, while in Norway it is mainly local organisations that are experimenting with self-driving vehicles.

6. Conclusion

In many countries, the experimental activities of autonomous vehicles on public roads are emerging, and a number of countries have introduced, or are considering introducing, rules for such activities (KPMG, 2019; Taeihagh & Lim, 2019). This paper has introduced a regulatory governance perspective on autonomous vehicles. It has described how new regulatory standards are being shaped for emerging technologies in the transport sector using the case of autonomous vehicles in Sweden and Norway. The concluding section is structured around three main arguments a) heterogenic regulatory modes, b) the structure of a regulatory governance process c, and c) the regulatory design of autonomous vehicles. The arguments are constructed based on the theory presented in Section 3 and the findings in Section 5 and presents illustrations/models that can helpful if one would like to expand the analysis to other countries' contexts as well.

6.1. Heterogenic regulatory modes in the autonomous vehicle regulatory governance process

New regulation is shaped within the existing regulatory regimes, in the sense that regulators draw upon existing regulations when framing new alternatives (Béland, 2005; Lodge & Wegrich, 2012). This is also relevant when explaining the development of new regulations for autonomous vehicles. The theoretical section described a mix of regulatory modes that may coexist within a country. A regulation may differ in relation to the obligatory nature imposed on its addresses. It may also differ in the level of discretion actors are granted in the implementation process (Jordana & Levi-Faur, 2004). Combining the two dimensions, four modes of intervention were presented in Table 1.

When analysing the two cases of regulating autonomous vehicles in Sweden and Norway, it was not possible to only identify one regulation mode. Instead, multiple regulation modes have been identified. This is explained by the fact that a regulation undergoes different phases, and within these phases different regulatory modes can exist in parallel (see Fig. 1).

The first phase illustrates the existing regulation, which is not adjusted for autonomous vehicles. The next phase is the transition phase. The transition phase emerges from a need to challenge the existing regulation due to technological innovations. It is in this phase that the paper has identified three types of regulation mode co-exist simultaneously: the existing regulatory standards, self-regulation, and elements of open method of coordination (OMC). The existing regulatory standards are in place until a new framework is adopted, and the existing standards also influence how new regulations are shaped. For example, both Sweden and Norway draw on existing regulations when shaping new ones. This is shown in the underlying reports from both countries. Other studies have shown similar results (see, for example, Fagnant & Kockelman, 2015). Parallel with this, there are elements of self-regulation in terms of industry setting standards for autonomous vehicle development which influence the regulatory process as well. For example, a central standard is the SAE classification. OMC is identified by the importance that international regulatory standards and international conventions have had on the countries' regulatory frameworks. Both Sweden and Norway shape their regulations based on benchmarks and learning experiences from other countries.

The final phase, the consolidation phase, symbolises the new regulation in place. In the case of Sweden and Norway, the new regulations of autonomous vehicles hold the most similarity to the mode defined as regulatory standards. In both cases, the regulation is detailed, and the findings have presented several examples in which the level of discretion was low for the implementing actor. This was evident, for example, in the DriveMe project, which was stopped for regulatory reasons.

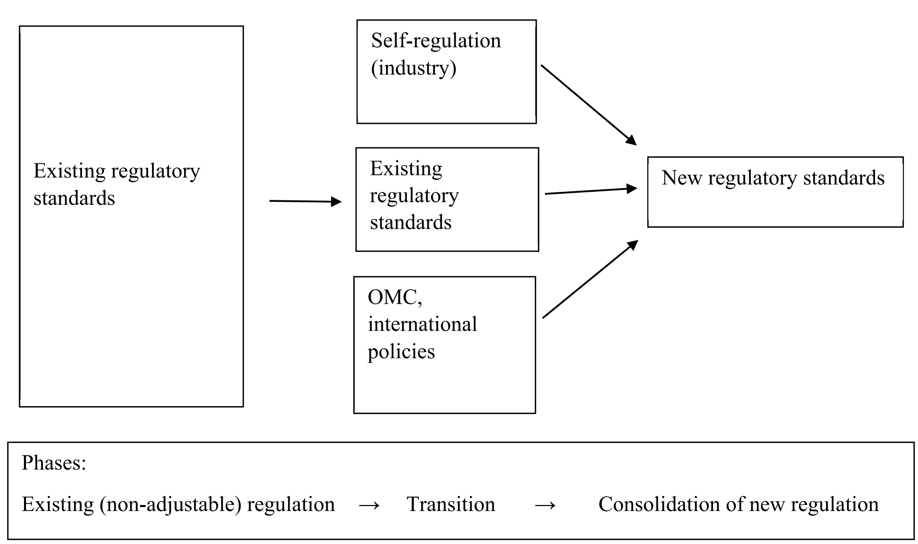

Fig. 1. Regulatory modes and phases of AV regulatory governance process.

6.2. *The structure of the regulatory governance process of autonomous vehicles*

The second argument brought forward is related to the structure of the regulatory governance process. First, it should be pointed out that the regulations in both countries are limited to control test-based autonomous vehicles. This goes in line with the distinction that Shladover and Nowakowski (2019) make between testing regulation and regulations for use by the general public.

Overall, the structure of the governance process can be summarized as three main components; a) the formal decision-making process, b) a supervising body ensuring the regulation is implemented correctly, and c) test arenas for autonomous vehicles. Fig. 2 illustrates the structure of the regulatory governance process.

It is within each component that some differences between the countries have been identified. For example, the formal decision-making process in Sweden was more extensive. However, Norway also relied on the Swedish underlying material when shaping its own decision. The arrow between the supervising body and the test site illustrates an interactive relationship in the consolidation phase of the new regulation. The supervising body and the autonomous vehicle testing arenas are adjusting and reshaping the requirements that are set by the regulator in order to go forward with more advanced testing.

In this way, the regulatory process can be defined as both limited and open. It is limited to control test-based autonomous vehicles, but open in terms of including numerous institutions that in interaction move the process forward.

6.3. *The regulatory design of autonomous vehicles*

The last argument is related to the regulatory design of autonomous vehicles. In Section 3, Table 2, general factors of regulatory design were matched with the existing autonomous vehicle literature on regulation. When analysing these factors in relation to Sweden and Norway, several similarities with the autonomous vehicle literature were found (see summary in Table 3).

The central difference between Sweden and Norway is related to the first factor, adjustment flexibility, and specifically how to deal with "the driver" (human or non-human). Norway shows a significantly higher level of adjustment flexibility in its regulation since they do not require a person to be inside or outside the vehicle. The other three factors point to several similarities. Both countries' regulations have aspects of flexibility related to context responsiveness in the sense that one experiment can have stricter limitations compared to another experiment, even though the experiments take place within the same country. Both countries have dealt with the uncertainty factor in similar ways, initiating autonomous vehicles in experiment-based settings.

This paper started with an introduction that argued that a number of countries have introduced, or are considering introducing, rules for AV activities and that the legal conditions for autonomous vehicles vary by country. However, taking into account the findings presented in this paper, one needs to refine that statement. It is mainly the first component, *adjustment flexibility* in terms of regulating the driver, that differs between countries. Taking into account the three other factors presented in Table 3, one sees many similarities between published studies on autonomous vehicles in different countries. This might be explained by the fact that regulatory governance processes related to autonomous vehicles are open processes which involve benchmarking strategies, but

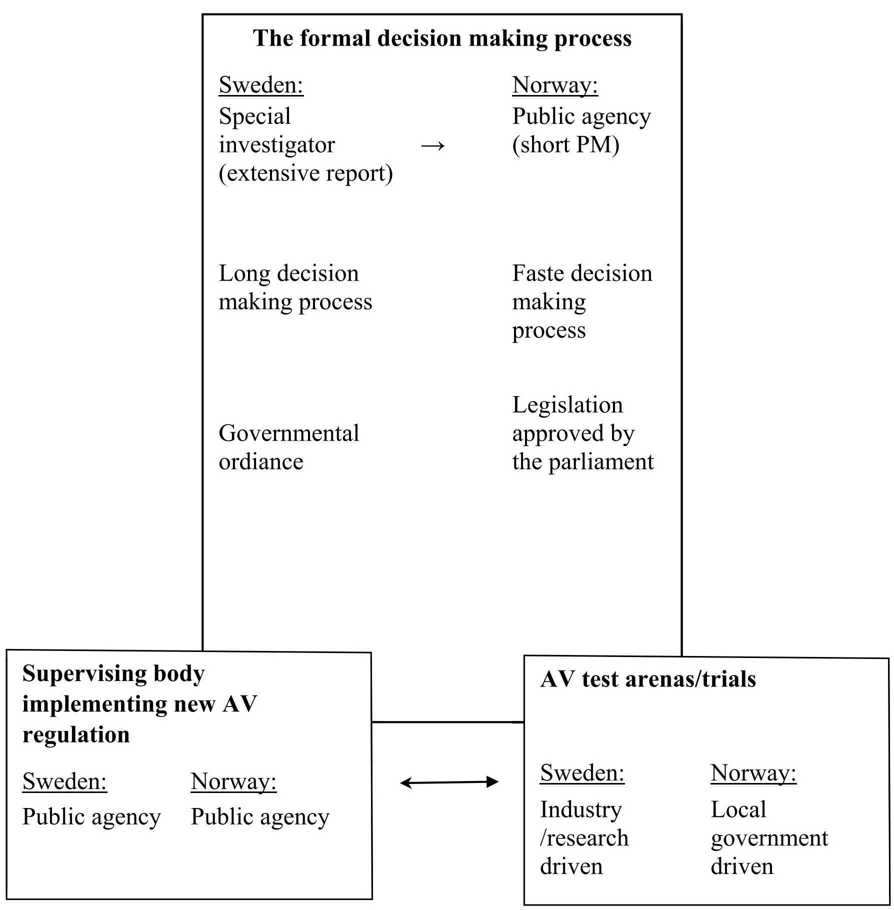

Fig. 2. Components involved in shaping the regulatory governance process of autonomous vehicles.

Table 3
Regulatory design factors applied to autonomous vehicle studies.

Regulatory design factors	Autonomous vehicle studies (findings from Section 3)	Sweden and Norway (findings from Section 5)
Adjustment flexibility	Current regulation of autonomous vehicles in many countries shows an inflexibility in meeting new technological advancement, particularly in dealing with the shift of responsibility from human drivers to non-human drivers.	Sweden and Norway have chosen different designs to address the issue of the 'driver,' resulting in a more flexible regulation in Norway.
Capture of problem	Open process in which different interest groups/ organisations are part of shaping and driving forward new regulatory standards.	Open process in which global trends and external actors further the need for new regulation. Both countries have spurred new regulations related to the need to be 'on-board.'
Context responsiveness	Studies from the US have shown that there are no cohesive standards/ regulations for autonomous vehicles. The context responsiveness is high in that sense; however, it brings uncertainty in terms of autonomous vehicle manufactures/developers.	Both regulations have aspects of flexibility related to context responsiveness. One experiment can have stricter limitations compared to another experiment, even though the experiments take place within the same country.
Predictability of outcomes	The autonomous vehicle literature brings forward several aspects on how uncertainty has been dealt with: • Restriction of technological development by fitting it into existing regulatory structures (e.g., requiring a human to be in the autonomous vehicle). • Controlling the environment by allowing testing/trials, which also captures potential policy challenges. • Shaping regulation in phases: regulating for trials and then regulating for open/public use.	Shaping the regulation based on trials and a controlled environment. Relational exchange between supervising body providing permits for trial and the actors performing the tests.

there is also pressure from multi-international industries and research facilities who have a need for harmonised standards. With that said, one can predict that the notion of the 'driver' will reach a more unified interpretation in the future.

Declaration of competing interestCOI

None.

Credit author statement

Lisa Hansson is the sole author of the paper and have performed all steps in the research process; from initiating the idea, collecting and analyzing the data and writing the paper.

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