The Technical Innovation System of Self-Driving Vehicles in Road Freight Transport

Towards an understanding of Actor Dynamics, Sustainability Outcomes and New Competencies

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Tekniskt innovationssystem för självkörande fordon inom vägtransport

Med sikte mot ökad förståelse för aktörsnätverk och hållbarhetsimplikationer och nya kompetenser

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EXAMENSARBETE INOM TEKNIK OCH LÄRANDE PÅ PROGRAMMET CIVILINGENJÖR OCH LÄRARE

Titel på svenska: Tekniskt innovationssystem för självkörande fordon inom vägtransport. Med sikte mot ökad förståelse för aktörsnätverk, hållbarhetsimplikationer och nya kompetenser

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Abstract

Over the last decade, advancements in connectivity, driving automation technology and electrification in combination with changing customer demands have started to rapidly transform the way in which goods are being transported. Following this fast rate of development, self-driving vehicles (SDVs) in road freight transport are anticipated to operate on public streets within the next couple of decades.

The road freight transport sector is particularly feasible and attractive for driving automation technology. In this sector, there are strong economic incentives and rationales to implement SDVs in road freight transport as it presents possibilities to eliminate or drastically reduce driver costs, optimize vehicle usage rates and improve energy efficiency. Widespread adoption of SDVs is especially feasible for so called node-to-node freight transport flows, carried out between important logistics hubs. Node-to-node road freight transport is characterised by repetitive and predictive flows of goods, conducted in less complex driving environments such as highways and industrial areas.

Although SDVs are predicted to bring significant impacts to the transport system and society, research on the potential influence of commercial use cases of SDVs in road freight transport is scarce. Research aiming to provide an overview of how different type of actors are involved in shaping the development, deployment and future operations of SDVs in road freight transport is also limited.

This paper provides an understanding of system-level impacts of SDVs in node-to-node road freight transportation. It also provides a synthesized view of opportunities and barriers that actors are facing in relation to a large scale use of SDVs in road freight transport. This understanding makes it possible for stakeholders to identify expectations, needs, policies and strategies to govern a sustainable transitions of the transport system. In addition, the paper provides an investigation of requirements for new knowledge and competencies along with development.

By using technical innovation systems (TIS) as a theoretical approach for the study, different components and aspects of the Swedish freight transport system are described and analysed in relation to SDV development and innovations. The TIS framework consists of a set of system components involved in the generation, diffusion and utilisation of a technology, and the relationships between the components. TIS components include actors, institutions, and networks, where networks describe the relationships between actors and institutions. In the paper, Sweden is used as case study. The results are based on 19 qualitative interviews with representatives from a broad spectrum of actors all being part of, or expected to be part of, a road freight transport system where SDVs is a central component.

By analysing the interview results using the TIS framework, one of the main findings is that the public sector together with truck manufacturers are key actors in governing and enabling a commercialization of SDVs in road freight transport. Truck manufacturers have a great power in shaping the system by driving the technical development of SDVs, while government agencies are responsible for regulations and guidelines influencing the direction of development.

The results further indicate that the introduction of SDVs in road freight transport would imply changing dynamics between the actors and other components of the TIS. One example is the role of road carriers and freight forwarders who are currently two of the most central actors in the freight transport system. In a transport system with SDVs, those actors may become less influential. Likewise, actors that are currently not having a central role in the freight transport system may become more influential. For instance, SDVs can catalyse a development towards electrification. This is a way of expanding the system boundaries and implies that new actors, such as energy companies and fuel retailing companies, begin to investigate how they could develop their business models to become a part of an evolving market. This is important in order to be able to compete and engage in a system with SDVs.
Another finding is that there is a consensus among interviewed actors that SDVs must be adapted to the existing road infrastructure system rather than the other way around. At the same time, a completely new digital infrastructure system is being created around SDVs, which is necessary to handle the large amounts of data required for SDVs to operate. Furthermore, the connection between electrification and automation is somewhat ambiguous - some claim that there is clear symbiosis between the two technologies while others argue that they just happen coincided in time.

Finally, the results indicate a lack of holistic and systematic perspectives among the actors on how the development and deployment of SDVs could contribute to sustainability in the freight transport system. It is critical to at this early state of implementation govern and shape technological development and business models in a direction that ensures a sustainable path for a future transport system with SDVs.

**Key words:** SDV, Node-to-node, Freight transport, TIS, Sustainability, Knowledge, Competencies.
Sammanfattning

Under det senaste decenniet har det gjorts flera framsteg inom teknik för självkörande fordon, uppkoppling och elektrifiering. Detta i kombination med nya krav från kunder har påbörjat en stor förändring i hur gods transporterar. Utvecklingen går snabbt och inom de närmsta decennierna förväntas självkörande lastbilar köra på offentliga vägar.


Trots att självkörande lastbilar förutses få betydande konsekvenser för transportsystemet och samhället är forskning om det potentiella inflytandet av kommersiell användning av självkörande lastbilar bristfällig. Forskning som syftar till att ge en överblick över hur olika typer av aktörer är inblandade i att forma självkörande lastbils utveckling, utbyggnad och framtida verksamhet är även den begränsad.

Denna uppsats syftar till att tillhandahålla en förståelse för systemeffekter av självkörande lastbilar i nod-till-nod godstransporter. Den syftar vidare till att ge en syntetiserad överblick av de möjligheter och hinder som olika typer av aktörer står inför i samband med en storskalig användning av självkörande lastbilar. Denna förståelse gör det möjligt för intressenter att identifiera förväntningar, behov, policies och strategier för att styra och möjliggöra en kommersialisering av självkörande lastbilar i en framtid där självkörande fordon är vanligt. Dessutom undersöks vilka nya behov av kunskap och kompetens som skapas i samband med utvecklingen.

Genom att använda tekniska innovationssystem (TIS) som teoretiskt ramverk för studien beskrivs och analyseras olika komponenter och aspekter i det svenska godstransportsystemet i relation till utveckling och innovation av självkörande lastbilar. TIS-ramverket består av en uppsättning systemkomponenter som är inblandade i generering, diffusion och användande av en teknik samt relationerna mellan komponenterna. TIS-komponenter inkluderar aktörer, institutioner och nätverk, där nätverk beskriver förhållandena mellan aktörer och institutioner. I uppsatsen används Sverige som fallstudie. Resultaten baseras på 19 kvalitativa intervjuer med representanter från ett brett spektrum av aktörer som alla ingår i, eller förväntas vara del av ett godstransportsystem där självkörande lastbilar är en central komponent.

Genom att analysera intervjuresultaten med hjälp av TIS-ramverket framkommer bland annat att den offentliga sektorn tillsammans med lastbilstillverkare kan ses som nyckelaktörer i styrning och möjliggörande av en kommersialisering av självkörande lastbilar. Lastbilstillverkare har stora möjligheter att forma systemet genom att driva den tekniska utvecklingen, medan myndigheter påverkar utvecklingsriktningen genom att ansvara för regler och riktlinjer.

Resultaten visar vidare att ett införande av självkörande lastbilar skulle innebära förändrad dynamik mellan aktörer och andra komponenter i TIS. Ett exempel är transportföretagen och speditörernas roller som för närvarande är två av de mest centrala aktörerna inom godstransportsystemet. I ett transportsystem med självkörande lastbilar kan dessa aktörer bli mindre inflytelserika. På samma sätt kan aktörer som för närvarande inte har en central roll i godstransportsystemet bli mer inflytelserika. Självkörande lastbilar kan exempelvis katalysera en utveckling mot elektrifiering, Det
här är ett sätt att utöka systemgränserna vilket leder till att nya aktörer, så som energibolag och drivmedelsföretag börjar undersöka hur de kan utveckla sina affärsmodeller för att bli en del av marknaden. Detta är viktigt för att kunna konkurrera och bli delaktiga i ett system med självkörande lastbilar.

Ett annat resultat är att det finns en enighet bland intervjuade aktörer om att självkörande lastbilar måste anpassas till det befintliga väginfrastruktursystemet snarare än tvärtom. Samtidigt skapas ett helt nytt digitalt infrastruktursystem kring de självkörande lastbilarna, vilket är nödvändigt för att hantera de stora mängder data som krävs för att fordonen ska kunna fungera. Dessutom är kopplingen mellan elektrifiering och automatisering något tvetydig. Vissa hävdar att det finns en tydlig symbios mellan de två teknikerna medan andra hävdar att de bara räkar sammanfalla i tiden.

Slutligen tyder resultaten på en brist av holistiska och systematiska perspektiv bland aktörerna om hur utvecklingen och användandet av självkörande lastbilar kan bidra till hållbarhet inom godstransportsystemet. Det är avgörande att i detta tidiga skede av implementeringen styra och forma den tekniska utvecklingen och affärsmodellerna i en riktning som säkerställer en hållbar utveckling för ett framtida transportsystem med självkörande lastbilar.

**Nyckelord:** Självkörande lastbilar, Nod-till-nod, Godstransport, TIS, Hållbarhet, Kunskap, Kompetens.
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1 Introduction

In today’s globalised economy, physical connectivity and mobility play a key role in facilitating economic and social development (World Bank, 2015). Efficient transport systems are essential in ensuring the flow of goods and services across supply chains worldwide, and to connect people to jobs, education, and health services (World Bank, 2018; IEA, 2017: 9). Over the last 10 years, a rapid pace of technological innovations in combination with changing customer expectations and new business models has begun to transform the way that passengers and goods are being transported. Under the combined effect of globalisation, population growth, urbanisation, and economic development, the demand for efficient and reliable mobility solutions has grown exponentially - making transport a cornerstone of the global development agenda (World Bank, 2015).

Although transportation is an essential activity, current transport operations present several negative externalities to society. Road freight vehicles account for a key segment of the global oil demand, and oil use by road freight has been documented to continuously increase even as oil consumption and energy use of passenger vehicle fleets have started to decline (IEA, 2017: 9). In addition to substantial greenhouse gas emissions, the transport sector is further associated with other sustainability issues such as air pollution, noise pollution, and risks of accidental injury and death (WHO, 2006).

Meanwhile, the transport and logistics sector are under constant pressure to deliver more efficient services. Individuals and businesses expect to get their goods delivered faster and more flexibly, at low or no delivery costs (PwC, 2016: 3). Simultaneously, the e-commerce sector is rapidly expanding, while there is already a shortage of capacity. The level of uncertainty the transport sector currently faces is also striking - there are uncertainties related to e.g. the pace of economic and trade development, the price of oil, technology and innovations. These challenges and uncertainties all render the future of the transport system difficult to fathom (OECD, 2017: 3-4).

According to the OECD (Organisation for Economic Co-operation and Development), the transport sector should be seen as an important enabler of sustainable development (OECD, 2017: 3). Some of the most influential trends that are currently starting to bring change to the transport sector are electrification, digitalisation, and driving automation. Together they have the possibility to shape the future of our transport system - with the goal to enable faster, cheaper, safer, and more sustainable transport of people and freight.

During the last decade, the attitude for self-driving vehicles (SDVs) and driving automation technique has been observed to switch gradually from “maybe possible” to “definitely possible” to “inevitable”. Several technology manufacturers have already started to present commercially available solutions. The automotive company BMW (2018) states that during the next coming decade, the automotive industry is expected to change more dramatically than it has over the past 30 years. Driver assistance systems are already common today, and as they are becoming more and more advanced the levels of driving automation will evolve to completely independent vehicles. Levels of automation is further described in section 2.2.1 Levels of Automatization below. In this study, SDVs are defined as vehicles that operate without any direct driver input.

There are reasons to believe that within the next 20 years, there is a possibility that fully automated vehicles will run on public roads across the globe (Guerra, 2016: 210). If such a transition takes place, it has the ability to bring structural changes to our society and infrastructure systems. It may change the ways in which roads are used, where households and firms choose to locate, and influence the labour market (Ibid). By applying SDV technologies to the freight industry, it might be possible to address efficiency as well as sustainability challenges (Kristoffersson & Pernestål Brenden, 2018: 2). However, such transition requires a holistic approach due to the complexity of transforming a big system involving both social, economic and technical aspects (Webb et al., 2018: 57). In today’s
research and development practices, there is a lack of practice when it comes to tackling issues requiring a multidisciplinary and strategic approach to be solved. Therefore, knowledge and competencies regarding new practices become important along with new expertise for driving automation technology in order to enable a sustainable implementation of SDVs on public roads.

1.1 Problem Background and Relevance

Many industry experts and developers expect that self-driving trucks will soon be able to drive on highways, but that it will take far longer before SDVs will be able to navigate local streets (UC Berkeley, 2018). UC Berkeley Labor Center therefore predicts that a likely scenario for a widespread adoption of SDVs in freight transport is between what they call “autonomous truck ports”, located on the outskirts of cities, close to major interstate exits. It is further predicted that the transport will mainly be on stretches of highway driving (UC Berkeley, 2018).

In general, the road freight transport system can be seen as a network of flows. Some of these flows are more “static” in nature, e.g. between important logistics hubs or “autonomous truck ports”. Freight transport on such road stretches can be described using the term “node-to-node road freight transport”. First- and last-mile transport on the other hand aims to consolidate or deconsolidate cargo and is often carried out in urban or semi-urban environments. Node-to-node freight transport differs from first- and last-mile transport as it is more predictable and often conducted in less complex environments such as highways or other non-urban environments. These factors make node-to-node road freight transport considered especially suitable for early applications of SDVs.

On top of the practical rationales of introducing SDVs in node-to-node freight transport, there are several other incentives for applying SDVs and driving automation technology in the sector. Two of the main incentives are increased road safety and efficiency in terms of decreasing time requirements and lower labour costs. As driving automation technology has the possibility of addressing challenges related to both safety, economy, and sustainability, the freight transport sector is often predicted to be the first sector operating SDVs at a large-scale on public roads.

Although there are strong rationalisations in applying driving automation in freight transport, not a lot of research have yet been conducted on application of SDVs within the field. Especially when it comes to wider impacts of SDVs on the transport system and society, there seem to be a gap in research. As the freight system is tightly interlinked with not only the general transport system but also economic and socio-economic systems, the impacts of introducing SDVs in the sector are likely to stretch far beyond the system itself. Hence, research is needed not only to address means and techniques of using SDVs in freight transport, but also to apply a holistic perspective to address sustainability and system-level impacts. This is however stated to be one of the main obstacles in the process of facilitating a change in the freight transport and logistics sector, as the complexity of the system has to be taken into account (VTI, 2012: 123). The logistics system involves several actors working in different disciplines, e.g. truck manufacturers, suppliers, urban planners, and governmental agencies. These actors tend to have sometimes contradictory interests, and the pace of development is reported to be slow despite several initiatives to improve service and efficiency (Ibid).

An autonomous node-to-node road freight transport will become a part of a large infrastructural system consisting of various components. Thus, in order to understand how the transition towards an autonomous node-to-node road freight transport could improve sustainability outcomes it is of importance to understand how a collaborative learning development could be designed. Options based on knowledge need to be identified in order to enable well-prepared decision making. Webb et al (2018: 58) means that “Researchers can contribute through collaborative knowledge development with urban stakeholders, capturing and translating learning for decision makers in a more systematic way, and facilitating innovation, evolutionary codesign and adaptive management of
our cities.”. Therefore, as a first step in order to develop collaborative learning for this new system, areas for desirable knowledge and competencies are identified in this study.

In order to enable such approach Webb et al. (2018: 57) describe a co-design process. This co-design process aims to generate the outputs: “(1) a shared framework to support more systematic knowledge development and use, (2) identification of barriers that create a gap between stated urban goals and actual practice, and (3) identification of strategic focal areas to address this gap.” (Webb et al., 2018: 57). In order to gather a system-level view a collaborative learning development such as this one is useful, however these kinds of processes are not common in practice (Webb et al., 2018: 57). By developing a shared understanding of a system development, it is possible to translate knowledge into well-prepared policies and practice. In addition, Webb et al. (2018: 62) emphasise the importance of the UN SDGs. These should guide the policy development.

The co-design process describes an approach enabling sustainable development by well-prepared decision making. Possibly accurate for the transition towards an autonomous road freight transport. However, there are yet uncertainties about the technology design and the SDVs’ adaptability to the surrounding system. Thus, both knowledge regarding the possibility of an implementation of SDVs and knowledge about a sustainable management are of interest. In addition, relevant competencies required become interesting as new areas of knowledge become important.

As new technologies such as SDVs emerge, it is of great importance for key actors in the freight transport system to explore future challenges and opportunities, as well as changing demands of the road infrastructure (SOU, 2018: 294). A transition towards a more automated transport system is likely to be linked to a series of new opportunities as well as challenges to overcome throughout the process. By understanding how an introduction of SDVs would impact the Swedish freight transport system and society, it is possible to identify expectations, needs, policies and strategies to govern a transitions and changes of the transport system at an early stage.

In this thesis, it is assumed that SDVs in freight transport will be implemented and issues regarding whether this is realistic or not is therefore not further investigated.

### 1.3 Aim and Research Questions

Subject to a shift to an increasingly autonomous node-to-node road freight transport system in Sweden during the coming years, the aim of this study is to provide an overview and understanding of system-level impacts, opportunities and barriers facing a set of actors involved in the transition. Since different actors have diverse and sometimes contradictory interests, an important part of the study is to explore how different types of actors engage, and what kind of incentives they have to adapt to SDVs and driving automation technology. In addition, a requirement for new knowledge and competencies due to the introduction of SDVs is expected. Thus, an understanding of new knowledge and competencies required among a set of actors involved in the transition towards an automated node-to-node road freight transport is provided. In order to fulfil the research aim, the following research questions (RQs) have been formulated:

**RQ1:** Which are the key actors involved in the transition towards an automated node-to-node freight transport system in Sweden, and what kind of driving forces are behind the process?

**RQ2:** How can the transition towards an automated node-to-node road freight transport system impact dynamics and collaborations between key actors, and which opportunities and barriers are they facing based on their incentives?

**RQ3:** How does a commercialisation of SDVs in node-to-node road freight transport relate to the UN sustainable development goals (SDGs)?
RQ4: What kind of new knowledge and competencies become important in the transition towards an automated node-to-node road freight transport?

1.4 Scope and Delimitations

This study is delimited to the geographical area of Sweden. This is due to the aim of the study, which is to understand opportunities and challenges facing key actors in a Swedish context. Focus is on transports between logistic terminals, on less complex high capacity transport sections such as highways, i.e. “node-to-node transports”. Issues and topics that are specifically related to first- and last-mile transports will not be covered.

![Figure 1: Illustration of node-node road freight transport](image)

Furthermore, the time frame of the study is year 2050 as previous studies estimates this to be a likely point in time for SDVs to be commercially available and running on public roads. Moreover, all SDVs are assumed to be electrified and able to operate without any human driver, thus delimited to the automation levels 4-5. Different levels of automation will be further defined in section 2.1.1 Levels of Automatization below.

2 Background

In order to understand the components of the studied system - the Swedish road freight transport system, it is important to determine key actors as well as well as the current technological trends and developments. Section 2.1 Self-Driving Technology provides an overview of the status of self-driving technology and levels of automation.

The road freight transport system involves several functions and thus several actors. For example, actors involved in the transport as service are suppliers, freight forwarders and road carriers. In addition, the system also consists of e.g. manufacturers, academia, organisations, regulative and policy making actors as they could have an impact on the system.

2.1 Self-Driving Technology

During the last couple of years, several new solutions for SDVs in freight transport have been introduced to the market. The industry can now provide logistic operations using both automation, connectivity and electromobility (Volvo Lastvagnar, 2018). The trucks are constructed without any driver's cab in order to decrease production costs and operating costs as well as maximizing the loading capacity (Einride, n.d.). As there is no longer any space for a driver, the truck can be remote-controlled if required. The vehicles are connected to an intelligent routing system or a control centre.
and receive real traffic data that enables the trucks to adjust their route for optimal efficiency (Einride, n.d.).

### 2.1.1 Levels of Automatization

The most commonly used taxonomy to describe different levels of automated vehicles is defined by Society of Automotive Engineers (SAE), presented in Table 1 below. The SAE taxonomy describes six levels of autonomy for on-road motor vehicles, from level 0 (no automation) to level 5 (full automation).

<table>
<thead>
<tr>
<th>Level of automatization</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0: No driving automation</td>
<td>Human driver controls and performs everything.</td>
</tr>
<tr>
<td>1: Driver assistance</td>
<td>Human driver performs everything but driver assistance of either steering or acceleration/deceleration is possible by an assistance system which uses information about the driving environment.</td>
</tr>
<tr>
<td>2: Partial driving automation</td>
<td>Human driver performs everything but one or more driver assistances such as steering or acceleration/deceleration is possible by an assistance system which uses information about the driving environment.</td>
</tr>
<tr>
<td>3: Conditional driving automation</td>
<td>An automated driving system performs all aspects of driving with the exception that human driver appropriately will respond when requested to intervene.</td>
</tr>
<tr>
<td>4: High driving automation</td>
<td>An automated driving system performs all aspects of driving even when human driver does not respond appropriately when asked to intervene.</td>
</tr>
<tr>
<td>5: Full driving automation</td>
<td>An automated driving system performs all aspects of driving full time and under all conditions that a human driver can manage.</td>
</tr>
</tbody>
</table>

**Table 1:** Levels of automatization (SAE, 2016).

The term SDV usually refers to vehicles with automation level 3–5, as these levels implies that the driving process is fully monitored by a system. Level 0-2 only implies a self-driving system as support for a human driver (SAE, 2018).

The driving system in level 4 (high automation) and level 5 (full automation) does not require any human intervention, while level 3 vehicles require human support as backup (SAE, 2014). Thus, level 4 or level 5 is required in order to operate a vehicle without any driver constantly sitting inside the truck. Furthermore, a level 4 vehicle is designed to enable human driving, but operates autonomously in some conditions, while a level 5 vehicle does not have a driving cab at all and need no human driving support at any time.

### 3. Theoretical Framework

The analysis of radical innovation and transformation processes, such as i.e. SDVs in node-to-node road freight transport, requires an integrated perspective capturing changes not only in technology but in socio-technical configurations such as new market structures, actors and institutional settings. This study will use the concept of technical innovation systems (TIS) as a basis for the theoretical framework. In addition, the TIS framework will be complemented by Large Technical Systems theory (LTS), Actor-Network Theory (ANT), Activity Theory, and a Sustainability framework. The theoretical frameworks give the research direction and provides scientific justification for the study by showing
how it is grounded in and based on scientific theory and will be further elaborated in sections 3.1 - 3.5 below.

3.1 Technical Innovation Systems (TIS)

In general, a system can be defined as an entity comprising elements that interacts together. It is a model of reality designed for analytical purposes, characterised by the system borders, types of system elements, and their interrelations and relations between the system and its environment (Markard & Truffer, 2008: 598). Technical innovation systems can be further conceptualised as a set of system components involved in the generation, diffusion and utilisation of technology, and the relationships between them (Markard & Truffer, 2008: 599). Actors are one type of component, typically encompassing private firms, governmental and non-governmental agencies, universities, research facilities, associations, etc. Institutions are another type, comprising laws and regulations, sociocultural and technical norms, etc. The third component of a TIS is networks (Markard & Truffer, 2008: 598; Bergek et al., 2008: 408).

The concept of TIS applied in this study is mainly based on literature by Markard and Truffer (2008), and Bergek et al. (2008). The literature aims to define an integrated framework for analysing technological innovation systems by combining an “emerging technology perspective” with a “transition perspective”. Markard and Truffer (2008) affirms that by doing so, it is possible to incorporate prospects and dynamics of a particular innovation, e.g. important barriers and drivers, as well as questioning which factors that are driving transformation processes. A technical innovation system is further defined as “a set of networks of actors and institutions that jointly interact in a specific technological field and contribute to the generation, diffusion and utilisation of variants of a new technology and/or a new product” (Markard & Truffer, 2008: 611).

In technical innovation systems, the relationships between actors are manifold (Markard & Truffer, 2008: 598). Actors may compete or collaborate (network), and trade goods, services or knowledge. They can support each other or be in conflict. Moreover, there may be hierarchies in institutional or organisational set up. Institutions may further set up incentives for actors to avoid each other or to perform certain activities (Ibid). Organisational actors can be said to be embedded in an institutional context, but they can also deliberately change or adapt existing institutions.

The TIS framework presented by Markard and Truffer (2008) is further based on the notion of previous literature on two conceptual perspectives: innovation system approaches and the multi-level perspective. It is stated that both of these perspectives aim to contribute to a deeper understanding of innovation and transformation processes, ideally leading to similar conclusions. Both innovation system approaches and the multi-level perspective aim to highlight the importance of networks and learning processes together with the crucial role of institutions and acknowledge phenomena such as path dependency, non-linearity and coupled dynamics. Further, they are both developed towards informing policy making (Markard & Truffer, 2008: 597). Lately, it has been observed that scholars are combining the two perspectives as they seem to complement each other, e.g. by applying the multi-level framework to the study of emerging technologies (innovation systems).

An improved understanding of technological innovation processes is stated to be important because of the far-reaching consequences it have for suppliers, producers and customers in a particular field as well as for policy makers and society as a whole (Markard & Truffer, 2008: 596). Technologies such as SDVs and driving automation has the capability of affecting and transforming an entire sector and is therefore suited to be examined from a TIS perspective. Furthermore, the driving forces and incentives underlying the innovation processes of large socio-technical systems are complex (Ibid).

By applying the integrated TIS framework as suggested by Markard and Truffer (2008), it is possible to attempt to explain technological transitions based on the interplay of processes between different actors at different levels in a socio-technical system. More specifically, the framework aims to capture
innovation dynamics at different levels, such as driving forces, opportunities, barriers, strategy formation and interactions of actors (Markard & Truffer, 2008: 610). It also provides a basis for an actor-oriented analysis, considering the strategies and resources of different actors. Additional frameworks to conduct this part of the analysis is further described in section 3.3 Actor-Network Theory.

3.2 Large Technical Systems (LTS)

In a broader sense, the concept of LTS can be regarded as a family member of technical innovation system approaches (Markard and Truffer, 2008: 598). In this study, LTS theory is used to provide an explanation to how big socio-technical systems behave when put through changes. The road freight transport system is a typical example of what can be defined as a large technical system, hence it is challenging to be able to address the complexity of the system and the actors in it.

LTS theory is a research framework focusing on infrastructural networks stretching geographical areas, e.g. electricity systems and road networks. In similarity to TIS, LTS theory has developed a particular model of analysis, looking at not only technical aspects of the system but focusing on socio-technical linkages such as people, regulations, and markets (Geels, 2007: 123). Changes in LTS involve several actions in different areas (technical, financial, institutional) and on different levels in society (Geels, 2007: 123). Furthermore, LTS are both socially constructed and society shaping (Hughes, 1987: 51). It is important that different actors participate and interact to develop support for policies.

According to LTS theory, the components in a technical system consist of physical artefacts such as road infrastructure or electric transmission lines. They also consist of organisations, scientific artefacts, and legislative artefacts, e.g. manufacturers, investment banks, research programs, and regulatory framework. These components work together towards a common system goal, and if one component is removed from the system or if its characteristics change, other artefacts in the system will alter accordingly (Hughes, 1987: 51).

Many large infrastructural systems, such as the transport system, are characterised by a “momentum”, i.e. a result of stable connections between technology and society that is making it more difficult to apply changes to the system (Geels, 2007: 124). The term “momentum” comes from physics, referring to the quantity of motion that an object has. The higher momentum, the more an object will continue along its trajectory (Ibid).

Hughes (1987: 76) describes the momentum of a system as the “mass of technical and organisational components”. The mass arises especially from organisations and people that are committed to the system, e.g. manufacturing companies, regulatory bodies, and, politicians (Ibid). This is due to the fact that large investments in the growth and durability of the system have been made and therefore, professional interests and strong institutional and organisational structures are making it difficult to bring change to the system (Hughes 1987: 77; Summerton, 1998: 26). Concepts related to momentum include vested interests, fixed assets, and sunk costs (Hughes, 1987: 77). Actor networks, described in section 3.3 Actor-Network Theory (ANT) below, further adds to the momentum of a system.

Yet another important concept of LTS theory is system builders. System builders can be defined as actors having a particularly big influence on the development and expansion of a system, i.e. innovators of new technology, engineers, funding agencies and political institutions (Summerton, 1998: 25-26). System builders have a strong vision for the development of the system and are further distinguished by their pursuit to fulfil their vision by managing and governing certain components of the system. Expanding system borders is a clear indication that a system builder has succeeded in taking control over the development (Ibid).
3.3 Actor-Network Theory (ANT)

In order to further explore how relationships, roles, and dynamics between different types of actors could be changing by transitioning towards a more autonomous node-to-node road freight transport system, the Actor-Network theory (ANT) is used. As stated in section 3.2 Large Technical Systems (LTS), the study of LTS is agency oriented, looking at interactions of different actor groups (Geels, 2007: 123). LTS theory is often accompanied by ANT.

ANT implies that when entrepreneurs want to introduce new technology to the market, it is important that not only the technology is in place. Rather, it is also important to coordinate and mobilise all involved actors in the network surrounding the technology in order for the technical system to be successfully established (overcoming both political, financial and institutional obstacles). In the actor-network, not only humans and technology but also artefacts such as institutional and organisational structures are accounted for. ANT stresses the fact that technical change and advancements happens through communication, coordination and conflicts between involved actors - engineers, politicians, managers, manufacturers, and consumers (Summerton, 1998: 29).

The networks consist of unlimited number of nodes connected in relationships that can be in a constant change. Latour (1996: 371) implies that the benefit of looking at relations as a network is the enabling of erasing the hierarchy of the real-world distances which leads to a focus on the connections shown in the network. It is important to note that the actors are not limited to human individual actors, thus it could also be non-human and non-individual - so called actants (Latour, 1996: 369). The requirement for an actant to be considered a part of the network is that it can make actions affecting the network or influence other actors/actants to make actions which in turn impact the network (Latour, 1996: 373). In this case, the technology of SDV itself could be considered an actant. This actant as well as other identified actors and actants should all be analysed at the same terms. In ANT all actors and actants are assumed being on the same level and if one takes on a more powerful, influential, organizational or larger position, ANT aims to analyse the reasons behind (Law, 1992: 380).

3.4 Activity Theory

Activity theory, as well as the ANT, argues that human actors, materials and ideas are not separated from each other, but rather parts of a system in need of collaborations. Unlike ANT, activity theory considers internal organisation and contradictions within the operation in addition to interaction between several activity systems (Engeström, 2001: 140).

![Activity Theory Diagram](image)

Figure 2: Third generation of Activity theory (Engeström, 2001:136)

Figure 2 shows the model of activity theory of which each activity consists of six parts. The object is described as the result of actions or target, the subject as the person or group performing the activity and the mediating artefacts are other tools participating in the activity. Furthermore, the community
consists of the people involved in the same action, the division of labour considers the division of
tasks as well as power relations, and rules involves e.g. regulations and norms.

To understand an activity, one need to look at the whole perspective of individual actions within the
activity as well as group actions, both target-oriented and automatic operations (Engeström, 2001: 136). Activity theory also takes different individual and collective cultural traditions and interests into
consideration by looking into the social group and environment where the action takes place as well
as historical aspects of the operation as all these kinds of aspects can influence activities. When
analysing development, so called contradictions play a central part as they are believed to pave the
way for change. Contradictions in activity theory refers to a situation where divergence appears within
or between different activities. Furthermore, a change within the activity system could lead to a
changed object and incentive which in turn could create an expansive transformation and open up for
new possibilities and collaborations with other new activity systems. According to Engeström (2001:
151), the first step of the expansive transformation is questioning, as it is a crucial triggering action
challenging old working traditions and organisation (Ibid). This creates an instability in the activity
which opens up for a potential change in the practice.

An example of a situation where contradictions could occur is when a new technology, such as SDV
technology is adapted by an activity system. Engeström (2001) describes four kinds of these
contradictions. The primary contradiction occurs within a node of the activity, such as the mediating
artefact or division of labour. For example, there could be a new mediating artefact that challenges
the old artefact as it benefits the object. The secondary contradiction occurs between two nodes. For
example, one node could become a barrier for improvement in another node. The tertiary
contradiction occurs when old traditions become a barrier for new ideas and incentives. The last,
quaternary contradiction occurs when another activity has an impact on the central activity by
affecting its subject and rules or produces artefacts to the activity or share the same object.

3.5 Sustainability Framework

In order to analyse sustainability aspects of this study, a sustainability framework has been adopted.
The sustainability framework is expressed in terms of a wider definition followed by the United
Nations (UN) Sustainable Development Goals (SDGs) and the CASI-F framework for assessment and
management of sustainable innovation, initiated by Popper et al. (2017). The SDGs and the CASI-F
framework has acted as a basis to provide elemental structure for the sustainability framework of this
study but has been adapted in order to suit the scope and research questions of this study.

Although there is no single agreed-upon definition of sustainable development, virtually all existing
definitions conceive of the principal in terms of a tension between the goals of economic development
and environmental protection. The term sustainability originally belongs to the field of ecology,
referring to an ecosystem’s potential to subsist over time, with almost no alteration. When the idea of
development was added, the concept of sustainable development would be looked at from not only
the environmental point of view, but from society as well (Jabareen, 2006: 181-182). In this study,
sustainability is something that is agreed to be achieved through effective balancing of social,
economic and environmental objectives.

3.5.1 The UN Sustainable Development Goals

The UN Sustainable Development Goals (SDGs) is a set of 17 goals and 169 targets. The goals are
transformative in nature and encompass global sustainability challenges such as poverty, inequality,
climate, environmental degradation, prosperity, and peace and justice (UN, 2018). The goals were
adopted by all UN member states in 2015 and should be resolved by 2030, as a part of an action plan
named Agenda 2030.
According to the United Nations Economic Commission (2015), the relationships between the SDGs and the transport sector are manifold. The transport sector is stated to be an essential component of social and economic development by linking markets and facilitating trade. The sector is further acknowledged as an important source of revenue and a major employer (UN Economic Commission, 2015: iii). Moreover, the transport sector is currently consuming significant energy resource and generating air and noise pollution. There is hence a potential to address many of the SDGs in the process of working towards affordable, efficient and environmentally sound transport systems.

In this study, the SDGs will be used to systematically evaluate and analyse different aspects of SDVs in node-to-node freight transport. The method and process is further described in section 4.3.1 Sustainability Analysis.

3.5.2 CASI-F Framework for Assessment and Management of Sustainable Innovation

The CASI-F framework is based on the understanding of innovation as a key driver for societal progress and aims to mainstream the research process of sustainable innovations. The framework is developed to respond to sustainability challenges by engaging, mobilising and promoting mutual learning across a wide range of actors in government, business, civil society, and academia (Popper et al., 2017: 11). The sustainability framework in this study applies some of the main approaches and conceptual ideas from the CASI-F framework as described in section 4.3.2 Using the Theoretical Frameworks in the Sustainability Analysis.

CASI-F aims to bring together the two complex terms Sustainable and Innovation. Innovation can refer to the process of creating something new. For an innovation to be sustainable, Popper et al. (2017: 11) argues that it needs to support sustainability goals or a sustainable network of practices. Innovations can be sustainable by directly contributing to e.g. social and environmental sustainability, or by contributing to moving into trajectories that are more sustainable in this sense. Sustainable innovations further involve various processes that are embedded in a wide range of sectors and research areas (Popper et al., 2017: 23).

The way of generating knowledge in the CASI-F framework is by combining evidence, expertise and creative thinking. Interactions with innovators should mainly take place in the form of open and voluntary interviewing. This helps promoting the multi-stakeholder approach, as innovations are led by different types of actors in product-, service-, social-, organisational- and institutional systems (Popper et al., 2017: 23). Nevertheless, the volume and complexity of socio-technical system transformations makes it difficult to devise a single optimal procedure to assess and manage sustainable innovations. The CASI-F framework originally consist of a comprehensive five-step approach aiming to generate results in the form of policy recommendations and action roadmaps. As this is outside of the scope of this study, not all of the steps of the CASI-F framework will be adopted.

For sustainability assessment, the CASI-F framework make use 44 criteria to assess different aspects of positive transformations in economic, societal, environmental, infrastructure and government systems (Popper et al., 2017: 25). These criteria will form the basis of the sustainability framework of this study, as described in section 4 Methodology.
4 Methodology

This section is providing a description of how the theoretical frameworks of this study relates to the research questions. Firstly, the general method of the study will be described, followed by the research approach in section 4.1. Following, the methods used to conduct this study is presented in section 4.2 - 4.3. Lastly, validity and reliability of the study is discussed in section 4.4.

The baseline for the method of this study was the TIS framework described in section 3.1 Technological Innovation Systems above. The TIS framework developed by Bergek et al. (2008) presented a scheme of analysis consisting of six steps, as seen in Figure 6 below. It should be noted that the analysis was not proceeded in a linear fashion as the "steps" might suggest. On the contrary, the analysis entails a great number of iterations between the steps in the analysing process.

The very first step of the TIS framework involved setting the starting point for the analysis. This was done by defining the system, i.e. SDVs in Swedish node-to-node road freight transport. The second step involved an identification and mapping of the structural components of the TIS - the actors, networks and institutions. In the third step, the focus shifted from the structure of the system to its functions. Bergek et al. (2008) defined seven functions comprising of key processes aiming to describe a system. The following steps, that are aiming to assess how well these functions are fulfilled in order to specify and suggest key policy issues, were not included in the method of this study as they are outside the scope of the study and its research questions.
In this study, the seven functions defined by Bergek et al. (2008) were used as a basis but was modified to reflect the aim and research question of this study, see Table 2 below. As this study focuses on a particular innovation system, i.e. SDVs in road freight transport, it was considered appropriate to further pinpoint the functions to be descriptive in this particular case. The defined functions used in the modified TIS framework of this study are presented below. Those functions are considered to have a direct and immediate impact on the development of the TIS (Bergek et al., 2008: 409). Hence, the functions were of central importance when it comes to understanding the system and its components, and it is in these processes policy makers may need to intervene.

<table>
<thead>
<tr>
<th>Function</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Influence on the direction of development</td>
<td>Addresses mechanisms having an influence on the direction of development, e.g. external factors such as climate change and sustainability debates. It can also be about e.g. technologies, business models, legislations and policies.</td>
</tr>
<tr>
<td>Market formation and driving forces</td>
<td>Assesses the general state of the market for SDVs in node-to-node road freight transport as well as driving forces. For a TIS that is emerging or in a period of transformation, markets may be developing, transforming or not existing.</td>
</tr>
<tr>
<td>Entrepreneurial experimentation</td>
<td>A TIS typically evolves under considerable uncertainty in terms of technologies and markets. A way of reducing this uncertainty is through different types of entrepreneurial experimentation. This implies probing into new technologies and application, as well as a social learning process.</td>
</tr>
<tr>
<td>Key actors and Actor-Network structure</td>
<td>Provides an analysis of key actors and significant actor-networks of the TIS of SDVs in node-to-node road freight transport. Actors and networks of actors are important components playing a crucial role in the development of any TIS.</td>
</tr>
<tr>
<td>Dynamics and incentives in the Actor-Network</td>
<td>The actors in a TIS often pursue different innovation strategies and/or control a set of different resources. The elements relate to finance, regulations and policies, road infrastructure, vehicle (e.g. body and control systems), fuel infrastructure, market and user practices, maintenance, and industry structure.</td>
</tr>
</tbody>
</table>

Table 2: TIS functions of the technical innovation system SDVs in road freight transport.

4.1 Research Approach

The purpose of all research is to discover answers to questions through the application of scientific procedures. Research aiming to gain familiarity with a phenomenon or to achieve new insights into a field are commonly termed exploratory research (Kothari, 2004: 2). Exploratory research is primarily concerned with discovery and with generating and building theory. Hence, the objective of exploratory research is stated to be the development of hypotheses rather than their testing (Kothari, 2004: 2-4; Jupp, 2018: 2).
As this study partly aims to synthesise viewpoints and perspectives of a wide range of actors, the research objective of this study is exploratory in nature. In order to answer the research questions, a holistic perspective and a general understanding of the interests of several actors linked to the Swedish node-to-node road freight transport system were required.

Exploratory research is a useful approach when analysing problems that are in a preliminary stage and data difficult to collect. As the technology for SDV is still being explored, the research field of SDVs and especially SDVs in road freight application is new and there is limited empirical data from real world operations. Researchers all over the world are currently exploring several fields related to driving automation and SDV - from complex moral and ethics questions, to develop software technologies, to real-world pilots and testing. Hence, it was considered important to provide an overview of the technology, the set of actors to be involved, and grasping different types of market forces. By doing this, it was possible to gain experience, establish priorities, and help develop formal hypotheses to be tested in future research.

Due to the chosen research approach and the exploratory nature of the research questions in this study, it was considered important to approach the problem not only from an academia point of view but to also grasp the viewpoints of businesses and industries. An important part of this study was therefore to interact with companies in their own environment and to explore the platforms for discussing SDV related topics that they are engaged in - such as workshops and discussion forums. By doing this, the aim was to obtain a basic understanding for what kind of questions are being discussed and what is considered to be relevant to business and industry - not only in theory but in practice.

4.2 Data Collection

In this study, qualitative interviews were used as the method for data collection. Qualitative interviews are a unique way of capturing experiences and content from the interviewee’s viewpoint and are stated to be an especially useful method when exploring complex subjects such as opinions and experiences of different actors/people and understanding how systems work and how different factors are interlinked (Kvale, 1997: 70; Denscombe, 2014: 263-265). It is also an efficient way of accessing privileged information - by talking to key individuals within a field that are able to get important information and insights that are exclusive to their specific experience or position (Denscombe, 2014: 265).

In-depth interviews involve meeting between the researcher(s) and only one interviewee. They are easy to arrange and there is only one source of information (the interviewee) which makes it easy to connect ideas and information to a specific person/actor (Denscombe, 2014: 267). However, there was a constraint in the number of people that can participate since in-depth interviews are time consuming. In this study it was decided that the interviews should focus on fewer participants (1-2 at the time) but their ideas were investigated more thoroughly.

As stated in section 3.1 Technical Innovation Systems (TIS) above, this study was in exploratory nature. The main aim of the interviews was to understand the actor’s perspective on challenges and opportunities related to the process of introducing SDVs in the Swedish node-to-node road freight transport, and their internal strategies in approaching such challenges and opportunities. Further, it was considered important to learn about their roles in the actor-network as well as exploring their ideas and visions for tomorrow’s transport system.

4.2.1 The Interview Process

The first step of the interview process was to conduct an actor analysis to map out different categories of actors with relations to the Swedish road freight transport system. Based on the actor analysis, key actors that were considered to be relevant and influential were then approached by mail and asked to
participate in this study through interviews. When identifying the actors involved in the Swedish road freight transport system, important factor was to acknowledge and keep the Triple Helix concept in mind. The Triple Helix concept assumes that in a knowledge society, the potential for innovation and development lies in the hybridisation of elements from academia, industry and government (Stanford University, 2018). The hypothesis is that by taking on new roles and moving towards more collaborative relationships among these three major institutional spheres, innovation policy increasingly becomes an outcome of interaction rather than a prescription from the government (Ibid).

In total, a number of 22 interviewees participated. The selection of interviewees was an iterative process. As mentioned above, the first stage of selection was based on the actor mapping where important actors from the road freight transport sector were identified. However, due to limited time, representatives from all categories could not be interviewed. In addition, there are several participants representing truck manufacturers and the public sector as innovators and institutions are described as important for the system expansion in the LTS theory. Furthermore, during the process of collecting the data, actors that were predicted to enter the road freight sector in connection to a commercialisation of SDVs were identified through being mentioned by the respondents. Thus, the selection of interviewees was expanded along with the process.

The interviews were conducted either in person or through Skype calls, all of them lasting more or less one hour. All of the interviews were in-depth, semi-structured and were conducted using a set of questions prepared beforehand (Appendix I). The questions were open-ended, meaning that they were formulated in a way to encourage the respondent to share their own experiences and point of view, and as the interview went along, questions were added and/or skipped depending on its relevance to the conversation. Semi-structured interviews are commonly used as a part of qualitative research and allows attitudes and questions to be explored in detail (Denscombe, 2014: 265). In semi-structured interviews, the interviewer has a list of topics/themes to be covered and certain questions to be answered. However, the interviewer is flexible when it comes to the order of discussing things. This allows the participant to develop ideas and give detailed descriptions about the topic (Denscombe, 2014: 266).

The structure of the interview in combination with the open-ended questions allowed freedom for both interviewer and interviewee, giving opportunity to explore additional points, change direction of the conversation, and to expand and add depth to the answers (Denscombe, 2014: 287-288). The interviews generated insights about the respondent’s view on introducing SDVs in the freight transport sector, as well as their view on the role of their own organisation. This was facilitating in extending knowledge about general, system-level issues as well as issues related to the specific actor, sector, or organisation.

4.3 Data Analysis

In this section, the methodology for data analysis will be described. The initial analysis of the interview data through thematic analysis using the TIS framework is described below in section 4.3.1 Thematic Analysis of Interview Data. The outcome of the thematic analysis is onward referred to as the interview results and is presented in section 5 Results.

The Sustainability Analysis and the Analysis of Knowledge and Competencies Requirements are further based on the interview results. These methods and how they relate to their corresponding theoretical frameworks are described in further detail in section 4.3.2 Using the Theoretical Frameworks in the Sustainability Analysis and 4.3.3 Method for Analysis of Knowledge and Competencies Requirements.
4.3.1 Thematic Analysis of Interview Data

The empirical data of this study was collected in the form of computer notes and voice recordings from the conducted interviews. In order to analyse and interpret the data, it had to be processed through several stages. The method used for data analysis in this study was based on thematization through thematic analysis.

Thematic analysis is a flexible method that allows adoption in a way suitable for each particular study (Clarke & Braun, 2006: 3). The aim of conducting a thematic analysis is to discover and relate themes in the data to the research questions. Thematic analysis was further considered to be an appropriate method in the context of this study, as it allowed to identify patterns, common themes and contradictions in opinion among a set of actors.

The method of thematic analysis is composed of a recursive process concluded by six phases: 1. Become familiar with the data, 2. Generate initial codes, 3. Search for themes, 4. Review themes, 5. Define themes, and 6. Write-up (Clarke & Braun, 2006: 4). The first phase, Become familiar with the data, was straightforward and involved a processing of the computer notes and the voice recordings. The voice recordings were transcribed and constituted as the fundamental data together with the computer notes. According to Clarke & Braun (2006: 17) a thematic analysis does not demand the transcripts to involve all details of the interview as long as it includes all the essential information. However, since this study is exploratory and the sought answers are to some extent unknown, it was decided to transcribe everything related to the research questions in as much detail as possible.

The next phase, Generate initial codes, was to organise the data by coding extracts of text from the transcripts. The codes used for the transcripts were not decided beforehand, instead they were identified during the process. This is a method called open coding, which was used in order to avoid preconceptions. By using this method, the coding was done in an inductive way which is “a process of coding the data without trying to fit it into a pre-existing coding frame” (Clarke & Braun, 2006: 12). The analysis aims to explore all possible connections related to the research questions rather than only exploring the most common aspects (Clarke & Braun, 2006: 12).

After the coding process was finished, the next phase was Search for themes. The codes were grouped into themes and sub-themes representing groups of codes capturing similar elements of the research questions (Clarke & Braun, 2006: 10). Furthermore, there are two levels of themes; semantic/explicit or a latent/interpretative level, where the semantic/explicit level is suitable for this study. This level aims to analyse the data of what the interviewees have said rather than finding a deeper meaning of what the interviewee could have meant by saying a certain thing (Clarke & Braun, 2006: 13).

After this, the themes were reviewed and reconsidered (step 4 - Review themes) before they were defined (step 5 - Define themes). When the first set of themes were found, the themes had to be reviewed in order to verify whether the themes were logically created from the codes and data, as well as ensuring that the themes gave a fair representation of the data material (Clarke & Braun, 2006: 21). The defined themes then acted as a source of data and a basis for the analysis of the TIS functions. As this study used TIS as a theoretical framework, the TIS functions defined in Table 2 were used to group identified themes. By defining distinct themes, the analysis of each TIS function was facilitated by ensuring that relevant information from the thematic analysis could be presented in a comprehensive way. The content in each theme was then presented (step 6 - Write-up) as TIS function in section and subsections of section 5 Results.

4.3.2 Using the Theoretical Frameworks in the Sustainability Analysis

In order to address RQ3, a sustainability analysis was conducted. The analysis was based on the interview results as well as a systematic sustainability assessment using the SDGs and assessment criteria from the CASI-F framework. The sustainability analysis was making use of three theoretical
frameworks: TIS, SDGs and the CASI-F framework. In this section, it is further described how these theoretical frameworks are linked and operationalised in the sustainability analysis.

The TIS framework and its functions played a central role in the sustainability analysis by defining the system and acting as a basis for assessment. One of the main challenges of the sustainable development discourse was that the concept of sustainability is complex and requires a holistic view. When attempting to assess the sustainability of a whole system, it hence became important to define the system and processes taking place within it. In this study, the Swedish node-to-node road freight transport system was defined using the five TIS functions presented in Table 2 above. The TIS framework further defined the components of the system and puts emphasis on the innovation processes in the system that are relating to a commercialisation of SDVs. Hence, the basis for assessment in the sustainability analysis was the interview results presented as TIS functions in section 5.1 – 5.5.

In order to answer RQ3 and address the question of how a commercialisation of SDVs relate to the UN sustainable development goals, a linkage has to be made between the TIS functions and the SDG targets. As there are a wide range of SDGs and corresponding targets, and not all of them were considered relevant for the scope of this study, the CASI-F framework was used to select a limited selection of relevant SDGs and targets. Those SDGs and targets were thereafter used to analyse possible outcomes and effects of a commercialisation of SDVs in node-to-node road freight transport.

The decision to use the CASI-F framework to support the selection of relevant SDGs was made as the framework aims to bring together the terms Sustainable and Innovation. According to Popper et al. (2017: 19), sustainable innovation systems have a potential to address many of the complex societal challenges that the world is currently facing. This calls for the development of more effective tools and approaches to facilitate better assessment and management of such systems. The diversity of actors involved in sustainable innovation processes was stated to pose a demand of an inclusive and versatile analytical framework (Popper et al., 2017: 23). The CASI-F framework was further supported by familiar concepts from the TIS framework and LTS theory by acknowledging concepts such as socio-technical systems, innovation systems, multi-level perspective, and a transition perspective.

Table 3 below shows a table of the 44 criteria used in the CASI-F framework to assess sustainability outcomes in societal, economic, environmental, government and infrastructure systems. Those criteria were mapped against the findings in section 5 Results in order to identify the most relevant criteria to assess for SDVs in node-to-node road freight transport. However, it was considered important to adopt a critical approach in this process, by reflecting on and identifying relevant sustainability issues that were not explicitly discussed by the interviewees as well.
<table>
<thead>
<tr>
<th>Systems category</th>
<th>CASI-F criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOCIETAL</td>
<td>Population development and composition; Income distribution and class structure; Social security and ageing provisions; Social interaction and communication; Social behaviour; Civil liberties and human rights; Gender, social class and groups equity; Individual autonomy and self determination; Education and qualification; Human health; Individual behaviour.</td>
</tr>
<tr>
<td>ECONOMIC</td>
<td>Production; Consumption; Local trade; International trade; Labour and employment; Financial system; other macroeconomics transformations.</td>
</tr>
<tr>
<td>ENVIRONMENTAL</td>
<td>Environmental protection laws and policies; Resource extraction policy and practice; Protection of renewable resources; Protection of species and ecological heritage; Protection of cultural heritage; Rights of future generations.</td>
</tr>
<tr>
<td>GOVERNMENT</td>
<td>Government administration; Public finances and taxes; New Governance institutions; Political participation and democracy; Conflict control and resolution; Population and immigration policy; Government intelligence; International assistance and aid policy; Industry and Technology policy.</td>
</tr>
<tr>
<td>INFRASTRUCTURE</td>
<td>Settlements and cities; Transportation and distribution; Waste management; Health services; Communication and media; Energy, water and food supply system; other goods supply system; Services supply system; Creation, destruction or modification of research, technology development and innovation (RTDI) institutions/organisations; Knowledge transfer channels; RTDI wiring up and collaborative connections.</td>
</tr>
</tbody>
</table>

**Table 3:** Overview of CASI-F criteria (Popper et al., 2017: 25)

### 4.3.3 Method for Analysis of Knowledge and Competence Requirements

In order to answer RQ4 the interview results have been analysed from a didactical perspective. The analysis in section 7 describes required and desirable knowledge and competencies in the transition towards an autonomous node-to-node road freight transport. This analysis was conducted with a thematic analysis following the steps described by Clarke & Braun (2013: 4). For a more exhaustively description of the thematic analysis, see section 4.3 Data Analysis.

In order to identify knowledge and competencies the writers have looked for the phrases: “We need to learn to...”, “…we need to know more about”, “We need to find insights about...”, “This is a barrier for the development of SDVs”, “There are questions concerning...” and similar phrases in the transcribed interview material. These findings have then been categorized into the didactical questions: “What”, “How”, “Why” and “For who?” in order to analyse the knowledge and what competencies it relates to. The analysis in section 7 is structured in the categories: vehicle technology, digital infrastructure, business development and policy development and decision making. Since these categories were pointed out in the interview results as important areas for the SDV development.

### 4.4 Validity and Reliability

In all research methods, great attention is applied to validity and reliability. These are two of the most acknowledged factors used to evaluate the rigor of a research study (Morse et al., 2002: 14). However, when it comes to qualitative research, lacking the certainty of hard numbers and values, other factors such as overall significance, relevance, impacts, and utility of completed research will also be recognised as indices of rigor (Ibid).

Verification can be defined as the process of checking, confirming, making sure, and being certain. In qualitative research, verification refers to a number of processes used during research to ensure the overall rigor of the study (Morse et al., 2002: 17). As qualitative research can be described as iterative rather than linear, verification mechanisms must be woven into every step of the inquiry. Qualitative
research moves back and forth between design and implementation to ensure conformity among research questions, literature, data collection, and analysis (Ibid). In this section, the main verification strategies used in this study will be further discussed.

4.4.1 Appropriate Sample
The main source of empirical data in this study was generated from the interviews conducted. As the interview data has a large impact on the final result, it was considered important that the sample of interviewees was appropriate, consisting of participants with experience and/or valuable knowledge of the research topic. By ensuring an appropriate sample, the data generated will be reliable and of sufficient quality, constructing a solid product.

In order to get a holistic and comprehensive understanding of the Swedish road freight transport sector, an essential part of this study is to capture information, viewpoints and observations made by a wide range of actors. As mentioned in section 4.2.1 The Interview Process above, it was assumed that actors from academia, industry, and government would play a crucial role in advancing innovation theory and practice. This was especially important as SDVs in node-to-node road freight transport as this is an emerging research field.

In each category of actors, participants were chosen and contacted in consultation with supervisors from ITRL and Trafikverket. The aim was to ensure that every interviewee was of relevance and would be able to contribute with useful insights from the actor category they belong to.

Furthermore, it was considered important to obtain sampling adequacy evidenced by saturation and replication in the interview data. Sampling adequacy implies that a sufficient amount of data is collected in order to account for all known aspects of the research topic (Morse et al., 2002: 18). When conducting the interviews, saturated data and high degree of replication were therefore considered as an indication that the data was being verified, which ensured comprehension and completeness.

4.4.2 Methodological Coherence and Consistency
An important part of any study is to ensure reliability, which can be described as the extent that any measuring procedure will yield the same result again when repeated (Morse et al., 2002: 18). The reliability of this study can be affected by two main factors: it focuses on a rather unexplored area, and the data is to a great extent based on qualitative and semi-structured interviews. Hence, all of the primary data would most likely not be the same if it were to be collected in a similar study in the future. Even if the agenda, the topics discussed, and some of the interview questions were the same in all interviews, it is not possible to yield exactly the same results again due to a number of reasons. This was affecting both validity and reliability of the interview data.

Primarily, as the interview structure was semi-structured, each interview took different directions of discussion. The structured and the order of questions were changed as was considered appropriate to the conversation, and there were different types of follow-up questions in each interview. Hence, it was difficult to get consistency in the interview data as the collected data was affected by context and the participating individual (Denscombe, 2014: 299). It was also important to keep in mind the interview effect, i.e. that what the interviewee was sharing could have been affected by the identity of the interviewer/researcher (Ibid).

When it comes to validity of the data, a known con of qualitative interviews is that the data generated is purely based on what was being said (Denscombe, 2014: 299). It is possible that interview data reflects visions and strategies rather than actual actions and plans in the organisation. In addition, as SDV is an emerging research field, it is safe to assume that the knowledge is constantly evolving. Breakthroughs in technology or legal environment may completely change what is relevant from one day to another.
4.4.3 Ethical aspects

Four ethical principles were used when conducting and planning the interviews in order to ensure an ethical approach in the study. These four ethical principles concern demand on information, approval, confidentiality and use of material (Vetenskapsrådet, 2002: 6). Thus, the interviewees were informed that the participation was optional. Furthermore, information about the topic of the study and the research questions were briefly described as an introduction before starting each interview. If the respondent agreed to, the interviews were recorded. During the interviews, notes were also taken on computer. Regarding confidentiality, names of all participants were excluded. However, names of certain actors are mentioned, although only if approved by the interviewee representing the actor. In accordance with the demand of the usage of material, the transcripts and audio records are not available for anyone outside of the study.

5 Results

This section presents the functions of the TIS framework used in this study. The functions are presented in section 5.1 - 5.5 below, consisting of a definition of each function followed by an analysis of the results from the thematic analysis, as described in section 4.3 Data Analysis.

5.1 Influence on the Direction of Development

The first function addresses mechanisms having an influence on the direction of development. If a TIS is to develop, a wide range of actors have to choose to enter it. Hence, there must be sufficient incentives and/or pressures for the organisations to be induced to do so. This is dependent on various factors such as visions, expectations and belief in the technology and its growth potential (Bergek et al., 2008: 415). External factors such as climate change and sustainability debates also have a big influence on the direction of development of the TIS. Other mechanisms having an influence on the direction of development are e.g. different types of competing technologies, business models, legislations and policies, and articulation of demand from leading customers (Ibid). In this section, results regarding factors influencing the direction of development will be presented and analysed. This includes factors that are controlled by several actors and organisations, as well as capturing general perspectives and strategies for development of SDVs in node-to-node road freight transport. In section 5.1.1 Swedish conditions, specific factors in the Swedish context will be reflected.

One of the main outcomes from the interviews is a prevailing uncertainty among the actors regarding when SDV and driving automation technique will be commercially available. Most actors have been observing a rapid development within the field during the last couple of years and agree that at some point, a commercialisation will definitely take place. Especially in node-to-node road freight transport, as there are strong economic incentives as well as several influential actors facilitating strong technology development. In general, there is a strong consent among all of the interviewees that technology should not be seen as a bottleneck for development. However, it is important to keep in mind that the development is still at a very early stage and hence it is difficult to predict when we can expect a breakthrough. Several actors indicate that it is likely to be some steps before SDVs become commercially available, e.g. applications of SDVs in restricted areas such as harbours, mines or industrial areas.

A few actors imply that it is likely that the pace of development of SDVs and driving automation is overestimated, while the societal impact and the effects of a commercialisation is highly underestimated. Especially in cities and dense urban areas where there is enough infrastructure and capital to fuel development, there is potential for advancements to take place at a very fast rate. Similar, almost exponential development patterns have been observed previously in history - e.g. when mobile phones and the internet became commercially available.
According to an interviewee representing Drive Sweden, the development of SDVs and driving automation can be thought of as four “blocks” - including not only vehicles and technology, but also development within digital infrastructure, business development, and policy development. The interviewee stresses a multidisciplinary approach where actors from different sectors cooperate to facilitate development in all four blocks. As most actors agree that vehicle technology is not currently a constraint for development, it is important that the three other blocks progress accordingly.

One of the interviewees from the truck manufacturing sector expresses that a transition towards a more automated road freight transport system would require many of the involved actors to rethink their long-term and strategic objectives. For an instance, many truck manufacturers have a history of producing combustion engines as their main operation and are now facing a challenge in breaking new ground in SDV and driving automation technology. One of the interviewees states that this shift towards a more autonomous and digitalised transport system brings a need for strategic thinking and cooperation’s with other actors. Historically, industries have great experience and confidence in the processes of solving technical issues within the organisation. Issues regarding digital infrastructure, cyber security, and moral and ethical dilemmas are now too starting to become highly relevant for such actors, which is expected to be challenging as these problems cannot be solved using the same actions and procedures as purely technical problems. Hence, there is a need for new approaches.

In the process of interviewing several influential actors in the Swedish node-to-node road freight transport system, it becomes clear that most of the interviewees can sense an uncertainty regarding the problem ownership and discourse. Several interviewees raise questions regarding who should be responsible for solving different types of questions related to development of SDVs and driving automation. Further, the interviewees agree there are several insecurities and unresolved issues related to how society will accept SDVs and driving automation technology - how will it be used and what role will it have in society? One of the interviewees believes that this has to become more clear for the government before a commercialisation could take place. It is stated that in general, issues regarding cyber security, ethical and moral dilemmas, as well as system level impacts have not yet been explored enough. An interviewee further states that this is in many ways a political question, as politicians have varying opinions in this matter.

However, one interviewee underlines that despite the challenge, the development of SDVs comes with a great opportunity to change the transport system and society to the better. Big infrastructural systems like the transport system are not easy to transform, but with the techniques currently emerging there is a potential to do so. Therefore, the interviewee means that it is important to focus on creating a better and more sustainable system than we have today.

Moreover, sustainability is becoming increasingly important for companies. According to one of the interviewees from the truck manufacturing side, the willingness to pay for socially and environmentally sustainable solutions have steadily increased over the last years. Even if such sustainable solutions or actions might be more costly or less profitable, more and more companies see it as a way of ensuring long term economical sustainability.

5.1.1 Swedish Conditions

This section reflects on specific factors in the Swedish context that could affect the process of making SDVs commercially available. According to the interviewees, the main factors distinguishing the conditions for SDVs and driving automation in the Swedish node-to-node road freight transport system can be summarised as an organisational climate supporting innovation, and the fact that some of the world’s leading truck manufacturers (i.e. Scania and Volvo) are based in Sweden.

One paramount aspect that almost every interviewed actor highlight about the Swedish conditions is the Swedish innovation climate. It is described as a well-recognised strength of the Swedish marketplace, in small start-ups as well as in big commercial business activities. Several actors believe
that the Swedish framework to facilitate interactions between actors on various levels is quite unique. It offers possibilities for businesses and the private sector to partner, as equals, with public authorities, academia, and the governmental sector. This type of flat organisational structure allows actors to disregard hierarchical structures and to freely innovate together in partnerships. By promoting pilot projects and demos with various actors involved, such partnerships and collaborations are prophesied to bring unparalleled value to the commercialisation and implementation process of SDVs and driving automation technology.

In general, Sweden seems to be a country that is perceived as open-minded when it comes to adopting new technological trends according to the interviewed actors. Several interviewees state that Swedes seem to be exceptionally open-minded and pragmatic, making Sweden a good country for introducing new techniques through testing, pilot projects, and demos. However, interviewees further state that this might change in the future. There has not been any incidents or accidents related to SDVs or driving automation in Sweden so far, and if it does there is a risk that the acceptance decreases drastically.

Moreover, one of the interviewees mentions the fact that the Swedish market is good at “taking the bull by the horns”, i.e. that there is a custom in the process of knowing that a big transition is about to take place and that this transition should be facilitated in the best way possible. Two other interviewees confirm this further by mentioning that there is a strength in the Swedish context as governmental authorities are proactive and well used to the process of venturing and setting ambitious and progressive objectives, e.g. when it comes to climate protection, environmental policies, technology, and innovation. They state that Swedish decision-makers are generally apt to try on new concepts, aiming to be at the forefront of new technology.

Sweden accommodates two influential actors in the global truck manufacturing market - Scania and Volvo. There is hence a big opportunity for Sweden to be a leading actor in developing SDV and driving automation technology in the freight transport sector. According to a trade association for road carriers, Sweden has many necessary qualifications to be able to contribute to set an example for the rest of the world with SDVs and driving automation in freight transport - e.g. leading truck manufacturers, ability to form a robust regulatory framework, collaborations between key actors both nationally and internationally, and trade associations. The interviewee believes that if politicians, authorities and decision-makers decide to pioneer in the SDV and driving automation field, Sweden can remain one of the countries leading the transition.

Likewise, several of the interviewees stress the fact that Sweden is headquartering leading networking and telecommunications companies, e.g. Ericsson and Telia. Such companies are strong actors in digitalisation and 5G, which in turn are important parts of SDVs and driving automation. The role of digital infrastructure, and its relationship to SDVs and driving automation, will be more thoroughly described in section 5.3.2 Digitalisation and Digital Infrastructure below.

When it comes to non-organisational factors, such as the physical infrastructural system, the fact that Sweden is a relatively big and sparsely populated country is mentioned as both an opportunity and a weakness. One of the interviewees mentioned that since Swedish roads are not very congested, the very first attempts to run SDVs on public roads might be eased. On the other hand, this could also be a drawback in the commercialisation process as it could be financially more challenging to establish 5G connection along every road stretch. Trafikverket also mentions the fact that Swedish road infrastructure seem to be rather inconsistent, with several different types of road shapes and conformations.

Another factor restraining an introduction of SDV that was recognised by a number of interviewees is the regulatory system. During innovation processes, the regulatory system is probably an inherent weakness in any geography as it is usually slow to respond and react to changes in society. But given
the Swedish innovation climate and the platforms and actor forums that have emerged the last 2-3 years, there is a high level of engagement and a good opportunity to steer regulations in a good way. Regulators in Sweden have good possibilities to be involved in the discussions regarding SDVs which is an important precondition for the regulatory framework to be able to respond to changes in society in a positive and timely fashion.

5.2 Market Formation and Driving Forces

For a TIS that is emerging or in a period of transformation, markets may be developing, transforming or not existing (Bergek et al., 2008: 416). Potential customers may not have specified their demands as they are lacking capacity to do, and uncertainties may prevail in many dimensions. Yet another important factor to keep in mind is that institutional changes, e.g. the formation of standards, is often a prerequisite for markets to evolve (Ibid). This section assesses the general state of the market for SDVs in node-to-node road freight transport as well as driving forces.

The interviewees mention that the implementation of SDVs is a great opportunity to change the society. “With the development of SDVs and driving automation, we have the same chance to transform society as when the car first came” states an interviewee, meaning that there are a lot of possibilities in the product development, but in order to meet the SDGs there is a need for a better system as whole. For that, it requires rules and a common goal. According to a truck manufacturer interviewee, the market will change with respect to various factors such as roles, as well as what truck manufacturers are offering, and where the profits and possibilities of influencing the market is. With SDVs, a whole new market of possibilities opens up, new actors such as telecommunication and power supplier companies can make new businesses.

The interview data reveals that many of the strongest driving forces behind the SDV and driving automation development relate to different types of market forces and economic incentives. The freight transport industry is in general described as a price-sensitive industry with high pressure and small margins by many of the interviewed actors. The interviewees agree that SDVs and driving automation have clear commercial values, and one interviewee even argues that in the future, SDVs could be a question of survival for many industries in the transport sector.

As the driver’s cost constitutes a large portion of the total transport cost, the most obvious economic incentive behind SDVs and driving automation is believed to be the possibility to totally eliminate that expense. This, in combination with a shortage in the number of truck drivers, presents a clear profitability case and market demand for this type of technology in the road freight transport sector. One of the interviewees representing a truck manufacturer stresses the fact that “If there is one truck manufacturer that manages to eliminate the driver cost, then they will have such a clear competitive advantage that all other competition will fade”. The interviewee implies that this is a strong incentive for every truck manufacturer to be involved and up to date in the development of SDVs at an early stage. Furthermore, one interviewee representing a shipper mentions that SDVs will likely simplify long distance transports significantly, as it would eliminate needs and expenses related to having a driver, e.g. required resting times and change of drivers when a shift is over.

One of the interviewees representing a truck manufacturer further mentions the production cost of vehicles as an economic driving force. With an SDV, it will be cheaper to design and manufacture the truck as there is no driver’s cabin. The driver’s cabin is usually the most complex part of a truck and different clients have different requirements on how it should be modelled and framed. A truck without a driver’s cabin allows a more standardised manufacturing process which would greatly reduce the total cost of a truck.

As several interviewees mention that the development of SDVs and driving automation is greatly governed and stimulated by market forces, it is discussed whether it has to be this way. What if
authorities and governmental agencies took a more proactive role? According to Trafikverket, the development of SDVs should not be a choice for them, as the companies and market itself must get to decide on what technology that should be implemented.

Standards and standardisations are further being raised as important issues of the development of infrastructure in general. One of the interviewees from a freight forwarder company highlights the issue of infrastructure developed for a specific vehicle brand or specific demands on vehicles in certain municipalities. The interviewee raises the technology for geofencing as an example of this. Geofencing is a technique used to create a virtual geographic boundary, enabling software to trigger a response when a vehicle enters or leaves a particular area. If geofencing are to be used to i.e. set speed limits, the interviewee stresses the importance of a standardised solution that applies to all vehicles. It is a problem if every municipality come up with their own geofencing models as freight forwarders have trucks running all over the country. Hence, universal standardisations for the road freight transport industry are highly requested by the freight forwarders.

Furthermore, as freight forwarders often have international transports, they wish to see standards applying not only on a national level but in Europe. One interviewee implies that this is a topic of high importance that should be dealt with at an early stage in order to avoid problems in the future. There is a variety of rules within Europe already, such as requirements on the length of a truck and winter tyres. These demands differ between countries but are considered manageable as of today. However, if SDVs and driving automation entail adding diverse rules to that list, the situation could get complicated.

5.3 Entrepreneurial Experimentation

A TIS typically evolves under considerable uncertainty in terms of technologies and markets. A way of reducing this uncertainty is through different types of entrepreneurial experimentation (Bergek et al., 2008: 415). This implies probing into new technologies and application, as well as a social learning process. When analysing this function, it is important to consider different types of experiments taking place, new entrants as well as the breadth of technologies available. In this section, such factors will be expressed in terms of technical opportunities and barriers related to digital and physical infrastructure in the node-to-node road freight transport system.

Related to the topic of entrepreneurial experimentation, the interviewees repeatedly mentioned things concerning road infrastructure, digitalisation and digital infrastructure, and electrification and charging infrastructure. These will be presented in section 5.3.1 - 5.3.3 below.

5.3.1 Road Infrastructure

When it comes to road infrastructure, actors from authorities as well as truck manufacturers agree that it is unlikely to demand extensive changes of the current road infrastructure systems. The interviewees argue that this would be expensive and time consuming, and hence none of the actors are deeming that physical infrastructure should be adjusted to facilitate SDVs and driving automation at the moment. Instead, the interviewees believe that technological advancements will enable SDVs to cope with existing road infrastructure conditions. Interviewees representing truck manufacturers and authorities state that the SDVs will be able to drive in the same lanes and at the same speed as any other vehicle.

According to an interviewee representing a truck manufacturer, “a separated lane for SDVs could ease the usage of SDVs but would be way too costly”. Moreover, the interviewee adds that “a technological development to make SDVs manage current road infrastructure would be cheaper and easier than building new lanes or deem other extensive infrastructural changes”. Further, respondents from authorities mean that a dependency of a certain road infrastructure would imply that the whole world would need to agree on one solution in the future, which would be way too expensive and an almost
impossible mission. Hence, it is clear that SDVs and driving automation technology need to be altered to manage any type of physical environment, and not the other way around. A spokesperson from an authority argues to put “as much intelligence as possible within the vehicle”. However, some degree of standardisations for physical and digital infrastructure will be needed in order to make the infrastructure manageable for truck manufacturers and freight forwarders.

Several actors, mainly freight forwarders and truck manufacturers, raise the topic of how loading and unloading will be carried out at terminals when there is no driver to do the job as it is today. One of the interviewees representing a truck manufacturer mentions that one of the difficulties is to adapt the delivery times as it could be a short time frame of when the goods can be delivered due to the workers’ schedule at the terminal. Furthermore, loading and unloading caused many discussions during the interviews.

The interviewee from the supplier company further states that the shape of the terminals or central stocks will most likely also be impacted by SDVs. For example, the interviewee argues that if the SDV is electric one will probably want charging spots by the stock or terminal. Moreover, more change for terminals may come in place as an increase of road transport is commonly mentioned as a threat and joint loading is pointed as one of the solutions. Along with this, transhipment terminals are needed, and an actor from a fuel retailing company believes that those could possibly be located in connection to petrol stations as they are strategically located along the road transport network.

5.3.2 Digitalisation and Digital Infrastructure

“This is another way to describe the development. It is a total digitalisation of transport work” states an interviewee representing a coordination network who believes the potential of digitalisation is big. According to a spokesperson from a research institute, “infrastructure is built on the assumption of human judgement”. Therefore, what is seen by the human eyes also need to exist in digital form as an interviewee representing an authority point out. Because of this need of digitalisation a lot of questions follows; Who shall have access to data? How can data be shared safely? How can we utilize this new possibility to optimize flows of transport?

According to several interviewees, one of the main opportunities related to digitalisation is that it enables optimisation of transport flows. Freight forwarders argue that data and digital infrastructure enables better planning and greater opportunities for joint cargo and less empty trucks running. An interviewee further argues that digitalisation also enables proactivity and will promote collaborations and actors working together.

Remote controlled SDVs have been introduced by some truck manufacturers. One of the interviewees representing a truck manufacturer states that it is possible that one single person will be able to have control of 10 to 20 vehicles from a control tower with this technology. According to the interviewee, remote control will be needed in complex urban areas such as roundabouts and road construction, but not on highways. The interviewee further elaborates that planning ahead will be necessary in order to enable to focus the attention of the person in the control tower on one vehicle at a time.

Another interviewee further states that a possible limitation for SDVs in freight might be in the telecommunication network. The interviewee however argues that currently available 4G network connections are technically feasible as long as the capacity is developed. The interviewees within telecommunications further argue that 5G is needed to obtain latencies short enough to operate good enough for remote control. Furthermore, an interviewee representing a telecommunications actor stresses that SDVs cannot be completely dependent on network connection in order to function, as there could be a blockage in the connection. However, it is stated that an SDV also have to be able to exchange information with surrounding vehicles, infrastructure and actors. This is important since some information, e.g. speed limits and information about congestion ahead might be transmitted to the SDV digitally.
There is a question concerning in what geographical areas of Sweden 5G for remote control should be developed. An interviewee representing the public sector argues that 5G network will be developed on commercial grounds. However, according to a telecommunications actor, this is a challenge in such a large and sparsely populated country as Sweden. 5G technology is more expensive than e.g. 4G as the frequency band is more costly - higher frequency implies faster data transfer but shorter network range. The interviewee believes that 5G network will be developed around the bigger cities at first, as there is a higher demand in urban areas, and then continue to be developed where it is profitable. The interviewee reasons that there could also be solutions such as subsidies and/or government funding in order to ensure 5G network along all road stretches.

Furthermore, another challenge is to elaborate how such information regarding traffic lights, signs, congestion, road conditions, etc. should be transmitted digitally through the telecommunications network. The information needs to be collected and available for relevant actors. A respondent at the telecommunications company believes that it is probable that several actors from different disciplines are to be involved in solving this challenge. However, an interviewee from the academy believes that this is an example of a challenge that needs to be handled by the public sector. The interviewee argues that this is due to the fact that all vehicles should have same possibilities to utilise the roads, hence it is important that techniques for communication between infrastructure and SDVs is standardised.

One actor from the public sector that is already involved in the process of introducing SDVs on commercial roads is Trafikverket, the Swedish transport administration. Trafikverket has started to develop the foundations of digital infrastructure for communications between vehicles and infrastructure. One of the interviewees states that, “until 2021, all data regulating the usage of roads will be digitally available for vehicles (for example velocity, road type). Hence, everything that you can see with your eyes will be digitally available for the vehicles”. The interviewee further states that developing the digital infrastructure will not only benefit the user of vehicles. By data being exchanged between vehicles and the digital infrastructure will provide Trafikverket with information and material that can be used for further advancing and improving the road infrastructure.

When it comes to sharing of data, there are more issues to consider. Data security and cyber security are such challenges, being stressed by several of the interviewed actors. This includes questions such as, who should own and have access to certain types of data? What price should data have? One interviewee from a truck manufacturer believes that it is going to take time before this type of challenges concerning data will be resolved, as actors are traditionally careful with sharing data. Depending on which type of data it is, it could be sensitive. Many interviewees believe that the information communicated by vehicles is sensitive if managed with wrong motives. In order to prevent this, an interviewee representing a telecommunications company means that every vehicle must have an identity that can be verified. If the vehicle has an identity it is possible to know where the data is sent and thus, enable safe data exchange.

Another challenge is how data should be shared between actors that have no contractual relationship. The interviewee at a telecommunications company gives an example of a case where a truck needs information from a traffic light. It is possible that a freight forwarder managing the truck has a contract with a transport administration authority such as Trafikverket, enabling safe data exchange between physical infrastructure and the truck. The interviewee further argues that there must be a safe data exchange between non-contractual relations as well. For example, foreign SDVs from e.g. Europe must be able to interact with the digital infrastructure as well. Therefore, the interviewee states that it is important to be able to transfer data between vehicle and digital infrastructure safely. This could be done by identifying individual vehicles as well as creating micro contracts between actors at all time.
5.3.3 Electrification and Charging Infrastructure

The interviews reveal that the relation between electrification and SDVs in node-to-node road freight transport is a controversial and well-debated topic among many actors. Electricity is discussed both in the form of electric roads, batteries, and charging infrastructure. Some actors indicate that there are clear synergies and positive effects by combining driving automation and electrification, while some actors argue that the two technologies just happen to coincide in time.

One of the main challenges related to node-to-node road freight transport according several interviewees is the risk of peaks of demand in the electricity grid. However, the interviewees representing the power supplier company do not see any major grid or network related risks in relation to SDVs in a mid-term perspective. Regarding issues such as peaks of demand and other technical issues in the grid, there are already plans, both internal plans and an external plans with the state-owned electricity transmission system operator - Svenska Kraftnät. As SDVs will be introduced gradually, the interviewees believe that it will be possible to meet the increasing demand through planning.

New kinds of collaborations have also been discussed. An interviewee representing a telecommunications company implies that there are possibilities for collaboration between charging infrastructure and telecommunication. The 5G will most likely require a dense infrastructure between transmitters and base stations, and it is discussed that they will also require electricity. Hence, it may be beneficial to coordinate the expansion with power suppliers. Nevertheless, transmitters may as well be placed in lampposts, and no coordination with electricity companies have yet been discussed.

5.4 Key Actors and Actor-Network Structure

Actors and networks of actors are important components playing a crucial role in the development of any TIS. As the road freight transport system as well as the transport system in general are expected to undergo immense changes if a commercialisation of SDVs and driving automation was to take place, this section provides an analysis of key actors and especially significant actor-networks of the TIS of SDVs in node-to-node freight transport. A combination of the TIS framework, the LTS theory and ANT is applied to assess and evaluate the qualitative findings of this study.

A TIS encompasses a variety of different actors in the sense that they pursue different innovation strategies and/or control a set of different resources. Based on Geels (2001: 1258) elements of socio-technical configuration in transport, actor categories involved in the transitional process towards driving automation in node-node road freight transport are identified. The elements relate to finance, regulations and policies, road infrastructure, vehicle (e.g. body and control systems), fuel infrastructure, market and user practices, maintenance, and industry structure (Ibid). The identified actor categories either correspond with or have the ability to impact one or several of these elements. These actor categories are shown in Table 4, along with examples of actors from each category.
### Table 4: Actor categories.

<table>
<thead>
<tr>
<th>Actor category</th>
<th>Example of actors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supplier</td>
<td>Lidl, IKEA</td>
</tr>
<tr>
<td>Truck manufacturer</td>
<td>Volvo, Einride, Scania</td>
</tr>
<tr>
<td>Public sector</td>
<td>Trafikanalys, Trafikutskottet, Regeringskansliet</td>
</tr>
<tr>
<td>Power supplier</td>
<td>Vattenfall, Svenska Kraftnät</td>
</tr>
<tr>
<td>Fuel retailing company</td>
<td>OKQ8, Preem</td>
</tr>
<tr>
<td>Freight forwarder</td>
<td>DHL, Postnord, DB Schenker</td>
</tr>
<tr>
<td>Terminal and warehousing actor</td>
<td>DHL</td>
</tr>
<tr>
<td>Academia</td>
<td>KTH</td>
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<tr>
<td>Research funder</td>
<td>VTI</td>
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<tr>
<td>Telecommunications company</td>
<td>Ericsson, Telia</td>
</tr>
<tr>
<td>Municipality and county council</td>
<td>Göteborgs kommun, Region Skåne</td>
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<tr>
<td>Coordination networks</td>
<td>Drive Sweden</td>
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<tr>
<td>Technical consultancies</td>
<td>ÅF</td>
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</tbody>
</table>

The actors having a particularly big influence on the development and expansion of a system are defined as system builders in the LTS theory (Summerton, 1998: 25-26). These could be innovators of new technology, engineers, funding agencies and political institutions. Thus, the system builders of the actor-network of SDVs in node-node road freight transport could be considered as key actors.

The innovative truck manufacturers have a strong vision for the development and are determined to fulfil the development and implementation of SDVs. Along with the development of SDVs, technologies such as digitalisation are becoming increasingly important. Thus, truck manufacturers have a strong influence on the structure of the system as this require an expansion of the system border for road freight transport. This is a clear indication that truck manufacturers have succeeded in taking control over the development.

Moreover, the public sector is also an important key actor. The public sector has the power to make crucial decisions that could influence the development of SDVs remarkably. In addition, telecommunication actors and coordination networks could also be seen as key actors. According to an interviewee representing a coordination network, the reason behind the creation of the network was the need of enabling actions from individual actors as there was so much happening on the technical side of the development of SDVs. Cooperation between these individual actors could make it possible to increase their influence in the development.

Furthermore, actors within the TIS are characterized by a certain division of labour. This means that we may typically identify an ‘innovation value chain’ or rather innovation networks with different types of actors (firms) focusing on different innovation tasks. In this system, digitalisation and vehicle functions are such examples. Thus, telecommunication actors are a part of the system builders for digitalisation and could therefore be described as a key actor. The roles of these actors are further examined in the next section, 5.4.1 Public Sector.

#### 5.4.1 Public Sector

The public sector comprises of both public services and public enterprises. It involves institutions, authorities as well as the government. The interview results reveal that in the commercialisation
process of SDVs in node-to-node road freight transport, the public sector is believed to be one of the most important and influential actors. Several of the interviewees mention the role of the public sector as highly important as they have the ability to impact and influence the behaviours of other actors. In this section, it is further elaborated how the public sector can engage in issues regarding SDVs and driving automation in node-to-node road freight transport, as well as how politics is influencing the commercialisation process.

The Swedish government has presented a national freight transport strategy, describing the desired direction of the development of freight transport. According to the Swedish government office, Regeringskansliet, the development of policies and strategies or involves collaborations with other departments, authorities, as well as representatives from the industry. The strategy acts as a basis for decisions made by other governmental authorities, and states that Sweden should aim to be a leading country within innovation as well as in meeting capacity and sustainability challenges.

Currently, the role of authorities in Sweden is mostly informative - informing society and the private sector about legislations, visions and strategies. One interviewee believes that with a commercialisation of SDVs, authorities will have to take on a more controlling role - ensuring that physical as well as digital infrastructure systems are functioning. This is expected to be needed as the road transport system may become more of a unified system rather individual vehicles operating separately. Parallels can be drawn to the train transport system, where there is usually a national or regional system operator. According to the interviewee, actors such as municipalities are already discussing what their future role and approach should be as SDVs start running on public roads.

Trafikverket is currently investigating what role they can have in managing data and digital infrastructure. Currently, companies do not generally wish to share their data which is preventing the possibility of an optimisation of traffic flows. Trafikverket is therefore investigating how a system of open data could be constituted. According to the interviewee, there are two types of data sets among freight transport; data owned by the truck owner, which includes information about routes, and the data owned by the shipper, which is information about the goods inside the truck. Moreover, interviewees representing Trafikverket mean that these data sets need to be further investigated as there are different owners and the data is collected in different ways and in different systems, and could therefore not be collaboratively collected that easily. It is further being discussed on a European level how to standardise the management of the data. However, an interviewee also questions if this will lead to a more optimised flow or if it is better as it is, before intervening into the already relatively well-functioning flow in the node-to-node freight transport.

5.4.2 Truck Manufacturers

Truck manufacturers can be defined as manufacturers of trucks or other technical equipment. A few interviewees believe that truck manufacturers may develop into tech-companies as the development of SDV emerge. It is mentioned that truck manufacturers might come to further develop their role and act as system operators in future. Several truck manufacturers developing SDVs and driving automation technology are currently responsible of facilitating all the software and hardware required for the manufacturing and operation of SDVs. Although, an interviewee implies that this is necessary in the initial stages of development. As the SDVs become established on the market, such tasks might become outsourced.

5.4.3 Transport and Transport Services

Suppliers are defined as the actors purchasing transport services. Additionally, freight forwarders are defined as actors organising shipments for individuals or shippers in order to get goods from a producer to a final destination, in this case a terminal. Road carriers are defined as the workers moving the goods when contracted by a freight forwarder.
The future role of road carriers is a topic that is debated by some interviewees. Some argue that the road carriers will not be needed once the road freight transport is fully automated and freight forwarders and/or truck manufacturers could take over their role of driving the truck by using the technology of remote control. However, the interviewee representing the trade association for road carriers argues that the role of road carriers stretches far beyond just driving the vehicle. In addition, road carriers handle tasks such as operating licenses, education, and customer service. They have valuable knowledge and experience from the industry that truck manufacturers and freight forwarders are lacking.

5.4.4 Emerging Actors
Emerging actors are defined as companies and organisations that did not have a role in the traditional road freight transport, but are aiming to enter the system as the SDVs are being implemented. The actors defined as emerging actors in this study are telecommunication actors, power suppliers and fuel retailing companies. Telecommunication actors are defined as the actors managing or operating the exchange of information between communication participants. Power suppliers refers to actors supplying electricity. Additionally, fuel retailing companies are defined as actors managing the retail of fuel, i.e. OKQ8 and Preem.

As the negative environmental impacts related to fossil fuels are becoming widely known, an interviewee from a fuel retailing company has started to work towards exploring alternative fuels. Thus, as the core business of fuel retailing companies (providing fuel) will decrease, they will probably be able to expand other businesses, such as regular maintenance, package distribution as well as emerging as an electricity provider. Hence, more cooperation with power supplier companies will be needed. By looking at current trends and technological development, a lot of factors are pointing towards a more electrified transport system. Furthermore, the interviewee states that they are trying to identify what kind of possibilities there are to create new business opportunities in the future as well as exploring their own role and how they can contribute to facilitating future vehicles and mobility services. The concept of providing charging and electricity for electric vehicles is not completely unfamiliar to the company, as the fuel retailing company already has started to develop a business in selling electricity to private customers. The fuel retailing company already has fuel stations for commercial trucks and heavy vehicles, so called IDS-stations. IDS is an international network and if the future holds a large share of electric vehicles in node-to-node freight transport, it is possible that those stations could also supply charging infrastructure and electricity.

Interviewees representing a power supplier states that the company has started to look into charging infrastructure and electrification of the transport system. The company engages in other electrification projects as well. For example, they are involved in the e-road Arlanda project which is a part of Trafikverket’s pre-commercial innovation procurement for development of electric roads. The interviewees from the power supplier company state that they are involved from a research and development and technology proof of concept perspective. The interviewees further state that they are not naturally a key player neither in freight and logistics or in SDV and driving automation, but that they are interested to get involved as soon as questions about energy supply becomes a part of the discussion regarding SDVs. One such question to be answered from a power supplier could be e.g. "what kind of energy planning do the driving automation service providers need?". By answering such questions, the power supplier company can start to see how they as well as other similar companies can be involved in the process of introducing SDV and driving automation applications on a commercial level.

5.4.5 Coordination Networks
Coordination networks are defined as actors facilitating coordination and cooperation between actors. The last couple of years, new types of networks and organisations for coordination and cooperation have been developing in the transport sector. CLOSER and Drive Sweden are two examples of such
networking programs initiated by Lindholmen Science Park being frequently mentioned by the set of interviewees participating in this study.

An interviewee representing the program called CLOSER describes their role as being a neutral facilitator in order to connect various actors from industry, business, and municipalities in order to discuss common challenges and issues within the freight transport system. By facilitating assemblies and roundtable meetings, the goal is to facilitate mutual learning experiences and to identify further areas where a collaborative approach is needed in order to increase transport efficiency. Drive Sweden is a similar program started by the same organisation, with the aim to promote and enable the transition to a more autonomous transport system for both people and freight. This is mainly done by promoting partnerships and collaborative projects.

5.4.6 Actants

The technology of SDVs in its different components can be seen as important actants. Furthermore, as technology is said to be a main actant it must according to Latour (1996: 373), be able to make actions affecting the network or influence other actors or actants to make actions, which in turn will impact the network. This raises questions of how the technology can affect the system and whether it can be seen as several actants or one. Digital infrastructure, charging infrastructure, control towers and technology in the vehicle have all been mentioned. Some interviewees imply the development of SDVs to be other words of describing a digitalisation of transport work, which indicate digitalisation as a powerful actant. Charging infrastructure however has not yet become an actant of influence.

An interviewee implies that it is not desirable to construct a vehicle that requires communication unless it will be needed due to regulation. If the person in the control tower will get the responsibility of the vehicle then digitalisation infrastructure and telecommunication actors could have a major influence on the possibility of implementing SDVs on public roads. However, the digitalisation plays other important parts as it could enable data exchange between actors. While the control towers are dependent on a well-functioning 5G net, the data exchange is not only technology dependent as it requires a willingness of sharing data, standardisation of data format and coordination between actors.

5.5 Dynamics and Incentives in the Actor-Network

This function concerns dynamics and incentives in the network of actors, as well as the knowledge base and evolution of the system. Factors affecting the dynamics and incentives are presented in sections 5.5.1 - 5.5.4 below.

Further, the knowledge base of the TIS is an important part of how the rest of the system is functioning and hence, a lot of effort will be put on analysing factors and mechanisms affecting learning processes of actors. In order to facilitate a commercialisation of SDVs in node-to-node road freight transport, it is of high importance to explore how activity systems need to transform and adjust to SDVs. In addition to the TIS framework, activity theory will therefore be used to examine common interests as well as contradictions within and between organisational activities of different actors.

5.5.1 Future Roles of Actors

According to several interviewees, a commercialisation of SDVs in node-to-node road freight transport system is likely to cause a shift in the dynamics between involved actors. Some actors might become more or less influential, while others might experience changes in their roles. Hence, it is of importance that actors in the Swedish node-to-node road freight transport system continuously adapt their roles as the system evolves. Interviewees representing a power supplier company mention that they are expecting to face several changes related to a commercialisation of SDVs, opportunities as well as threats. In order to benefit from the development of SDVs, the interviewees emphasise the
importance of being able to predict how other actors’ business models will develop. As an example, if a power supplier were to become a key investor of highway electric road systems, it could imply a great business and profits. On the other hand, if other actors’ business model were to abruptly change, the electrified highways may become a great economic loss instead.

Another aspect that may bring significant changes to the dynamics of the actor-network is related to business models and truck ownership. A representative from a trade association for road carriers states that a commercialisation of SDVs might imply that the ownership of the trucks change. Currently, trucks are typically owned by road carriers. With SDVs in node-to-node road freight transport, the interviewee argues that the owner takes a higher economical risk as SDVs are technically more complex. Thus, it may become more common for road carriers to lease a truck from the freight forwarder or truck manufacturer.

The small margins in the industry further makes it difficult to make large investments and/or focus on long-term development, according to interviewees from the freight forwarding side. In Sweden, the road carrier industry is mainly organised by small companies. The interviewee from the trade association for road carriers estimates that approximately 90% of Swedish road carriers own five or less trucks. For small organisations, it is more difficult to make large initial investments in SDVs. In order to make freight forwarding with SDVs feasible at the initial stage, shippers might have to be willing to pay more for their transportation of goods. Furthermore, a respondent from a trade association for road carriers implies that it is difficult for them to be at the forefront of technology development, thus they will be ready to use and test the SDVs once it is ready and the regulations have caught up.

5.5.2 Policies and Legal Framework

It appears that many actors believe that regulations are an important issue. According to one interviewee representing a coordination network, “technology has come a long way, while operational processes such as regulatory information and digitalisation need to be improved to make it work”. Policies and legal frameworks are therefore considered to be crucial in order to enable SDVs and driving automation technology on the roads. Regulations and economic restrictions will also play an important role in preventing negative externalities from SDVs, such as increased total transport work. According to an interviewee from a freight forwarder company, regulations are the solely most important mean to be able to reach the best solution for the society and facilitate cooperations. The interviewee believes that truck manufacturers would not cooperate unless they have to, otherwise they will only focus on their own technical solutions and what is best for their company.

One of the interviewees representing a trade association for road carriers views regulations as a current barrier for the commercialisation of SDVs in node-to-node road freight transport. It is argued that politicians have not been focusing enough on regulations for road transport the last couple of years. The interviewee further states that politicians are generally positive to new technology. However, clear and consistent regulations must be in place before road carriers can make investments.

Currently, one of the main challenges regarding regulations is stated to be the Vienna convention on road traffic, stating a need for every vehicle having a driver capable of being in control. According to an interviewee from a coordination network, it has been suggested that in Sweden this challenge could be solved by adding a remote controller as a driver capable of being in control.

On the truck manufacturer’s side, one interviewee believes that technical development could be facilitated by eased regulations, i.e. by making it easier to conduct big demonstration projects. Several interviewees mention the importance of regulations to come in place in order to know what to develop and what to prepare for. Although, a truck manufacturer interviewee further argues that it is also important “to wait with establishing regulations until we know which technology that will work and
how to make things as good as possible. Regulators need to be open to all possible solutions, even those they do not believe in”.

When it comes to limiting the traffic, many actors mention regulations in different forms to be the only solution to avoid an increased amount of traffic as the transport becomes easier and probably a lot cheaper. A truck manufacturer raises the issue with free returns and fast delivery. The interviewee thinks that showrooms could decrease returns of goods, and question whether it would be a possibility to regulate terminals by the state or municipality. More specifically, make actors deliver their goods to the terminals, not allowing them to do direct home deliveries, and let the public sector arrange the last mile and enable joint loading.

An interviewee from a trade association for road carriers states that liability is an important issue. In a recent Swedish governmental investigation, the owner has been suggested to be responsible and liable for SDVs in a situation of an accident or incident. The interviewee believes that it would be better for the truck manufacturer to be liable. The interviewee further claims that it is unreasonable to demand that the vehicle owner should have the capability of analysing the vehicle and its hardware, as they may have to. This responsibility should instead rest on the truck manufacture, as they are believed to have more assets and competence to do so. Although, another interviewee personally believes that it will be difficult for the public to accept a regulation with no individual person responsible for an accident.

One of the interviewees representing the public sector argues that the development for SDVs in node-to-node road freight transport does not mainly depend on implementation of regulations, it is rather about making the public and market to work towards a common goal. Moreover, there are means of actions other than regulations that could be used to control the development, such as investments, budget, organisation, and ambitions communicated by the government. It is argued that these kinds of actions could have a major effect on the development as investments on infrastructure and research will impact the technical solutions. However, the interviewee also implies that the government tries to keep a neutral approach to technical solutions in order to enable a market driven development.

5.5.3 Coordination and Cooperation

An interviewee representing a freight forwarder company states that there is little contact between freight forwarders and truck manufacturers, as they make their technical/digital solution and provide their customers - i.e. the road carriers. The interviewee believes that it would be reasonable for truck manufacturers to involve the freight forwarders and their systems in the process to a greater extent.

Today, mostly big companies are observed to be involved in the cooperation in SDV projects. Therefore, one interviewee from the telecommunications sector argues that a variety would be beneficial and hopes for more smaller companies to get involved. Furthermore, an interviewee representing a power supplier company argues that the transition will require strong relationships, for example in order to electrify Sweden. Business to business partnerships as well as partnerships towards platforms could be a good way according to the interviewee.

Cooperation is also stated to be necessary in order to sort out legal issues, such as the question of responsibility and liability as mentioned previously in section 5.5.2 Policies and Legal Framework. An interviewee from the telecommunication sector means that it is also necessary to solve the issue of implementation of a big number of cameras. Remote controlling operations will require a lot of cameras. Currently, it is difficult to get permissions for installations, and as we are careful of our integrity the interviewee means that this is something that needs to be discussed.
5.5.4 Activity Transformation

The freight transport system has been considered stabilised for a long time, which is due to stable connections between technology and society described by Geels (2007: 124). However, no network is complete, and the appearance of new actors can affect the order in the actor-network according to Law (1992: 382) and the implementation of SDVs is mentioned to be a great opportunity to change the society. An interviewee means that “It is the same chance as when the car first came”. The interviewee further argues that there are a lot of possibilities in the product development, but in order to meet the SDGs there is a need for a better system as whole. With SDVs, a whole new market of possibilities opens up, new actors such as telecommunication, power suppliers and fuel retailing companies can make a new business. The market will change in various ways such as what truck manufacturer are offering, and where the profits and possibilities of influencing the market lays.

In order to get the most beneficial solution for society, it is important to make all actors strive towards a common goal. An interviewee representing the public sector argues that it is not the market nor the government alone that can drive the development as both regulations and market measures are required. However, several contradictions are yet to be conquered in the process of learning the new activities. Some actors are stuck in their old roles and cannot match the expectations, as well as some may not realise the need of a change in their objectives due to old traditions.

Some truck manufacturers have acted as innovators on the market by introducing the new technology of SDV. These actors have transformed or created a new business model that they are now examining.

![Figure 7: An interpretation of Engeström's (2001) third generation activity model adapted to a general truck manufacturer's activity for SDVs in freight transport](image)

However, truck manufacturers that do not traditionally have a business model for SDVs in their core business will have to make some transformative actions. According to Engeström (2001: 151), it is important to be questioning the old practices in the process of implementing a new technology that requires new practices. Hence, a need of rethinking strategic objectives among established truck manufacturers. According to an interviewee representing a truck manufacturer, the industry has a great knowledge in managing technical solutions for combustion engines, however SDVs require new kinds of knowledge, which require new approaches. This new form of activity needs to be developed during the process. It is now challenging the old working conditions and organisations as a step on the way of shaping a new model of practise. A secondary level of contradictions described by the activity theory occur as one node, in this case the object, affects the other nodes in the activity model, visualised in Figure 7. As an example, the new target of implementing SDVs will require a new division of labour among truck manufacturers as some workers have to take care of new tasks following the construction of SDVs. Thus, a new group performing the activity could be necessary, as well as new mediating artefacts required to accomplish the new object.
Shifts in coordination and cooperation are related to actors’ objects (Engeström, 1987: 25). Thus, it is of value to look into the objects of the involved actors. Shippers, freight forwarders and truck manufacturers have a goal of improving the business they already have with cheaper and more efficient transport, and as for truck manufacturers SDVs are essential to guarantee competitiveness in the market. While emerging actors such as fuel retailing companies, power suppliers and telecommunication actors seek to build new businesses around SDVs. In the meanwhile, the public sector wants to find the best solution for the society as a whole and as previously described in the results cities should be driven by the needs of their citizens. In the ways of which the interviewed actors are involved in the implementation of SDVs in node-to-node road freight transport are visualised in Figure 8-9 below. These ways of involvement relate to the actors’ object and the implementation of SDVs can be seen as the common target in the new network surrounding SDVs.

*Figure 8: The involved actors’ object with the target of implementing SDVs in node-to-node road freight transport*

Truck manufacturers have an explicit object to construct SDVs, while suppliers aim to buy the transport service. The object of the government activity is to regulate the implementation of SDVs. Moreover, from the collected data it appears that the government holds a positive view of the development which indicate a positive impact on the common object. However, regulations are also necessary in order to enable SDVs in node-to-node road freight transport.

Furthermore, the academy will conduce advances to the implementation of SDVs with its research. Trafikverket aim to use research in order to explore solutions that will enable functional regulations. Moreover, Trafikverket are looking into required digital infrastructure on governmental order, such as providing map data and regulative data in digital form as described in section 5.3.2. *Digital infrastructure* is also the object of telecommunication companies, however their focus is different as they look into e.g. 5G and safe data exchange.
A new actant, the SDV, is entering the actor-network, thus disappearance or appearance of new actors could occur (Law, 1992: 382). Figure 9 visualizes how the new actor-network for SDVs in node-to-node road freight transport may develop. Currently, power suppliers and fuel retailing companies are observing other actors to be developing their business models and doing fundamental proof of concept work regarding SDVs. Furthermore, according to an interviewee representing a power supplier company, the actors involved in the development of SDVs have no fundament to expand their value proposition to incorporate actors such as them for another couple of years. Nevertheless, both power suppliers and fuel retailing companies are looking into new business models for charging infrastructure. However, the process of implementing SDVs is stated to be a challenge for the power supplier as it is outside of their core business to develop constellations and networks to work with topics such as ICT, logistics and digital communication technologies such as 5G. Moreover, these emerging actors are dependent on SDV development to remain focused on electrical vehicles.

However, other aspects could also influence the transformation of activities. In this case, the representative from the power supplier company means that it is difficult to bring unique value to the table before being involved in any demonstration projects to get experience and a deeper understanding of what the key actors really need from power supplying companies. The interviewees representing a power supplier believe that these actors will not have a very strong fundament to incorporate actors such as power suppliers for another 2-3 years. But as the discussions become more mature, it is believed that those actors will start to look for possible partnerships with power suppliers.

Furthermore, the interviewees representing the power supplier company stresses the need to “start putting together the puzzle between autonomous logistics task, the transport task, and the energy and power task”. In order to do this, the interviewees states that further research will be needed to identify what kind of hotspot mapping between supply and demand will be needed given the types of technical parameters that will be found for SDVs and driving automation. These parameters could be e.g. the size of the trucks, what kind of battery they will use, operating range etc. By taking such factors into consideration, it is believed that the organisation as well as the industry will become more confident in issues such as where charging hubs should be located to meet the demand.

The basic incentives of truck manufacturers and freight forwarders are primarily similar - to improve business with cheaper and more efficient transport, although as the competitiveness of SDVs may
change the market, truck manufacturers’ objectives will most likely change. There is a possibility of truck manufacturers taking over the activities of road carriers and freight forwarders as they develop the whole system surrounding SDV. One interviewee representing a freight forwarder requests more involvement in the SDV development, however as it appears, freight forwarders do not necessarily have a natural place in the new actor-network. In addition, the industry is described as very conservative and marginalised which could further restrain freight forwarders from becoming a key actor in the new system and instead leave them to be phased out of the system.

There is also a possible outcome that road carriers no longer will be needed when SDVs are implemented on a big scale. However, it is mentioned by an interviewee that road carriers have more responsibilities and competencies than only driving the vehicle.

Furthermore, actors are speculating on another further developed role for truck manufacturers as system monitors. In this scenario, there may be a possibility for freight forwarders and road carriers to become a part of the truck manufacturer’s system instead. However, these actors do not seem to know how their activities should develop or transform in order to become a part of the actor-network for driving automation in freight transport. As it appears for now, the freight forwarders and road carriers are involved in networks discussing SDV, although they argue that it is better if they wait until SDVs are implemented before adapting their business model and their incentives. Although, in order to enable new practises it is crucial for them to continue questioning their traditional practice and to visualise internal contradictions evolving from the changed incentives among surrounding activity systems.

There are different opinions concerning the progress of policies. As described in the section 5.5.2 Policies and Legal Framework, a proactive government is requested due to a need of e.g. standardisations and control. The role of the government is of importance as it has major impact on other activities’ possibilities of operating the practice in the way it is being transformed. The government also holds the possibility to speed the phase of the development by allowing more demonstration projects. Moreover, the concern of liability that is described by interviewees. Depending on how the regulations will be defined different actors will benefit.

Among many interviewees, a representative from a freight forwarder company stresses the need for Trafikverket to take on a more proactive and leading role, paving the way for truck manufacturers. Although, this is a debated topic. Some interviewees believe that the responsibility of managing the process of commercialisation should be on driving forces in the market. An interviewee representing a telecommunications company further argues that “authorities must expand their role”. There are not yet any authority responsible for digital infrastructure, and the interviewee believes that this will be demanded as SDVs are becoming more common. It is further argued that it is possible that Trafikverket will take on this role, as the authority is already responsible for physical infrastructure.

6 Sustainability Analysis

The concept of SDVs and driving automation opens up for many opportunities for increased sustainability but, at the same time, raises concerns and issues that need to be further analysed and discussed before attempting a commercialisation. The results of this study prove that the most obvious potential sustainability benefits of SDVs in node-to-node road freight transport are related to lower costs, enhanced safety, and improved fuel economy. There are also potential benefits in reduced need for future infrastructure investments and a more efficient use of existing road infrastructure.

Based on the results presented in section 5 Results, it is clear that most actors view SDVs and driving automation very much as a part of the future. There are strong economic incentives to implement this new technology, and the technology level is already mature enough for several actors to be involved
in application cases or pilot projects. However, there also seem to be a deep-rooted and well justified concern among actors from both government, truck manufacturers and the public that great obstacles will follow the path of the technological development. Although the positive potential effects of SDVs are often being mentioned, it is important to be aware that it is far from certain that SDVs and driving automation will actually lead to positive sustainability- and system level impacts.

In this section, the sustainability framework is applied as described in section 4.3.2 *Using Theoretical Frameworks in the Sustainability Analysis* in order to reflect on RQ3 by assessing sustainability aspects of the TIS functions. A systematic approach is used to evaluate possible sustainability outcomes of different types of transformations and processes of the TIS surrounding a commercialisation of SDVs in Swedish node-to-node road freight transport. By assessing the findings in each TIS function, it is determined which CASI-F criteria that are of interest. The relevant CASI-F criteria are thereafter endorsed by SDGs in order to further evaluate and analyse different aspects of sustainability- both aspects that are commonly brought up as well as aspects that lacks focus. Table 5 presents the relevant CASI-F criteria and SDGs for SDVs in node-to-node road freight transport.
Table 5: Overview of relevant sustainability criteria

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<thead>
<tr>
<th>CASI-F criteria</th>
<th>Sustainable Development Goals (SDGs)</th>
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<tr>
<td>SOCIETAL</td>
<td>3 GOOD HEALTH AND WELL-BEING</td>
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<td>4 QUALITY EDUCATION</td>
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<tr>
<td>6.1 Societal Systems Criteria</td>
<td>8 DECENT WORK AND ECONOMIC GROWTH</td>
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<td></td>
<td>12 RESPONSIBLE CONSUMPTION AND PRODUCTION</td>
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<td>ECONOMIC</td>
<td>7 AFFORDABLE AND CLEAN ENERGY</td>
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<td>13 CLIMATE ACTION</td>
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<tr>
<td>ENVIRONMENTAL</td>
<td>13 CLIMATE ACTION</td>
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<tr>
<td>6.1 Societal Systems Criteria</td>
<td>16 PEACE JUSTICE AND STRENGTHENED INSTITUTIONS</td>
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<td>17 PARTNERSHIPS FOR THE GOALS</td>
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<td>GOVERNMENT</td>
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<td>INFRASTRUCTURE</td>
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<tr>
<td>6.1 Societal Systems Criteria</td>
<td>2 ZERO HUNGER</td>
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<td></td>
<td>9 INDUSTRY INNOVATION AND INFRASTRUCTURE</td>
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<td></td>
<td>11 SUSTAINABLE CITIES AND COMMUNITIES</td>
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<td>13 CLIMATE ACTION</td>
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<td>17 PARTNERSHIPS FOR THE GOALS</td>
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6.1 Societal Systems Criteria

The societal systems criteria regard social aspects such as income, behaviour, equity, health and human rights. In this study, the most widely discussed sustainability benefit of SDVs would come from improved road safety. This relates to the health criteria as well as SDG 3 – *Ensure healthy lives and promote well-being for all at all ages*. The SDG further has a target to halve the number of global injuries and deaths from road traffic accidents by 2020. In Sweden alone, 253 people died from traffic accidents in 2017 (Transportstyrelsen, 2017). By adopting SDVs and driving automation technology,
several actors agreed that there is a potential to positively affect targets of SDG 3 by making the general road transport system safer, saving both lives and costs.

If driving automation is combined with electrification as discussed in section 5.3.3 Electrification and Charging Infrastructure, there is also potential to reduce air and noise pollution caused by the freight transport sector. In 2010, as many as 3.1 million deaths globally were caused by unhealthy air quality from pollutants. As a reference, the number of traffic related fatalities were around 1.3 million globally (Eugensson et al., 2013: 9). Furthermore, some air pollutants are causing negative effects on the environment by causing water and soil pollution causing eutrophication and acid rain (Europaparlamentet, 2018). Hence, air pollution is a big sustainability issue and heavy vehicles and trucks are a known contributor for this. By implementing electrified SDVs in the node-to-node road freight transport sector, there is hence a potential to further address human health related aspect and contributing to SDG 3 and the goal’s target to substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution contamination by 2030.

The sustainability impacts of the Individual behaviour criteria is only being acknowledged by very few of the interviewed actors. These actors believed that changes in behaviour are equally important as technical solutions in order to address sustainability issues. For example, one of the interviewees mention that the current development and expansion of the e-commerce sector is not pointing in a sustainable direction. In order to increase sustainability of the freight transport sector, behavioural changes will be needed to prevent continuous, almost exponential increase in the demand of transport operations.

To increase public awareness about the sustainability impacts of individual behaviour, education plays an important role. This relates to SDG 4 - Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all. A target of this goal is to ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship and appreciation of cultural diversity and of culture's contribution to sustainable development (UN, 2018). Hence, academia is an important means of spreading knowledge about general societal problems.

When it comes to the CASI-F criteria Equity, there is the potential issue of 5G network development. As stated in section 5.1.1 Swedish Conditions, 5G network technology is believed to first be expanded around bigger cities, as the development is market-driven. This creates inequalities in terms of urban and rural populations accessing different levels of technologies and services. The fact that the access to technology and services is depending on which area you live in can create gaps between people and further increase inequalities. One of the interviewees from the telecommunication industry reasoned that governmental fundings or subsidies could be a potential way of addressing such problems. The role of the government and its sustainability implications will be further analysed in section 6.4 Government Systems Criteria.

6.2 Economic Systems Criteria

As it is revealed in the TIS function described in section 5.2 Market Formation and Driving Forces, economic incentives and market forces are strong in the development of SDVs in node-to-node road freight transport. Hence, there are multiple relevant CASI-F economic systems criteria to be further analysed.

The economic systems criteria touch upon aspects such as production and consumption, local and international trade, business models, as well as labour and employment (Popper et al., 2017: 25). All of these aspects are highly relevant for SDVs in freight transport, and related issues are repeatedly being addressed by the interviewees.
One of the most prevailing aspects in this category of assessment is labour and employment. This criterion regards factors such as improvement of occupational health and safety, labour rights and conditions. An issue raised by almost every interviewee participating in this study, is the fact that many job opportunities for truck drivers would disappear if a commercialisation of SDVs were to take place. This further relates to SDG 8 - *Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all*. Even though there is currently a lack of drivers in the freight transport sector, this is an important apprehension to be acknowledged. After all, truck driver is one of few middle-class jobs not requiring any specific education. What would be the impact if those jobs were to disappear?

According to UC Berkeley Labor Center (2018), the effects of driving automation in the trucking industry would be largest in the industry sectors with long stretches of highway driving, such as node-to-node freight transport. Further, UC Berkeley Labor Center distinguishes three key segments in long distance trucking: full truckload, less-than-truckload and parcel. Truckload drivers are typically those working for large trucking/freight forwarding companies, hauling full trailers directly from one customer location to another. These drivers rarely perform work such as loading or unloading and working conditions in this segment is tiring due to long working hours, and hence the turnover rate is high. These factors make the risk for job loss particularly high in the truckload segment of long-distance trucking, as those jobs are more likely to be automated (UC Berkeley Labor Center, 2018).

Nevertheless, SDVs might free drivers to engage in other types of activities, or just change the way the service of the drivers is provided. As stated in section 5.4.3 *Transport and Transport Services*, an interviewee representing a trade association for road carriers believes that the competence of drivers and road carriers will still be highly valued and be coveted regardless of how SDVs affect the business models and relationships between road carriers, freight forwarders and shippers. Road carriers have great experience of coordinating the interests of a wide range of actors, as well as consolidating goods to be transported. The interviewee states that truck manufacturers and driving automation technology providers do not possess this knowledge yet, and hence the knowledge of drivers and road carriers is predicted to still be in demand in some way.

Furthermore, UC Berkeley Labor Center (2018) states that growing e-commerce and lower freight costs over the coming decades could create many new driving jobs - “perhaps more than will be lost to automation”. As there is a trend of consumers ordering more goods online and expecting rapid last-mile delivery, the need might increase for local drivers to move loads to and from autonomous truck ports, deliver packages to customers’ doors, and to shuttle goods from centralised warehouses outside cities to smaller local depots. However, the interviewee stresses the fact that policy intervention will be important to prevent low wages and poor working conditions in these new jobs.

If business models change and fleet models are adopted as described in section 5.5.1 *Future Roles of Actors*, there is a potential to address SDG 12 – *Ensure sustainable consumption and production patterns*. According to Futures Centre (2017), fleet owners are more likely than individual owners or small road carriers to transition to e.g. electric vehicles, given the long-term cost savings and the large initial investments required. The ownership of cars in large, organised by large businesses rather than individuals or small road carriers could therefore expedite the adoption of carbon-saving technologies such as new fuel mixes or electric vehicles. This is further supported by UC Berkeley Labor Centre (2018), stating that large firms have both capital to buy, and expertise to integrate, new technologies. Furthermore, several actors participating in this study stress the fact that smart transport systems can go hand in hand with sustainable consumption and production. Especially since the development of SDVs and driving automation technology was proven to be dependent on market forces, it is possible to steer development in a sustainable direction by subsidies, taxes and other incentives. One of the targets of SDG 12 is to:
“Rationalize inefficient fossil-fuel subsidies that encourage wasteful consumption by removing market distortions, in accordance with national circumstances, including by restructuring taxation and phasing out those harmful subsidies, where they exist, to reflect their environmental impacts, taking fully into account the specific needs and conditions of developing countries and minimizing the possible adverse impacts on their development in a manner that protects the poor and the affected communities.”

(United Nations, 2018)

Something that is not being highlighted in this study but is highly relevant for the CASI-F criteria Local trade is how transport price mechanisms might affect local trade. There might be a risk that if long-distance transports are becoming cheaper, local producers of e.g. food and groceries will be rivalled by cheaper producers more far away. Such scenarios will lead to increased CO2-emissions, even though SDVs initially make transport more efficient and less CO2-intense.

6.3 Environmental Systems Criteria

The environmental systems criteria aim to assess e.g. environmental protection laws and policies, protection of renewable resources, and the rights of future generations. This includes aspects such as measures to decrease fossil fuel usage and investment in sustainable energy sources (Popper et al., 2017: 25).

An important opportunity for SDVs and driving automation to improve the sustainability performance of the node-to-node freight transport sector and achieving SDGs would lie within the possibility to significantly improve fuel efficiency of trucks. This can be done e.g. through algorithms for more efficient driving, the possibility to use more but lighter weight trucks, or solutions such as platooning to reduce drag. The practice of platooning, allowing truck fleets to travel with minimal following distance, is perilous for human drivers who must account for human reaction times. Platooning is especially suitable in highway driving, and fully implemented it has the potential to reduce energy intensity between 10% and 15%. Driving automation and driver assistance systems in general have also been verified to significantly improve fuel economy of trucks (Eugensson et al., 2013: 10). The possibility that SDVs brings to increase efficiency of the road freight transport sector relates to SDG 7 – Ensure access to affordable, reliable, sustainable and modern energy for all and SDG 13 - Take urgent action to combat climate change and its actions. SDG 7 has a target to double the global rate of improvement in energy efficiency by 2030.

The target of SDG 7 regarding energy efficiency can be further approached by expanding intelligent transport systems for multi-modal traffic control and intelligent route modelling to reduce congestion (KPMG, 2016: 9). This is confirmed by the results, as several actors mentioned the opportunity to obtain more efficient route modelling systems through optimisation. However, this requires challenges and issues regarding privacy and sharing/ownership of data to be resolved.

Another possible but somewhat debated possibility for improved sustainability performance of the node-to-node freight transport sector is by the electrification of trucks. The TIS function presented in section 5.3.3 Electrification and Charging Infrastructure elaborates that many of the interviewed actors question the actual sustainability outcomes of combining electrification and driving automation. The actors advocating synergies between the two technologies entail that in order for both of them to reach their full potential, they need to be combined. Currently, it is a great challenge to decrease the charging time for electrified vehicles in freight transport as the drivers’ cost is high. It is also a great challenge to increase the utilisation rate of trucks and other types of vehicle used in freight transport. Hence, by combining electrification and driving automation it is possible to address both of these challenges at the same time. Moreover, according to a supplier, the main argument that SDVs should be electrified is because it makes sense from both an economic and a sustainability point of view. In general, the weight of the battery and the charging time causes profitability problems for
manually driven electrified vehicles. If the vehicle is electrified and self-driving, this is not a problem anymore as there is no drivers cost. A truck manufacturer further confirms this by arguing that by combining electrification and driving automation, it makes sense to charge without fast charging solutions.

The interview findings further reveal that it is important to consider how the electricity is being produced in the case of electrified SDVs and electrified vehicles in general. One interviewee state that in countries like the US, where much of the electricity is gained from burning fossil fuels, electric vehicles may not provide much net reduction in carbon emissions as a whole. Sweden, however, might be a good case to implement electrified SDVs in node-to-node freight transport as the country’s electricity mix is derived from renewable energy sources such as hydro power. In general, it can be complicated to estimate the environmental impact from electrified vehicles as they do not generate any local emissions during usage. Emissions are instead associated with the generation process of electricity (Energirådgivningen, 2018).

6.4 Government Systems Criteria

Governmental systems criteria cover aspects regarding the public sector and its institutions, e.g. government administration, public finances and taxes, conflict control and resolution, and industry and technology policy (Popper et al., 2017: 25).

The results of the study reveal that Sweden has several strengths in innovation climate by facilitating close relationships and partnerships between government, business and academia. This relates to SDG 17 - Strengthen the means of implementation and revitalise the global partnership for sustainable development. The goal encompasses targets to encourage and promote public private partnerships and networking between actors from different societal sectors. Such networks for collaboration can be used to approach not only SDVs and freight transport related questions but also broader sustainability issues. By forming a basis for discussion issues involving multiple actors, positive synergies can be achieved. Several interviewees in this study argue that the next step in SDV and driving automation development will require a wider, semi-holistic view of not just how to make the vehicles operate but also exploring how actors can interact and exchange knowledge in order to do it in a more sustainable and efficient way.

Many interviewees further imply that in the process of commercialisation of SDVs in node-to-node road freight transport, governmental institutions and authorities carry a big responsibility. In section 5.4.1 Public Sector, it is stated that authorities may have to move from their current role of being mainly informative, to take on a more controlling and operating role. In this way, some interviewees believe that the system will become more standardised. By providing official guidelines and regulating the system to a greater extent, it is further believed to be possible to address challenges regarding e.g. cyber security, equity issues and environmental impacts. This relates to SDG 13 - Take urgent action to combat climate change and its impacts and SDG 16 - Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels. SDG 16 includes targets regarding responsive, inclusive, participatory and representative decision-making at all levels as well as promoting and enforcing non-discriminatory laws and policies for sustainable development (UN, 2018).

Furthermore, it is also clear that dealing with legality, liability, infrastructure usage and driver acceptance challenges will be critical in order to make SDVs truly a part of the future in node-to-node freight transport system. Many actors agree that these are major challenges before SDVs on public roads can be a reality (Eugensson et al., 2013: 1). In Sweden, present national laws require a person in form of the driver to be liable in the case of an accident. Several interviewees participating in this study argued that for higher levels of driving automation, liability needs to rest with the manufacturers or another entity not in form of a person. This is further underpinned by Eugensson
et al. (2013: 1), stating that legal implications and constraints will have a major influence on the speed of the development and the applications and directions of driving automation. Currently, the legal frameworks affecting the development of SDVs and driving automation varies considerably between the US, Europe and the rest of the world (Ibid). It even varies within Europe, which according to the results could be a challenge to many Swedish freight forwarders and road carriers as they have transports within Europe.

6.5 Infrastructure Systems Criteria

The CASI-F infrastructure systems criteria covers sustainability aspects that are highly relevant in relation to SDVs in node-to-node road freight transport, i.e. transportation and distribution; communications and media; goods supply systems; energy, water and food supply systems. The criteria also cover knowledge transfer channels, and technology development and innovations (Popper et al., 2017: 25).

From the interview findings of this study, it is clear that a commercialisation of SDVs and driving automation in Swedish node-to-node road freight transport would imply some impacts on how infrastructure and goods supply systems are being operated and used. Several of the interviewees highlighted that the digitalisation following the SDVs has the possibility of improving planning and preparation of transports, optimising routes. One interviewee from a governmental authority further implies that a transformation to a road transport system with only SDVs also could have the possibility to decrease the demand on new road infrastructure. As SDVs and driving automation has a potential to optimise traffic flows, and opens up possibilities for e.g. night time freight transports, the capacity of current road infrastructure will be more efficiently utilised. However, some interviewees highlighted the fact that SDVs could cause effects on the road infrastructure that have not yet been considered or explored. One example is groove formation which could be a problem if all SDVs are programmed to position themselves in the lanes in exactly the same way.

With increasing transport demands, the cost of congestions will increase as well, and new road infrastructure investments will most likely be needed to cope with the increasing demand. Eugensson et al. (2013: 12) concludes that approximately 16.6 trillion USD will be needed to be invested in roads worldwide through 2030 to match the increasing demand, making road investments the single largest investment needed in infrastructure all over the world. However, with a higher traffic density made possible if SDVs and driving automation techniques are fully implemented, it is predicted that the required road space will be less. As the environmental aspects of building and maintaining roads are complex (mortality of species, habitat fragmentation, air & noise pollution etc). It would imply environmental benefits to be able to increase the capacity of current road infrastructure while maintaining or even improving traffic efficiency and safety aspects (Eugensson et al., 2013: 12).

The potential of SDVs to improve sustainability performance in terms of more efficient use of road infrastructure relates to SDG 9 – Build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation. The goal includes targets to develop quality, reliable, sustainable and resilient infrastructure. This includes regional as well as trans-border infrastructure to support economic development.

In relation to road infrastructure is also the issue of food security. This is highlighted by targets in SDG 2 – End hunger, achieve food security and improved nutrition and promote sustainable agriculture. The freight transport system is an important means of ensuring access to food by making it possible to deliver food and groceries to stores and supermarkets all over the country. Almost every person is relying on national and international freight transports in order to get their everyday nutrients. Moreover, as climate change has already started to affect food production it will be an even more relevant issue in the future to ensure that people all over the world gain access to sufficient food all year round.
7. Analysis of Knowledge and Competence requirements

Interviewees express requirements for developed knowledge and competencies among multiple sectors. They speak both of knowledge requirements necessary in order to enable a use of SDVs on public roads as well as knowledge important for a sustainable long-term use of SDVs in node-to-node road freight transport. According to interviewees, the development of SDVs consists of four blocks: vehicle technology, digital infrastructure, business development and policy development. In addition, cyber security and moral and ethical dilemmas are mentioned as important components in the transition towards an autonomous road freight transport. Thus, this section is divided into these four blocks with cyber security as a subsection to 7.2 Digital infrastructure and moral and ethical dilemmas as a subsection to 7.4 Policy development and Decision Making. The analysis is based on a didactical perspective as described in section 4.3.3 Method for Analysis of Knowledge and Competence requirements.

7.1 Vehicle Technology

As described in section 5.3.1 Road Infrastructure, the interviewed actors imply that SDVs will adapt to current road infrastructure, hence drive in the same lanes and same speed as other vehicles. However, several questions follows. For example, an interviewee question the possibility of using current highway entrances and exits. This indicates a need to investigate the effect and possibility of implementing SDVs among other vehicles in the current road infrastructure, and thus, a requirement for more knowledge and competence in the area.

According to an interviewee representing Trafikverket “There are several questions concerning SDVs that one does not think about at first.” The interviewee elaborates “For example, we have now started to look into a research project called “What happens with the road?””. As mentioned in section 6.5 Infrastructure Systems Criteria, SDVs could cause effects on the road infrastructure. In this project, Trafikverket looks into aspects such as groove formation. This indicates a need to further explore effects on the road infrastructure and gather more knowledge of how groove formation and similar effects could be prevented.

An interviewee representing a truck manufacturer implies a need for development of new technology for battery recycling. Moreover, the interviewee means that sustainability is of second priority after economic aspects for most companies. Thus, as the economic benefits with SDVs become evident (as predicted by many interviewees) along with the implementation of SDVs, the sustainability aspects will become increasingly important. In addition, a demand for knowledge and competencies regarding sustainable technologies such as battery recycling will increase along with the transition towards an automated node-to-node road freight transport.

7.1.2 Vehicle Technology: How and For Who?

As indicated above, there is a need for new knowledge and competencies in this area, mainly through further research. The public sector looks into the effects on the road infrastructure while the truck manufacturers consider how the road infrastructure can be utilised in order to limit the requirement of expensive new road infrastructure. Furthermore, battery recycling will become more important along with the development of SDVs. Thus, knowledge concerning technologies for recycling will be requested among truck manufacturers. However, these technologies could be developed by other actors.

7.2 Digital Infrastructure

According to an interviewee representing a coordination network: “There are several important steps before an implementation of SDVs, such as looking into the issues concerning data exchange and
how data should be transferred between vehicles. Cyber security is another important issue, as well as a robustness in the digital infrastructure.”

An interviewee representing a truck manufacturer implies that remote control for complex areas will solve problems regarding complex driving situations such as highway entrances and exits mentioned in previous section 7.1 Vehicle Technology. On the other hand, as it is revealed in the TIS function in section 5.3.2 Digitalisation and Digital Infrastructure, the interviewee representing a telecommunication actor means that SDVs cannot be completely dependent on network connection due to risk for blockages in the connection. Thus, knowledge concerning the requirements on the network is needed as well as developed competencies regarding the management of remote control.

In addition, knowledge and competence regarding data exchange between actors are required. Following three areas in need of new knowledge and competencies are described in the interview results. At first, in order to create a possibility to collaboratively collect data a common system needs to come in place. However, today, data standards vary between actors and in order to collaboratively collect the data the format needs to be the same. Thus, in order to enable such collection of data, data standards need to be investigated. Secondly, the question of “who should have access to data?” needs to be investigated. Thirdly, further exploration and knowledge concerning the data transmission is required.

As previously stated in the section 5.3.2 Digitalisation and Digital Infrastructure, the issues concerning the exchange of data will take time. A representative from a truck manufacturer means that many actors are careful with publicising data as the information could be sensitive. Thus, there is a risk for conflicts between the data owner and the actor in need of data. As this problem is very complex, there is a need for investigation and more knowledge in the area.

7.2.1 Cyber Security

According to the interview results, cyber security will become a major challenge within the transport system. As described in section 5.3.2 Digitalisation and Digital Infrastructure, information communicated from vehicles could be sensitive, thus every vehicle require an identity that can be verified in order to communicate the data safely. However, there are yet several issues (explained in section 5.3.2 Digitalisation and Digital Infrastructure) in need of solution. This indicates a need for more analysis of how the data can be transferred safely and thus, a need for more knowledge and competencies in the area.

7.2.2 Digital Infrastructure: How and For Who?

As mentioned in section 5.1 Influence on the direction of development, vehicle technology is not a current constraint, however, the truck manufacturers developing the vehicles are also involved in the digital infrastructure. These industries are used to solve technical issues and now they need to learn about cyber security, ethical and moral dilemmas along with the digital infrastructure. Thus, a lot of new competencies will be required among truck manufacturers.

As revealed in section 5.3.2 Digitalisation and Digital Infrastructure, Trafikverket has started to look into solutions for data exchange, aiming to have all data regulating the use of road infrastructure digitally available. Thus, Trafikverket has carried out a study about systems for digital communication. According to an interviewee representing Trafikverket, the importance of this study is to find routines and processes that will meet demands on security and robustness.

According to the interview results the actors will get the desired knowledge and competencies and facilitate the new transport system through cooperation. As described in section 5.4 Key Actors and Actor-Network Structure as well as 5.5 Dynamics and Incentives in the Actor-Network, coordination
networks will enable coordination and collaborative learning between actors that previously have not been coordinated. However, a lot of research will be required as well.

In order to gather information and knowledge pilots and demos are required. However, according to a representative from a truck manufacturer, changes in the regulations could make it easier to implement big demos and thus, speed up the learning process.

7.3 Business Development

As stated in section 5.2 Market Formation and Driving Forces, SDVs open up a whole new market of possibilities. Thus, actors seek new business opportunities. However, in order for actors to create their new business model they first need to learn about it and identify new required areas for knowledge and competence improvements.

As revealed in section 5.5.4 Activity Transformation, truck manufacturers could become service providers instead of truck providers. Thus, more knowledge of what such transformation implies is necessary. Operating licenses, education and customer service are tasks performed by road carriers today. Tasks that truck manufacturers may have to learn depending on what their role as service provider will imply. Another example is Trafikverket, which may become responsible for the digital infrastructure as discussed in section 5.5.4 Activity Transformation.

As previously described in the TIS function in section 5.3.1 Road Infrastructure, there are concerns among freight forwarders and truck manufacturers regarding practical issues. “Looking at the transport industry in general, it is a rather conservative branch of industry, but a lot has happened lately. But basically it is still quite conservative when we talk trucks - there are freight bills.” says a representative from a freight forwarding company. In today’s system, the driver takes care of tasks such as loading, unloading and signing consigning notes. An interviewee representing a truck manufacturer indicate a need for knowledge and competencies in order to find new solutions for such tasks. These solutions are essential in order to make the autonomous node-to-node road freight transport efficient and functional. Furthermore, the representative from a freight forwarding company means that this issue also involves a question of responsibility and legal obligations. In addition, the interviewee indicates a need for new processes in order to enable an inspection of goods when the driver is removed.

As stated in section 5.5.4 Activity Transformation, knowledge concerning how all parts of the system e.g. the logistics task, transport task and energy and power task will work together is needed. The interviewees representing a power supplier gives further examples of things they and the industry in general need to gather more information about, e.g. the size of the trucks and operating range. This knowledge become important in order for them to improve their business development.

Freight forwarders need to be able to plan their transport and delivery. However, an interviewee representing a truck manufacturer mention a need for more flexibility in the transports and deliveries as the SDVs become dependent on charging stations. The interviewee further indicates that the owner of the charging station will have to control and schedule the charging times for trucks. Thus, new competencies may be required for the workers at the charging stations unless other solutions are found.

7.3.1 Business Development: How and For Who?

Several actors are exploring their roles and how their business models could develop. Thus, a lot of new knowledge as well as new competencies will be required among the actors. Involved actors also need to rethink their long term and strategic objectives. Nevertheless, as the driving automation technology range over multiple sectors, actors developing their business need to be attentive on actions made by several actors.
7.4 Policy Development and Decision Making

This section reflects both on policy development and decision making regarding an enabling of an implementation of SDVs as well as policy development and decision making required for a sustainable transition towards an autonomous node-to-node road freight transport. Thus, this section is divided into 7.4.1 Enabling an implementation of SDVs and 7.4.2 Moral and ethical dilemmas, 7.4.3 A Sustainable Development with SDVs followed by 7.4.4 Policy Development and Decision Making: How and For Who?.

7.4.1 Enabling an implementation of SDVs

Before implementing SDVs in node-to-node road freight transport, knowledge concerning regulation formation is required. This is mentioned by several interviewees as it is essential for them in order to know how to develop their business. The development could for example vary depending on regulation demands on remote control and liability.

Knowledge about regulations concerning standardisations and technology is needed. Although, as described in section 5.5.2 Policies and Legal Framework, in order for the government to keep a neutral approach in the technology development they need to be open to all possible solutions. There is a contradiction between the government’s perspective and the other actors. Even if the actors want the government to be neutral they still require information in order to enable investments in certain technology.

Interviewees express concerns about power peaks as the electricity use for vehicles increase. All actors do not agree, but the lack of concern among interviewees representing a power supplier seems to depend on a belief of a “step by step” development where there will be enough time to fix such problems. An interviewee representing a truck manufacturer also express a need for regulations in order handle the power peaks. Nevertheless, since there are uncertainties in the area there is a need for knowledge and developed competencies.

7.4.2 Moral and Ethical Dilemmas

A representative from a coordination network states that “There are a lot of challenging moral and ethical concerns.” Some interviewees question the role of the SDV in the society. They point out an unresolved issue regarding how society will accept SDVs on public roads. As described in section 5.5.4 Activity Transformation, depending on decisions made concerning liability actors will be affected differently. However, one interviewee implies that the issue concerning liability needs to be solved in order to enable an acceptance in the society. Moreover, the interviewee believes that “our legal consciousness has difficulty accepting an order in which no physical person is responsible when it comes to life/health damage.” Thus, although the legal issues considering liability can be fixed, the issue of acceptance could make it even more complex.

The interviewee representing a coordination network discuss whether it is desirable to move towards a society with more “control”. The interviewee means that “Traditionally, authorities have a more informing role, however, in future the authorities may have to get a more monitoring role. For example, today we have speed limit signs for 30 km/h, but with SDVs it is possible to control and make it impossible to drive any faster.”

According to the interviewee representing the coordination network, municipalities are struggling with what their approach towards SDVs should be. Thus, more knowledge and competence regarding moral and ethical aspects are required in order to enable societal acceptance and make well prepared decisions regarding control of SDVs.
7.4.3 A Sustainable Development with SDVs

Policies and legal framework are stated as crucial factors in order to get a sustainable development of SDVs. The TIS function presented in section 5.1 Influence on the Direction of Development elaborates that some interviewees mean that the speed of the development is overestimated but the effect of the development is underestimated. Thus, more knowledge of the effects of an implementation of SDVs would be useful.

There is a need for more knowledge and competencies concerning strategies for preventing an increase of transport work if transports become cheaper and more efficient. As stated in section 5.5.2 Policies and Legal Framework, there are several things that could be done. One example is changing the trend of free shipping and returns offered by retailers. Another is to regulate transport terminals. However, these kinds of strategies need to be evaluated in order to implement the most effective method that could prevent an increase of vehicles on the roads.

Furthermore, an interviewee representing the public sector implies a risk of making the system less flexible. With those words, the interviewee indicates the SDV to be less flexible than a normal truck due to its required components. Thus, knowledge regarding this effect could be of interest in the decision making.

7.4.4 Policy Development and Decision Making: How and For Who?

An interviewee representing Trafikverket indicates an importance of looking into the decision making in order to get a desirable effect on the transport system. However, as a representative from a coordination network states “The technology is developing fast, how to know the best approach at an early stage? The city will last for several hundreds of years while the technology develops rapidly. We do not want to get trapped in an expensive infrastructure. Right now, we must have an agile approach in order to enable new technology but at the same time we cannot get stuck”. With those words it is clear that the decision makers have a complicated task to tackle.

An increased amount of traffic is suspected and policies and regulations are mentioned as possible solutions in section 5.5.2 Policies and Legal Framework. An interviewee representing the academy means “that continuous raised energy costs along with improved efficiency could enable a decrease in the energy consumption”. Although, the interviewee also indicate that a ban could be more efficient. Thus, economic and political decisions appear as possible solutions, perhaps a combination could be the better solution. This needs to be further explored by the public sector as they have an opportunity to govern the development.

An interviewee representing a truck manufacturer believes that there “is a huge risk of limiting the possibility of achieving the potential for society, which should be inclusive, environmental, sustainable, by having an attitude of letting others do it first and imitate whatever works out.” According to the interviewee, this is a risk as the transport system may become difficult to change once SDVs are already implemented. The transport system is a big infrastructural system that is difficult to transform and it could possibly become more difficult with SDVs involved. However, the interviewee also indicate a huge possibility of making sustainable changes while the system is undergoing such major changes as an automated road transport entails. With this in mind, it is of importance to focus on sustainability already from the start and be proactive.

Moreover, according to Webb et al. (2018: 57) there is a need for a holistic approach in order to enable a sustainable development in this kind of complex system. Luckily, the interview results indicate a willingness of such course of action as a multidisciplinary approach with cooperation between all blocks is requested by the interviewees. Thus, coordination networks have an important role to play by facilitating cooperation and dialogues between actors.
In recent years, sustainability has become more and more important for companies. The reasons are market demand and long-term economic aspects according to an interviewee representing a truck manufacturer. This indicates a willingness among the industry to learn more about sustainability outcomes in order to make well-prepared decisions concerning SDVs. Thus, there is a possibility for actors to create a better infrastructural system if managed right. However, many interviewees believe that regulations are the only way to prevent an increased amount of traffic. If so, the policymakers need to gather information and knowledge about potential effects of different strategies in order to design the content of one or several regulations.

Webb et al. (2018: 62) further means that the direction of development should be guided by the UN SDGs. In order to reach the SDGs, interviewees emphasize the importance to establish clarified goals. In addition, the first step of enabling the decision making could be to create a shared framework where knowledge can be collectively collected and used (Webb et al., 2018: 60). Then, gaps between goals and practice can be identified which is of importance in order to find strategies to address the issues (Webb et al., 2018: 57). By facilitating knowledge from multiple sectors, decision making could be made on a solid basis. This would not be possible without profound knowledge of the issue.

Furthermore, as the new system is quickly emerging, the public sector needs to adapt their roles, gather knowledge and competencies and act proactively to fulfil expectations. If not, their ability to influence the market will decrease and perhaps there will be no consideration of an emerging issue of traffic congestion when the market expands their profits.

8 Discussion

This section provides a general discussion and a critical reflection of the interview results, the sustainability analysis as well as the analysis of knowledge and competence requirements presented in sections 5, 6 and 7. This is followed by section 8.2 providing a criticism of the methodology used in the study. Lastly, a discussion of further research topics related to the study is presented in section 8.3 Further Research.

Actors involved in the freight transport system are currently observed to be trying to adjust their role to be compatible with SDVs. Along with new actors, they are trying to find a way to be a part of the actor-network as the SDVs are finding their way into the market. Important actors in the transport sector like to believe that they can maintain their position on the market, although their success will be dependent on how they approach the transition of the system. Traditional actors will have to start questioning their core business and redesign their business models in order be a part of a future actor-network for SDVs in node-to-node road freight transport.

The findings of this study reveal a wide range of driving forces and incentives within the technical innovation system of SDVs in node-to-node road freight transport. While SDVs could bring a significant improvement on transport efficiency, cost and environmental impacts, there are also several challenges to tackle. As described by the LTS theory, the road freight transport system is a system of large momentum and a lot of effort may be required from all involved actors to establish new ways of cooperating, communicating and addressing sustainability aspects.

Even though sustainability and the UN SDGs are acknowledged and comprehensively used by organisational as well as institutional actors on all levels, one observation made during the study was a prevailing lack of a systematic way of incorporating sustainability on operational and tactical levels. A general problem with the notion of sustainability seem to be that the goals we have are broad, long-term and mainly on a strategic level. In order for actors in innovation systems to achieve these goals, it is believed that there should be further emphasis on creating practices for translating the strategic level sustainability goals into tactic and operational activities.
In terms of sustainability, an interesting issue to further debate is the risk of rebound effects. For an instance, if transport become cheaper and more efficient, there is the possibility that the total transport work will increase. Such feedback loops in large technical systems are difficult, if not impossible, to predict. Only in the freight transport system, there is an endless amount of internal and external factors affecting the outcome actions taking place within the system. Even though energy efficiency is stated to be one of the most important motivations for SDVs and driving automation, reductions in the overall fuel consumption would not necessarily lead to lower fuel consumption. Instead, it might just change freight transport practices to farther, faster, and more often.

When considering the findings of section 6 *Sustainability Analysis* it is therefore important to keep in mind that the predicted outcomes are not certain. They are based on the logical concepts of the theoretical framework, as well as a reflection of the reasoning and predictions of the interviewed actors.

As there is no simple way of predicting rebound effects, it is also difficult to mitigate them. Several of the interviewees mentioned that the only truly efficient way of dealing with similar issues is to use government interventions such as regulations, taxes and subsidies. But at the same time, those actors are also promoting the free market to fuel development of new techniques such as SDVs and driving automation. This is a dilemma – to which extent should the government intervene in the economy and the ways in which new techniques can be used?

The analysis in section 7. *Analysis of Knowledge and Competence requirements* indicates a need for improved knowledge and competence in several areas. Many interviewees express a need for more knowledge concerning digital infrastructure, cyber security, business development, policy development and decision making. While only a few interviewees have mentioned needs for knowledge concerning moral and ethical dilemmas and vehicle technology. The interview results describe the vehicle technology to not be of current constraint. However, moral and ethical dilemmas may be of major concern among the public which are not represented in this study.

The need for knowledge and competencies vary between actors. Truck manufacturers require knowledge for a functional digital infrastructure. The public sector needs to develop an understanding for how SDVs will impact the system as a whole and how they can govern the infrastructure in the most suitable way. Fuel retailing companies and power suppliers require facts about the SDVs and how they will operate in practice. These are only a few examples.

The analysis of required knowledge and competences indicate a high pressure on the public sector. The public sector’s involvement in the road freight transport appears to increase considerably in a transition towards an autonomous transport. Overall, actors will also become more dependent on coordination when the freight transport becomes dependent on multiple components.

### 8.2 Reflection and Criticism of Methodology

This section critically reflects on factors affecting the reliability of the findings of this study. As the aim of this study has been to gather a general understanding of the implementation of SDVs in node-node road freight transport every detail has not been thoroughly investigated as the focus was to gather as many perspectives as possible. Due to a limited time period and a focus on a variety of actors, only a few actors from each category could be interviewed. It is possible that other interviewees within those categories of actors would have highlighted different aspects of the development which could have led to other results.

Another factor affecting the quality of the interview data is the fact that all but two of the interviews were being recorded. The fact that the interviewees were aware of that they were being recorded might affect the participants in various ways. They may not say certain things or avoid mentioning
information they are not completely sure of. As the study is exploratory in nature, part of the aim of the interviews was to just explore the thoughts and ideas of people involved in the sector. However, a few of the interviewees expressed concern that some of their comments were based on personal thoughts and/or beliefs and should not be mistaken to represent the organisation they are working for.

Furthermore, one drawback of using interviews as the primary method to collect data is that it was difficult to apply the principle of source triangulation of information. Since applications of SDV in freight transport is an emerging research field, the findings from the interviews could not always be supported by e.g. published scientific articles. However, as previous studies of SDVs have been mainly focused on normal passenger cars this study is expected to give important insights for SDVs in freight transport and pave the way for future studies in the area.

Lastly, by using the theoretical frameworks the analysis of the implementation of SDVs may have been simplified. Popper et al. (2017: 11) highlights the fact that the simple formulation in the CASI-F framework of sustainable innovation is pointing to a very complex set of issues. Activity theory and ANT may also give simplified versions of activity transformations and actor-network establishments that do not properly reflect the reality.

### 8.3 Further Research

As this study is exploratory in nature, it provides a broad and synthesised perspective of system-level impacts and requirements for new competencies as well as driving forces and incentives for a wide range of actors. Hence, it is possible to use this study to get an overview and to navigate in this emerging research field. By conducting this study, several topics to be further studied were also identified.

Firstly, the conclusions of this study are mainly based on qualitative data, i.e. the interview results. To solidify those theories and conclusions, an important part of future research will be to model and quantify them by using different methods. As pilot projects, demonstrations and cases where SDVs are actually being applied in real scenarios are becoming more common, it will also become important to study such cases in depth - both qualitative and quantitatively.

Another interesting approach would be to look deeper into questions regarding responsibility and liability in relation to SDVs in node-to-node road freight transport. E.g. cyber security and legislations alone are big and complex research fields. Such issues are equally important as technical solutions for the development of SDVs to move forward.

As another suggestion for future research, we propose that the linkage between SDVs and electrification can be further investigated. The results as well as the analysis of this study reveal that this linkage seem to be a controversial topic, and that the effects of combining the two techniques should be further studied before any final conclusions can be made regarding whether it is beneficial or not.

Lastly, this study is limited to node-to-node road freight transport. It would be interesting to study how SDVs and driving automation can affect first- and last-mile transports as well.

### 9 Conclusions

One of the main conclusions is that the next step in SDV and driving automation development will require a wider, semi-holistic systems view. The exploratory approach of the study in combination with the aim (to provide an overview and understanding of system-level impacts, opportunities and barriers facing a set of actors involved in the transition) allowed to explore the research questions in
a multidisciplinary manner. It became evident that transformations of large technical systems such as the freight transport system involves not only technical aspects, but also sustainability issues, processes of knowledge transfer, as well as changing dynamics between the actors of the system. In this section, the main conclusions are presented in relation to corresponding research questions. Section 9.1 Key Actors, Driving Forces, Dynamics and Collaborations presents conclusions regarding both RQ1 and RQ2. Section 9.2 SDVs and Sustainability and section 9.3 Knowledge and Competencies presents conclusions regarding RQ3 and RQ4 respectively.

9.1 Key actors, driving forces, dynamics and collaborations

**RQ1:** Which are the key actors involved in the transition towards an automated node-to-node freight transport system in Sweden, and what kind of driving forces are behind the process?

**RQ2:** How can the transition towards an automated node-to-node road freight transport system impact dynamics and collaborations between key actors, and which opportunities and barriers are they facing based on their incentives?

By applying the TIS framework, it could be concluded that in the process of commercialisation, truck manufacturers will have major role along with the public sector. In the results of the study, those key actors are repeatedly mentioned as system builders that have a great power of influencing the development. In addition, the main driving forces behind an implementation of SDVs in node-to-node road freight transport relate to market forces and economic incentives.

Based on the interview results, it is clear that the public sector holds a great potential of shaping the future of the road freight transport system. Actors within the public sector are believed to have the influence and the possibility to further enable the development by changing regulations and enabling demo projects and tests of SDVs on public roads. Changing regulations and engaging in real world-applications of SDVs in freight transport were two factors believed to be important in order to enable the next leap in a commercialisation process.

The truck manufacturers play a natural key role as they introduce SDVs to the market. A technology of which they request an entire sector to adapt to and engage with. Although, the truck manufacturers must wait for regulations and policies to come in order before making huge investments. However, the truck manufacturers have a great power to influence the government and hence, the regulations and policies, as the government tries to keep a neutral approach to technical solutions in order to enable a market driven development.

Actors other than the public sector and truck manufacturers are believed to be more dependent on how the development emerge, rather than having the capability to influence the direction of development. These actors cannot control the process at the same extent as the truck manufacturers, and the public sector comprising of many actors controlling legislations and research fundings.

For some actors, the biggest insecurity regards future business models. SDVs and driving automation has the capability to completely change the market structure and the relationships between freight forwarders, truck manufacturers, suppliers, and the public sector. Several interviewees seem to agree that a commercialisation of SDVs in the node-to-node road freight transport system would imply that the dynamics between the actors will experience drastic changes. Some actors will become more influential, some actors might lose customers and become less influential, and some completely new actors might enter the system. One type of actor that is repeatedly highlighted as an actor possible to become a key actor is telecommunications companies. Along with new system boundaries, a digital infrastructure will become a major part of the road freight transport system and thus, innovators within the digitalisation such as telecommunication companies could become key actors.
Actors that are currently a part of the road freight transport system, but not adopting their objectives for SDV technology, are in the risk of facing various challenges to keep their influential role as the road freight transport system is changing. However, new opportunities are believed to be created for emerging actors as well as opportunities for intersectional coordination as new types of interactions and coordination networks emerge. Hence, as revealed in the interview results, coordination networks are believed to have a central role for all minor actors as it enables those actors to coordinate issues and collaboratively work towards a common goal.

By conducting this study, it becomes clear that a transition towards an automated node-to-node road freight transport system will entail expanding system boundaries and a total change in the current market structure and the relationship between the actors of the system. A road freight transport system that is embodying SDVs will require new actors to enter the system, and current actors to re-evaluate their business models as the system expands. There is no doubt that power suppliers, fuel retailing companies and telecommunication companies will have a key role in the future actor-network if the development continues as predicted. However, there are still nodes in the actor-network to fill. New technology actants require a management of data exchange and standardisations which new or old actors in the actor-network can be a part of.

9.2 SDVs and Sustainability

**RQ3: How does a commercialisation of SDVs in node-to-node road freight transport relate to the UN sustainable development goals (SDGs)?**

By conducting this study, it is concluded that the concept of SDVs and driving automation opens up for many opportunities for increased sustainability but, at the same time, raises concerns and issues that need to be further analysed and discussed before attempting a commercialisation. The results of this study prove that the most obvious potential sustainability benefits of SDVs in node-to-node road freight transport are related to lower costs, enhanced road safety, and improved fuel economy. There are also potential benefits in reduced need for future infrastructure investments and a more efficient use of existing road infrastructure.

Based on the interview results, it is clear that most actors view SDVs and driving automation very much as a part of the future. There are strong economic incentives to implement this new technology, and the technology level is already mature enough for several actors to be involved in application cases or pilot projects. However, there also seem to be a deep-rooted and well justified concern among actors from both government, truck manufacturers and the public that great obstacles will follow the path of the technological development. Many of the interviewees participating in this study believe that there is a great task of not only making the vehicles operate, but also to do it in a sustainable and efficient way.

Even though the positive potential effects of SDVs are often being mentioned, it is important to be aware that it is far from certain that SDVs and driving automation will actually lead to positive sustainability- and system level impacts. On the contrary, the lack of a holistic perspective on sustainability issues among many of the actors participating in this study can be seen as an indicator that there is still a lot of progress to be done in the process of incorporating sustainability goals and targets in innovation processes.

However, if the risk of rebound effects is disregarded, the sustainability analysis of this study indicates a great possibility to make contribution on several SDGs. Moreover, SDVs and driving automation holds the potential to increase road safety, decrease air and noise pollution, improve fuel efficiency and contribute to sustainable consumption and production, resilient infrastructure and food security.
9.3 Knowledge and Competencies

RQ4: What kind of new knowledge and competencies become important in the transition towards an automated node-to-node road freight transport?

In order to enable a transition towards an automated node-to-node road freight transport there are numerous areas of expertise in need of development. These areas concern vehicle technology, digital infrastructure and cyber security, business development and policy development and decision making as well as moral and ethical dilemmas. There are yet many questions to answer in order to solve issues regarding safe data exchange and other technical components.

At the same time, there is a need for a multidisciplinary approach in order to enable a collective learning. Facilitating and collecting knowledge from multiple sectors is necessary in order to set strategic goals and create useful regulations. Thus, coordination networks could again play a significant role, this time by facilitating dialogues between actors and enabling collective learning. Furthermore, these regulations and direction of development need to be guided by the UN SDGs in order to enable a sustainable development.

It is further important to keep in mind that sustainability is not a measurable, fixed state but rather a continuous and constantly changing process where synergies between technical innovation processes, actor-networks, coordination, and learning processes need to be well understood. A future commercialisation of SDVs could potentially trigger radical transformations in society, and at the same time address several sustainability goals and targets. SDVs are offering a unique possibility to transform current transport and logistics operations to the better, an opportunity that should be governed with great consideration by all involved actors, especially the public sector.
References


