Scenarios for the development of self-driving vehicles in freight transport

Ida Kristoffersson\textsuperscript{a}, Anna Pernestål Brenden\textsuperscript{b}

\textsuperscript{a}VTI Swedish National Institute for Road and Transport Research, SE-102 15 Stockholm, Sweden
\textsuperscript{b}ITRL, KTH Royal Institute of Technology, SE-100 44 Stockholm, Sweden

Abstract

This paper extends previous research by developing future scenarios for self-driving vehicles and their societal impacts in freight transport using Sweden as a case study. Freight experts from vehicle manufacturers, agencies, universities and hauliers were recruited for a workshop where they assessed the benefits, costs, possibilities and barriers for self-driving vehicles in freight transport. The paper shows that reduction in driver and vehicle costs, reduced number of incidents and more fuel-efficient driving are seen as the main benefits of self-driving vehicles in freight transport, and increased vehicle costs, lost jobs, reduced degree of filling and more transport as the main costs. Furthermore, reduced drivers’ costs, more hours-of-service and new business models are identified as the main drivers of the development and traffic management, small hauliers, loading and unloading and cross-border transport as the main barriers. The paper also integrates the description of possible developments of self-driving vehicles in freight transport into the four future scenarios developed for passenger transport in Sweden.

Keywords: Self-driving vehicles; Automated transport; Freight transport; City logistics; Long haulage; Future scenarios; Societal scenarios;
1. Introduction

The technology for self-driving vehicles (SDVs) is developing rapidly and will soon have an impact on mobility and transport. Even though most literature about SDVs concern the technological development from different aspects, see e.g. Piao and McDonald (2008), there is a growing field of research discussing societal effects and possible future scenarios for the development of SDVs (Fagnant and Kockelman, 2015; Milakis et al., 2017; Pernestål Brenden et al., 2017). This previous literature is however heavily biased towards passenger transport, and in particular urban passenger transport.

Freight transport differs from passenger transport since it most often implies business to business (B2B) services. Freight transport is commercial, and decisions related to transport are almost always made on a rational and economical basis. Passenger transport choices on the other hand are often influenced also by emotions and non-rational behaviour.

Studying impacts on freight transport is highly important for several reasons. First, a significant part of CO2 emissions come from road freight transport. For example, in Sweden, road freight transport accounted for 53.1 million ton-km in 2016, which is nearly 50% of total freight transport (Trafikanalys, 2017) and heavy trucks account for 25% of CO2 emissions (Trafikverket, 2017). Also in the EU, heavy duty vehicles account for about a quarter of the CO2 emissions from road transport (European Commission, 2017). Second, road freight transport is important for the industry. Transport is part of the logistics chain in almost all industries, including e.g. food, manufacturing and production, forest, and the building industry, but transport does not add value to the product (Flämig, 2016). Thus, reducing freight transport costs is of high interest for the industry. Third, road freight transport is also a significant industry in itself. For example, in Sweden, the transport industry accounts for 7% of GDP (Gabrielson et al., 2017). Fourth, road freight transport is a highly competitive industry, implying that new technology which enables improved efficiency could have a fast break-through.

The main contribution of this paper is an analysis of plausible impacts of self-driving (automation) technology on road freight transport, on a system level and from several different perspectives including e.g. business ecosystems, urban planning and security. The analysis of the impacts of SDVs on road freight transport is based on a workshop performed with experts within the broader freight transport industry in Sweden. During the workshop, the experts were instructed to have in mind vehicles using self-driving technology of SAE level 4 and 5 (SAE International, 2016), and that SDVs are allowed to operate on public roads. The input from the workshop is analysed in two ways: (1) identification of benefits, costs, possibilities and barriers of the SDV development in freight transport; (2) descriptive stories building on the scenarios derived in Pernestål Brenden et al. (2017).

This paper focuses on road freight transport and includes both city logistics and long haulage. Automation in closed-off areas such as harbours and container terminals is an interesting field, which has gained attention in literature (Flämig, 2016; Konings et al., 2005) but is not the focus of this paper. Instead, this paper discusses the impacts of self-driving technology on public roads, which are influenced by national and regional planning policy. The paper continues in the next section with an overview of existing literature on impacts of self-driving vehicles in freight transport. Section 3 then describes the method and section 4 and 5 present the results. The implications of the results are discussed in section 6 and section 7 concludes.

2. Previous work

The literature on impacts of self-driving vehicles is heavily biased towards passenger transport. Research on impacts of SDVs include simulations of new mobility services based on autonomous taxis (Fagnant and Kockelman, 2014; Meyer et al., 2017; OECD International Transport Forum, 2015), impacts on travel demand (Auld et al., 2017), as well as qualitative descriptions of uncertain dimensions via future scenarios (Fagnant and Kockelman, 2015; Gruel and Stanford, 2016; Milakis et al., 2017; Pernestål Brenden et al., 2017). For freight transport, this type of research is scarce. Muddhar et al. (2016) lists possibilities of the new technology for freight transport, including improved driver environment and safety, and implementation barriers including e.g. costly technology, liability issues, and the fact that, at least initially, automated vehicles will be perceived as unsafe. Muddhar et al. (2016) come to the conclusion that self-driving technology “has the capability to change the entire logistics system and would be a step towards fully automated supply chains” . Lutin et al. (2013) identify impacts of self-driving technology on the transport engineering profession and include e.g. the need for redesign of loading and unloading areas, and a need for dedicated lanes for the virtual road trains (platoons). Aspects related to the
operation of SDVs on the streets are transferrable from passenger transport, and include the importance of supporting legislation, the impacts on safety for other road users, and potential capacity increases in the road network. However, a similar transfer from passenger transport cannot be done for aspects related to the usage of the vehicles.

Automation of in-house logistics in warehouses and productions plants started already in the 1950s. Development continued with automated transport in other closed-off areas such as harbours and container terminals (Flämig, 2016). Automation has been shown to provide substantial improvements in operation, efficiency and reliability at container terminals (Stahlbock and Voss, 2008). The application of SDVs in freight transport on public roads differs from closed-off areas as the vehicles must be part of a larger transport system. It also enables several new applications in different parts of the logistics chain. Flämig (2016) discusses four use cases with different levels of automation in road freight transport: automated highway driving with a driver on board, i.e. an advanced auto pilot; automated driving without a driver on board; automated driving with a driver present for extended availability; and automated parking. The author suggests that improved traffic safety and reduced amount of exhausting/challenging work for the driver are common benefits in all four use cases. Furthermore, the author argues that successful implementation of automated road freight transport is heavily dependent on finding a new role or relevant work tasks for the driver, at least as long as there is a need for a driver to be present as a fall-back solution.

Platooning, i.e. vehicles (typically heavy trucks) driving in virtually connected trains, has gained a lot of attention in road freight transport (Alam et al., 2017; Arem et al., 2006; Bergenhem et al., 2012; Janssen et al., 2015; Liang et al., 2016). Since the truck leading the platoon can be manually driven and being a following truck is assumed to be easier than being fully self-driving, platooning can be a way to obtain benefits of automation while avoiding some of the challenges of full automation. Benefits of platooning are primarily decreased fuel consumption (slipstream) (Tsugawa et al., 2016, 2011) and release of the drivers’ burden in the following trucks (Muddhar et al., 2016). There are many completed and ongoing projects on platooning e.g. the European project “Safe Road Trains for the Environment (SARTRE)” (SARTRE, 2012), the Californian program PATH (California PATH, 2017), and the Japanese project Energy ITS (Bergenhem et al., 2012). These projects include practical implementations with truck platoons, and besides technology they also target collaboration between brands and nations.

3. Method

The results of this paper are based on predictions made by an expert group that was gathered for a half-day workshop in Stockholm in January 2017. The expert group consisted of seventeen experts from nine different organizations, representing the fields of authority, research, industry, hauliers, and union for transport workers. The workshop was organized around four themes: Long haulage, city logistics, societal effects and actors/driving forces. Conditions differ a lot between long haulage and city logistics and they were therefore discussed separately. Societal effects and actors/driving forces were chosen to direct focus of the workshop towards societal impacts. The experts were divided into groups of four to five people. Each group discussed each of the four themes, and discussion leaders recorded the ideas brought up in the discussions.

For long haulage and city logistics themes the questions given to the experts were:

- Which possibilities do SDVs create for long haulage / city logistics transport?
- Which barriers exist for SDVs to penetrate the long haulage / city logistics market?

For the actors/driving forces theme the questions were:

- Which actors demand SDVs?
- Which are the driving forces behind the demand for SDVs?

Finally, for the societal effects theme the questions were:

- Which societal effects are likely if there is a breakthrough for SDVs in freight transport?
- Which areas will be most affected, e.g. environment, cost-effectiveness, safety, mode choice, punctuality?
After the workshop, the authors of this paper analysed the outcome of the discussions and transformed it into one table with benefits and costs and one table with drivers and barriers associated with SDVs in relation to road freight transport. The authors also used the material from the workshop to extend and deepen the future scenarios for passenger transport presented in Pernestål et. al (2017) with a road freight transport perspective.

4. Implications of SDVs for freight transport

4.1 Benefits and costs of SDVs in road freight transport

The impacts of SDVs in road freight transport as benefits and costs to the society was discussed by the expert group especially under societal effects theme. The results are summarized in Table 1.

Table 1: Benefits and costs of SDVs of level 4 and 5 in road freight transport

<table>
<thead>
<tr>
<th>Domain</th>
<th>Benefit</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle driver</td>
<td>The driver can relax or work while transporting him/herself and/or goods.</td>
<td>Increased cyber security risk of the vehicle being hi-jacked by hackers.</td>
</tr>
<tr>
<td>Common to passenger transport</td>
<td>Reduced number of accidents caused by human error.</td>
<td>Risk of accidents due to system failures. The SDV technology may have difficulties in certain conditions, e.g. snow.</td>
</tr>
<tr>
<td>Environment</td>
<td>Improved working conditions for truck drivers. SDVs facilitate a change towards a more service-oriented occupation. SDV technology can automate loading and unloading at platforms.</td>
<td>Lost jobs. SDVs could imply fewer jobs for truck drivers.</td>
</tr>
<tr>
<td>Truck driver</td>
<td>Lower transport cost. Reduced/removed driver cost can decrease costs for hauliers. Increased vehicle usage can decrease costs for hauliers. Reduced impact of driver shortage. SDVs can be part of a solution to the current truck driver shortage.</td>
<td>Higher transport costs. Increased vehicle cost for trucks equipped with SDV technology. Segregation in the business. Smaller hauliers may not have the economic possibility to invest in the new technology.</td>
</tr>
<tr>
<td>Specific to freight transport in general</td>
<td>SDVs facilitate fuel efficient driving and monitoring of fuel consumption. Less freight transport during peak hours. SDVs facilitate night time deliveries if no driver needs to work night time shifts.</td>
<td>Reduced degree of filling. Lower fixed cost per vehicle-km decreases economic incentives to keep filling rates high and thereby lead to more transport.</td>
</tr>
<tr>
<td>Environment</td>
<td>SDVs facilitate fuel efficient driving and monitoring of fuel consumption. Less freight transport during peak hours. SDVs facilitate night time deliveries if no driver needs to work night time shifts.</td>
<td>Risk for impoverished city centres. SDVs increase the cost of transport to complex traffic environments and reduce cost of transport to external shopping malls.</td>
</tr>
<tr>
<td>Innovation</td>
<td>Increased control of goods flow. SDVs facilitate connected vehicles which can improve consolidation of goods and collection of data for truck maintenance.</td>
<td>Risk for impoverished city centres. SDVs increase the cost of transport to complex traffic environments and reduce cost of transport to external shopping malls.</td>
</tr>
<tr>
<td>Truck driver</td>
<td>SDV technology can assist drivers in narrow streets.</td>
<td>Modal shift to road transport. Increased utility and reduced costs of road transport may shift transport from rail/sea to road.</td>
</tr>
<tr>
<td>Specific to city logistics</td>
<td>Flexible last mile transport. SDVs facilitate development of small vehicles/robots/drones and thereby new types of logistics flow.</td>
<td>Modal shift to road transport. Increased utility and reduced costs of road transport may shift transport from rail/sea to road.</td>
</tr>
<tr>
<td>Specific to long haulage</td>
<td>SDVs can reduce fuel consumption by driving at low speeds during night because of the removal of driver cost and schedule.</td>
<td>Modal shift to road transport. Increased utility and reduced costs of road transport may shift transport from rail/sea to road.</td>
</tr>
</tbody>
</table>

Some of the benefits and costs identified by the expert group are common to passenger transport, e.g. the possibility...
to utilize time spent travelling to perform other tasks, the reduced number of incidents expected when the impact of the human factor is reduced, the induced travel as a reaction to improvements in the road transport alternative, as well as the risk of system failures and cyber-attacks. Others are specific to freight transport in general, to city logistics or to long haulage. Benefits and costs that are shared with passenger transport are included in Table 1, but will not be explored in more detail since this paper focuses on freight transport. The benefits and costs in Table 1 are further categorized into one of five domains: truck driver, safety/security, economy, environment or innovation. As depicted in Table 1, the expert group identified reduction in truck driver costs, reduced number of incidents, more fuel-efficient driving, improved working conditions for truck drivers, increased control of goods flow and flexible last mile transport as the main benefits of self-driving vehicles in road freight transport, and increased vehicle costs, lost jobs, reduced degree of filling, risk for impoverished city centres, modal shift of long haulage transport from rail and sea to road and in general more road transport as the main costs. Although fewer jobs for truck drivers is identified as a cost by the expert group, it can also be seen as a benefit of SDVs in freight transport since a lack of truck drivers is predicted within the next ten years (Muddhar et al., 2016).

4.2 Driving forces and barriers for implementation of SDVs in freight transport

Table 2 shows the driving forces of and barriers for implementation of SDVs in road freight transport as identified by the expert group when discussing the themes actors/driving forces, long haulage and city logistics. Driving forces are factors that may speed up the implementation and penetration of SDVs in road freight transport, while barriers may delay the development. As in Table 1, the results are divided into the domains truck driver, safety/security, economy, environment or innovation.

<table>
<thead>
<tr>
<th>Domain</th>
<th>Driving force</th>
<th>Barrier</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Common to passenger transport</strong></td>
<td>Safety/Security Reduced number of accidents in road transport is a key issue for authorities and vehicle manufacturers.</td>
<td>Liability issues are not yet settled – who is responsible if an accident occurs?</td>
</tr>
<tr>
<td></td>
<td>Economy</td>
<td>High vehicle and infrastructure costs might delay adoption of SDVs.</td>
</tr>
<tr>
<td></td>
<td>Environment</td>
<td>Increased attention by authorities to air pollution and CO2 emissions.</td>
</tr>
<tr>
<td><strong>Specific to freight transport in general</strong></td>
<td>Safety/Security SDVs enable safe transport in dangerous environments such as mines and these closed-off areas are well suited for testing the SDV technology.</td>
<td>A management system for connected trucks regardless of brand is needed.</td>
</tr>
<tr>
<td></td>
<td>Economy</td>
<td>Hauliers can reduce their costs spent on driver salaries and utilize the vehicles for more hours-of-service.</td>
</tr>
<tr>
<td></td>
<td>Environment</td>
<td>Increased attention is currently given to off-peak deliveries.</td>
</tr>
<tr>
<td></td>
<td>Innovation</td>
<td>SDVs can benefit from platooning being present already: SDV technology can be used in real world business models at an early stage.</td>
</tr>
<tr>
<td><strong>Truck driver</strong></td>
<td>Safety/Security</td>
<td>City logistics often implies a chain of loading and unloading spots, where a person often is needed.</td>
</tr>
<tr>
<td></td>
<td>Innovation</td>
<td>SDVs facilitate flexible last mile goods transport.</td>
</tr>
<tr>
<td><strong>Specific to city logistics</strong></td>
<td>Safety/Security A complex environment with pedestrians and cyclists is demanding for SDVs.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Innovation</td>
<td>SDVs can benefit from platooning being present already: SDV technology can be used in real world business models at an early stage.</td>
</tr>
</tbody>
</table>
Table 2 shows that safety and environmental factors are driving forces that are shared with the development of SDVs for passenger transport. One main driving force for SDV development which is specific to the freight transport sector, is the reduced transport cost. Costs for the truck driver is often approximated as one third of total transport costs, with vehicle and fuel costs making up the major part of the other two thirds. Since SDVs have the potential to reduce all three of these, and since the freight transport industry is commercially driven, cost reduction is the likely main driving force of development together with possibilities to develop new logistics concepts. Another enabler of SDV development in road freight transport is that the technology can be tried out in closed-off areas such as mines, harbours or private roads, where self-driving vehicles provide benefits even if they are self-driving only under certain conditions. Yet another important driving force for the implementation of SDVs in road freight transport is the fact that platooning is a technology that is already tested in several European projects and can be expected to be used in real applications within the coming years. The main barriers identified are the costs for rebuilding infrastructure and terminals to suit self-driving trucks and the changes needed in legislation and regulations. Furthermore, the large investment cost related to the self-driving technology can be a major barrier, especially for smaller hauliers. Specific to city logistics, the complex traffic environment and the many loading and unloading stops were identified as major barriers. For long haulage, cross-border challenges such as differences in legislation and system standardization were seen as the major barriers.

5. Scenario descriptions from a freight perspective

This section describes scenarios for the development of SDVs in freight transport with Sweden as a case study. The scenarios are developed by extending the scenarios derived in Pernestål Brenden et al. (2017), where two scenario dimensions, representing the two main uncertainties that are expected to have significant impact on the development of SDVs in 2030, were identified:

- Whether planners and policy makers will take a proactive role and lead the development, or if they will take a more passive role and let the commercial market lead the development.
- Whether the sharing economy, including data sharing, will have a breakthrough or not.

A summary of the potential development of SDVs and their impact on road freight transport is also given in Figure 1. This summary is based on an analysis and a mapping of the results from the expert workshop with respect to the scenario dimensions derived by Pernestål Brenden et al. (2017). The complete description of the process to derive the scenario dimensions, as well as scenario descriptions for passenger transport are provided in Pernestål Brenden et al. (2017).
In the remainder of this section the scenario descriptions from a freight perspective are given. Note that they are written as fictitious stories from the year 2030 perspective, which is standard procedure in the scenario development process (Lindgren and Bandhold, 2009).

5.1 Same, same, but different

Advanced driver assistance functions are now standard in all freight transport vehicles. They have made city logistics safer in complex urban environments with pedestrians and cyclists and help truck drivers to e.g. back into narrow alleys. These advanced computer systems do not only offer driver assistance functions, they also collect data on driver behaviour, vehicle speed etc., which is used to monitor driver compliance with rules and how fuel-efficient he/she is driving. The collected data is also used to monitor compliance with the strict governmental regulations on emission levels and energy consumption. Diesel and petrol vehicles are banned from most city-centres in Sweden. Therefore, city logistic carriers have started to replace their vehicle fleets with small electric vehicles. Although a lot of data is collected, this data is only shared to a very limited extent. Due to a terror attack in 2025, when a self-driving truck was hi-jacked by a hacker and driven into a crowd, vehicles are designed to communicate as little as possible with the outside world.

Nowadays, truck platoons are common views on the highways. Drivers take over and reload the goods into several smaller vehicles at distribution centres outside the city. This way, drivers can be based in one city and still participate in the situations that are most difficult to automate. The platooning services are developed within each truck brand, and truck manufacturers are competing with their platooning services as much as with the trucks themselves. The telecom industry has realized that there is a business opportunity to bridge the platooning services, and recently several multi-brand-platooning services, including a payment service, have been released. The highways in Sweden are electrified and electric trucks can therefore be used also for long-distance transport with larger vehicles. A kilometre charging system has been implemented for trucks in Sweden and the kilometre charge is substantially higher for diesel vehicles, further favouring the electrified long-distance transport.

5.2 Sharing is the new black

In the early 20’s, the state and the municipalities made huge investments in dedicated lanes for self-driving vehicles, as well as in supporting digital infrastructure. This, in combination with the general trust that data can be shared has fostered a fast development of SDVs. The policy makers’ main motivation to support self-driving vehicles was to improve traffic safety, but it has also had a great impact on the whole freight transport business. By removing the drivers, the operational costs for freight transport have been significantly reduced compared to...
the mid 10’s. This has also enabled hauliers to invest in the expensive SDV technology, which in turn has led to several new business models. Furthermore, as the dedicated lanes are less congested, transport efficiency has increased. However, the changed road freight transport business has also led to that many smaller hauliers, that did not have the economic possibilities to invest in the new technology could not stand competition.

A digital platform now exists for sharing data between different truck brands. It is mandatory for freight transport vehicles to share data on vehicle speed and fuel consumption, as well as data collected about the surroundings, such as slippery roads, accidents and congestion, something which is enforced by the state. The Swedish Transport Administration and other national and local authorities then use this data to deliver high-quality real-time services to citizens concerning travel times etc. Carriers also frequently use data about the position of their vehicles to optimize freight routes and load factors and consolidate goods.

5.3 Follow the path

The development of SDVs in freight transport has not been as fast as predicted during the late 10’s, and truck drivers have still an important role, even though automation have provided more and more intelligent support systems. The trucks are slowly becoming more and more self-driving, but the drivers are still important for loading and unloading. In 2017, Volvo showed a concept in which a waste truck was manually driven to an area for waste collection. Within the area the truck was then self-driving at low speed between the waste bins, while the driver could walk beside the truck and only help with bringing the waste bins to the truck. This concept has become standard for waste handling in Sweden and has dramatically reduced number of work related injuries for dustmen. Similar concepts have been developed also for other application areas.

In the years around 2020 it was a big worry that thousands of truck drivers would lose their jobs when vehicles became self-driving, and there was a lively debate in media. Truck driver was not seen as an occupation for the future. This uncertainty about the future led to very few young people choosing to become truck drivers. However, it turned out to be more complicated than expected to automate road freight transport and deliveries, and even if the role of the truck driver has changed to become more of a service-oriented task, driver or service personnel is still needed for virtually all deliveries. All together this has led to a major driver shortage and a challenge for carriers to find competent staff. The development of SDVs, both for passenger and freight transport has been slower than expected, but instead the development of high capacity trucks (HCT) has been fast, and 100-ton trucks are now standard on the roads. This development has also been a solution to the lack of drivers. Platooning services have become more and more common. The platooning services imply that drivers can do other things in the cab during long-distance travel, and therefore focus on the interior of the cab has increased. One reason for the slow development of SDVs is the lack of investments in infrastructure to support SDVs. During the last years of the 10’s the government decided to make a large and long-term investment in a new high-speed rail. The vast part of the national infrastructure budget has been dedicated to that project.

5.4 What you need is what you get

In road freight transport in 2030 the key success factors for carriers are deep customer insight, flexibility and on-demand deliveries. Also, autonomous mini robots, both on road and in the air, have become very popular for last mile deliveries. Deliveries are included in the full service to the customer. More and more people do not shop groceries at supermarkets any longer. Also, clothing and furniture stores have been rebuilt into show rooms. Instead services that guarantee your fridge and wardrobe to be filled with all you need are gaining ground. ‘Mail-box-refrigerators’ possible to open from the inside as well as from the outside are increasing in popularity. This way companies can fill your fridge and keep track of what it contains. Bot-chosen clothes are delivered home well in advance of your important meeting or party.

Vehicle manufacturers have together with robotics companies created new delivery concepts with electric trucks combined with robots that help with loading and unloading. Transport has become cheaper due to the reduced driver costs and possibilities to utilize the vehicle during more hours a day now that the schedule of the driver does not have to be accounted for. The slow and careful policy and planning has not managed to keep up with the pace of the commercial sector and therefore the reduced cost for transport has led to more transport, resulting in increased vehicle kilometres travelled by trucks. Fortunately, emissions in city centres still have decreased due to new innovative small electric distribution vehicles. Long haulage suffers however from lack of major investments such as electric motorways and still account for a substantial amount of CO2 emissions, which has been amplified by a modal shift from rail and sea to road. A few large companies dominate the freight transport market, some of
which combine freight transport with passenger transport in new types of business models. Urban passenger transport is highly automated and freight transport has benefited from the development of SDVs for passenger transport.

6. Discussion

The impacts of SDVs of level 4 and 5 on road freight transport identified by the experts in this paper capture the aspects previously identified in literature, including e.g. improved traffic safety, possibility to use in-vehicle time for other tasks than driving, fuel savings, and a predicted increase in transport demand (Flämig, 2016; Konings et al., 2005; Muddhar et al., 2016). However, the impacts presented here also goes beyond earlier findings, and address business ecosystems and changes in the road transport industry. For example, implementation of self-driving technology typically involves complete systems. This will make it challenging for smaller hauliers.

Although most of current research on SDVs, especially when considering the impacts of them, is focused on passenger transport, it is difficult to predict whether freight or passenger transport will lead the deployment of real applications. It may depend on how fast reliable and cost-effective applications are developed. If economically viable solutions, for example based on partly automated driving, are developed fast, they are likely to be taken-up by the freight transport industry, as the road freight transport business is a highly competitive business. On the other hand, if the implementation of reliable systems is more difficult, passenger transport may be leading the development, as humans also base their choices on irrational values and emotions. One reason freight transport could take the lead in the development and deployment of SDVs is the question about passenger safety, security and privacy. Privacy is an area which is likely to be very important for passenger transport, but which is less of a problem in freight transport, since goods themselves do not have a problem with being traced (even though the routes of certain goods might be sensitive information for companies).

Within road freight transport there are different forces driving the development of SDVs for city logistics and long haulage. While city logistics align well with the concept of small electric SDVs for flexible city transport, it has the disadvantage of a very complex traffic environment with pedestrians and cyclists and typically involves a chain of many unloading stops. Long haulage, on the other hand, has the advantage of an easier motorway environment and transport between few big nodes, but is more dependent on the development of EU standardizations and legislations.

7. Conclusion and future work

In this paper an analysis of the impacts of SDVs on road freight transport based on results from an expert workshop has been presented together with four future scenarios for the development. The results show that it is difficult to predict the overall impact of SDVs, and several of the expected consequences may be both positive and negative from a societal perspective. Self-driving technology is expected to provide cheaper road transport, as the driver can be (at least partly) removed. This is beneficiary for the production industry. On the other hand, cheaper transport is likely to induce more and longer transport, and thereby increased CO2 emissions and energy consumption. At the same time, removing the truck driver enables new opportunities for vehicles operating at lower speeds, which is both safer (with less impact of an accident when operating at lower speeds) and more environmentally friendly. Furthermore, the removal of the driver enables night time deliveries, which has the potential to reduce congestion. Those direct implications will also have impacts on the business eco system.

Whether SDVs will contribute to more sustainable road freight transport depends on the vehicle technology, but also on infrastructure investments, business ecosystems, policies and regulations. To further support policy and decision makers, those relationships need to be further investigated.

Acknowledgements

This project was funded by the Integrated Transport Research Lab, KTH Royal Institute of Technology, and the Swedish Ministry of Enterprise and Innovation. The authors would like to acknowledge the professionals from the freight transport sector in Sweden contributing with their knowledge and experience in the expert group.
References


