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The Economic Impact of Autonomous Vehicles in the Logistics Industry

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Abstract

In an ever-changing industry where competition between actors is growing, technical improvements and investments can be a way to outperform competitors and gain competitive advantages. In a relatively under-developed industry, technological developments may lead to major improvements and change the layout of the whole business.

Purpose – The main purpose of this thesis is *to investigate potential cost reductions obtained by autonomous vehicles within the Swedish logistics industry*. Studying opportunities for companies to strengthen their competitive advantage can create new markets, chances or ensure a strong market position. To investigate said opportunities, the following research questions were stated:

1. *What is the actual cost of implementing an autonomous vehicle?*
2. *Which costs will be affected by an implementation of autonomous vehicles?*
3. *How do these costs impact the Swedish logistics market seen from a cost perspective?*

Method – The data necessary to answer the questions was collected from document studies, literature studies and interviews. These were carried out simultaneously in an iterative process. Moreover, a pragmatic philosophy was undertaken, together with an abductive approach. The data was compared with existing theory by pattern matching and analysed with thematic approach, in order to ensure the level of trustworthiness.

Findings/Implications – The findings of this thesis is that autonomous vehicles will heavily impact the logistics industry. By gradually implementing autonomous vehicles, the Swedish logistics sector can save upwards of 13,4 billion SEK between 2020 and 2030. This shift towards autonomous vehicles will move jobs from the long haul sector to urban logistics and telecommunications. Additionally, the society will see great benefits as 90% of all traffic accidents will not happen when all vehicles are autonomous. It is clear that the Swedish logistics industry will benefit from an implementation of autonomous vehicles. Simultaneously it will also be beneficial for the society and the Swedish welfare.

Limitations – The major limitation of this thesis is the time horizon. Because of being future oriented, much data was based on external estimations that might change over time. Moreover, only costs directly connected to transportations has been investigated, leaving room for further studies related to indirect costs, as well as the organizational impacts on future supply chains.

Acknowledgement

Writing a master's thesis is a long and difficult process. Along the road, we have encountered several obstacles and challenges and we would like to acknowledge the following individuals for helping us overcome these challenges. This thesis would not have been the same without their help and guidance.

Therefore, we would like to show our gratitude towards our tutor and supervisor, assistant professor Imoh Antai. Professor Antai's assistance have truly helped us to steer the thesis in the right direction, while also continuously challenging us to work hard. Additionally, we would like to thank Professor Sönke Behrends at Chalmers University of Technology for great insights in the academia. We would also like to thank Oscar Zewebrand at Rosenlunds Åkeri and Christer Eliasson at GDL for an insight in the industry, along with Ayman Hassan at Tesla Motors for the hands-on experience with autonomous vehicles. Lastly, we would like to thank Björn Paulsson at InQuire for providing us with a 4PL perspective of future logistics.

Johan Bergvall & Christoffer Gustavson

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Abbreviations

LOA	Level Of Automation
SAE	Society of Automotive Engineers
NHTSA	National Highway Traffic Safety Administration
GPS	Global Positioning System
GLONASS	Globalnaja Navigatsionnaja Sputnikovaja Sistema
RADAR	Radio Detection and Ranging
LIDAR	Light Detection and Ranging
ROI	Return On Investment
VAT	Value Added Tax
SEK	Swedish Kronor
KSEK	Thousand Swedish Kronor
B2B	Business to Business
B2C	Business to Customer

1 Introduction

The first chapter consist of an introduction that will introduce the thesis from a logical and understandable perspective. A background of the thesis is presented, followed by a problem description that will lead to the purpose and research questions of the thesis. Delimitations, scope and disposition can later be obtained in the end of this chapter.

1.1 Background

Today companies' face a continuous and rapid change in their environments, causing competitive relationships (Levitt, 1983; Ohmae, 2000; Yip, 1995). This has forced many companies into being more aware of their cost efficiency to be able to remain economically viable (Douglas & Craig, 2011). To stay competitive and keep market shares in today's globalized market situation, it is important for companies to find a way of operating that differs from their competitors, gaining a competitive advantage (Jackson et al., 2003). Moreover, there is a need for initiatives that enable companies to maximize their performance in order to be successful in a winning oriented culture (Pfeffer, 1994). A well-defined and implemented value creating strategy will result in superior performance that will help companies to outperform any current or potential competitor (Porter, 1998).

When a competitive advantage has been achieved, it is necessary to both maintain and develop it to prevent competitors to close the performance gap. One way of remaining it is by new technology. According to Armstrong and Kotler (2014), technology has become a major force of change and development. This change has exploded during the recent years, which has fundamentally changed the way we live. It has enabled companies to find new innovative ways of operating and helped them to differentiate, primarily by reducing costs and enhance performance efficiency (Mitchell, 2007). The same rapid development of new technology is expected in the future and has therefore made companies more future oriented by researching new ways of operating in a more cost efficient way (Clulow et al., 2003).

One side effect of new technology developments that allow companies to reduce costs is the increasing level of automation. Automation, also known as automatic control, have become a big part of our society. It can be explained as the usage of different control systems to either monitor or operate resources and assets. It is often used in connection with easy, repetitive and sometimes dangerous processes. Moreover, it eradicates human errors and frees up time that can be spent on more suitable tasks (Martin, 2013). Automation is today commonly used within many companies and their supply chains. The main reason is the beneficial impacts on costs. It enables companies to reduce costs from a long term perspective by reducing costs such as labour costs, inventory costs and operating costs (Rifkin, 1995).

Many supply chains have during the recent year become leaner and more efficient. These changes have often resulted in reduced operating costs. By investigating and analysing processes from a cost saving perspective it might be possible to reallocate resources to be used in more important and performance-enhancing operations (Kotler & Armstrong, 2014). Creating a lean supply chain is often very complex and involves many different operations that most often are performed by multiple actors (Jonsson & Mattsson, 2011). This has led to that many of the improvements of supply chains are often restrained to each actor. Operations that are taking place over the whole supply chain is rarely taken into consideration, rather these improvements are formed by either new innovations or incentives on a larger scale. One area that is affected by this is the transportation sector, where many improvements has been done seen to the cargo carrier and infrastructure, but seen to the core of the operation it can be seen as slightly underdeveloped (Aberle, 2007; Paulsson, 2016).

All transportations have one thing in common. There is always a need for some kind of carrier. The recent developments within the transportation carriers have instead of focusing on cost efficiency, rather been aiming at sustainability and environmental aspects. Current technology has led to an opportunity of change within this area. Big leaps have been taken in the developments of autonomous vehicles during the recent years and are predicted to change the whole logistic industry, both from a sustainable and environmental point of view, but mainly from a cost perspective (AXA, 2015).

1.2 Problem Description

Transportation has become a vital part of the Swedish business environment and society. It is not only considered as prerequisite of business developments, it also increases competitiveness and contribute to the societal developments. Today, road transportation is the most used way of transporting goods in Sweden with 86% of all transportations. The majority of these are carried out by trucks (Trafikanalys, 2012).

The transportation industry has during the recent years gone through many changes, both beneficial and undesirable. Even though there have been developments within the industry itself in terms of the developments of intermodal transports. There have not been many improvements of the actual carriers. Transportations are still carried out in a similar way as it was decades ago (Behrends, 2016; Paulsson, 2016).

In order to stay competitive in the rough economic environment in Sweden, the amount of foreign drivers has increased dramatically. Moreover, many deregulations have been made from the European Union. This forces logistics companies to act on an international market, which increases the competition (Svenskt Näringsliv, 2005).

According to Trafikanalys (2014) the percentage of Swedish trucks are the lowest since the beginning of the 21th century while the amount of foreign trucks is higher than ever. Furthermore, trucks are in general overrepresented when it comes to fatal traffic accidents. Trucks are three times more likely to cause a fatal accident than a regular car (Engström, 2007). Additionally, AXA (2015) states that 87% of all traffic accidents are caused by human errors.

One solution that is not only expected to reduce costs, but also increase safety and be more sustainable is the use of autonomous vehicles. The technology behind autonomous vehicles has been under development for many years and has lately received much attention. Many companies such as Google, Ford, and Volvo are taking great steps towards introducing autonomous vehicles (Waldrop, 2015; Google, 2016; Volvo, 2015; Blake, 2015; Ford, 2016). Even though the technology is not yet developed enough to introduce a fully automated vehicle, there is technology and a level of automation that is far beyond the technology and automation of the transportation industry. Today there are autonomous cars that are able to drive itself, eliminating the need for a human driver and according to AXA (2015) the technology can without any major problems be implemented into trucks and heavier vehicles.

The technology behind autonomous cars is generally a software technology that interacts with technological components such as sensors to enable the cars to be self-driven. Therefore, the technology itself is not tied to cars. Since the technology is not fully developed, full automation may not be possible at a current state. Instead, an implementation of autonomous vehicles should be gradually increased. McKinsey (2013) states that it would be more beneficial to implement the technology available today and by time develop it rather than wait until it is fully developed since there is still many possibilities of reducing costs.

In best case scenario McKinsey (2013) expect that if an implementation of autonomous vehicles would take place today, it could lead to an annual total economic impact of 1,9 trillion dollars by 2025. Among these 1,9 trillion dollars, 500 billion dollars derives from autonomous trucks. Moreover, AXA (2015) estimate that only in UK goods industry, autonomous vehicles could reduce costs by almost 48 billion pounds throughout the next ten years. Not only could it lead to extensive cost savings, McKinsey (2013) also expect 70-90% less accidents on the roads by implementing autonomous vehicles. From a sustainable perspective, autonomous vehicles could annually save up to 300 million tons of carbon dioxide by 2025 (McKinsey, 2013).

Sweden can be seen as a pioneer within the development of autonomous vehicles. Companies such as Volvo and Autoliv are continuously setting new standards. Next year, Volvo will launch their project called Drive Me where they will release 100 autonomous vehicles on streets of Gothenburg. This motivate why the study is conducted within the Swedish industry. More promising is that an implementation in the near future could create better opportunities for even more extensive cost savings in the future.

1.3 Purpose and research questions

From the background section above, it is safe to say that many logistics companies today experience tough competition that forces them to find new ways of reducing costs in order to remain competitive. One way of managing this could be by new, innovative solutions with the help of technology. As mentioned in the problem description one solution could be by the use of autonomous vehicles. Thus, the purpose of this thesis is:

To investigate potential cost reductions obtained by autonomous vehicles within the Swedish logistics industry

To achieve the purpose, it is necessary to examine which factors that affect the costs of an implementation of autonomous vehicles seen to how companies operate today and how autonomous vehicles impact the companies. Thus, the first question is:

1. What is the actual cost of implementing an autonomous vehicle?

The first research question creates a solid foundation by stating an actual cost of an autonomous vehicle that later will be used as a focal cost in this thesis. To further investigate cost reduction opportunities it is important to identify what other costs which would be affected when an implementation has been done. Therefore, the second question is:

2. Which costs will be affected by an implementation of autonomous vehicles?

Furthermore, it is important to create an understanding how these costs impact their way of doing business. This gives a natural connection to final research question, which is:

3. How do these costs impact the Swedish logistics market seen from a cost perspective?

The combined result from the first and second research question are linked with the third question as well as the purpose of this thesis. The first and second research questions are linked in a way that the answers can be compared and allow the authors to answer the third research question in a logical way. When the research questions have been answered, the purpose is fulfilled.

1.4 Scope and Delimitations

The scope of the thesis is the transport aspects of supply chain management and how costs could be affected by the implementation of autonomous vehicles. Level of Automation (LOA) 4 & 5 in the Society of Automotive Engineers' (SAE) will be used as the term autonomous vehicle. In this thesis autonomous vehicles are considered as trucks. Equally, even if autonomous vehicles such as automatic forklift trucks may impact the logistics industry, the focus will be transportation by autonomous trucks, such as long haul trucks.

The thesis will only consider the implementation costs and factors that are involved in the actual transportation process as seen in Figure 1. Therefore, potential external impacts on the supply chain will not be investigated, such as infrastructure or service level. Studies of infrastructure are not necessary, since autonomous vehicles do not need any specific infrastructure to be functional.

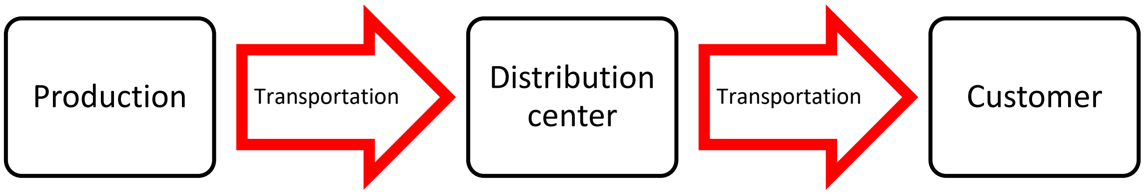


Figure 1: Scope of this thesis

Moreover, technological aspects will be taken into considerations as far as needed, such as how existing technology can be used to reduce costs or not. The technology itself will be explained but not in any further depth since the main focus of this thesis is the cost aspect. The main time frame of the thesis will be within the next 14 years (year 2030).

For the first research question costs connected to the implementation, direct costs will be the main focus. Even though indirect costs will be looked upon and included these are very difficult to estimate and therefore will the focus rely on the direct costs instead. For the last two research questions all costs that are direct related to transportation will be investigated. Costs such as organizational costs that comes as a response of the implementation of autonomous vehicles will not be taken into consideration. Additionally, neither inflation nor depreciation is included in the cost assumptions.

The thesis will only take the Swedish market into consideration, even though data will be collected from international sources.

1.5 Disposition

In order to make the master thesis manageable a disposition is needed. In every chapter there will be a short introduction of the chapter's content. This will enable a holistic view for the reader. Additionally, it will make it easier to understand. This text is written in italic and only consists of a few sentences.

The background and problem description is the initial part of the thesis, to provide a basic understanding for further reading. After the purpose and research questions are introduced, scope and delimitations are presented to make the thesis manageable in the time frame and clarify some uncertainties.

The second chapter consists of the frame of reference which provides necessary information in terms of theories needed to answer the research questions. Since the topic of this thesis is seen as new and unexplored, it also serves as a technological explanation of autonomous vehicles. The content in chapter three is then used throughout the thesis.

The third chapter is method. The main idea of this chapter is to explain how the study have been conducted and what strategies and approaches have been used. Furthermore, it explains how data have been collected and analysed to increase of the trustworthiness of the thesis.

Results and analysis use theory and collected data to answer the research questions and fulfil the purpose. In the analysis chapter the findings will be compared and evaluated.

The last chapter is the discussion. This section will allow the authors to both discuss and present their own opinions regarding the findings and future scenarios. To finalize the thesis, a conclusion will be given as well as suggestions for possible future studies. References and appendixes are found at the end of this thesis.

2 Frame of references

The theories later used in the thesis is presented in this chapter. In order to introduce the theories in a logic and understandable way, a table is given to connect the research questions to each topic in the frame of references. Some theories are well known and general while some are more specific for this thesis. The chapter is divided into several sub-topics where the theories are described.

2.1 Connection between research questions and theory

To create an understanding of the thesis and topic itself, theories introduced in this chapter has be chosen carefully. Each theory is connected to the research questions earlier stated. Moreover, it is important to state that certain theories are more important than others but all are essential to answer the research questions. This also enable readers not familiar with autonomous vehicles to get a better understanding.

To be able to answer the first research question there is a need of understanding the technology that is used and integrated in autonomous vehicles as well as the components needed and how this is related to automation. Moreover, an understanding of implementation cost is needed. Most importantly, an understanding of the autonomous vehicle must be provided, especially since they are most often misunderstood. This is illustrated in Table 1.

Table 1: Connections between research questions and frame of references

Research Questions	Theoretical topics
1. What is the actual cost of implementing an autonomous vehicle?	Automation Autonomous vehicles Implementation costs
2. Which cost will be affected by an implementation of autonomous vehicles?	Transportation costs Automation Autonomous vehicles
3. How do these costs impact the Swedish logistics market seen from a cost perspective?	Innovativeness Competitive advantage Transportation costs Automation Autonomous vehicles The last mile

There are many costs that need to be taken into consideration for the second research question. As mentioned before in delimitations only costs related to the actual transportation will be investigated. Furthermore, automation and the theory of autonomous vehicles are connected to the second research question to provide better knowledge for the final result and analysis.

When it comes to the third and final research question, theories applied to answer are automation, competitive advantage, innovativeness, transportation cost, autonomous vehicles, and finally the last mile problem. All these theoretical concepts are necessary to answer the third research question in the most precise way possible. When the third and final research question has been answered, the purpose of this thesis is fulfilled.

2.2 Automation

As labour costs are ever rising, automation can be a great help for companies to overcome many of the economic issues they are facing in today's competitive market. If a process were to become automatized, the results are often greater efficiency and increased performance in both quality and consistency compared to a manual process (Food Engineering & Ingredients, 2009). As automation is implemented, two major benefits are labour cost savings and enhanced quality of services.

In the current market, customers demand higher flexibility and adaptability. Automation can be a way to meet those demands. Nevertheless, automation is permeated with problems. Two examples of this issue are strategic planning or human relationship tasks where human interaction is involved. Additionally, automation goes hand in hand with high initial costs and time consuming implementations. To achieve a fully automated process, big investments are often necessary, together with time consuming activities (Bennett, 1993).

When deciding on implementing an automation process, there are a few things a company needs to consider, such as the tasks that are supposed to be made and the work environment. For example, if the work environment is dangerous, monotonous, tedious or time consuming, automation may help to reduce the human exposure to that environment. Furthermore, automation often frees capacity for the workforce to focus on more important tasks (Heizer & Render, 2010).

As the processes vary, the level of automation needs to be aligned to fit the processes. If an activity is better performed by a human, a human should perform the task and vice versa. Automation should only be used where it is best suited (Sheridan, 1995). Every process cannot be fully automated and one way to determine the automation level is the level of automation (LOA) presented by Endsley (1999). The LOA is used to make operations more effective and optimized. It also specifies to what degree the processes and activities should be automatized to achieve an effective combination between human workforce and automation (Endsley, 1999). There are five steps of automation: (Endsley, 1999)

1. **Manual control** – No assistance from the system

2. **Decision support** – The operator gets recommendations provided by the system

3. **Consensual artificial intelligence (AI)** – The system interacts with the operator to carry out actions

4. **Monitored AI** – The system automatically take action, unless the operator has another opinion

5. **Full automation** – No operator interaction

In today's market, automation is often used in high-capacity production facilities where it can be used to increase efficiency and reduced labour costs (Sheridan, 1995). Therefore, much of the previous theory is focused on using automation to improve producing processes. However, Heizer & Render (2010) introduces the following table where advantages and disadvantages of automation in general are presented against each other. Refer to Table 2.

Table 2: Advantages and Disadvantages of Automation (Heizer & Render, 2010).

Advantages	Disadvantages
Reduced labour cost	High initial cost
Higher and more predictable quality	Long implementation time
Reduced lead-times	Cannot handle strategic planning as good as humans
Reduced amount of energy spent	Unemployment
Safety and environmental aspects	

2.3 Autonomous vehicles

The idea behind a self-driving vehicle started in the 1920s but was not truly actualized until 1980s when Carnegie Mellon University was able to develop a working autonomous vehicle, called the NAVLAB (Sharfer & Whittaker, 1987). Since then, many carmakers have researched and released concept cars but it was not until the last few years the industry really took off and now Ford is planning on mass producing autonomous cars in the year 2020 (Butler, 2016).

Self-driving vehicles or Autonomous vehicles is one of the practical uses of automation. The Levels of automation stated by Endsley (1999) can be applied to autonomous vehicles and the agency National Highway Traffic Safety Administration (NHTSA), a part of the United States' government department of transportation, have used Endsley's definitions to identify five LOAs regarding autonomous vehicles. These levels range from no automation where the driver is complete control without any technological assist from the vehicle to full automation where a driver is not needed. According to Törngren (2015) these LOAs are important in many cases since it decides when the driver is responsible, consequently LOAs are of great interests for insurance companies. Presented in the list below are NHTSA's definition of LOA (NHTSA, 2013).

0. **No-Automation** - The driver is in complete control at all times and with no computer interaction.

1. **Function-specific Automation** - The second level includes one or more control functions. Examples of this include automatic emergency braking or blind spot warning systems. Combining these control functions and the second level is given.

2. **Combined Function Automation** - If more than two functions are designed to operate together the driver will be relieved of some control. Adaptive cruise control working in unison with lane centering could be one example.

3. **Limited Self-Driving Automation** - Several control functions working together allowing the driver to surrender control over the vehicle under certain conditions, such as highways or during normal traffic. The vehicle should provide a comfortable ride without much interference. However, this level of automations relies on the ability of

the human to seize control if needed. Currently, the Google car is an example of this level but Google is working towards level 4 (Google, 2016).

4. **Full Self-Driving Automation** - This level of automation allows the vehicle to perform all driving functions and continuously monitor road conditions throughout the entire trip. Even if the self-driving automation may require an administrator to input destination via Global Positioning System (GPS), a driver is not expected to be physically present or interrupt the vehicle at any time.

SAE further developed NHTSA's framework in 2014 and released the organization's version of the LOA regarding autonomous vehicles as seen in Figure 2. SAE's version is comparable to NHTSA, but with the exception that level 4 of NHTSA is split into two levels in SAE's LOA (Smith, 2013).

SAE level	Name	Narrative Definition	Execution of Steering and Acceleration/ Deceleration	*Monitoring* of Driving Environment	Fallback Performance of *Dynamic Driving Task*	System Capability *(Driving Modes)*
***Human driver* monitors the driving environment**						
0	No Automation	the full-time performance by the *human driver* of all aspects of the *dynamic driving task*, even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a
1	Driver Assistance	the *driving mode*-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	Human driver and system	Human driver	Human driver	Some driving modes
2	Partial Automation	the *driving mode*-specific execution by one or more driver assistance systems of both steering and acceleration/ deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	**System**	Human driver	Human driver	Some driving modes
***Automated driving system* ("system") monitors the driving environment**						
3	Conditional Automation	the *driving mode*-specific performance by an *automated driving system* of all aspects of the dynamic driving task with the expectation that the *human driver* will respond appropriately to a *request to intervene*	System	**System**	Human driver	Some driving modes
4	High Automation	the *driving mode*-specific performance by an automated driving system of all aspects of the *dynamic driving task*, even if a *human driver* does not respond appropriately to a *request to intervene*	System	System	**System**	Some driving modes
5	Full Automation	the full-time performance by an *automated driving system* of all aspects of the *dynamic driving task* under all roadway and environmental conditions that can be managed by a *human driver*	System	System	System	**All driving modes**

Figure 2: Summary of Level of Automation (SAE, 2014)

These six levels of autonomous vehicles can ease classification and also help decide the amount of technology necessary in the vehicles (NHTSA, 2013). The technologies used in autonomous vehicles are examples of new technology meeting existing technology where a vehicle is capable of monitoring and analyzing the surrounding environment to navigate and drive without human input (Gehrig & Stein, 1999). The vehicle uses several highly technological systems to enable driverless navigation. The systems vary depending on the vehicle, but the majority of vehicles use most of the following technologies (Blake, 2015)

2.3.1 Satellite Navigation

Satellite navigation consists of multiple organized satellites in space with a known time and location. The time and positioning data is then transmitted to other satellites and to receivers on earth. If collecting this data from at least four different satellites, a location and trajectory on earth can be determined. If the satellite navigation covers all areas on earth it is called a Global Navigation satellite systems (GNSS) or more commonly, GPS. GPS is the term for the American GNSS but there are other systems available such as the Russian Globalnaja navigatsionnaja sputnikovaja sistema (GLONASS) and the European Galileo positioning system. Satellite navigation tools are often used by vehicles, smartphones and other devices that need accurate positioning and trajectory calculations (The Library of Congress, 2011).

2.3.2 **Radar & Lidar**

Radar and Lidar are two similar systems for identifying the surrounding environments to create a virtual three dimensional map of the roadway. Lidar (Light detection and ranging) is the modern version of Radar (Radio detection and ranging). Radar systems sends out radio waves that reflects on any object and are then sent back to the Radar transmitter. The Radar system processes these waves by calculating the time between emission and receiving. This frequency can then determine the properties of the object, such as size, location, relative distance from transmitter, speed and direction (Hofmann, Rieder, Dickmanns, 2003).

A Lidar system is similar to a Radar system, but emits ultraviolet, visible and near-infrared light instead of radio waves. Lidar is often more accurate than radar systems due to the narrow light beam. Therefore, Lidar systems can provide an accurate virtual picture of the surroundings which allows the vehicle to recognize obstacles and road conditions (García et al., 2012). However, Lidar can only distinguish objects up 80 meters so Lidar systems are often paired with Radar to increase visibility range up towards 200 meters ahead of the vehicle. In combination, these systems can detect road signs, lanes, red lights, other vehicles, pedestrians, cyclists etc. (Google, 2016; Waldrop, 2015).

2.3.3 **Camera & Sensors**

Today many vehicles use some kind of camera sensor to ease parking or enable adaptive cruise control. These systems gather and interpret data of the surroundings and act according to the environment. Many vehicles currently available on the market can be fitted with adaptive cruise control and even collision avoidance systems that senses vehicles or other objects ahead and apply brakes if the driver is not doing so (Volvo, 2015).

One example when the technology has been taken even further is the Jaguar Land Rover Range Rover research vehicle. It is fitted with ultrasonic sensors and cameras that creates a 360° safety ring that detects obstacles and hazards. The radius of the safety ring is made to correspond to the stopping distance of the Range Rover (Blake, 2015). Furthermore, the vehicle is equipped with automatic parking technology that uses the sensors to find a suitable parking space and navigates the vehicle in and out of the parking space (Blake, 2015).

Sensors are not only used to create a virtual copy of the surroundings but also to sense road conditions and lanes. In January 2016 Ford published a report of their research vehicles autonomously driving in snowy and slippery conditions. Lidar cannot see the roads if they are covered in snow or if the Lidar lens is snow-covered and therefore other technology is necessary. Ford circumvent the problem by sensors collecting data to create a 3D map with information including road signs, landmarks, geography and topography (Ford, 2016).

2.3.4 **Architecture of autonomous vehicle systems**

The information gathered by the sensors and cameras are then processed to gain Odometric data (information about motion and measurements changing over time). Odometric calculations are then combined with satellite navigation (GPS) to give a pose estimation as shown in Figure 3. This estimation provides the vehicle with known position, speed, direction and whereabouts (Gordon & Lidberg, 2015).

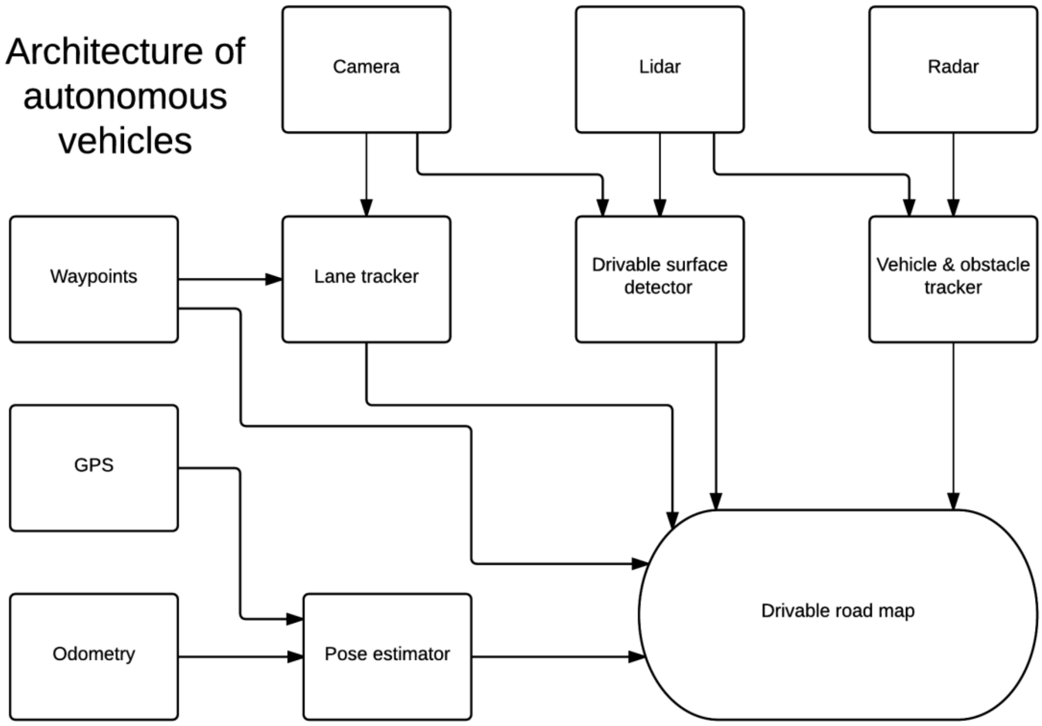


Figure 3: Architecture of autonomous vehicles (Simplified own illustration, inspired by Gordon & Lidberg (2015))

The data from the pose estimations are then connected with data from camera sensors, Lidars and Radars to generate a virtual drivable road map used by the vehicle to automatically navigate and drive itself on any normal road (Gordon & Lidberg, 2015).

2.4 Implementation costs

In the past, implementing new ways of operating was considered as a cost, today it is rather looked upon as an investment. Even if it is seen as an investment, it is important to identify all the costs involved to estimate an implementation cost and by that be able to calculate the return on the investment (ROI) period. If the ROI period is satisfying, the investment is motivated. It is important for a company to make sure they will be able to stay in business and have an economic buffer in case the ROI period becomes longer than estimated (Philips, 2010).

Moreover, it is important to take future aspects into consideration such as new operating procedures and therefore a new implementation would be needed. If this takes place, the ROI period must already have been met for a company to become profitable. An implementation seen as an investment need to take all costs into consideration and these are costs generally related to assessing, designing, developing, training and evaluating the implementation (Philips, 2010).

2.5 Transportations costs

According to Oskarsson et al. (2006) transportation costs are those costs that appear when goods are physically transported. All costs affected by administrative operations connected to the transportation should be included (Coyle et al. 2003). Additionally, the value of the goods that is being transported should be considered as a cost in terms of tied up capital. This can be explained by the tied up capital in the goods could have been used to other investments to increase profitability (Jonsson & Mattsson, 2011).

A common misunderstanding of transportation is that it is seen as a non-value adding activity. But transportation adds value in terms of the locational advantage the customer gets of retrieving the goods closer the final usage area. The closer the goods are to where it is supposed to be used or sold, the more value has been added through the transportation. Since the transportation is seen as a value adding activity, the value of the goods will increase the closer it gets to its final destination. This results in higher costs in terms of tied up capital (Jonsson & Mattsson, 2011).

Transportations are generally divided into two segments, internal and external transportations. Internal transportations are those that take place by moving goods and packing it within a firm's facilities. The external transportations are defined by loading, re-loading and unloading goods together with the actual transportation between different locations. It involves transportations between suppliers, customer and even a company's own departments if they are geographically dispersed (Oskarsson et al., 2006).

Other costs that need to be taken into consideration is the labor costs, both for the driver and administrative staff interfering with the transportation by route planning etc. Additionally, fuel costs, insurance and safety cost and the cost of the vehicle utilization needs to be included in the transport. The cost of insurance is the cost the transportation firms and companies use both to insure the actual vehicle but also the goods loaded onto it. Vehicle utilization cost is connected to efficiency and show a cost for the usage of the vehicle (Oskarsson et al., 2006).

2.5.1 Fuel

The cost for fuel consumption is one of those transportation costs that are direct related to both the distance and time of the transportation. This means that the longer time and distance the transportation requires, the more it will cost. The cost for fuel consumption has throughout the years been decreased by the initiatives of new technology that enable carriers to consume less fuel during longer distances. It is still considered as the second largest variable cost in relation to fleet management (Hatfield & Christensen, 2014). Due to the recent years' technological advancements such as a connected GPS that show the closest and most efficient way possible, has enabled carriers to reduce time and distance. There have also been developments aerodynamics that will allow further savings in fuel consumption (Lammert et al., 2014).

Another aspect that is difficult to estimate is the actual price of oil or gas. This cost is rather dependent on the oil price which is affected by many factors in the international environment (Lammert et al., 2014).

2.5.2 Labor

Labor cost can be summarized as all wages a company pays to their employees, together with the costs of benefits and payroll taxes that are connected to each employee. It can further be divided into either direct or indirect costs. Direct costs are those costs that appear for an employee physically producing a product or perform a service. For example, an employee working in a production site assembling different components. Indirect costs are related with the support labor such as maintenance that are not directly connected to the product or service itself (Herzog-Stein et al., 2013).

Relocation, also known as outsourcing, can lead to loss of knowledge when skilled employees are replaced and this can sometimes affect the overall quality. This fact has led to that during the recent years, many companies have reduced labor cost by automation to both get higher quality and remain close to market (Zitkova, 2004).

2.5.3 Insurance and safety

Insurance cost is generally part of vehicle cost (Behrends, 2016) but an implementation of autonomous vehicles will impact the insurance cost to a degree where it will become a major cost base in the cost estimations and therefore is looked upon as an individual cost.

There are insurances for the employees, but these are considered as labor cost. The cost for insuring the vehicles depends on the risk factor that is involved, the higher risk in terms of probability for accidents or if the vehicle is developed for dangerous goods transports, the higher will the insurance premium be (AXA, 2015; Herzog-Stein et al., 2013).

2.5.4 Vehicle utilization

If a certain vehicle can only be used for a specific amount of time because of constraints in terms of working hours or operational factors, a cost appears since the vehicle will be standing still and therefore potential incomes are lost (AXA, 2015). There have been many improvements in new technology, such as GPS and other telematics solutions that enable drivers to cut out on unnecessary mileage. This also discourage excess usage that might occur when drivers think they cannot be monitored by the companies (Hatfield & Christensen, 2014).

The utilization cost also involves fill rate and naturally, return flows or when the carrier is used without bringing any value, such as being empty. This has led to a lot more focus on the return logistics the recent years. Today, companies try to reduce cost by increasing their return logistics and in this case it means that carriers should preferably never run empty loaded. (Lumsden, 2012).

2.6 The last mile problem

All goods transportations start by collecting the amount of goods, to which degree it creates economies of scale. This means that the transportation cost is marginally increased when the amount of goods is increased. To enable economies of scale and assemble the goods, consolidation is needed (Lumsden, 2012). Normal transportation is inefficient and often very costly because goods need to be distributed on a product level. This means that all individual packages that are loaded on a transport need to be delivered to the final destination that most often differs among all the goods on the transport carrier. This is also called deconsolidation and appears in the end of the transportation process and is shown in Figure 4.

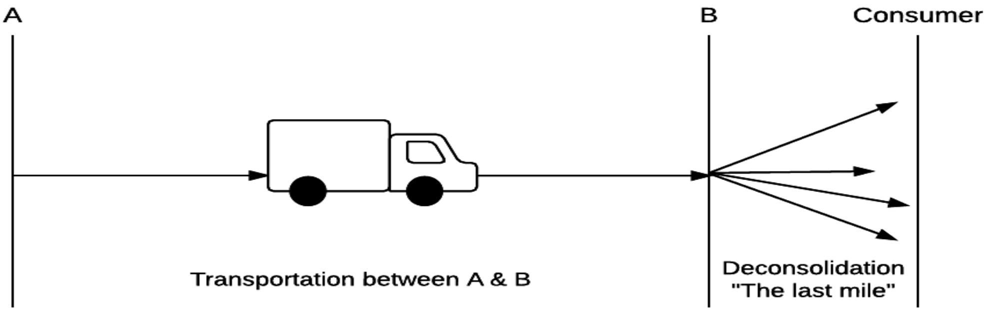


Figure 4: The last mile problem, own illustration

The deconsolidation that means that each individual customer or unloading point needs to be reached is often mentioned as the “Last mile problem”. This problem often occurs when the consolidated goods are moved from point A to B and then later needs to be deconsolidated. The costs that occur on a product level is most likely to be higher than the cost for the whole transportation of the consolidated goods. This can lead to that short transportations what involve deconsolidation can generate a negative impact on profitability (Lumsden, 2012).

2.7 Innovativeness

Miltenburg (2005) states that innovativeness is the ability companies get by developing and produce new products or solutions by the help of either new or existing technology. Moreover, it includes modification of an already existing product. One perspective or definition that is often overseen when it comes to innovations is its relation to manufacturing. According to Nonaka (1994) it can be easier to get an understanding of innovation if it is looked upon as a process, by defining deficiencies and by that, develop new knowledge and strategies to solve these.

Innovativeness can be seen as differentiation and therefore be used as a competitive advantage by taking, increasing or maintaining market shares to enhance a company’s profit (Thornhill, 2006). The concept is characterized by the idea of early introduction for new products on the market seen to competitors and cause an advantage that can generate a larger market share. One problem that is often discussed is if the level of technology is saturated in a market. According to Miltenburg (2005) innovativeness can still provide improvements and opportunities to increase efficiency and enhance profitability, especially from a manufacturing perspective. By investing and improving processes and operations with innovativeness, efficiency will increase, which in return can enable cost reductions (Miltenburg, 2005).

2.8 Competitive advantage

According to Besanko et al. (2004) competitive advantage can be defined as when a company possesses a higher profit rate than the average profit of other companies within the same area of business. To gain competitive advantage, a firm must start with developing a successful strategy. This is often referred to as strategic positioning and aim to find a position within the industry that is the most profitable. A more profitable position will increase the odds of surviving and stay in business. The main goal with the strategy should be to reach long term profitability. The strategy can be divided into two smaller strategies as shown in Figure 5 where one is the competitive strategy that involves the competitive advantage. The second strategy is often called corporate strategy and helps the company to define which market they should position themselves in. When these two strategies are integrated and carried out in the right way it will lead to an overall strategy that will allow the company to be profitable (Besanko et al., 2004).

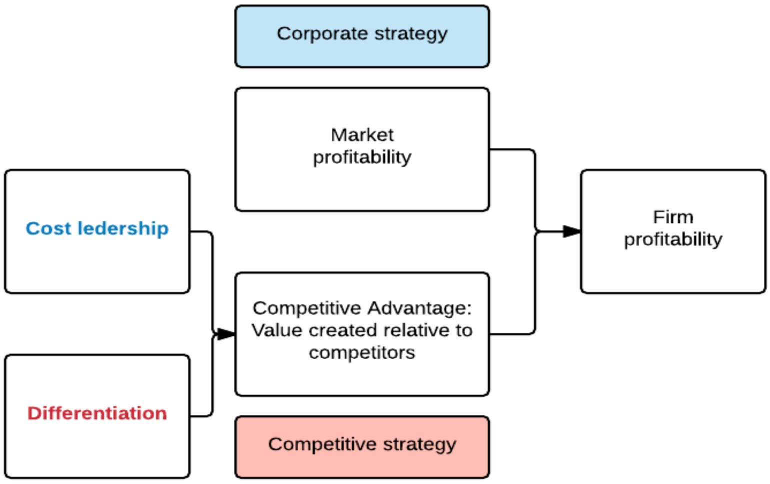


Figure 5: Strategy & competitive advantage (own illustration, inspired by Conti, 2015)

When it comes to the competitive advantage itself, it is important for companies to focus on the value they bring to their customers. To reach long term profitability it is important to develop and deliver economic value, exceeding their competitors. The value created can be defined by Equation 1.

$$\textit{Value created} = (B\text{-}P) + (P\text{-}C) = B\text{-}C$$

$$B = \textit{Willingness to pay} \qquad P = \textit{Price} \qquad C = \textit{Cost}$$

Equation 1: Competitive Advantage Equation (Conti, 2015).

What the formula demonstrates is that a company should focus on either increase customers' willingness to pay or reduce cost to create as much value as possible. By increasing the willingness to pay among customers, companies generally adapt a so called differentiation strategy. When companies instead focus on reducing their costs they have adopted a cost leadership strategy (Porter, 1998; Conti, 2015).

Differentiation is better suited when the target group is not particularly price-sensitive or if the market is already saturated. Customers that are not price-sensitive are in general more concerned about specific needs or specifications of the product, than low prices. When adopting a differentiation strategy, it is important for a company to ensure that it is difficult for competitors to copy either the product or service. This can be done with help of patents, licenses or a well functional research and development department (Porter, 1998).

A cost leadership strategy focusses on attracting customers by offering products to a lower price. This is done by reducing the cost, thus lowering the final price. It does not necessarily mean that a company need to offer the lowest price possible, rather to gain as high value compared to the price. To be able to fulfill their goal of being profitable, companies need to operate at a lower cost than their competitors.

Cost leadership can be divided into three different dimensions; high asset utilization, low direct and indirect operating costs and control over the value chain. High asset utilization focuses on gaining economies of scale by for example having a truck that got close to 100% utilization. The second dimension, low direct and indirect operating costs aims at finding new ways of operating to reduce costs for both assets and labor. The third and last dimension where companies try to control their whole supply chain is usually used by companies to streamline their operations and create a leaner and agile value chain by being highly integrated (Srinivasan, 2011).

According to Besanko et al. (2004) it is important for companies to choose either differentiation or cost leadership to become successful. If a company choose to use both these strategies, there is a big risk that the company get "stuck in the middle" which means that the company will have neither an advantage by the cost leadership or the differentiation. It further increases the difficulty of decision making since many factors of each strategy are counterproductive for the other. From a customer point of view, it is often seen as an uninspired product or service that only fulfill their needs to a certain level (Besanko et al., 2004).

3 Method

The method chapter is necessary to increase transparency and present the author's work process. The chapter is introduced with a connection between research questions and methods used to answer those questions. A work process and timeline is presented as well as the research philosophy, approaches, including data collection methods and data analysis. The chapter ends with an overview and evaluation of trustworthiness.

3.1 Connection between research question and method

To answer the first research question, both document studies and literature reviews were undertaken. The data that has been collected is necessarily not only used to answer one specific research question, but also it is used to provide additional information and knowledge for the other research questions. The connection between the research questions and choice of data collection methods are clarified in Table 3.

Table 3: Connections between research questions and methods used

Research Questions	Methods used
4. What is the actual cost of implementing an autonomous vehicle?	Document studies Literature review
5. Which cost will be affected by an implementation of autonomous vehicles?	Document studies Literature review Interviews
6. How do these costs impact the Swedish logistics market seen from a cost perspective?	Document studies Literature review Interviews

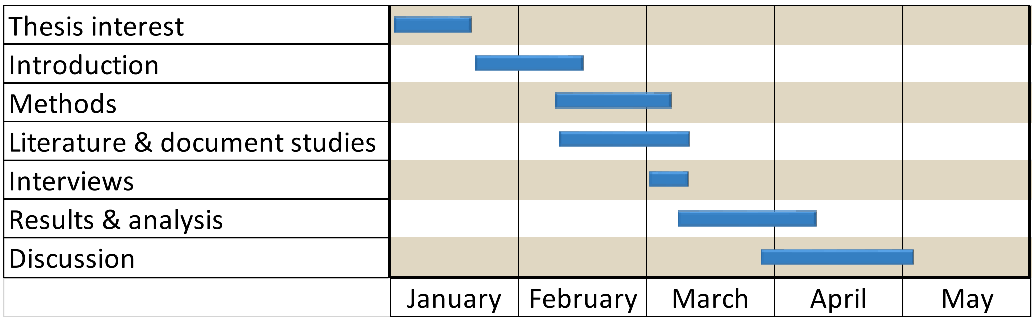
As the first research question has more of a theoretical character, document studies and literature reviews were the main source of data. Additionally, the data needed to answer the first research question have quantitative characteristics and was therefore easier accessed by the used methods. The data for the second research question was mainly collected through document studies and literature reviews. However, interviews helped to retrieve specific and more precise data, since the second question itself is somehow based on future scenarios.

Similar to the second research question, the third is also based on future scenarios. Hence, the same methods were used. In the third question, the interviews focused on retrieving information and data from the current state of the autonomous vehicle industry as well as getting professionals' opinions about future scenarios. Moreover, literature studies are considered as iterative processes, thus enabling the third research question to be answered in a better way.

3.2 Work process

In order to increase transparency and understanding, a walk-through of the work process is provided. A rough time scope of the work process is shown in Table 4. This section gives an estimation of how work has been carried out throughout the thesis.

Table 4: Time frame of the thesis



In September 2015 AXA, a French insurance company, released a report about the "the future of driverless haulage" which got the authors interested in autonomous vehicles in the logistics industry. This topic was quite underdeveloped and much of the scientific research was focused on autonomous cars. The major problem was that the ideas was not yet applied to the logistics industry.

The problem was defined and thus, a purpose was created to solve this problem. To establish a clear course of action, three research questions were defined. To start working with the background and problem description, some information was obtained via literature and previous experiences. Document studies provided the basic knowledge of the topic. To further increase the data collection methods and increase triangulation, the authors contacted some companies working with autonomous vehicles, as well as a professor that is currently studying the future of supply chain management.

The data was collected from both qualitative and quantitative methods, and compared to each other, and later used to form the Frame of reference chapter.

At the end of February and early March the interviews were supposed to be held. Two interviews were carried out during that time. One by telephone and one face to face. The remaining interviews were conducted in late April, mainly to test and prove the thesis' transferability and generalizability. The interviews were recorded to later be transcribed.

Following the interviews, the results and analysis took part. This was a very time consuming process as data needed to transcribed, categorized, analysed and summarized. In fact, the authors had to allocate more time for this process and postpone the discussion chapter to late April. The main reason for this was to make sure that the gathered information was collected in the right way, and analysed in the appropriate way.

The postponement of the discussion chapter meant that the thesis was slightly behind schedule. But progress was made, and the final product started to take shape. The research questions were answered, and thus the purpose was fulfilled.

3.3 Justification of the thesis

During the first steps of this master thesis, we performed a pre-study to see if the topic actually could generate enough data for a master thesis and if any research gaps could be examined. A brief literature review was carried out in a critical way in order to gain an objective overview and in order to position the research within the right context. Once we gathered enough data to get a grasp of the area, we quickly realized that the area was vague and unexplored.

As autonomous vehicles is an emerging topic, there is very little academic knowledge about the impacts on the logistics industry. Most of the academic articles about autonomous vehicles relates to the technology in autonomous vehicles and its development, rather than the application of the technology. This shows that the topic is still evolving as academics still discuss technology instead of the application. Moreover, the concept of autonomous vehicles is vague and unclear. The associated theories are indefinite and previous studies do not adequately describe how data was collected. We find it important to provide a clear overview of the cost structures both directly and indirectly and at the same time as filling the research gap.

The topic of autonomous vehicles is also seeing a dramatic increase in popularity. During the last couple of years, autonomous vehicles have been trending on the internet and social medias. The number of google searches for autonomous vehicles has increased by 400% since 2014, much due to Tesla's and Google's autonomous cars and the research being made by truck manufacturers (Google, 2017).

To our knowledge, there is no academic literature concerning how autonomous vehicles could impact the Swedish logistics market. This is a clear academic gap and this thesis aims to fulfil the gap between technology and application in the logistics sector. Hence, we find this study highly relevant and justified.

3.4 Research philosophy

Even though the purpose of this thesis is relatively specific, it will develop new knowledge and therefore it is important to explain the underlying assumptions that have been taken into consideration. In relation to research philosophy, these assumptions explain on how the authors view the world and further underpin the research strategy (Saunders et al., 2009). It is important to be aware of which philosophy is utilized, in order to understand the motivations to why the research have been conducted in a specific way. Additionally, it enables understanding why the choice of methods and strategies, and why certain issues are addressed as more important than others (Johnson & Clark, 2006).

Since this study is based on research questions, the underpinned philosophy is Pragmatism. Pragmatism is defined by the determinant of research questions. It states that one of these philosophies might be more appropriate for answering certain research questions, and therefore different ones can be applied to different questions. Pragmatism provides opportunities since it allows variability in epistemology, ontology and axiology. This is related to a later described methodological concept, mixed method strategy, that explain how both a quantitative and qualitative strategy can be highly appropriate to use within a study (Saunders et al., 2009).

Pragmatism also allows the thesis to only consider what is important and interesting. This is reflected on how the world is observed, and also prevents researchers to investigate or engage in pointless arguments about what is seen as truth and reality (Tashakkori & Teddlie, 1998).

When it comes to ontology which explains researcher's view of the nature of reality, pragmatism is applied by choosing the best and most appropriate view to answer the research questions. The epistemological perspective will be applied by a pragmatism philosophy by the idea of both observable and subjective meanings can provide sufficient knowledge in connection to the research questions. Furthermore, different perspectives will be used to explain the data. Axiology explains the researcher´s view regarding the role of values has in research. Axiology is a big part of the pragmatism philosophy and allows both objective and subjective stances (Saunders et al., 2009).

3.5 Research approach

When it comes to theory in this study, existing theory was used to create both the research questions as well as the purpose. This proves that the aim of this study is to connect existing theory with data that has been collected, to gain deeper knowledge and understanding, to answer the research questions, and fulfil the purpose. However, to fulfil the purpose, the data collected is later compared with theory to achieve a result. This means that a deductive approach is in combination used together with a mixed method approach. A deductive approach is based on existing theory that leads to a theoretical position that is later compared to the data collected (Saunders et al., 2009). Another important characteristic of a deductive approach is that the involved concepts are required to be operationalized that allow facts to be monitored or measured quantitatively (Patel & Davidsson, 2011). This further explains why a deductive approach would the appropriate for this thesis. To strengthen the motivation behind a deductive approach, the questions asked in interviews were based in theory. Finally, regarding the analysis and result chapter, the empirical findings are compared to earlier theoretical findings, thus strengthening the argument for a deductive approach.

Even though this thesis is mainly based on existing theory it is not a fully deductive study. The study does not only test an already existing theory; it also contributes with new theory in terms of geographical spread. Earlier theory describes implementation of autonomous vehicles on an international level or other countries than Sweden. Since different circumstances apply to Sweden, such as regulations and costs, this study might result with new theory or show some different conclusions compared earlier theory.

Still, as this thesis focus on future technology, and existing theory is often outdated, collected empirical data is considered as very important compared to old existing theory. This causes an inductive reasoning since theory is instead created after data has been collected (Saunders et al., 2009).

The interaction between deduction and induction is generally known as abduction, which is when theory and empirical evidence is compared throughout the process (Patel & Davidson, 2011). Moreover, it can be seen as the mix that appear when using both deduction and induction. When a theoretical position is tested and compared with the empirical findings, the result is a greater overall picture (Saunders et al., 2009). An abductive reasoning does involve a continuous process of comparing existing theory with collected data, often requiring much time. An abductive approach can sometimes be very similar to a deductive approach, though it is important to understand that unlike a deductive method, an abductive reasoning does not guarantee the conclusion made of the premises. Rather it is used to assume the most likely and best explanation (Sober, 2012). Since this study will contain deductive reasoning, as well as some inductive reasoning, an abductive research approach is most suitable.

The authors have undertaken this study with the prior knowledge that consist of the authors own experiences and knowledge within the area. Later on an abductive approach will be applied by using existing theory with data collected through both document studies and interviews. From each of these data collection methods, new data will be found and be looked upon to see if it is connected to the existing theory or if it changes the perspective on reality and therefore contribute with a development of new theory. This process will be on going until the authors reach a stage of theory saturation, which is reached when there is sufficient amount of theory to conduct this study.

3.6 Research strategy

There are generally two ways of conducting research, qualitative and quantitative. Concerning qualitative research, it is often done by interacting with other people to retrieve data, such as interviews or focus groups. The main focus is to gain an understanding of human behaviours (Kirk & Miller, 1986). Qualitative research is generally mentioned as non-experimental research and is further characterized by the data collection procedure, which normally require a decrease of control to some degree in return for obtaining the data (White & McBurney, 2013). A quantitative strategy is generally based on numbers and data. Document studies and observations are often a part of the data collection, thus better suited when it is important to gain an unbiased result (Yin, 2011).

One thing that is generally used to separate these two strategies is the distinction between dependent and independent variables. A dependent variable measures or shows the behaviour of the subject. Furthermore, the dependent variable can be explained as a response or cause of an action and is shown by a score or response that can be measured. Dependent variables are often connected to a quantitative strategy since it often provides data in form of numbers or measurable variables (White & McBurney, 2013).

An independent variable is explained as a variable that cause a change in a dependent variable by changing its value. It can also be explained as the condition manipulated or chosen by the researcher, to investigate and find behavioural impacts (White & McBurney, 2007). This explains why independent variables often are connected with qualitative research strategies.

These two variables are used in this thesis to gain a more sufficient result. First the dependent variable will be used to calculate costs, which can be measured and compared to other dependent variables. This is highly relevant to all three research questions since they need to be answered form a cost perspective. Independent variables will also be used and taken into consideration in terms of investigating how certain costs will be affected. This will create a research approach commonly called a mixed method approach (Saunders et al., 2009).

Mixed method research undertakes both a quantitative and qualitative strategy by its different ways of collecting and analysing data, either at the same time or sequential. It is though important to mention that this cannot be done in a combination, rather they are used at different times. Even if a mixed method strategy is used by quantitative and qualitative processes, quantitative data is analysed quantitatively, and qualitative data is analysed qualitatively (Saunders et al., 2009).

According to Tashakkori and Teddlie (2003) this strategy is better than a specific one, as long as it provides better opportunities for analysing research findings in a more trustworthy way. Mixed method further provides two big advantages, namely the usage of different methods for different purposes within the study. As an example you can use interviews at an exploratory level to gain an understanding about the key issues and later use a questionnaire to collect descriptive or explanatory data. This ensures that the right issues are addressed in an appropriate way (Tashakkori & Teddlie, 2003).

The mixed method strategy is applied to enable an unbiased result. An unbiased result is important in this study since it aims at investigating a whole industry (Yin, 2011). The qualitative contribution will further enable an understanding of the potential causes that an implementation of autonomous vehicles might have on costs.

Bryman and Bell (2006) argue that there are seven different reasons to use a mixed method design, as seen in Table 5. Since this study will use two or more independent sources of data collection methods to authenticate research findings (commonly called triangulation), there is an underlying reason why a mixed method is used.

Moreover, aid interpretation, which is when qualitative data is used to help explain relationships between dependent variables, will be used to answer the research questions and therefore argue for a mixed method approach. Finally, a "solving a puzzle" method will be used since the topic itself is future oriented, and the use of alternative data collection methods are necessary when much of the current data is based on either estimations or personal opinions. This is important due to the fact that projected future scenarios can be seen as insufficient to provide a reliable conclusion.

Table 5: Reasons to use mixed methods

Reason	Explanation
Triangulation	Use of two or more independent sources of data or data collection methods to corroborate research findings within a study.
Facilitation	Use of one data collection method or research strategy to aid research using another data collection method or research strategy.
Complementarity	Use of two or more research strategies in order that different aspects of an investigation can be dovetailed.
Generality	Use of independent source of data to contextualize main study or use quantitative analysis to provide sense of relative importance.
Aid interpretation	Use of qualitative data to help explain relationships between quantitative variables.
Study different aspects	Quantitative to look at macro aspects and qualitative to look at micro aspects.
Solving a puzzle	Use of alternative data collection method when the initial method reveals unexplainable results or insufficient data.

Performing research can take three different purposes, either explaining a subject (Explanatory research), exploring a subject (exploratory research) or describing a subject (Descriptive research). An explanatory research is often used when there is a need to further explain the relationships between objects while exploratory research is conducted when a subject needs exploration and particularly useful when clarifying the understanding of topic. This area is also closely related to the descriptive research when the goal is to describe characteristics and phenomena (Saunders et al., 2009). Exploratory research is often done in three ways: literature review, interviewing experts in the area of studies, and conducting focus group interviews to gather empirical data (Saunders et al., 2009).

3.7 Data collection

The data used in this thesis originated from many sources and the information was collected in different ways. The following sub-headings describes how the data was collected.

3.7.1 Literature

To answer the research questions and thus fulfil the purpose, the authors needed to read literature to get a clear understanding of the topic. The literature study contains peer-reviewed articles and books earlier used at Jönköping University. The majority of the literature was accessed via Jönköping University's library and through databases like Emerald, EBSCO or ProQuest. To streamline the search for literature, google scholar and Jönköping University's library was used to find both English and Swedish articles. The search for literature also consisted of news articles and more informal news media. However, these sources were always backed up by official statements from companies and organizations. Presented below are the most common keywords the authors used to find literature:

automation, autonomous vehicles, self-driving vehicle, competitive advantage, globalization, google car, autopilot, future logistics, cost of transportation, levels of automation, LOA, autonomous trucks

The literature studies added important information regarding the current state of autonomous vehicles and how the different levels of automation have affected the private car industry. The literature studies also complemented the interviews and document studies to achieve a more reliable result.

3.7.2 Interviews

Interviews are qualitative in nature and were used to get basic information, as well as professionals' opinions about autonomous vehicles. In this exploratory research, interviews were conducted to gain experts' insight and knowledge in the area of studies, as proposed by (Saunders et al., 2009).

According to Yin (2011), interviews are a good way of collecting information, and the interviews conducted in this thesis are semi-structured. This means that the general topics are predetermined, along with some questions, to set the stage for the interview. Along the course of the interviews, the authors came up with new questions to increase a two-way communication between researchers and interviewees. These interviews would be classified as a mix of structured and qualitative, according to Yin (2011).

All interviews carried out for this thesis are listed in Table 6, but due to the fact that most experts in this area are not located in Jönköping, the authors carried out some interviews by telephone. This may reduce some of the interaction that a face-to-face interview provides such as being able to use visual aid or body language (White & McBurney, 2013). Moreover, Yin (2011) states that the conversation is rarely as spontaneous as would be preferred but phone interviews are still a reliable source of information, especially when recorded and typed to form a transcript. The transcriptions were read several times to ensure the correct information was entered, as suggested by Saunders et al. (2009). However, the interviewees where not given the chance to edit their transcriptions since that may affect the statements in a negative way (Saunders et al. 2009).

Table 6: Interviews

Date	Organization	Who	Role	Duration (Minutes)
29/2 2016	Chalmers University of Technology	Sönke Behrends	Professor	30
14/3 2016	Tesla Motors	Ayman Hassan	Product Specialist	60
25/4 2016	Rosenlunds Logistik	Oscar Zewebrand	Traffic planner	30
29/4 2016	InQuire Logistik	Björn Paulsson	CEO	35
15/11 2016	GDL	Christer Eliasson	Quality- and environmental manager	30

3.7.3 Document studies

The documents studied in this thesis consists of reports from companies around the world. They form a connection between theory and real life cases and can be a good complement to interviews (Yin, 2011). The main difference between the document studies and literature studies is that the information is obtained from companies or organizations rather than scientists or authors.

Documents and reports, such as the *Future of Driverless Haulage* by AXA (2015) was among the authors' first encounter to autonomous vehicles and thus helped to get an understanding of the topic. Much of the research within autonomous vehicles is driven by companies that wish to be innovative. Therefore, most of the studied documents are based in specific cases (often autonomous cars) and the authors needed generalize the ideas. Moreover, document studies are generally more up to date than other sources of literature (Saunders et al., 2009).

According to Saunders et al. (2009) document studies are often a good source of data when it comes to detailed information. Since document studies are included in primary literature that is generally more detailed than secondary literature, it will more likely allow the authors to find details – including specific cost bases in relation to technological instruments related to autonomous vehicles.

3.8 Data analysis

Data analysis is of great importance, especially when using mixed methods, to compare and understand data acquired from multiple sources. Different data analysis methods were used depending if the data is classified as quantitative of qualitative. A simplified version of the data collection and analysis process is found in Figure 6. Figure 3 also highlights the iterative process of abduction where old theory (literature) is continuously compared and analysed with new data from documents and interviews to generate new theory. This iterative process allows pattern recognition, finding important themes and relationships between literature and collected data (Yin, 2007).

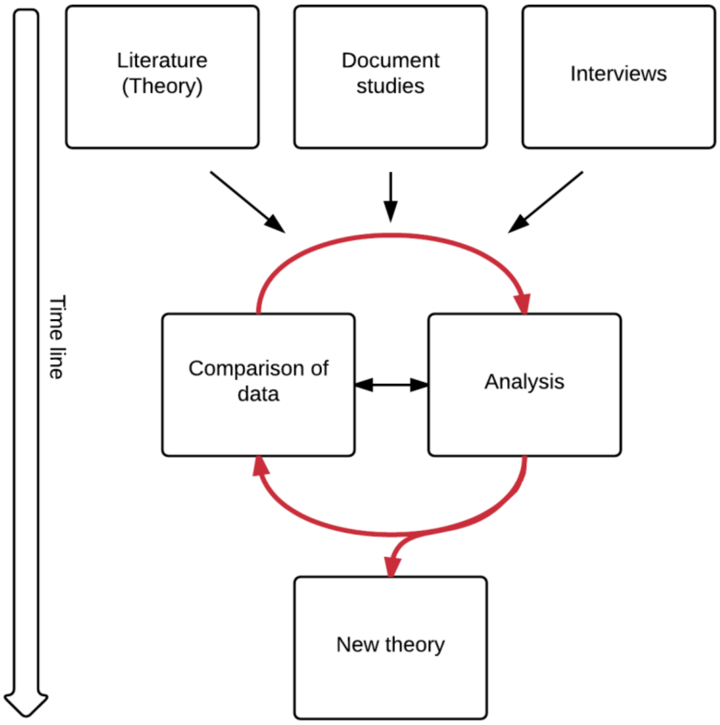


Figure 6: Data analysis process (Own illustration)

The collected quantitative data from literature and document studies was categorized according to the framework presented by Saunders et al. (2009), Figure 12:1 pp. 417. (Also shown in the appendixes, section 8.3.1). This framework defines the data type depending if the data is numerical or categorical. Categorical data can be further divided into descriptive data or ranked data and numerical data can be broken down to continuous data and discrete data. These four categories of quantitative data have been used to analyse the collected literature and documents. They all have varying characteristics and preciseness that defines them. According to Saunders et al. (2009) the four types are ranked by precision and accuracy, starting with the highest: discrete data, continuous data, ranked data & descriptive data. This thesis always aims towards collecting discrete data when available, since accurate data opens up more analytical tools and can for example be regrouped into less precise levels to be further analysed (Saunders et al. 2009).

The numerical data was imported into Excel spread sheets as the software provides a great way of handling and analysing data (Bullington, 2012). The categorical data was ranked and described in Word.

The qualitative data collected in the thesis ranges from shallow questions regarding organizational facts and to in-depth interviews with professors and professionals within autonomous vehicle research. The transcribed text from interviews was also extrapolated and summarized to form a more condensed text. The sentences were then categorized into themes related to the literature review. For example, if one question concerned transportation costs, the summarized interview answers were moved to the topic transportation costs. This is seen as a thematic analysis.

After the classification and categorisation of interview answers, the sentences were structured and ranked in terms of importance from the authors' point of view. The information given from these sentences was later compared with each other to analyse congruity and conformity. Furthermore, the sentences were compared to previous data from the literature review.

These tools are not only used to ensure that the right information was collected and used in the theoretical framework, but also to ensure that the purpose of the thesis can be achieved. Since the data collection methods overlap each other, the analysis and comparisons are important to see the connections between the different data as well as supplementing each other.

3.9 Trustworthiness

As this thesis involves a variety of data collection methods, the trustworthiness of the data is crucial. Hence, this section is dedicated towards clarifying and developing trust within the study.

3.9.1 Quantitative research

Quantitative research is often connected to logical or experimental positivism, and quantitative measures to test a hypothetical generalization. It further strive after finding casual relationships by comparing variables. To measure the trustworthiness within a quantitative research the most common concepts are reliability and validity (Golafshani, 2003).

3.9.1.1 Reliability

Reliability is to which extent a research can be reproduced, when using the same methods and the same conditions. Further, this shows how consistent the results are in relation to time (Golafshani, 2003). According to Kirk and Miller (1986) there is three kinds of reliability which are:

1. The degree to which a measurement, given repeatedly, remains the same.
2. The stability of a measurement over time.
3. The similarity of measurements within a given time period.

Moreover, reliability can also be used to show how reliable the method is, in relation to the measurements (Andersen, 1994). The quantitative approach in this study is mainly document studies. This mean that the measurements are not decided by the authors, though the authors are able to use the data to convert it into other measurements, which can later be used or compared to each other. Generally, this data consists of actual costs in relation to autonomous vehicles.

To measure the reliability in terms of Kirk and Miller's three categories, the first one compares data from different sources to control consistency, and by that be able to specify the certain necessary costs. The second category is not as easy. Data will change over time as a possible implementation of autonomous vehicles takes place. Additionally, the industry is continuously changing as technical advancements are utilized. To reach a satisfying reliability, the thesis uses current data based on estimations about the future, and use the first category to find the most possible future scenario.

The third and final category is applied in the same way as the second. To still reach a satisfying level of reliability, currently available data is carefully used and compared with each other to assure a high accuracy and consistency.

3.9.1.2 Validity

Validity can be explained by measuring the right thing that was intended to be measured, or how truthful the results are (Golafshani, 2003). Furthermore, validity can be divided into three categories as well as reliability. These are internal validity, external validity and statistical conclusion validity (Kazdin, 2003). Internal validity refers to how studies can be conducted in relation to independent variables without any external impacts, affecting the result. External validity explains how well the study can be applied on other areas as well as the generalizability. The last, statistical conclusion validity shows how accurate and relevant the collected quantitative data is (Kristensson, 2011; Merriam, 1994). Furthermore, validity can be explained as the interplay between construct data and data affected by the authors. This is done in order to validate the study and is most often applied in a quantitative context.

In this study the authors will involve both independent and dependent variables which in turn reduce the internal validity. Nevertheless, the independent variables will not be affected by any external factors – Instead, the independent variables will affect the dependent as mentioned earlier. Therefore, the internal validity is considered satisfying. The external validity is satisfying because of the fact that the study can be performed in any other country or region, with similar results. The only disadvantage in external validity is that the data itself might be difficult to use, regarding studies that are not connected to autonomous vehicles.

The conclusion is that validity is fulfilled, by collecting the most precise and up-to-date data from companies involved in the autonomous vehicle industry.

3.9.2 Qualitative research

As stated earlier, qualitative research is based on producing findings without using statistical procedures or means of quantification (Corbin & Strauss, 1990). Focusing on real world conditions and understanding cause and effect relationships, its estimations of trustworthiness is often discussed in terms of generalizability, credibility and transferability.

3.9.2.1 Generalizability

Generalizability can be defined as to which degree the study can be generalized so that when conducting the same study with the same conditions, but in another industry or scenario, the results are the same (Saunders et al., 2009). Marshall and Rossman (2011) state that generalizability in relation to qualitative studies, allow the authors to relate the research to existing theory and by that enable your findings to prove a more theoretical significance.

In order to increase the generalizability in this study, a clear relation to existing theory is established to produce more significant findings. This will provide higher generalizability, since it allows a more detailed picture on how the relationship to existing theory been established and led to the results (Bryman, 1988). It is though important to mention that this study is carried out in a relatively unexplored area, thus reducing the stability of generalization over time. The closer the estimations of future scenarios of autonomous vehicles are in relation to the actual future, the higher generalizability and vice versa.

3.9.2.2 Credibility

Credibility is a very important factor that has to be taken into consideration. A high credibility means that the findings are truthful, leading to a valid result. Many researches states that you cannot truly know if the results are wrong, rather it is about reducing the possibilities of getting the wrong results. This is why a well-developed research design and strategy is crucial. Raimond (1993) define credibility as

"*Scientific methodology needs to be seen for what it truly is, a way of preventing me from deceiving myself in regard to my creatively formed subjective hunches which have been developed out of the relationship between me and my material.*"

To enhance the credibility of this study, data have been collected from both the academic and business world. Additionally, the data have been compared with existing theory using an abductive approach to assure congruity and therefore increase credibility. One negative aspect in terms of credibility of this study is its future. Since parts of this research is based on estimations about future scenarios, it cannot assure that these estimations will be true even though they are the most likely ones, according to both theory and data collected.

3.9.2.3 Transferability

Transferability refers to which degree the findings of a qualitative study can be transferred and made in other settings and under other conditions. A well-explained description of how the study has been carried out is one of the most common ways to enhance transferability. This helps other researchers to transfer the actions and results into other contexts. It is important to mention that it is other researchers' responsibility to consider how sensible a study is when transferring it into other contexts. (Trochim & Donnelly, 2006). This study's transferability is satisfied by the fact that the authors describe their work process in terms of methodology, theories and data collection methods used. Moreover, the study is fully transferable geographically, since the costs involved already occur in all transportation industries no matter of geographical spread. It is also important to mention that this study focus on the cost of an implementation of autonomous vehicles, which also increase the transferability compared to investigating the costs of already implemented autonomous vehicles, since the technology might not be accessed all over the world.

3.10 Research ethics

When conducting a study, situations that causes ethical issues may arise, especially when accessing, collecting and analysing data. Research ethics can be explained by conducting your study in the most correct ethical way seen to your behaviour, in relation to those that are either the subject or those to get affected by the study (Zikmund, 2000). It involves almost everything that is being done within a study – from formulating and clarifying the research topic to collecting and analysing data.

According to Saunders et al (2009) there is two different perspectives that can be applied when conducting a study within business and management. The first one is a deontological view that states that the results of the research cannot justify the use of the research, and thus becoming unethical itself. The other stance is a teleological one that will be applied in this study (Saunders et al. 2009). A teleological perspective means that the result of a research justifies the means. The beneficial parts of a study will be compared against any unethical actions, and further lead to a decision of acting morally correct.

Furthermore, to increase the ethical point of view in this thesis, everyone involved in this study were clearly introduced to the topic, and also participated by their own free will. The interviewees were also offered the choice of remaining anonymous and all recorded interviewees gave their permission beforehand. The data collected will only be used for this study, and not distributed to any other parties. Additionally, the data is stored at three home PCs for 1 year. This further enhances the anonymity (Saunders et al. 2009).

This study will discuss an opportunity for implementing autonomous vehicles which may lead to reduced job opportunities in the long term. Since the study only focus on cost estimations, ethical issues in this matter will not be addressed.

4 Results

In this chapter the main results from the studies are presented. The results are given in a value-free way to ensure credibility. The chapter is based on the research questions and they provide a natural way of presenting the results. This part of the thesis ends with a brief look at Rosenlunds Åkeri and GDL, two Swedish logistics companies

4.1 Introduction

The logistics industry is a highly competitive market (Angheluta & Costea, 2011) and many companies are working hard to be either cost efficient or innovative to gain competitive advantage over their competitors. If logistics companies focus on cost leadership as the main competitive advantage, competitors may find cheaper labour or lowered costs and thus being able to outperform the other actors with the same cost efficiency focus. While on the other hand, if the logistics companies were to focus on innovativeness and differentiation, they are rather utilizing a long term strategy that can be profitable in the long run.

Many logistics companies are starting to realize the long term profits of offering innovative, good quality services instead of lowering costs to unprofitable levels. This can be seen in the amount of services many logistics companies offer (Hertz & Alfredsson, 2003). Additionally, many vehicle manufacturers like Volvo trucks and Volkswagen group are researching innovative technologies that may change the way we transport goods and people in the future.

Over last decades many researchers and especially car manufacturers have starting to see the possibilities of autonomous vehicles (Sharfer & Whittaker, 1987; Butler, 2016). Multiple companies are researching autonomous vehicles but no-one has been able to release a fully developed autonomous vehicle. However, Ford is planning on releasing a level 4 autonomous car in year 2020 (Butler, 2016) and other car manufacturers are following suit. Tesla's model S can be classified as level 3 and many other new cars are made to level 2, with capabilities such as adaptive cruise control working along with lane departure warning (Butler, 2016; Hassan, 2016).

Despite the fact that technological advancements have had breakthrough in the automotive sector, the trucking industry is a few years behind in the autonomous development. Some of the biggest truck manufacturers (Volvo trucks and Volkswagen group) have included level 2 capabilities in their trucks (Volvo Trucks, 2016; MAN trucks, 2016) but there is little research on higher LOA in the logistics/trucking industry. Even though the Swedish road administration states that technological advancements made in the logistics industry could lower the number of lethal accidents involving heavy trucks by 43% (Vägverket, 2008).

McKinsey (2013) argues that the technology is not going to be the greatest obstacle when it comes to implementing autonomous trucks, but rather legal frameworks and winning the public support are going to be two major hurdles. To quote the McKinsey report: *In fact, after 20 years of work on advanced machine vision systems, artificial intelligence, and sensors, the technology to build autonomous vehicles is within reach* (McKinsey, 2013).

In order to answer the first research question, calculations based on research is needed. The thought process to calculate these cost can be seen in Figure 7. As an input for these results, the thesis uses existing knowledge in logistics and economics combined with research in autonomous vehicles. The combined input is presented, analyzed and presented as a decision framework for Swedish logistics companies whether to invest in Autonomous vehicles or not.

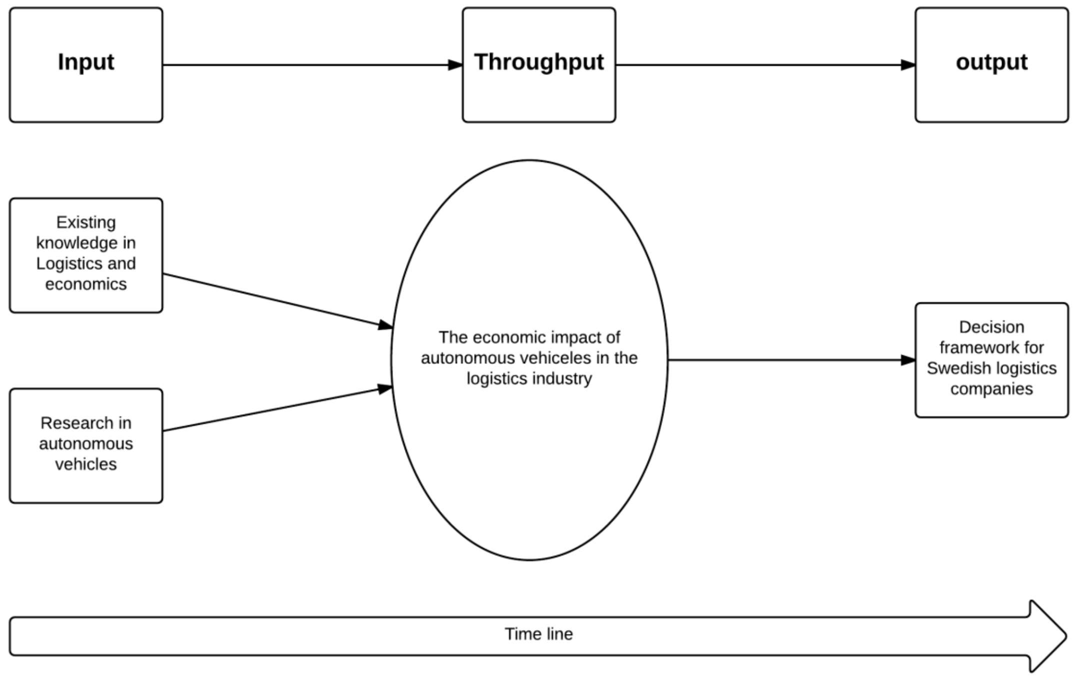


Figure 7: Calculations thought process

Figure 7 further illustrate the predeterminations of the study and also explains the scope to some degree. With this model in mind the authors knew what stance to undertake in relation to the re-search of autonomous vehicles. All information that was gathered was retrieved without any previous settings of sorting out irrelevant information. As seen in Figure 7, the input does not refer to any kind of information that does not concern logistics and economics as well as autonomous vehicles. Instead the throughput were the determining factor of sorting out irrelevant information. The figure complements the result chapter since it shows the connections from early reasoning and preparatory research to the actual output, which is presented as the result of this master thesis.

The following sections of this chapter are divided into sub-headings where the research questions are being answered.

4.2 What is the actual cost of implementing an autonomous vehicle?

Since the data needed for research question one have quantitative characteristics, literature and document studies are the most appropriate ones. The findings are based on first proving that the technology can be applied onto trucks and will later be presented by costs that occur when implementing.

According to AXA (2015), KMPG (2015a; 2015b), Volvo (2015), Daimler media (2015) McKinsey (2013), PWC (2014) and Boston Consulting Group (BCG, 2015) there are no barriers in terms of applying the same technology used for cars onto trucks. As quoted in the introduction part of this chapter, McKinsey states that the technology is within reach. Volvo's director of the autonomous driving programme, Marcus Rothoff states that Volvo is building test vehicles of LOA 4 at the moment and that the first customers will get their autonomous cars in 2017 (Rothoff, 2016). He further states that Volvo is aiming at launching the first fully autonomous vehicles with a LOA 5 at year 2020 that is further strengthen by Volvo's senior technical leader for safety and driver support technologies (Coelingh, 2016). Furthermore, Erik Coelingh states that Sweden is an exceptional country to implement autonomous vehicles because of the close cooperation between the automotive industry and authorities, which is highly necessary (Volvo, 2016)

Moreover, the British mining company Rio Tinto already use autonomous haulage trucks in their production facilities. According to Rio Tinto they have 69 autonomous trucks in their production site in Pilbara and because of the increased productivity, they expect an increased amount of autonomous trucks in the coming years (RioTinto, 2016).

The German automotive corporation Daimler recently presented an autonomous truck of LOA 2-3 that allow the driver to let go and the truck is operated by itself (Daimler, 2016). The truck introduced by Daimler has already got that far in technological advancements that it is already approved for use on public roads (Daimler, 2016). Furthermore, Daimlers truck manager Dr Wolfgang Bernhard states in a press release 2015 that they got the technology and it is realistic to introduce autonomous trucks at year 2020 (Daimler media, 2015; Bernhard, 2015).

The data found through document studies shows a clear pattern, even though the technology has come far it is not as well-developed that it can be fully applied within the logistics industry. Instead the implementation of autonomous vehicles and especially trucks is a progressive process that is according to MAN (2016), Rothoff (2016), Daimler media (2015), Bernhard (2015), Daimler (2016), estimated to take its start in early 2020.

The data collected regarding the cost for an implementation has been gathered from companies active within the truck industry as well as multinational consultant companies and previous studies. It is important to notice that these cost are only additional cost to either convert a normal truck, or additional cost when purchasing a new one. The costs only reflect estimations at year 2020 and 2030, which means that there is no data collected between these years. Table 7 shows the costs based on external organizations predictions at year 2020. The costs also include the markup from the manufacturing company.

Table 7: Additional cost for autonomous vehicles by 2020

Sources	**Cost estimation (SEK)**
Volvo (Di Dimension, 2015)	80 000
Boston Consulting Group (BCG, 2015)	50 400
Victoria Transport Policy Institute (Litman, 2013)	83 400
DMV (Perch, 2014)	83 400
IHS (IHS, 2014)	71 400
AVERAGE	**73 720**

When it comes to the cost in terms of each component, Boston Consulting Group (2015) included the components needed to turn a non-autonomous vehicle into autonomous in terms of LOA 4-5. They based the components needed on the autonomous self-driving Google car and later estimated the costs for each of these components. It is important to remember that the following costs are purely for the materials. Labour cost and cost for installation is not included. The summary of the components' cost is shown in Table 8.

Table 8: Cost of components in autonomous vehicles by year 2020 (BCG, 2015)

Components	Cost estimation (SEK)
GPS	37 800
Lidar	50 400
Video camera (Stereo)	1 700
Ultrasonic sensors	170
Odometric sensor	1 000
Radar sensor (Long range)	1 300
Radar sensor x2 (Short range)	1 700
Central computer	8 400
TOTAL	**102 470**

The focus of this thesis is the time frame between 2020 and 2030 and therefore implementation costs by 2030 are also necessary. The costs for 2030 according to external organizations are shown in Table 9.

Table 9: Additional cost for autonomous vehicles by 2030

Sources	Cost estimation (SEK)
Volvo (Di Dimension, 2015)	40 000
Boston Consulting Group (BCG, 2015)	42 000
KPMG (2015)	10 500
IHS (2014)	37 800
AVERAGE	**32 575**

Volvo (2015), Boston Consulting Group (2015), IHS (2014) and KPMG (2015b) expect a decreased implementation cost in 2030 compared to 2020. This is due to economies of scale and technical advancements progresses, which results in an average cost to manufacture an autonomous vehicle in year 2030, compared to a normal vehicle, is 32 575 SEK including markup.

Regarding the cost reductions of new technologies, the Santa Fe Institute made a study that compares 62 different technologies and their cost data over a 39-year period. This study is the largest database of such information compiled, throughout history. The study shows a clear pattern. New technologies follow an almost exact linear pattern in cost reduction, meaning that the cost reduction per year will be equal throughout the time scope (Santa Fe Institute, 2012). This is also shown in the appendixes, section 8.1.3.

As there is very little known of the cost of the components in an autonomous vehicle by 2030, these cost are estimated in section 5.2.

4.3 Which costs will be affected by an implementation of autonomous vehicles?

In order to identify which costs that will be affected by an implementation of autonomous vehicles, data has been collected through literature studies, document studies as well as interviews.

The data gathered from literature studies mainly consist of data helpful to the authors to understand how the costs are affected by autonomous vehicles. Therefore, the majority of the data gathered through literature studies is of qualitative characteristics rather than quantitative.

AXA (2015), KPMG (2015a), Boston Consulting Group (2015) and other research institutes have identified the potential cost savings in terms of labour costs, costs for fuel consumption, insurance costs and vehicle utilization cost. Furthermore, in an interview with professor Behrends, he was asked the question regarding transportations cost and replied the following:

> "…as a rule of thumb of transport cost, one third fuel, one third vehicle and one third labour, and I think insurance cost are included in the vehicle cost. So this is the main costs and I think it is probably still the same, even though fuel cost has gone down a little bit. I don't know about labour cost development /…/ but if labour cost is one third of the total cost I think that there are definitely incentives for autonomous vehicles". **[Behrends, 2016]**

4.3.1 Fuel

According to Volvo, Volvo trucks consume an average 4 litres of diesel per 10 Km (Volvo Trucks, 2016). The distance a truck drive in average per year is according to Scania (2013) 150 000 Km.

With the Scania statement of 150 000 km per year, this translates to an average fuel consumption of 60 000 liters annually per truck. To transform this consumption into cost, the average fuel cost for diesel from 2015 and until today (2016-04-18) is 12,95 SEK per liter including 25% Value-Added Tax (VAT) (Shell, 2016). However, as companies in Sweden do not need to pay VAT, the cost per liter is instead 10,36 SEK, or an annual cost of 622 000 SEK.

According to AXA (2015), an implementation of autonomous vehicles would reduce the fuel consumption for trucking companies by 10-15 % only because computers are more fuel-efficient drivers than humans (AXA, 2015; McKinsey, 2013). Additionally, once autonomous vehicles start communicate with each other further fuels savings can be achieved due to platooning and vehicle to vehicle communication. Platooning basically means that vehicles use adaptive cruise control to maintain a steady distance to the vehicle ahead, thus reducing air resistance. This alone can reduce fuel consumption by 7,7 % (Alam, 2014).

Moreover, if the vehicles communicate with each other, there is no need for safety distances between vehicles on highways and vehicles will be able to drive very close to each other (less than 5 meters in-between). This reduces air resistance to such extent that fuel consumption will be lowered by additionally 14% (Alam, 2014). Bullis (2011) supports those numbers by estimating that 15-20 % of fuels will be saved by platooning and vehicle to vehicle communication. McKinsey (2013) also agrees with these fuel savings statements. They estimate that autonomous vehicles will have a 10-40% improved fuel efficiency compared to today's trucks.

4.3.2 Labour

Labour cost is one of the major incentives towards an implementation of autonomous vehicles due to the ever increasing labour costs. According to the Swedish Transport Workers' Union, the average starting salary for a truck driver in Sweden is 260 000 SEK (Transport, 2015). Adding to this is the mandatory 12% holiday compensation and on top of that is the 31,42 % payroll tax (Skatteverket, 2016). Additionally, most companies pay their employees insurances (approximately 12000 SEK annually (Bolagsverket, Skatteverket & Tillväxtverket, 2016)). This sums up to 382 700 SEK per year.

McKinsey (2013) argues that half of all trucks will still need human drives present even if it has a LOA 4-5, mainly due to the last mile problem. This problem will still remain even if the vehicle has autonomous capabilities. Most reports believe that the long haul industry will be first to adopt autonomous vehicles (AXA, 2015; McKinsey, 2013; KPMG, 2015). McKinsey (2013) further estimates that one or two administrators will be able to drive 10 truck simultaneously (among those 50% that does not need human drivers present), thus reducing labour cost by 80-90 % for long haul businesses.

4.3.3 Insurance and safety

In the normal assumption as stated by Behrends (2016), one third of transportation cost is labour, one third is fuel and one third is vehicle costs. Vehicle insurances are covered in the vehicle cost but according to researchers and reports, the insurance cost will be drastically lowered since autonomous vehicles are much less prone to accidents (AXA, 2015; McKinsey, 2013, KPMG, 2015b). This is due to the fact that 87 % of all traffic accidents are caused by human errors (AXA, 2015) while Waldrop (2015) means that 90% of all accidents are caused by human errors. This statement is supported by the Swedish society for road safety (NTF, 2014) whereas the NHTSA have statistics that prove that 94% of the accidents are caused by some kind of human error (NHTSA, 2015).

Truck insurances are quite expensive. A truck insurance with the Swedish insurance company Trygg Hansa can cost up to 50 000 SEK per year (Trygg Hansa, 2016) but according to Dexheimer (2015), the cost of insurance could be reduced by as much as 60% by year 2030, translating to a cost saving of 30 000 SEK per year. Also, the automotive insurance company Metro Mile (2015) further states that insurances premiums will reduce by upwards of 8200 SEK annually when using autonomous vehicles on highways. Thus, LOA 4 vehicles can see an insurance cost reduction in the near future.

Furthermore, as manufacturers move up the LOA scale towards fully automated vehicles, liability will move from the driver to the manufacturer. This will cause a shift in insurance industry as 90% of today's accidents will not occur and according to KPMG (2015b), the insurance business will shrink to less than 40 % of its current size. However, the report also states that the insurance companies will not witness a significant change within the next decade since the number of autonomous vehicles will still remain relatively low.

As liability is transferred to the truck manufacturer, vehicle insurances may not be necessary. One example of manufacturer insurances is the Volvo Drive-me project. Volvo will cover all costs caused by an accident if the vehicle is in autonomous driving. This is still only used in the automotive sector but it soon to be transferred to logistics industry. Insurances for the goods will remain unchanged as they are most likely not covered by manufacturers (Matson, 2016).

Additionally, it is possible to calculate the indirect costs for insurance and accidents. As traffic accidents occur, great costs arise due to material costs and loss of capacity, especially when heavy trucks are involved. NTF (2014) argues that 20% of all accidents with lethal outcome are caused by heavy trucks, and 48% of all heavy trucks in Sweden belong to the logistics industry (SCB, 2016). Deadly traffic accidents cost the society 3,1 billion SEK every year, most of it in loss of production capacity (MSB, 2005).

4.3.4 Vehicle utilization

Regarding LOA 4 vehicles, the vehicle utilization will not be considerably improved since there is still need for a physically present driver. Though, reports states that drivers could enable the auto pilot on the highway and then focus on other tasks while the vehicle is driving by itself (KPMG, 2015a). According to a patent of autonomous vehicles assigned by Volkswagen, an autonomous vehicle provides better utilization of transport capacity of traffic routes (USA Patent No. US6151539 A, 1998). Furthermore, Conway (2013) states that autonomous vehicles would provide higher vehicle utilization and therefore reduce the need for capital spending on new investments in terms of trucks.

According to Parreira (2013) the degree of utilization for LOA 5 autonomous trucks could be increased by 21% compared to non-autonomous trucks. This is a fairly low estimation since Antich (2015), the former president for the American Automotive Fleet & Leasing Association and also inducted into the Fleet Hall of Fame, estimates that the vehicle utilization could increase by nearly 50% by using autonomous vehicles.

According to the American Transportation Research Institute (2014), the cost of operating one truck is 8,50 SEK per kilometer. This is further strengthen by the investigation made by Trafikanalys (2012) that states that the cost for a truck in Sweden is 8,60 SEK per kilometer. Since the report made by Trafikanalys (2012) is based on the Swedish market this number will be used for further calculations in the analysis. A study made by Gustafsson (2007) shows that a truck often generates an annual average profit of 99 400 SEK.

It is clear that the vehicles utilization rate will increase if the vehicle is autonomous. Another aspect that might be forgotten is that even if there is a need of human driver to handle the last mile problem, the drivers themselves can increase their performance by instead of driving focus on for example administrative operations.

> "The technology used in autonomous vehicles in the future will allow busy people to deal with tasks in order to save time while the vehicle will drive itself. For example, it will be possible to sit in the car and answer emails while letting the vehicle deal with the driving." **[Hassan, 2016]**

4.4 How do these costs impact the Swedish logistics market seen from a cost perspective?

The data collected in order to answer research question 3 is to the majority already presented in the two earlier research questions. Therefore, the same data collection methods are to some degree used. One thing that was necessary is the fact that earlier data is only presented in relation to one truck. Therefore, has data been collected in terms of applying the data earlier found onto the whole Swedish logistics industry and by that all the trucks active within logistics in Sweden.

Furthermore, the interviews that have been conducted highlighted the problems that might occur with the last mile problem in relation to autonomous trucks. Today, the last mile is an area of interest for researchers and there is plenty of room for improvements. Therefore, this is an area that needs to be considered when implementing autonomous trucks, and how autonomous vehicles affect the last mile problem, both directly and indirectly.

> "Autonomous vehicles can drive to the receiver's location and also probably find parking and so on, but then how is the goods or parcel or pallets delivered the very last mile into the store and factory?" …" This might be another barrier." **[Behrends, 2016]**

The technology is not the problem anymore, rather external factors that need to be restructured or rearranged to enable an implementation of autonomous vehicle to its full usage. One additional barrier today is the legal aspects, and how law and regulations are in use. The technology has come so far that there is basically no need for operating the vehicle when driving on major roads. The vehicles can basically drive by itself without any need of human interaction. The problem is that regulations does not allow the vehicle to operate by itself.

> "There is not a technology problem anymore. I think it is more or less about the legal aspects. There are for sure barriers from a legal aspect. But I think there will be a future for autonomous vehicles in logistics." …" I think that one enabler is the development in the car industry or the passenger sector" …" I definitely see a future for autonomous vehicles when it comes to passenger cars. Sooner or later we will see them on the market and probably they will also have an impact on the logistics industry. I am sure about that. I think we will see it in the future, due to the fact that the car sector is quite far already." **[Behrends, 2016]**

> "As a matter of fact I recently drove a Tesla model S from Malmö to Gothenburg without barely touching the steering wheel. The only problem with autonomous vehicles in Europe is that the laws states that the hands are not allowed to completely leave the steering wheel and thus, not enable the benefits with autonomous vehicles." **[Hassan, 2016]**

When these barriers are dealt with and the industry is ready for an implementation, autonomous vehicles will impact the logistics industry, especially seen to the developments already made within the car sector that has created a good foundation for further improvements.

> "…seen to how far Tesla has come today, as well as other car and truck manufacturers when it comes to technological advancements, I am sure that autonomous vehicles will be a part of our future and will for sure have an impact on many businesses" **[Hassan, 2016]**

Regarding the implementation of autonomous vehicles in Sweden, it is necessary to know the market. The number of trucks active within the Swedish logistics industry needs to be taken into consideration. Table 10 show the amount of trucks registered in Sweden used in the logistics industry the last six years according to the Swedish Central Bureau of Statistics (SCB, 2016).

Table 10: Number of trucks in Sweden within the logistics industry (SCB, 2016)

Year	2010	2011	2012	2013	2014	2015
Logistics trucks in Sweden (Pcs)	37 628	38 381	38 111	37 716	37 856	38 103

Since the numbers does not show any major increases or decreases, the average is calculated to show an estimation for the time period. The average number of trucks active within the Swedish logistics industry is 37 966. This figure is round up to 38 000 trucks for further calculations.

4.5 Framework Application

To put the calculations and result into a greater context, a practical example is helpful. We have chosen to conduct two smaller case studies in order to complement the theory and figures gathered at an earlier stage and at the same time add a third dimension (practice) in order to retrieve more precise data (Bell, 1987). Furthermore, Edwards and Talbot (1999) states that a case study is highly representative when exploring and investigating a field of study that is fairly unexplored, such as autonomous vehicles.

The Swedish logistics company Rosenlunds Åkeri AB was contacted in order to prove that the result of this study can be applied to actual cases. GDL, another Swedish logistics company, was also contacted to further support this thesis' findings. Additionally, since the focus of this thesis is the Swedish logistics industry, it can be a bit too big to understand. Therefore, some real life cases can provide further possibilities for the reader to get a better grasp the content.

4.5.1 Rosenlunds Åkeri

Rosenlunds Åkeri AB is a middle size transportation firm that was founded in 1964. They are currently located in Jönköping because of its central location in the Nordics, from a geographical point of view. Their range of services includes transportations within Sweden, Norway and Finland.

The company has an annual revenue of 225 million SEK and has been growing steady the last couple of years by both expansions of geographical areas and company acquisitions of smaller transportations firm. The firm is one of Sweden's largest family-owned logistics companies with more than 220 truck drivers and 115 trucks, of which 90 are in the long haul sector. This makes Rosenlunds Åkeri a perfect practical test for this framework, as Autonomous vehicles are most likely to first be seen in the long haul industry.

The firm is located south of Jönköping, Sweden where they also have two storage and warehouse facilities. They operates as an agent for DHL, performing transports for the worldwide logistics giant. The majority of the transports take in southern Sweden, but the firm also transports goods to Europe (Rosenlunds Åkeri, 2016).

According to Zewebrand (2016), the trucks within the long haul sector drive an average of 110 000 kilometers per year, which is lower than the 150 000 kilometers stated by Scania (2013). The average fuel consumption is 4,1 liters per 10 kilometer. Regarding the vehicle utilization, the drivers spend approximately seven hours per day inside of the truck. In the interview with Zewebrand (2016), Rosenlunds state that they pay an average of 19 000 SEK per year for insuring a vehicle. These numbers are later used in the analysis chapter to calculate and investigate the potential cost reduction opportunities by implementing autonomous vehicles at Rosenlunds Åkeri AB.

4.5.1.1 Fuel

When using the figures from Zewebrand (2016) and combining with the fuel cost savings presented by Alam (2014), Bullis (2011), AXA(2013) and McKinsey (2013), Rosenlunds Åkeri could save between 46 700 SEK and 116 800 SEK annually per truck, depending on LOA. 46 700 SEK is based on LOA 4 where current fuel prices are multiplied with a 10% reduced fuel consumption and distance covered per year. 116 800 SEK is instead based on LOA 5 with 25% reduced fuel consumption.

4.5.1.2 Labour

According to the labour union Transport (2015), labour costs are estimated to be 382 700 SEK per year per employee. If the McKinsey (2013) estimation is applied to Rosenlunds Åkeri, the company could reduce labor costs by 80-90 % in LOA 5 as their main operations is long haul industry.

4.5.1.3 Insurance and Safety

Currently, Rosenlunds Åkeri pays approximately 19 000 SEK in insurance per vehicle and year. This can be expected to be lowered by 8200 SEK when using LOA 4, and an additional 60 % out of the original cost when using LOA 5 (Metro Mile, 2015; Dexheimer, 2015).

4.5.1.4 Vehicle utilization

The vehicle utilization is expected to increase with about 21% when using LOA 5 according to Parreira (2013). For Rosenlunds Åkeri this would mean an increased annual profit by 21 000 SEK per vehicle according to the Gustafsson (2007) estimation.

4.5.2 GDL

GDL is a company that offers transport- machinery- and logistics services. They are one of the larger national transport companies within Sweden and are currently located at 15 different locations in Sweden with their head office in Helsingborg. The revenue reaches the amount of 2,7 billion SEK.

This company was chosen because of larger size, as the first case company introduced in this paper is of a smaller character the authors would like to apply the calculations and theories onto a bigger company to see if the same results are shown.

Today, GDL has a total of 100 trucks running within Sweden and each of these trucks run approximately 2000 kilometer per week, or 104000 km per year. Seen to their mileage they consume 3,1 liter per 10 kilometers in average, which adds up to 32 240 liter per year. Since the company does not own their trucks, the insurance cost per truck is included in truck lease. In this thesis, insurance cost savings for GDL-trucks are set to 8 200 SEK per year per Truck based on the Metro Mile (2015) estimation.

4.5.2.1 Fuel

As mentioned by Eliasson (2017), an average GDL truck drives about 104 000 km per year. In the same time, the truck consumes a 323 232 SEK worth of fuel. With the 10% reduced fuel consumption from LOA 4, an average GDL truck with LOA 4 would have a 32 300 SEK lowered fuel cost. With the LOA 5 estimation, that number increases to 80 800 SEK in reduced fuel costs (Alam, 2014; Bullis, 2011; AXA, 2016; McKinsey, 2013).

4.5.2.2 Labour

The Swedish labour union Transport estimates the annual costs per employee to be 382 700 SEK. The McKinsey (2013) estimation of reduced labour costs in LOA 5 emphasizes on cost savings in the long haul sector. However, GDL's main operations is not long haul. Hence, the company would still need about 50% of the trucking staff due to the last mile problem. If the McKinsey (2013) estimation is applied to GDL, the transport organization would rather reduce their labour costs by approximate 40-45%.

4.5.2.3 Insurance and Safety

As GDL does not own their own vehicles, their insurance costs will remain zero. However, as autonomous vehicles are estimated to reduce insurance costs by 8200 SEK (Metro Mile, 2015), it can be seen as great leverage when negotiating new lease contracts. Therefore, the increased safety of autonomous vehicles can lower GDL's lease costs by 8200 SEK per vehicle and year.

4.5.2.4 Vehicle utilization

The vehicle utilization is expected to increase with about 21% when using LOA 5 according to Parreira (2013). For GDL this would mean an increased annual profit by 21 000 SEK per vehicle according to the Gustafsson (2007) estimation.

The above numbers are necessary to calculate whether if an investment in autonomous vehicles would be justified in the long term. The complete calculations can be found in the appendixes.

5 Analysis

After the presentation of the collected data related to autonomous vehicles, this next chapter will provide an analysis of findings. This part includes the authors' own opinions regarding autonomous vehicles. Just as the previous chapters, the analysis is divided into subheadings, organized according to the research questions.

5.1 Introduction

As autonomous vehicles is an emerging topic, there is very little academic knowledge about the impacts on the logistics industry. This is why the application and analysis of data is of highest importance. With a good application of the two inputs, and a thoughtful analysis, this thesis may be used as an investment decision framework for Swedish logistics companies whether to implement autonomous vehicles or not.

Previously mentioned, the collection of data, its comparison and the analysis is an iterative process to generate new theory that can add to the research gap. This can be seen in the data analysis section of Figure 8. The framework shown in Figure 8 is the conceptual model that this thesis uses to generate new theory.

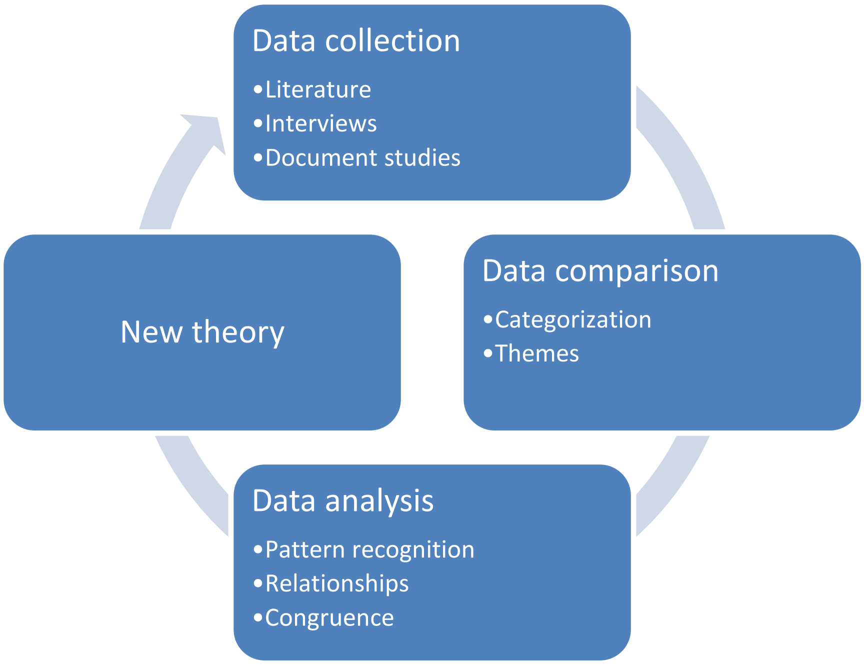


Figure 8: Iterative analysis cycle

The first cycle in this thesis' data collection was to identify which costs occurs during transportation. During the data collection process, we tried to reach data satisfaction. If the amount of collected raw data was not satisfying, more data was necessary in order to proceed. Once that data was collected from multiple sources, there was an ongoing process between comparison of data and analysis in order to benchmark the most critical costs. At this point the authors analysed the data in order to see if it could form any form of new theory. The raw data were categorized into themes where the most frequent and relevant ones were compared. After the first cycle, the authors decided to start a second cycle since there was a need for more complementary data to move towards new theory before data satisfaction could be achieved.

The second cycle was to gain a better understanding of how the identified costs are structured and how they should be calculated in a correct way to get the most precise result possible. Thus, another cycle of data collection was carried out. When the amount of data collected in this specific area was satisfying, the authors once again compared and analysed the data. This lead to that the authors could get a clear view upon how these costs should be calculated and what factors that needs to be considered, such as how the implementation rate affect the final cost of the implementation. However, as the complete data was not satisfactory, a third cycle was necessary to reach data satisfaction.

The third cycle of the process started once again with data collection, comparison and analysis. This third cycle was performed in order to find how the costs earlier identified actually are going to be affected within the Swedish logistics market when autonomous vehicle are implemented. The data collected in this cycle focused on how the Swedish logistic market was structured and functioning from an operative perspective. When a satisfying level of data was collected, the analysis later took the earlier data in consideration and this time the authors could see that these three categories of data together complimented each other in a way that could lead towards new theory. The data in this thesis is therefore regarded as satisfactory and adequately comprehensive to move on to deeper analysis and calculations.

Today there is a clear cost structure in regards to transportations within the Swedish logistics market. There is also evidence that the costs related to transportations will be affected by an implementation of autonomous vehicles, but only at a general level. The fact that these two cost structures are distinct and different is assured by data collected and presented. The issue and the whole reason to why this thesis was undertaken is to combine these two cost structures in order to identify variations in the cost structures when combined, in order to show a potential future cost scenario of the Swedish logistics. We cannot assure that the outcome of the study will show a positive or negative affect by an implementation of autonomous vehicles, but we can assure that the cost structure will change. The costs involved will change by different factors influencing the way of operating and they will also change seen to the proportions of the total transportation cost.

The following sections are analysis based on the three research questions and the subheadings represent each research questions respectively.

5.2 What is the actual cost of implementing an autonomous vehicle?

As previously presented in the results chapter, the average additional cost of an autonomous vehicle in 2020 is 73 720 according to the external organizations, and 102 470 SEK for the components (BCG, 2015). As for 2030 it is 32 575 SEK according to the external organizations. It is important to note that these cost are only for one truck. The overall cost for several trucks and the impacts on the logistics industry in Sweden will later be shown in question three.

To gain a more accurate result, since there are great differences in the cost estimations, the authors calculates an average in Equation 2.

$$73\,720 + 102\,470 = 176\,190$$

$$\frac{176\,190}{2} = \mathbf{88\,095}$$

Equation 2: Cost of an autonomous vehicle by 2020

This is thus the average estimated cost in 2020, which is used in this thesis. As for 2030 there will be calculations based on economies of scale over the time period. These two costs will later be used to find the average cost decrease in percentage throughout the ten years between 2020 and 2030 to be able to calculate each years' costs.

Due to the fact that there is little know of the cost estimations of the components by 2030, it is necessary to calculate the estimated cost using the same cost reduction rate as presented by the organizations. The cost difference is 56% which translates into an estimated cost of the components by year 2030 to be 45 087. The calculations can be found in the appendixes, 8.1.1. Lastly, to find the average additional cost of an autonomous vehicle in 2030, the components' cost and the estimation made by the external organizations are averaged in Equation 3.

$$32\,575 + 45\,087 = 77\,662$$

$$\frac{77\,662}{2} = \mathbf{38\,831}$$

Equation 3: Cost of an autonomous vehicle by 2030

38 831 SEK is thus the average additional cost for an autonomous vehicle in year 2030 compared to a non-autonomous vehicle.

As it is difficult to precisely foresee the future, the cost savings for each year in-between 2020 and 2030 are estimated according to the Santa Fe Institute's study of reduces cost for technology over time. The calculations are shown in the appendixes, 8.1.2.

The table in the appendixes 8.2.1 shows a linear relationship between cost and time which is well strengthened by the study made by Santa Fe Institute. Therefore, these calculations are considered as realistic and sufficiently precise.

Since the table shows the cost of implementing an autonomous vehicle yearly, the first research question is hereby fulfilled. This table also generates the foundation for calculations later found in connection to research question three where the number of autonomous trucks for each year will be taken into consideration as well.

As mentioned before, these costs do not involve any external costs that might occur in relation to the use or development of the manufacturing or implementation process. Rather this cost is only connected to the components and technology used to produce an autonomous vehicle together with a potential markup.

5.3 Which costs will be affected by an implementation of autonomous vehicles?

In order to understand what cost will be affected by an implementation of autonomous vehicles, it is necessary to first present the cost of transportations in the current state. This means that cost for labour, fuel and vehicles etc. needs to be calculated. When the total of today's transportation cost has been calculated, it is compared with the cost scenario after the implementation has been carried out.

The four major costs in this thesis are presented in the results chapter and as stated by AXA (2015), these will undergo significant changes. In the following sections the four costs are compared pre-implementation and post-implementation and analysed accordingly.

5.3.1 Fuel

Over the years the fuel prices have fluctuated heavily and price for fuel will continue to change over time, affected by supply and demand. With this in mind, it is difficult to calculate actual fuel costs to precision, especially when most logistics companies buy their fuel in bulk and receive negotiated discounts. However, it is possible to calculate the fuel savings companies can achieve by implementing autonomous vehicles.

In today's transporting industry, a common way of estimating fuels costs is one third of the total transportation cost (Behrends, 2016; Olsson, 2015).

Using the earlier stated estimation of fuels costs of 622 000 SEK per year, a company could thus save between 62 200 SEK to 248 700 SEK annually per truck if fitted with autonomous capabilities, when using the 10-40% presented by McKinsey (2013). This cost saving is highly dependent on the price of fuel, road conditions, and to which degree the vehicles drive on highways where platooning may be used. As a comparison, if autonomous vehicles would be implemented at Rosenlunds Åkeri or GDL, they would save between 32 300 SEK and 116 800 SEK per truck and year, depending on LOA and usage.

5.3.2 Labour

Labour is expensive and correlates to one third of the total transportation cost (Behrends, 2016). And without any extra insurances, compensations, or bonuses, employers pay an average 382 700 SEK to employ one truck driver per year.

By implementing a level 4 autonomous vehicle the company would not achieve any major cost benefits since a truck driver is still needed to be present in the vehicle for the majority of the transport. The only benefit for a level 4 vehicle could be that the driver could take breaks or have lunch while driving on the highway, thus increasing the vehicle utilization in a small scale. This is also mentioned by Tesla in the vehicle utilization section 4.3.4.

However, by implementing a level 5 autonomous vehicle the labour cost savings would be immense. As stated in the frame of reference, a vehicle with level 5 capabilities will be able to drive by itself without a driver, thus eliminating the need for a truck driver. The only labour needed would be terminal workers loading and unloading the vehicle and some kind of administration managing the transports from a control tower.

The labour cost is also very much connected to the last mile problem. While autonomous vehicles may be able to transport goods automatically between A and B, there is still the matter of getting the goods to the final destination. Hence, there is still a need for someone to transport the goods to the receiver. This someone could either be a bicycle courier, mail man, or a concierge.

Moreover, while labour is often bound to certain working hours, autonomous vehicles are not. It is still possible to hire labour to drive during night times but most often the employer has to pay compensation fees. This nightly fee and per diem fees can add up to great sums. An autonomous vehicle is not bound to any working hours, does not require any additional fees and can for way longer than a human. Therefore, autonomous vehicles can have great benefits for transports during night times. The only labour required would be an administrator that can manage up to ten trucks simultaneously.

5.3.3 **Insurance and safety**

As autonomous vehicles will not make human errors while driving, approximately 90% of all traffic accidents will not occur when the 100% of all vehicle are autonomous. This will cause a dramatic change in the insurance industry.

Regarding the costs of insurance and safety, they can be divided into direct and indirect cost. The direct cost affects the insurance taker as they need to pay for insurance and any potential accidents. The indirect cost is rather a cost for the society, caused by accidents injuring people.

As mentioned earlier, an implementation of autonomous vehicle will increase the safety on the roads and eliminate the risk of human errors which is the major underlying reason to traffic accidents. This will have a direct impact on the insurance costs. The cost of insurance premiums will be reduced and thus enable cost savings. The indirect cost will be reduced by implementing autonomous vehicles as well. The major indirect costs that will see a change in the future are aid needed in connection to accidents, cost for damaged goods, and loss of capacity.

It is difficult to calculate the potential direct cost savings of insurances since the price for insurances varies a lot. Prices vary depending on many factors such as coverage, comprehensiveness, and deductibles. Dexheimer (2015) argues that insurances will be 60% cheaper by 2030, but show no numbers to prove the argument. Therefore, this thesis uses the Metro Mile (2015) estimation instead. The insurance company states that an autonomous truck is 8200 SEK cheaper to insure, compared with a normal truck.

Lastly, the indirect cost savings that applies on the society will not be included in the final result. Though it is important to highlight this cost since it show a great side effect of autonomous vehicles. If the logistics industry were to implement autonomous vehicles, the society could thus save upwards of 300 million SEK per year (SCB, 2016). However, it is important to know that these costs are indirectly beneficial for the society, and will not affect businesses significantly.

5.3.4 **Vehicle utilization**

As most transportation companies only make money while they are actually moving goods, it is crucial for them to keep the trucks running with as high fill rate as possible. This means that for every minute a truck is standing still, whether it is for lunch break or overnight rest, the truck is not making any money. It is seen as an investment that does not generate any income while stationary. So in order to achieve the highest profit possible, the vehicle would theoretically be moving around the clock with high fill rate. However, this is not possible since loading, unloading and breaks take up lot of time, causing stationary downtime for the vehicle.

To improve the vehicle, utilization many companies use several drivers to drive around the clock in shifts. But using several drivers working full-time is very costly and might not be worth the extra expenses. But if those extra drivers would be replaced by automation, an autonomous vehicle could theoretically drive for many hours without having breaks or stopping for night time.

As earlier stated, it would be possible to increase the vehicle utilization by level 4 vehicles. But these savings will not generate any substantial impact. On the other hand, if the industry were to adapt autonomous vehicles of level 5 capabilities, the vehicle utilization could enable big opportunities for companies to further gain competitive advantages by near-100% utilization. This would allow truck transportation without any driver present in the vehicle, but rather with administration staff monitoring the vehicle from a central location.

As the terminal workers finish loading the truck, a message is sent to the control tower to give green light for departure. The vehicle automatically calculates the best route and drives to the unloading location. Regardless of distance and time, the vehicle automatically drives without stopping, as long as within range of the vehicle. If the driving distance exceeds the range of the vehicle, the administrators plan a fuel stop at a manned truck stop along the route.

As autonomous vehicle can drive at any time of the day, without any additional fees or labour costs except from administration staff, long distance transports can take place during night-time when roads are less congested. Additionally, as vehicle utilization increases and operation times extends, job opportunities are created in logistics terminals and other external services working together with the autonomous vehicles.

However, a major negative aspect of autonomous vehicles is the removal of job opportunities for truck drivers, especially in the long haul sector. Many people may lose their jobs or are required to move when logistics companies reallocate their resources to focus on last mile logistics.

Furthermore, due to increased vehicle utilization, there will be less need for more trucks to raise capacity. When a company reaches their maximum capacity, it would be possible to install autonomous capabilities to trucks rather than purchasing additional trucks to create a bigger fleet. It is reasonable to assume that an autonomous vehicle would have the same degree of utilization as two non-autonomous trucks due to the doubled utilization. But since no company have come this far, it is impossible to foresee how big of an impact the autonomous vehicles will have regarding the vehicle utilization. It might even be justified to sell a truck to find money for converting the rest of the vehicles.

5.4 How do these costs impact the Swedish logistics market seen from a cost perspective?

To answer the third and final research question there are many things that need to be taken into consideration to create the most accurate estimation. First of all, the implementation rate of autonomous trucks needs to be estimated. Ford claims to have their first autonomous vehicle with a LOA 4 on the market by 2020 (Butler, 2016). Additionally, Volvo will introduce 100 autonomous vehicles in Gothenburg in 2017 with the “Drive me” project; these cars have LOA 4 (Volvo, 2016). This proves that autonomous vehicles are currently at a developing stage and will reach the market in 2020. These findings, along with literature and professionals’ insight, have been extrapolated to form the following market penetration prognosis. Table 11 shows the percentage of trucks, within the Swedish logistics sector, that is estimated to be either LOA 4 or LOA 5.

Table 11: Market penetration prognosis

Year	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
LOA 4	1%	2%	4%	7%	11%	15%	20%	26%	33%	37%	38%
LOA 5					0%	4%	7%	8%	12%	16%	25%

As shown, autonomous trucks with LOA 4 will be introduced year 2020 and trucks with LOA 5 are estimated to be implemented year 2025. At the later stages of the time scope, the amount of LOA 4 trucks will start to stagnate. This can be explained by the increasing number of LOA 5 that is expected to be a more natural choice and basically follows the product life cycle that explain why products get outdated when new more innovative and better products reach the market. This is shown in Figure 9.

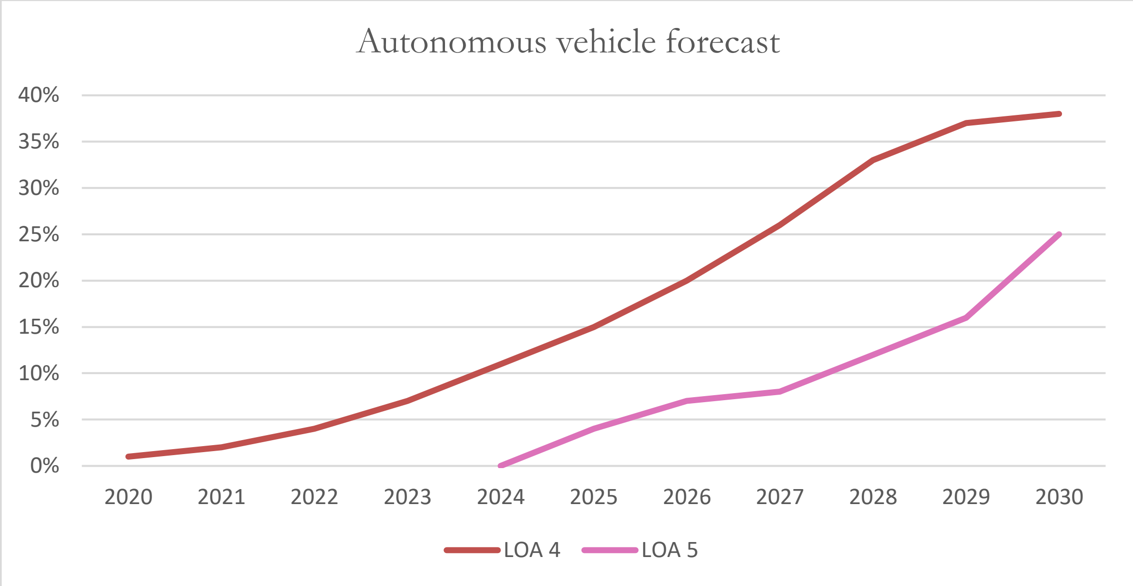


Figure 9: Autonomous vehicle forecast

Now that the implementation rate is set, it is compared to the Swedish market to show the estimated number of automated vehicles for every year. These numbers are shown in the appendixes, 8.2.2. It is important to mention that this table only shows the aggregate amount of autonomous trucks within the Swedish logistics industry. This mean that the implementation cost for 2021 cannot be calculated with 760 trucks. Instead 760 minus 380 (last year's amount of autonomous trucks) shows the number of newly registered autonomous vehicles in 2021, which is estimated to be 380 units. The aggregate table is thus only used to calculate each year's cost saving. The table of numbers of newly registered autonomous vehicles can be found in the appendixes, section 8.2.3.

In order to answer research question one, tables 8.2.1 and 8.2.3 need to be multiplied. This will provide the total implementation cost per year, based on the market penetration prognosis. The results of these calculations are shown in the appendixes, 8.2.4. As seen, the different LOAs have been divided, but the same cost applies since the technology itself is the same no matter if it is LOA 4 or 5. The main aspect that differs between LOA 4 and 5 is the software, not the hardware. The total cost to implement the estimated number of autonomous vehicles over a 10-year period is thus 1 309 636 636 SEK.

To analyse and see if this implementation is worth investing in, the gained benefits needs to be calculated. Once the numbers are compared, it is possible to see if the implementation is motivated and further if and when it could generate a competitive advantage.

In the following sections, each potential area of cost saving will be calculated for one truck. These potential cost savings will later be applied on the number of autonomous truck estimated to be in use in each year between 2020-2030. The total potential cost savings will later on, in the final part of this chapter, be compared to the total implementation cost to see if an implementation is justified.

5.4.1 Fuel

As mentioned earlier, the annual fuel cost for one truck is 622 000 SEK. It is though important that this number may vary a lot since there the consumption is highly dependable on the road conditions and the continuously changing price for fuel. The authors still justify the estimation as trustworthy enough to use in further calculations.

According to AXA (2015) and McKinsey (2013) an autonomous truck could reduce the fuel consumption by 10-40%. This is further supported by Alam (2014) and Bullis (2011) that estimate the potential cost savings to 20-25%. 10-40% correlates to an annual savings of 62 200 SEK to 248 700 SEK. It is estimated that a LOA 4 vehicle can easily gain 10% reduced costs while a LOA 5 can achieve upwards of 40%. How much a LOA 5 vehicle can save is heavily dependent on the road conditions and how the vehicle is used. Therefore, the average fuel savings used for a LOA 5 vehicle is 25%, or 155 500 SEK.

The complete results can be found in the appendixes, 8.2.5. The second and third rows are cost savings per vehicle while the fourth and fifth rows are aggregated cost savings for the entire fleet of autonomous vehicles in the Swedish logistics industry. As seen, the total cost savings are calculated to be 8 836 616 558 SEK over the ten-year period.

5.4.2 Labour

Regarding the cost savings calculations for labour, it is important to clarify the prerequisites. As mentioned earlier the average cost for one truck driver is today 382 700 SEK per year. In this study the cost savings will first appear when the truck has a LOA 5, when there is no need of a driver. Practically, this does not work since an autonomous truck may not be able to handle the last mile problem and other issues that appear close to the end destinations. This is according to McKinsey (2013), assumed that half of the autonomous trucks would still need drivers to solve the last mile problem

Moreover, to be able to use autonomous trucks and monitor them, there will be an estimated need for one or two administrators for every 10 trucks which further reduce the cost by around 80-90% assumed that there is no need for a human driver. (One can argue that administrators may require higher salary compared to a truck driver, but since there is no data supporting this statement, they are regarded as one and the same). The summary of these calculations are to be found in the appendixes, section 8.2.6.

As seen, LOA 4 trucks are excluded since they do not provide any substantial benefit, and only 50 % of the vehicles are seen as eligible, due to the last mile problem. The number of eligible vehicles is then reduced by 85% to show the number of administrators needed. The number of administrators is then multiplied with the salary and then compared with the scenario where one truck equals one driver. Results show a total cost savings of 4 450 0356 000 SEK for the entire time scope.

5.4.3 Insurance and safety

As earlier mentioned, cost for insurance will be approximately 8200 SEK cheaper when using an autonomous vehicle. Others have stated it to be upwards of 30 000 SEK. This also depending on the LOA and how the vehicles are used. But since both LOA 4 and 5 supports autonomous driving, the same cost savings are used for both. Even though it is reasonable to believe that cost savings may be greater in a LOA 5 vehicle, there are currently no facts that supports this statement.

So with an annual cost saving of 8200 SEK for each truck the authors have multiplied this number with the total amount of autonomous trucks on the market for each year, which is further shown in the appendixes, 8.2.7. As seen in the table, the total cost savings between 2020 and 2030 with Metro Miles' estimations are approximately 828 856 000 SEK.

5.4.4 Vehicle Utilization

The last cost saving that will be included is the cost for vehicle utilization. This cost is as earlier described not an actual cost, rather a missed opportunity of further incomes that appear when a truck is not used to any value adding activities. To maintain objectivity, the thesis chose to use the 21% increased utilization rate (Parreira, 2013) since it is based in research rather than professionals' estimations.

Since the increased vehicle utilization depends of autonomous trucks are driven without any human driver, LOA 4 will be excluded from the calculations. Regarding the cost savings of vehicle utilization there are two ways the savings can be affected. First aspect is by being able to use the truck in a more efficient way, thus increasing income. The other aspect is more short term, by not having to invest in new trucks due to increased utilization. This will postpone the need for investment. However, since it is not really possible to estimate the second aspect, only the first one is calculated.

The cost of operating a truck in the logistics industry in Sweden cost 8,5 SEK per kilometer. This equivalent to an annual cost of 1 290 000 SEK. Added to that is the estimated 99 400 SEK profit, and a revenue of 1 389 400 SEK is given, showing a markup of approximately 7,7%.

The cost savings are calculated by comparing the generated profit per year, before and after an implementation of LOA 5. Since a normal vehicle generates 99 400 SEK per year, an autonomous vehicle should generate an estimated 120 000 SEK. This new profit translates to a markup of approximately 9,3%. The profit is then multiplied with the number of LOA 5 trucks, as seen in the table in the appendixes, 8.2.8. The table also shows the total cost savings, 571 112 640 SEK.

5.5 Rosenlunds Åkeri

It is clear that Rosenlunds Åkeri would decrease their costs on the long term by implementing autonomous vehicles. It is still very important to consider implementations different aspects and not only focus on the potential cost savings. First of all, the company should start an investigation if it is even possible, due to the initial investment, and also try to estimate the amount of resources necessary to implement autonomous vehicles. A small size company in a relatively small city are most likely going to struggle with an implementation of autonomous vehicles. The geographical area where Rosenlunds Åkeri operates in does not have any high density of expertise when it comes to autonomous vehicles and therefore external resources and professionals are probably required during the implementation phase. In turn, this will lead to higher implementation costs in terms of external consultants, costs of new equipment etc.

Another aspect that is highly relevant is if Rosenlunds Åkeri existence is dependent on developments or if the current business operations is working well. This can refer to many different things, such as if the economical situations would allow an implementation or if the company is in need of higher margins and an increasing income to survive in the future. As earlier stated in this paper, autonomous vehicles is most likely going to revolutionize the logistics industry in the future and most companies will have to adapt to autonomous vehicles. Therefore it is an important decision to make if you want to be an early adopter or first see how it works for other companies before you implement it yourself. Considering it is a substantial initial investment both seen to the company's cash flow and time, a relatively small company as Rosenlunds Åkeri should instead consider to implement autonomous vehicles first after they been proven efficient and an established way of doing business within the logistics industry. This in turn would leave a room of opportunity for competitors of different sizes to act before them and potentially take market shares from Rosenlunds Åkeri.

5.6 GDL

When it comes to GDL which is a nation-wide transportation firm within Sweden they will more likely be able to implement autonomous vehicles at an earlier stage, compared to Rosenlunds Åkeri. Not only because of their market position which most likely put more pressure on them to stay competitive and future oriented, but also because of the geographical area they are operational in. Being a nation-wide actor do also mean that your competitive environment is different and often competing with many national and international transportation firms. From this point of view, an implementation of autonomous vehicles would be more important for GDL than Rosenlunds Åkeri.

Another important factor for GDL that needs to be considered is their future coverage. Even though they are a national firm, the main offices are located in Stockholm, Gothenburg and Helsingborg. If further expansions are planned either within Sweden or abroad, these needs to be considered in relation to an implementation of autonomous vehicles. Is the expansion more important than an implementation of autonomous vehicles or will they be carried out simultaneously? What would be the new areas of expansion and would they be in favor of autonomous vehicles?

Moreover the same issues that applies to Rosenlunds Åkeri applies to GDL as well when it comes to implementing autonomous vehicles. Is the financial situation stable enough to invest into the technology and is the surrounding infrastructure ready for the technology? Additional investments in the companies' immediate environment may be required which might hinder the future investments and development.

GDL will need to undertake a long and comprehensive investigation whether to proceed with the future idea of being the early adopter to invest in autonomous vehicles or rather try to remain profitable with today's technology.

5.7 Summary of analysis

In order to investigate if the implementation of autonomous vehicles within the logistics industry provides any competitive advantages, the formula earlier presented in Equation 1 is used.

The identified implementation costs and cost savings for each year provides the data needed to see if and when a competitive advantage will be reached. The kind of competitive advantage that will be gained is discussable. At the same time as the cost for the technology will decrease the willingness to pay will most likely increase throughout the years, due to a greater acceptance of autonomous vehicles. Since this study undertake a cost perspective and the data provided is focused on costs rather than increasing the willingness to pay among customers the potential competitive advantage will more likely have cost leadership characteristics than differentiation.

When it comes to the three different dimensions of cost leadership earlier described in the frame of reference, an implementation of autonomous vehicles fulfils the criteria for all dimensions. Hence, no specific dimension applies. The high asset utilization is fulfilled by the increased utilization rate gained by autonomous vehicles. The dimension related to low direct and indirect operating costs are realized by the decreased costs in fuel, labour and insurances. Finally, the last dimension that aims towards gaining more control over the value chain is applied to autonomous vehicles, since they provide a leaner and flexible value chain and at the same time it will be easier to monitor and control the transportation operations.

As stated, the implementation of autonomous vehicles will lead to a cost leadership strategy rather than differentiation, if competitive advantages are reached. Because of this, the calculations will only consider the cost leadership, which is price minus cost. The price in this case will be the cost savings that have been identified for each year. These numbers are subtracted by each years' implementation costs in order to see the final result. This means that as long as the result is positive, it is worth investing in, and competitive advantage has been gained from a cost leadership perspective.

As Table 12 states, a competitive advantage from a cost leadership perspective will be gained already at year 2021, when the estimated profit will be almost 22 million SEK. This further strengthen the motives for implementing autonomous vehicles. Especially as mentioned earlier, the acceptance of the technology will most likely increase throughout the years and thus increase the willingness to buy among customers which further motivate an ongoing implementation.

Moreover, these results are supported by the empirical data and calculations for Rosenlunds Åkeri and GDL. A similar table can be found in the appendixes, section 8.2.10. The table shows how Rosenlunds Åkeri would benefit by implementing autonomous vehicles by 2021. The major differences from the whole Swedish logistics industry, is that Rosenlunds Åkeri's vehicles does not drive as much as the average truck does. Hence, the fuel cost savings are slightly lowered, but not to any significant levels. It is still very profitable to implement autonomous vehicles, providing a 634 % ROI for Rosenlunds Åkeri between 2020 and 2030. But as mentioned earlier, even if it would be profitable their current situation and their environment might not be ready for it yet. Compared with Rosenlunds Åkeri, GDL is more likely to find it appropriate to implement autonomous vehicles at an earlier stage. It is not only shown profitable, but their coverage includes the two largest cities in Sweden and will most likely be the two areas where autonomous vehicles will be implemented at first.

As seen in Table 12, the final results of the implementation have been calculated. From a financial perspective the results are clear. The Swedish logistics industry will save an estimated 13,4 Billion SEK by implementing autonomous vehicles according to this thesis' implementation rate. This would this give a ROI of 1021 % over ten years.

With this table, the third and final research question has been answered. Hence, the purpose of this thesis has also been fulfilled.

Table 12: Final Results

Final Result												
Implementation costs	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**Sum**
Cost LOA 4 (KSEK)	33 476	31 604	59 464	83 580	103 952	96 464	111 220	122 231	129 499	66 511	14 756	852 757
Cost LOA 5 (KSEK)	0	0	0	0	0	96 464	66 732	20 372	73 999	66 511	132 802	456 880
Total	33 476	31 604	59 464	83 580	103 952	192 928	177 951	142 603	203 498	133 022	147 558	**1 309 637**
Savings												
Fuel (KSEK)	23 627	47 255	94 509	165 391	259 900	590 683	886 024	1 086 857	1 488 521	1 819 303	2 374 545	8 836 617
Labour (KSEK)	0	0	0	0	0	247 224	432 642	494 448	741 673	988 897	1 545 151	4 450 036
Insurance (KSEK)	3 116	6 232	12 464	21 812	34 276	59 204	84 132	105 944	140 220	165 148	196 308	828 856
Utilization (KSEK)	0	0	0	0	0	31 728	55 525	63 457	95 185	126 914	198 303	571 113
Total	26 743	53 487	106 973	187 203	294 176	928 840	1 458 324	1 750 706	2 465 599	3 100 262	4 314 308	**14 686 621**
Resulting Value (KSEK)	-6 733	21 883	47 509	103 623	190 225	735 912	1 280 372	1 608 103	2 262 101	2 967 240	4 166 750	**13 376 984**
ROI (%)	-20%	69%	80%	124%	183%	381%	720%	1128%	1112%	2231%	2824%	**1021%**

6 Discussion

In this chapter the authors will present the discussion of this thesis. Personal opinions related to the subject as well as the implications and practical contributions will be introduced. Furthermore, the methods used to gather data together with the methodological approach will be discussed.

6.1 Contributions & Implications

According to the result and analysis, it is clear that an implementation of autonomous vehicles would lead to major cost savings in the logistics industry, as well as for the society. However, a problem today is that acceptance and laws does not fully support autonomous vehicles of LOA5 5. Though, it is within reach and is estimated to see the market in 2020.

As earlier mentioned in the analysis, the implementation cost of 2020 exceeds the cost savings, and therefore it might be difficult to convince logistics companies to implement autonomous vehicles at that time. Still, the authors think that the earlier autonomous vehicles are implemented, the faster improvements can be made. This will make it easier to identify problematic areas when they are used in reality. This may also lead to even faster decreasing costs of the technology and further increase the implementation rate. A faster implementation rate would lead to greater benefits for the logistics industry as well as the society.

The costs involved in this thesis might shift over time. For example, there will most likely be improvements in fuel efficiency, which will lower consumption and the fuel cost. On the other hand, the cost savings from autonomous vehicles will higher than the cost savings from more fuel efficient vehicles.

The increased vehicle utilization of 21%, is according to the authors very low. Compared to the data from Rosenlunds Åkeri, where a driver spends approximately seven hours in the truck per day, a LOA 5 truck could increase the vehicle utilization by at least 100% seen to the current state. Even if the utilization is doubled, there will still be ten hours left for operations such as loading or unloading goods.

Concerning the actual development and implementation of autonomous vehicles, it is not the logistics industry that are developing. It is rather companies within the automotive industry. To be able to implement autonomous vehicles, both within the society, but more importantly the logistics industry, the technology need improvements as well as redefined regulations and laws. The companies involved in the development of autonomous vehicles are the ones that need to push the technology. They also need to convince society and the logistics industry that autonomous vehicles are beneficial, compared to the current scenario.

Additionally, close collaboration between governments and automotive industry is necessary in order to enable the full usage of autonomous vehicles and their benefits. Most likely, the automotive industry needs to take initiative and first enable autonomous vehicles to in line with laws. When this has been done, they technology can be shifted towards the logistics industry.

This should be done as soon as possible once regulations allow it, since there is a great interest for autonomous vehicles among many global logistics companies. It is also worth mentioning that those will probably be the first one to adopt to autonomous vehicles, rather than small independent companies. This is because the early adopters will most likely struggle with autonomous vehicles since the industry and society have not accepted the new technology. This may cause some operations to become problematic and even inefficient. However, this is arguably just the first few years, and as soon as the industry has become acquainted with the technology, the problems should disappear. Furthermore, since an implementation of autonomous vehicles is costly, especially in an early stage, the first companies to adopt are those who are financially strong.

When it comes to the benefits of implementing autonomous vehicles, it is clear that big cost savings are to be realized, both for the logistics industry as well as the society. The logistics industry will be able to reduce their operating costs immediately and the payback time will be short in relation to other major investments. This will allow the logistics industry and the companies using autonomous vehicle to gain a competitive advantage by their reduced operating costs. A reduced operating cost will allow them to lower their price for their customers and therefore be considered as a more attractive choice, assumed they keep the same quality. The quality will most likely be the same if not even improved, since the increased vehicle utilization will enable shorter lead times, and autonomous vehicles are less likely to be involved in accidents. The reduced number of accidents is also major societal benefit since it will allow the society to save roughly 300 million SEK a year. This is money that could be spent on far better things to increase the social welfare. For example, these 300 million SEK almost cover the cost that the Swedish government set aside to increase export among businesses in Sweden (Regeringen, 2016).

As long as the industry and society accepts autonomous vehicles, the authors believe solutions for other problems such as the last mile problem can be solved. DHL is already researching different ways to handle this problem if an implementation of autonomous vehicles would take place, such as the DHL packstations in Germany (DHL, 2013).

Concerning the last mile problem, the authors, as well as many other organizations and professionals suggest, the best solution would be to change the mindset of how transportation is carried out today. Instead of getting parcels and packages delivered to the doors, they could instead be delivered to a hub that is located strategically. From this hub the receivers can pick up their parcels.

By using autonomous vehicles and deliver the goods to hubs or service points, rather than to each final customer, the freight cost can also be reduced. This could be seen as enough motivation to pick up the goods at a hub or service point rather then get it delivered to the door. This could to some extent work within the B2B sector as well. Though the authors believe that it will be easier to handle the last mile problem when it comes to B2B rather than B2C. This is due to that many businesses have well functional infrastructure in their facilities and are often located in strategic places such as the outskirts of cities rather than in the heavy trafficked central areas.

Unfortunately, ethical issues will arise when implementing LOA 5 autonomous vehicles. A lot of truck drivers in the long haul sector will lose their jobs or be reallocated. Other businesses that might get affected is traffic schools (especially those focusing on trucks) since the will most likely be no need for a driving license when all vehicles are fully autonomous. On the other hand, autonomous vehicle will create a lot of job opportunities as well, but these jobs may require higher educational levels than required for truck drivers. This is an ethical issue that both the industry and the society need to consider, whether or not it is ethically correct to reduce the number of jobs offered. Because of this issue, actors must be very careful and take everything into considerations when this transition process will be rolled out.

Finally, going back to the main topic of this study, the cost perspective. Cost savings will increase as more and more autonomous vehicles get implemented. The more autonomous vehicles there are in use, the more effective the logistical flow will become, since vehicles are able to communicate with each other, thus leading to a better vehicle utilization and more efficient fuel consumption. With this said, the authors argue that an implementation of autonomous vehicles within the logistics industry in Sweden should be highly useful both for the industry itself but also the society. As soon as the technology is ready to use, there should be incentives from both the government, automotive- and the logistics industry to implement autonomous vehicles. If this is performed by a close and highly integrated collaboration, costs can be saved and social welfare increased.

6.2 Limitations

As there is always a risk of things being unclear and this study may be criticized, the authors will respond to the critique by explaining the content, the methods and approaches used. This part will consist of a discussion of what was done correct and what could have been done better.

6.2.1 Content limitations

One limitation in this study is the scope of what costs that are included. One can argue that more costs should have been taken into consideration, both seen to the implementation cost and the cost savings. Because of the time scope these costs were the only one that the authors could investigate to the extent where they could fulfill the trustworthiness. The costs used within this study are also the ones that are the most important ones according to data gathered.

Additional costs could have been taken into considerations to form a more comprehensive study. Possibly, other direct costs could have been included, such as installing the autonomous hardware in a vehicle. Additionally, indirect costs would maybe have been suitable, but since the study is future oriented it would become even more difficult to predict these costs in a future scenario.

Other costs that could not be included because of the strict time frame, were potential taxes and subventions towards autonomous vehicles. The authors believe, that in the future, autonomous vehicles should be tax subsidized in order to motivate an implementation of them and thus, benefit the society.

Because of the fact that the topic of this study is future oriented much data is based on professional estimations. This data might be proven to be either wrong or correct in the future but the authors have tried to minimize the amount of estimations. Though, throughout the study, estimations are based on data gathered or through mathematical calculations in order to decrease the risk of errors and to have a scientific foundation.

Another limitation is how the curve of the decreasing cost of the technology between 2020 and 2030 that is presented in this study. The authors would say that the cost decrease of new technology is most likely lower in the first few years, and by time it lowers exponentially, as shown in scenario 1&2 in the appendixes, section 8.1.3. But as the study made by the Santa Fe Institute showed, this is not the actual case. That is why a linear cost reduction curve was chosen for this thesis. This does not necessarily mean that the technology of autonomous vehicles will be linear. Even if the cost reduction over time might turn out different than the one used in this study, it is still reasonable to use that one, since it is most likely.

Regarding the studied area, the geographical spread only includes Sweden and its logistics industry. It is important to mention that the result might be different if applied on logistics industries in other countries since they all are in different stages seen to its maturity and the development. Therefore, the same results may not be reached if the study would be applied to another country. This also applies to the costs investigated, as these might differ. For example, the average salary for a truck driver or taxation may not be the same as in Sweden. However, the same calculations can be used anywhere since the same costs appear no matter if it is Sweden or any other country implementing autonomous vehicles.

6.2.2 Methodology limitations

In order to create a clear structure and a plan to complete the study in time and at the same time reach the best and most realistic result, a time plan was set. It was established to facilitate the work process in order to keep up with the deadlines and make sure that the right topics and areas were investigated.

As abduction was used as the main approach, literature studies were conducted at the same time as empirical data was gathered. These were later compared with each other by pattern matching. The study started with a basic information that was gathered through literature and document studies.

6.2.3 Data Collection

In the following part, there will be a discussion regarding the data collection methods. This is made to clarify why the methods used were chosen in comparison to others and by that answer any potential critique

6.2.3.1 Literature Studies

The literature studies have been an iterative process throughout the whole study. The reason to use literature studies was because of the future oriented topic, which both made it very interesting but also a bit difficult in order to find relevant literature. Because of the limited amount of literature regarding autonomous vehicles the authors constantly needed to make sure that the literature studied and used were trustworthy and credible. It was also clear that some areas have had more extensive research than others.

Even though the authors had access to many different search engines and databases, it was complicated to find relevant data regarding autonomous trucks. Therefore, the data extrapolated from literature was sometimes useful while some parts was not used at all. Data gathered through literature studies was later evaluated and analyzed by pattern matching to ensure a level of trustworthiness.

6.2.3.2 Document studies

The document studies that have been conducted in order to collect relevant information mainly derives from companies, either directly involved within the automotive industry or bigger consultancy firms that made estimations of the potential of autonomous vehicles. Documents regarding autonomous vehicles were one of the first sources of information the authors stumbled upon, which later formed the topic of this study. As well as with the literature studies, the document studies have been an ongoing process throughout the whole study. The authors further believe that the data gathered through document studies are among the most reliable as they are up to date compared to many other sources.

The data collected through document studies has been read with an objective perspective and later analyzed with each other, in order to find a pattern. The analyzed data has been compared to other sources in order to find relevant, credible and trustworthy information.

6.2.3.3 Interviews

In order to gather data connected to research question one and two, interviews were made. They were conducted to primarily gather qualitative data. Additionally, the interviewees were given the opportunity to remain anonymous, even if no one chose to. A semi-structured method was preferred. However, one interview was used with a structured approach. Depending on the answers from the respondents, further questions were given in order to collect additional information. This method allowed the respondents to provide wider and more general answers, compared to if a structured approach would have been undertaken (Yin, 2011).

The interviews involved represents from the automotive industry, transportation industry as well as the academic world, and therefore covered the most necessary areas in this study. Since some of the respondents were geographically dispersed the interviews were sometimes made by phone. The authors are aware that phone interviews are not the best method for data gathering, but they did provide the data necessary. Therefore, these sources are considered as credible.

As stated earlier, the interviews were recorded and later transcribed in order to sort out the information needed. Some questions were used in all interviews, which allowed the authors to analyze and verify the answers to find a pattern in comparison to the theory.

To categorize the data, thematic analysis was used. According to Boyatzis (1998), it is a good way of encoding qualitative data. It allowed the authors to review the data, make notes and later categorize it. The authors categorized words or phrases that later were served as labels for different sections of data. It further enabled a closer connection to the data that allowed deeper analysis of the content (Boyatzis, 1998).

6.2.4 Data analysis

The data collected through the different methods used has been analyzed in different ways depending on if they are of quantitative or qualitative characteristics. As mentioned in the method chapter the quantitative data collected through literature and document studies have been categorized either by being numerical or categorical.

The qualitative data gathered was instead analyzed by the help of pattern matching and thematic analysis. This meant that authors could compare different theories with data, in order to find a pattern and see if the theories were adequate. According to the authors, this is a sufficient method of analyzing data.

6.2.5 Trustworthiness

As this study consists of both quantitative and qualitative data, trustworthiness needs to be considered. The work process that was set in the beginning and later used, allowed the authors to keep high level of trustworthiness throughout the entire study. The work process assured that the right things were done at the right time accordingly to the research strategy.

Since several methods and sources of data were used, the reliability and validity were strengthened and thus good in this study. The data gathered through different methods was analyzed and compared with each other, which further strengthens the reliability and validity. Because the topic of this study is future oriented, some of the data was based on estimations and thus decreases the reliability since the estimations will most likely change throughout time. Furthermore, the internal validity of this study is reached by the pattern matching that was used in order to analyze empirical data and how it was related to the theory used. The external validity of this study is seemingly strong if applied in different logistics industries, and can be used in different geographical areas. However, the external validity is decreased since this study cannot be applied in different industries other than the logistics one.

The generalizability is closely connected to the external validity and as mentioned can be regarded as relatively weak. This is because the study cannot be applied to any other industries than the logistics industry. However, geographical generalizability is slightly better as the results can be transferred to any region. Additionally, as there is a clear relation to existing theory, the generalizability is also improved. Since the study was conducted in a relatively unexplored area, generalizability is negatively affected.

In order to create a high credibility, data has been gathered both from the academic and business world. This data has been analyzed and compared with existing theory to ensure congruity. Since credibility is mainly built on reducing the possibility of getting the wrong results, credibility is affected negatively by the estimations used to define future costs.

As stated in the method chapter, the transferability is improved by the fact that the authors have clearly described their work process, methodology, theories and data collection methods used. It is though important to note that since the study undertake a cost perspective related to Sweden, the calculations may be replicated in other areas under other conditions but the findings may not, since the costs involved will most likely differ in other geographical areas.

6.3 Further Studies

Throughout this study, it became clear that there are areas that need further investigation. Even if the major direct costs connected to transportation have been investigated, a study of other costs could have provided a different result.

There are also other areas that would add value to this study. Areas that would be indirectly affected by autonomous vehicles could have been investigated in order to create a more comprehensive decision support, if it was not for the time limitation. If an implementation of autonomous vehicles would take place it would most likely impact many supply chains and operations involved in these. There is no discussion made on how the structure of supply chains can be changed, or impacted by an implementation, nor how the relationship between different actors involved would get affected.

Today, many transportations within the Swedish logistics industry goes either to or from destinations in Europe. Together with other countries' logistics industries they form a transportation network in Europe. Because of the international characteristics of today's the logistics industry, there might be difficulties to implement autonomous vehicles on only national basis. Legislation in Europe needs to be congruent and this is something that has not been investigated in this paper.

Another aspect that needs further consideration seen to a safety aspect is the security management and processing of data and information. In order to enable an implementation of autonomous vehicles, manufacturers must ensure that information stays confidential and more importantly, ensure that the vehicle cannot be hacked. There are cases where autonomous vehicles have been hacked and the hackers have been able to control the vehicles brakes and engine. From a safety and security perspective this area must be further researched to make an implementation of autonomous vehicles realistic (KPMG, 2015c).

Finally, the futuristic perspectives of this study are based on current data. It would be very interesting to come back to this study in the future, or even increase the time span beyond 2030. How different will the logistics industry be in 2050?

6.4 Conclusion

The conclusions drawn from this study clearly shows that implementing autonomous vehicles within the Swedish logistics industry is highly encouraged. By using autonomous vehicles, the Swedish logistics industry can reduce total costs by approximately 13,4 billion SEK, equivalent to a ROI of more than 1000% in a ten-year period. The cost savings is only one motivating factor among many others, such as the increased safety.

However, the authors of this study stress that the implementation of the autonomous vehicles might not be possible today, but should be taken in consideration as soon as possible. The faster the implementation of autonomous vehicles take place; the faster improvements will be made. It is extremely important that the movement towards using autonomous vehicles is completed in a highly-integrated collaboration between the government and the automotive industry itself, because the biggest issue today is the legislations of the vehicles. An implementation could also lead to ethical issues, such as reduced job opportunities for the trucking industry, but these jobs could instead be replaced by administrative jobs and jobs in other sectors. Even though the technology is well developed there are issues that need to be addressed in order to prevent unwelcome consequences.

Finally, the Swedish logistics industry would indeed benefit from an implementation of autonomous trucks. The authors of this study believe that there is no doubt that it would save a lot of money and increase the competitiveness among parties involved in the logistics industry. It will not only benefit the Swedish logistics industry but also the society as a whole.

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8 Appendixes

8.1 Calculations

8.1.1 Calculation to estimate the cost of components by 2030.

2020 cost estimation of components: 102 470 SEK

$$\frac{32575}{73720} = 0.44$$

$$1 - 0.44 = 0.56 = 56\%$$

$$102\,470 * \ 0.44 = 45\,087$$

2030 cost estimation of components: 45 087 SEK

8.1.2 Calculation to estimate the cost reduction per year

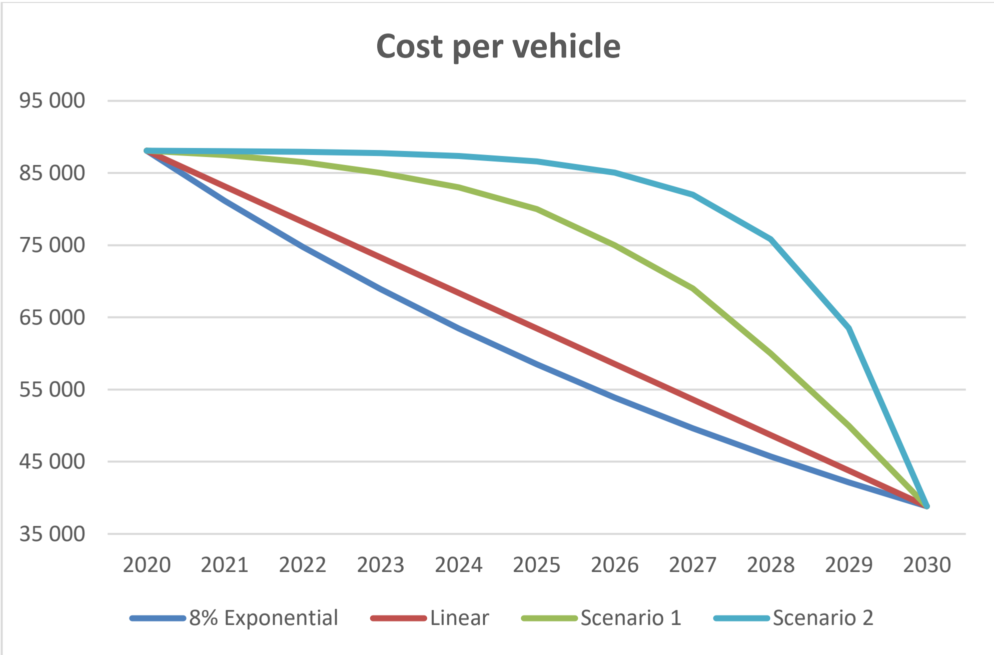
2020 cost estimation: 88 095 SEK

2030 cost estimation: 38 831 SEK

$$88\,095 - 38\,831 = 49\,264$$

$$\frac{49\,264}{10} = 4926{,}4\ SEK\ Annually$$

8.1.3 Cost reduction scenarios



8.2 Tables

8.2.1 Cost of an autonomous vehicle per year 2020-2030

Year	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Cost (SEK)	88 095	83 169	78 242	73 316	68 389	63 463	58 537	53 610	48 684	43 757	38 831

8.2.2 Number of autonomous vehicles in Sweden forecast

Year	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
LOA 4 (PCS)	380	760	1 520	2 660	4 180	5 700	7 600	9 880	12 540	14 060	14 440
LOA 5 (PCS)						1 520	2 660	3 040	4 560	6 080	9 500

8.2.3 Number of newly registered autonomous vehicles in Sweden

Year	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
LOA 4 (PCS per year)	380	380	760	1 140	1 520	1 520	1 900	2 280	2 660	3 040	3 420
LOA 5 (PCS per year)						1 520	1 120	380	1 520	1 520	3 420

8.2.4 Implementation cost

Implementation costs	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Sum
Cost LOA 4 (KSEK)	33 476	31 604	59 464	83 580	103 952	96 464	111 220	122 231	129 499	66 511	14 756	852 757
Cost LOA 5 (KSEK)	0	0	0	0	0	96 464	66 732	20 372	73 999	66 511	132 802	456 880
Total (KSEK)	33 476	31 604	59 464	83 580	103 952	192 928	177 951	142 603	203 498	133 022	147 558	**1 309 637**

FUEL	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Total
Cost (KSEK)	622	622	622	622	622	622	622	622	622	622	622	
Cost savings per vehicle LOA 4 (KSEK)	62	62	62	62	62	62	62	62	62	62	62	
Cost savings per vehicle LOA 5 (KSEK)						155	155	155	155	155	155	
Cost Savings LOA 4 (KSEK)	23 627	47 255	94 509	165 391	259 900	354 410	472 546	614 310	779 701	874 211	897 838	4 583 699
Cost Savings LOA 5 (KSEK)	0	0	0	0	0	236 273	413 478	472 546	708 820	945 093	1 476 707	4 252 917
Cost Savings(KSEK)	23 627	47 255	94 509	165 391	259 900	590 683	886 024	1 086 857	1 488 521	1 819 303	2 374 545	8 836 617

8.2.5 Fuel cost savings

8.2.6 Labour cost savings

LABOUR COST	2025	2026	2027	2028	2029	2030	Total
Salary (KSEK)	383	383	383	383	383	383	
Trucks Eligible (LOA 5) (PCS)	760	1 330	1 520	2 280	3 040	4 750	
Administrators required (PCS)	114	200	228	342	456	713	
Cost (KSEK)	43 628	76 349	87 256	130 883	174 511	272 674	785 300
Cost Savings (KSEK)	247 224	432 642	494 448	741 673	988 897	1 545 151	**4 450 036**

8.2.7 Insurance and Safety cost savings

INSURANCE	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Total
Insurance Savings per vehicle (SEK)	8 200	8 200	8 200	8 200	8 200	8 200	8 200	8 200	8 200	8 200	8 200	
Number of LOA 4 Vehicles (PCS)	380	760	1 520	2 660	4 180	5 700	7 600	9 880	12 540	14 060	14 440	
Number of LOA 5 Vehicles (PCS)						1 520	2 660	3 040	4 560	6 080	9 500	
Total (KSEK)	3 116	6 232	12 464	21 812	34 276	59 204	84 132	105 944	140 220	165 148	196 308	**828 856**

8.2.8 Vehicle Utilization cost savings

UTILIZATION	2025	2026	2027	2028	2029	2030	Total
Normal profit per vehicle (KSEK)	99	99	99	99	99	99	
Autonomous vehicle profit per vehicle (KSEK)	120	120	120	120	120	120	
Number of LOA 5 Vehicles (PCS)	1 520	2 660	3 040	4 560	6 080	9 500	
Normal profit (KSEK)	151 088	264 404	302 176	453 264	604 352	944 300	2 719 584
Autonomous Vehicle profit (KSEK)	182 816	319 929	365 633	548 449	731 266	1 142 603	3 290 697
Total Cost Savings (KSEK)	31 728	55 525	63 457	95 185	126 914	198 303	**571 113**

8.2.9 Final result

Final Result

Implementation costs	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Sum
Cost LOA 4 (KSEK)	33 476	31 604	59 464	83 580	103 952	96 464	111 220	122 231	129 499	66 511	14 756	852 757
Cost LOA 5 (KSEK)	0	0	0	0	0	96 464	66 732	20 372	73 999	66 511	132 802	456 880
Total	33 476	31 604	59 464	83 580	103 952	192 928	177 951	142 603	203 498	133 022	147 558	**1 309 637**
Savings												
Fuel (KSEK)	23 627	47 255	94 509	165 391	259 900	590 683	886 024	1 086 857	1 488 521	1 819 303	2 374 545	8 836 617
Labour (KSEK)	0	0	0	0	0	247 224	432 642	494 448	741 673	988 897	1 545 151	4 450 036
Insurance (KSEK)	3 116	6 232	12 464	21 812	34 276	59 204	84 132	105 944	140 220	165 148	196 308	828 856
Utilization (KSEK)	0	0	0	0	0	31 728	55 525	63 457	95 185	126 914	198 303	571 113
Total	26 743	53 487	106 973	187 203	294 176	928 840	1 458 324	1 750 706	2 465 599	3 100 262	4 314 308	**14 686 621**
Resulting Value (KSEK)	-6 733	21 883	47 509	103 623	190 225	735 912	1 280 372	1 608 103	2 262 101	2 967 240	4 166 750	**13 376 984**
ROI (%)	-20%	69%	80%	124%	183%	381%	720%	1128%	1112%	2231%	2824%	**1021%**

8.2.10 Rosenlunds Åkeri

Rosenlunds Åkeri												
Implementation costs	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**Sum**
Cost LOA 4 (KSEK)	88	83	235	220	342	254	351	375	389	219	39	2 595
Cost LOA 5 (KSEK)	0	0	0	0	0	317	176	54	243	175	427	1 392
Total (KSEK)	88	83	235	220	342	571	527	429	633	394	466	**3 987**
Savings												
Fuel (KSEK)	47	93	234	374	607	1 378	2 009	2 453	3 411	4 112	5 443	20 161
Labour (KSEK)	0	0	0	0	0	287	459	517	804	1 033	1 665	4 765
Insurance (KSEK)	8	16	41	66	107	196	280	349	471	558	691	2 783
Utilization (KSEK)	0	0	0	0	0	104	167	188	292	376	605	1 733
Total (KSEK)	55	110	275	439	714	1 966	2 915	3 506	4 978	6 078	8 405	**29 441**
Resulting Value (KSEK)	-33	27	40	219	372	1 395	2 388	3 077	4 345	5 685	7 939	**25 454**
ROI (%)	-38%	32%	17%	100%	109%	244%	453%	717%	687%	1443%	1704%	**638%**

8.2.10.1 GDL

GDL												
Implementation costs	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**Sum**
Cost LOA 4 (KSEK)	88	83	156	293	274	254	351	322	389	175	39	2 425
Cost LOA 5 (KSEK)	0	0	0	0	0	254	234	54	195	175	388	1 300
Total (KSEK)	88	83	156	293	274	508	585	375	584	350	427	**3 724**
Savings												
Fuel (KSEK)	32	65	129	259	388	840	1 358	1 632	2 214	2 667	3 507	13 091
Labour (KSEK)	0	0	0	0	0	230	459	517	746	976	1 550	4 478
Insurance (KSEK)	8	16	33	66	98	164	246	303	402	467	558	2 362
Utilization (KSEK)	0	0	0	0	0	83	167	188	271	355	564	1 628
Total (KSEK)	41	81	162	324	486	1 318	2 230	2 640	3 634	4 465	6 178	**21 558**
Resulting Value (KSEK)	-48	-2	6	31	213	810	1 644	2 265	3 049	4 115	5 751	**17 834**
ROI (%)	-54%	-3%	4%	11%	78%	160%	281%	604%	522%	1175%	1346%	**479%**

8.3 Miscellaneous

8.3.1 Defining your data type ((Figure 12.1, pp. 417), Saunders et al. 2009)