MASTER'S THESIS

MARKET POTENTIAL FOR AUTONOMOUS TRUCKS

An Extensive Study in the middle of a Technology Shift

JONATAN ARNLUND
JOAKIM WAHL

May 2021

LUNDS UNIVERSITET

LTH
LUNDS TEKNISKA HÖGSKOLA

Kurs: Degree Project LTH
Institutionen för Teknisk Ekonomi och Logistik
Avdelningen för Produktionsekonomi
Lunds Tekniska Högskola (LTH)
Ole Römers Väg 1, 221 40 Lund, Sweden
www.pm.lth.se

Sammanfattning

Titel
Market Potential for Autonomous Trucks - An Extensive Study in the middle of a Technology Shift

Författare
Jonatan Arnlund
Joakim Wahl

Akademisk Handledare
Ingela Elofsson
Föreläsare, Produktionsekonomi
Lunds Universitet

Handledare på fallföretaget
Handledaren kommer av konkurrensmässiga skäl benämnas *"The Supervisor"*
Säljansvarig, Avdelning X
Fallföretaget kommer av konkurrensmässiga skäl benämns "*The Case Company"*

Bakgrund
Den globala transportindustrin står inför nästa stora teknologiska skifte; införandet av självkörande fordon. Detta skifte kan gradvis eliminera behovet av fysiska chaufförer, öka säkerheten och förbättra flexibiliteten. Därmed ändras grundprinciperna för industrin i stort. Självkörande förväntas lastbilar kommer implementeras inom begränsade områden med privat väg för att därefter successivt användas för längre transporter på publik väg i takt med att lagstiftningen tillåter det.

Syfte
Syftet med studien är att identifiera, beskriva och analysera teknologiskiften och teknologiska behov inom transportindustrin. Studien ämnar att värdera marknadspotentialen, samt undersöka hur en 'first mover' kan exploatera självkörande fordon på bästa sätt.

Metod
Denna uppsats använder en hybrid mellan ett beskrivande och ett utforskande tillvägagångssätt. The Case Company används som det huvudsakliga studieobjektet, tillsammans med flertalet andra företag där lämpligheten för The Case Companys produkter och tjänster studeras närmare.

Avgränsningar
Denna studie är avgränsad till att enbart behandla korta transporter (s.k. "First Mile Delivery") inom hamnar och logistikcenter (vilket också innefattar intern logistik hos tillverkande företag) i en B2B-kontext. Ingen hänsyn har tagits till legala aspekter eller till politiska regulationer, vilket med andra ord innebär att dessa inte inte ses som begränsning för att implementera självkörande lösningar inom de valda segmenten.

Slutsats

Baserat på den insamlade informationen och den utförda analysen är slutsatsen att självkörande lastbilar är på väg ifrån en utopi till verklighet. Teknologiskiftet som kommer med självkörande fordon har bedömts att befinna sig i en *Era of Ferment* där företag konkurrerar om att utveckla *the Dominant Design.* Ett substantiellt marknadsvärde har identifierats för The Case Company inom både hamnsegmentet och segmentet för producerande företag, samtidigt som marknadsvärdet för logistikcenter bedöms vara begränsat till större flygplatser. Fortsättningsvis är *Automation readiness*-nivån hög inom alla segment som undersökts, även om nivån varierar från fall till fall. De faktorer som har identifierats som gemensamma *Customer drivers* inom segmenten är kostnadsreducering, effektivitet och hållbarhet.

Nyckelord

Självkörande fordon, Automation Readiness, Marknadsvärdering, Teknologiskifte, Innovationsteori, Teknologistrategi, Global Transport, First Mile Delivery.

Abstract

Title
Market Potential for Autonomous Trucks - An Extensive Study in the middle of a Technology Shift

Authors
Jonatan Arnlund
Joakim Wahl

Academic Supervisor
Ingela Elofsson
Lecturer, Production Management
Lund University

Supervisor The Case Company
The supervisor will, due to competitive reasons, be referred to as the *"Supervisor"*
Head of Sales, Department X
The case company will, due to competitive reasons, be referred to as "*The Case Company"*

Background
The global transport industry stands in front of the next big technology shift; the implementation of autonomous vehicles. This shift might remove the physical driver from the truck, increase safety and improve flexibility. This will most likely change the fundamentals of the transportation industry. Autonomous trucks are anticipated to be implemented for short distance transportation in gated areas with private roads and then gradually be implemented for longer distance transportation on public roads once the legislation allows it.

Purpose
The purpose of this study is to identify, describe and analyse technology shifts and needs within the industry of transportation. Furthermore, to assess the market potential and to explore how a first mover can exploit autonomous solutions.

Methodology
This Master's Thesis has had a hybrid between a descriptive and an exploratory approach. The Case Company served as the main case company studied, together with several other companies serving as case studies for specific implementations of The Case Company's solutions.

Delimitations
The study was limited to first mile delivery within ports and logistics centers (including internal logistics at manufacturing companies) in a B2B-context. No consideration has been taken to legal aspects and political regulations, hence, the assumption is that legal and political regulations present will not constitute any obstacles for the implementation of the solution.

Conclusion

Based on the analysis and information gathered during the research, it can be concluded that autonomous trucks are slowly going from being a future utopia to reality in everyday operations. The technological shift is identified to be in an era of ferment where companies fight to develop the dominant design. There is a substantial market value identified for The Case Company within first mile delivery in ports and manufacturing companies, while the market value found in logistic centers is considered limited to bigger air freight hubs. Moreover, automation readiness is considered to be high in all segments, even though it varies from case to case. Customer drivers identified across the different segments are cost reduction and efficiency as well as sustainability.

Keywords

Autonomous Vehicles, Automation Readiness, Market Valuation, Technology Shift, Innovation Theory, Technology Strategy, Global Transportation, First Mile Delivery.

Acknowledgements

This Master's Thesis was written during late autumn of 2020 as well as during the spring semester of 2021. The authors Jonatan Arnlund and Joakim Wahl have been studying Industrial Engineering and Management at The Faculty of Engineering at Lund University. The thesis serves as the last deliverable of a five years education worth 300 ECTS and the study itself accounts for 30 ECTS among the total amount.

We would like to thank Ms Ingela Elofsson, Production Economy, Lund University for being an extraordinary supervisor during the work process. Her constructive and educative methods of giving feedback, her academic expertise and her dedication to help us succeed with this thesis has been very valuable. Many thanks!

We would also like to present our gratitude towards all the people from The Case Company and The Case Company Group that have helped us obtain knowledge within the complex world of transportation. We would like to thank the Supervisor for serving as a good supervisor at The Case Company.

Finally, we would like to thank all the business professionals and academic researchers that have participated during our data collection phase. This study could not have been completed without your participation.

Joakim Wahl

Lund, 13th May. 2021

Jonatan Arnlund

Lund, 13th May. 2021

List of Abbreviations

Abbreviation	Word/Phrase	Description
AGV	Automatic guided vehicle	A portable robot that follows along marked lines on the floor, or uses other technologies for navigation
AI	Artificial Intelligence	The ability of a computer or robot to mimic human intelligence
ATS	Autonomous transport solution	Transport solutions without human driver
AV	Autonomous vehicle	A vehicle that is capable of sensing its environment and moving with little or no human input
B2B	Business-to-Business	When a business makes a commercial transaction with another business
B2C	Business-to-Consumer	When a business makes commercial transactions with the consumer market
CFS	Container freight station	A warehouse that specializes in the consolidation and deconsolidation of cargo
FEU	Forty-foot Equivalent Unit	A shipping container that is twice the size of a TEU.
GDP	Gross domestic product	The market value of all final goods and services produced in a specific time period
GNI	Gross national income	GDP plus money flowing from foreign countries, minus money flowing to foreign countries
GNSS	Global navigation satellite system	Collective name for satellite based navigation and positioning systems
IATA	International Air Transportation Association	A trade association of the world’s airlines
ICT	Information and communication technologies	A broad term referring to all types of communication technologies including e.g. internet and computers.
KPI	Key performance indicator	A type of performance indicator
LTL	Less than Truckload	A truck that is not loaded to its maximum capacity.
OBC	Overhead bridge cranes	Crane found in industrial environments
OECD	The organisation for economic cooperation and development	An intergovernmental economic organisation founded to stimulate economic progress and world trade
R&D	Research and Development	A unit within the company that is responsible for research and development activities.
RMG	Rubber mounted gantry cranes	Vehicle used for port transportation operations
RTG	Rubber tired gantry cranes	Vehicle used for port transportation operations
SAM	Serviceable available market	The segment of TAM that is targetable by the product or the service

TaaS	Transport as a service	New concept where transport is sold as a service instead of eg. trucks sold as vehicles for transportation
TAM (1)	Technology Acceptance Model	Theoretical model that describes how new technology is being adopted by users
TAM (2)	Total available market	The total market demand for a service or a product
TRL	Technology readiness level	A method for measuring the maturity of technologies
ULD	Unit load device	A pallet or container used to load freight on aircrafts

List of Figures

List of Tables

List of Diagrams

Table of Contents

1. Introduction

1.1 Background

Technology shifts have a major impact on companies and their business models. Not only can it provide opportunities for new value-creating processes, but it may also be a lethal threat to existing business models. Many companies have throughout the history been forced to face the ruthless truth of Schumpeter's theory of *creative destruction* as a result when mature companies have a difficult time to adapt to a technology shift (Tongur & Engwall, 2014).

The modern technology shift takes its start in the 18th century with the *Industrial Revolution.* During this period, a transformation towards machinery and manufacturing industry from the previous handicraft and agrarian dominated economy took place in Britain, which eventually spread throughout Europe to the rest of the world (Britannica, 2020). Two major sources that strongly influenced the development were 'Taylorism' and 'Fordism'. The former refers to Fredric Taylor and his thoughts on how to measure drivers of success in production facilities through bureaucratization and structure of control (Litter, 1978). 'Fordism' on the other hand originates from Henry Ford and his adaptation of 'Taylorism', which eventually resulted in the development of the modern way of mass production (Jessop, 2020).

Technology shifts are driven by innovation and innovation has become increasingly important for companies to survive in the constantly changing business climate. Maintaining an extensive knowledge of the moves of the competitors and possible new entrants is a necessity. Innovations can come in different shapes and from different departments of already existing companies. One example of the shapes of innovation is incremental innovation, which refers to a series of small improvements to a company's already existing services or products. The incremental changes made by Apple for every new release of the next generation of Iphones is an example of this type of innovation. On the opposite side of the innovation spectrum, radical innovation is to be found. Unlike incremental innovation, radical innovation is about introducing a brand new product or service with a purpose to replace an already existing one. Radical innovations dramatically change the consumer landscape and leave the status quo far behind, just like cars eventually replaced horse-drawn carriages (Carleton, 2019).

Disruptive innovation is another type of innovation that can be placed somewhere between incremental and radical innovation on the innovation spectrum. A disruptive innovation is a process by which a product or a service powered by a technology enabler initially starts in more simple applications at the low end of the market, often by being less expensive and more accessible, and then relentlessly moves upmarket, displacing already existing competitors. These innovations often appear as modest in the beginning but over time they have the potential to transform an industry (Christensen, 1997). A great example is the hotel industry that had not been disrupted for decades before it was completely caught off guard by Airbnb (Dillon, 2020).

Autonomous technology is today transforming a large share of the world's industries. It is defined as a technology concerned with performing a process by means of programmes commands combined with automatic feedback control, resulting in a system that is operating without human intervention (Groover, 2020). It creates an opportunity to realize passive but intelligent control and it is speeding up innovation in a remarkable way (Kimmel, 2017). In parallel to the development of autonomous technology, several industrial sectors have enjoyed the productivity and economic gains that automation technology can offer. One example is the manufacturing industry, where automation has transformed factory floors, the nature of manufacturing and the economics of many manufacturing industries, while there still is potential to increase the level of automation even more (Chui, 2017). However, looking beyond the economic gains from automation and instead examining it from a social perspective, there are different opinions whether automation is killing jobs or creating new ones. There is a consensus that automation eliminates repetitive, simple jobs but creates jobs in a more complex nature. However, skeptics mean that this is a problem, since more complex tasks often require staff with higher educational levels, making it hard for already educated adults to adapt and re-qualify to the new educational requirements. Furthermore, the wages of jobs that could be automated have been reduced while high skill jobs like engineering and design, as a by-product for automation, have experienced an increase in salary. Therefore, although wealth generation is guaranteed in the future, the uneven distribution of the wealth in society is a problem. (Nouzil et al, 2017). According to a study conducted by McKinsey, in low-skilled labour, approximately 70-80% of the labour hours are automatable. For medium skilled labour, that number is decreased to 50-70% and for high-skilled labour, the percentage is 40-50% (Chui, 2017).

From a political perspective, there are debates regarding where the responsibility of the action taken by the autonomous technology lies as well as discussions if it really can perform better, or in higher quality, compared to humans. Another dilemma is the fact that an autonomous technology is not able to make moral decisions, which is a factor emphasized by many ethicists. Within this area, the problem of trust is also present since a lot of people do not trust robots and other autonomous solutions to the same extent they would if a human would have been involved (Nouzil et al 2017). A typical example in this area involves a car on a freeway that suddenly has to swerve left or right into other vehicles to avoid hitting a person on the road. Swerving into the small car to the right side could endanger the one in the passenger seat and the people in the small car. Swerving into the big car on the left could protect the passenger but risk the driver’s life. Once you encode the decision that should be made, you automatically discriminate against a particular class of vehicles through no fault of their own, other than the fact that the owner maybe not could afford a larger car or had a large family and had to buy a large car. It is important to remember that programmed decisions are premeditated decisions that law and ethics may treat differently (Olson, 2017).

Since autonomous technologies are one of the most promising technologies of the future, it is imperative that one take necessary measures to limit its effect on the environment, from an ecological point of view. The associated electricity consumption should therefore be considered. For instance, Artificial Intelligence, which often is a part of autonomous technology, can produce great achievements as computers learn to perform new tasks. However, all those advances require huge amounts of computing power, and thereby electricity, to device and train algorithms. As the damage caused by climate change becomes more apparent, AI experts are increasingly worried about the energy demands (Knight, 2020). From a cultural point of view, autonomous hardware and software will take time to replace human cognitive skills and creativity. The current form of automation can extend the limits of creativity, but only in collaboration with humans (Nouzil et al 2017).

Autonomous technology is currently spreading towards the transportation industry and new autonomous solutions are currently being developed all over the world (Uzialko 2019). In March 2018, 52 different companies had permits to test autonomous vehicles on the roads of California alone. Self-driving vehicles represent a fast-paced field of technology as companies are competing for dominance in the field of emerging transport capacity. However, rather few members of the traveling public have experienced rides in autonomous vehicles (Hancock et. al 2018). Participants in the race towards completely autonomous solutions come in various sizes (from startups to big mature companies) and from various applications (from human transportation to the transportation of freight). All of these companies have one thing in common; find ways to exploit the technology behind autonomous solutions in a legal and profitable way (Boutan, 2020).

1.2 Purpose

The purpose of this study is to identify, describe and analyse technology shifts and needs within the industry of transportation. Furthermore, to assess the market potential and to explore how a first mover can exploit autonomous solutions.

1.3 Delimitations

This study will be limited to first mile deliveries, defined as the transportation of goods from a factory, port or airport to a distribution center or warehouse. Also, the study will focus on a business-to-business context. In addition, no consideration will be given to legal aspects and the political regulations that may be present today. To clarify, it will be assumed that the legal and political regulations present will not constitute any obstacles for the implementation of the solution.

2. Methodology

2.1 Research Purpose

The methodology is the fundamental approach that is chosen to execute the Master Thesis. There are several different methodologies to choose between and they are all suitable for different purposes. There are four main purposes of a Master Thesis; (1) descriptive studies, (2) exploratory studies, (3) explanatory studies and (4) problem solving studies. A descriptive study aims to figure out and describe how the research subject functions or is executed. An exploratory study aims to develop a deep understanding of how the research subject functions or is executed. An explanatory study aims to find causation or explanations to how the research subject functions or is executed. Lastly, a problem solving study aims to find a solution to a problem that has been identified (Höst et. al, 2006, p. 29).

A thesis does not need to have only one of the above mentioned purposes; instead it can consist of several part studies with different purposes. As an example, a problem can be identified in a descriptive or exploratory study, followed by a problem solving study where solutions to the identified problem are produced. With the previously stated purpose: *identify, describe and analyse technology shifts and needs within the industry of transportation. Furthermore, to assess the market potential and to explore how a first mover can exploit autonomous solutions,* a hybrid between a descriptive approach and an exploratory approach was used. The trends and current technology shifts within the transportation industry was not known prior to the literature review process and was therefore described in the study. This was followed by a deep dive in market sizing, customer drivers and possibilities for autonomous technology through the analytics of the empirics to ensure that a deep understanding of the research subject was generated, motivating the choice of an exploratory study.

2.2 Research Strategy

The research strategy describes the research approach and the research process of this study. Different kinds of logical reasoning methods are defined and described as well as a quantitative versus a qualitative approach. Finally, the research processes' two parts, namely literature review and case study, are explained.

2.2.1 Research Approach

2.2.1.1 Logical Reasoning

A good starting point for the research strategy is to determine what approach the study will have towards theory. Broadly speaking, there are three kinds of ways for approaching theory and logical reasoning, namely inductive-, deductive- or abductive approach. An *inductive* approach uses an element of probability to develop results based on what is previously known or observed. If the aim of the study is to test a hypothesis or theory based on gathered data, the *deductive* approach is preferable. A deductive approach either confirms or falsifies the hypothesis by observing results. Lastly, an *abductive* reasoning starts from consequences and builds results based on logical reasoning, which furthermore can be described as a phenomena of cause and effect for the target research question, in relation to similar situations (Timmermans & Tavory, 2012, pp.167, 170-171).

Table 2.1. Logical reasoning (Timmermans & Tavory, 2012, pp.167, 170-171)

Type of reasoning	*Example*
Inductive	Consider that all observations confirm that X > Y and Y > Z. Inductively, X > Z and the probability of this increases as the number of observed cases increases.
Deductive	Consider X > Y and Y > Z. Deductive reasoning leads to X > Z.
Abductive	A surprising fact X is observed. If Z is true, X would be a matter of course. Therefore, Z might also be true due to abductive reasoning.

With a purpose to *...assess the market potential and to explore how a first mover can exploit autonomous solutions...* an abductive approach is suitable. Based on a case study, extensive data gathering and various interviews, logical reasoning was used to build up an explanation of the consequences observable from the current technology shift in the transport industry. During the study, an iterative approach was used to react to the data gathered, with a purpose to obtain a deep understanding of factors influencing the objective of the study. All along, *cause and effect* thinking drove the research process towards finding the underlying reasons and customer drivers for the innovative technology.

2.2.1.2 Quantitative or qualitative approach

When pursuing research there are numerous ways of analysing data and these are generally categorized into either quantitative or qualitative research. A research strategy can depend on one of these separately, or be a combination of the two of them (Denscombe, 2010, p. 244). The former of the two is characterized by data that can be counted and classified and it can be scrutinized through statistical analysis. Qualitative data consists of words and descriptions enriched by nuances and details and different analysis methods built upon sorting and categorisations. (Höst et. al, 2006, p. 30).

The choice between a quantitative or a qualitative approach affects the researcher's level of involvement in the extraction of data. Ideally, for quantitative research, the data can be considered fully objective hence it is extracted from research instruments that are reliable and valid. Therefore, this approach can be associated with researched detachment. On the contrary, qualitative research is based on researcher involvement and no standardized tools can be used for data gathering. Instead, the researcher himself can be seen as the "measurement machine" and his/hers background, beliefs, values, etc might influence the collected data (Denscombe, 2010, p. 245).

A quantitative approach often involves a larger-scale research, especially since the help of computers can be used to process vast amounts of data. Greater datasets leads to better reliability in the results, statistically, which speaks for larger-scale research. A qualitative approach by contrast is often linked to small-scale studies since the data gathering process is more time consuming. Without the help from computers, data can not easily be extracted. Instead, the research depends on in-depth studies of a topic and this is only possible for a limited number of cases (Denscombe, 2010, p. 245).

In this study, a combination of a quantitative and qualitative approach was used. Hard data, such as transport statistics, trade patterns, financial metrics, etc. was collected and analyzed using a quantitative approach. When no hard data has been possible to find, assumptions have been made. In this case, it is clearly stated in the text that the number is an assumption, and it is based on the extensive knowledge that has been built up through the literature review and the interviews.

Questions regarding the understanding of the customers and their wants and needs were obtained from qualitative interviews and secondary data sources.

2.2.1.3 Fix or flexible approach

A research approach can be either fixed or flexible where the former stipulates predetermined rules in the beginning of the project (e.g. survey or questionnaire). The flexible approach is more agile and allows for changes along the way (e.g a case study) (Höst et. al, 2006, p. 31) .

For this master thesis, a flexible approach was chosen with the motivation to be able to adapt to input along the way to better answer the broad purpose of the study.

2.2.2 Research Process

2.2.2.1 Literature review

According to Saunders et. al (2009) the literature review is an important process for any research process. There are two main reasons for proceeding with a literature process. Firstly, it helps to refine the initial research idea and find new angles on the research topic. Secondly, it assures that the research is built upon theories and literature that have been critically reviewed (Saunders et. al, 2009, p. 58). A research project is seldomly built from scratch, instead it builds upon already existing theories and research. Instead of reinventing the wheel, new research should build upon what has previously been found and discovered to generate new insights and new theories (Saunders et. al 2009, p. 59). There is a wide variety of sources available and these are commonly divided into primary, secondary and tertiary sources (Saunders et. al 2009, p. 68-69). A summary of examples are presented in the *Table 2.2* below.

Table 2.2. Literature sources available (Saunders et. al, 2009, p. 69)

Primary	**Secondary**	**Tertiary**
Reports	Journals	Indexes
Theses	Books	Abstracts
Emails	Newspapers	Catalogues
Conference proceedings	Some government publications	Encyclopaedias
Company reports		Dictionaries
Unpublished manuscript sources		Bibliographies
Some government publications		Citation indexes

The literature review process can best be described as an iterative process where the researcher goes through several loops to finally deliver a written critical review of the literature the research relies on. The process is initiated when the questions and objections are outlined and the researcher has defined the main parameters for the research. This is followed by a phase where keywords are refined and generated. Subsequently, a conduct search is made where literature is obtained and evaluated. The findings are then recorded and the researcher once again goes back to the drawing board to evaluate and refine the chosen keywords and to redefine the research parameters. This process continues until the critical review of the literature is done (Saunders et. al, 2009, p. 60).

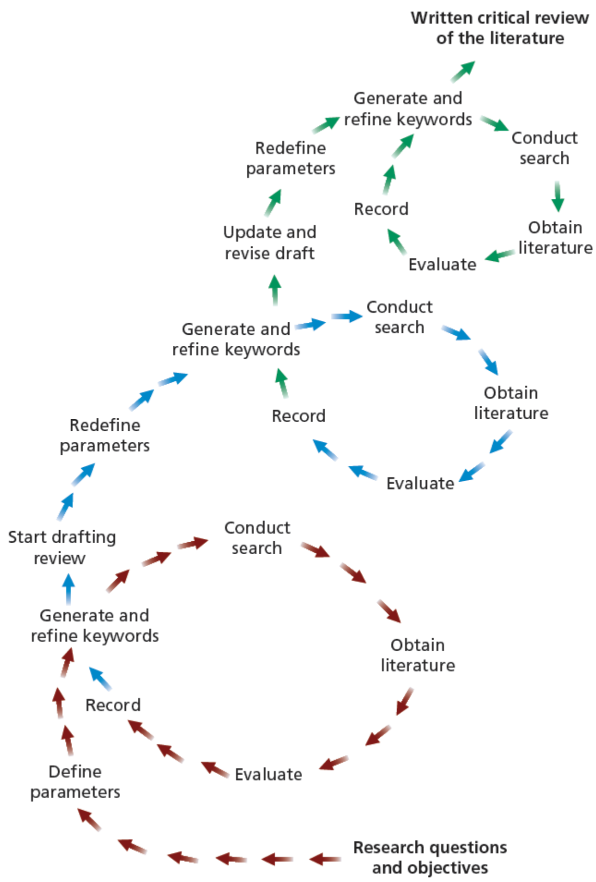


Figure 2.1. The Literature Review Process. Source (Saunders et. al, 2009, p. 60)

2.2.2.2 Case study

To expand the picture given by the literature review and to give more in depth knowledge, a case study may be done. A case study is exploratory by its nature and the study is often done within an organization to understand how this functions and works. Although the results may not present a general finding, a case study can give the researcher answers to specific questions regarding the participating organization. In some cases, it may also give the researcher a hint of general patterns that can be explored further (Höst et. al, 2006).

A case study is flexible and the study itself can consist of interviews, observations or archive analysis of material given by the participating organization. Interviews can be *structured*, *partly structured* or *open* and the choice between these three options affects how the data is being collected. Interviews should be recorded and transcribed for later analysis. (Höst et. al, 2006). Observations are being done by closely following and noting courses of events at the study objective and this can be done by a participating observer (someone that has a role in the process that is being observed) or by an naturalistic observer (someone that does not participate in the process that is being observed) (Höst et. al. 2006).

Finally, a case study can consist of archive analysis, where documentation produced by the research unit is being analysed. Examples of research material can be reports from previous projects, commercial material or other internal documents. The data can be both qualitative and quantitative and it is of great importance for the researcher to investigate the cause to why the documentation has been developed originally (Höst et. al. 2006).

To reach the goal and fulfill the purpose of the study, an exploratory approach was needed. To achieve this, a case study was used to gain in-depth knowledge, and the case company was, due to competitive reasons, referred to as "*The Case Company".* The Case Company was chosen for being in the forefront of the development of autonomous transportation solutions. The Case Company is the newest business area in The Case Company Group. The Case Company was recently founded and the company develops and commercializes industrial autonomous transport solutions. Within the company, automation experts from all The Case Company Group areas are coming together to develop the concept of Transport as a Service (Taas), including total integrated transport solutions that aims to improve customer productivity (The Case Company (1), 2020).

2.3 Data Gathering

As mentioned above data can be either quantitative or qualitative and there are numerous ways for collecting data including e.g. interviews, surveys, observations and literature reviews (Höst et. al, 2006). To ensure that transparency and credibility are maintained, a journal was established. This journal was updated continuously throughout the data gathering process to help the analysis phase and to keep track of the decisions and suppositions that were made.

The data gathered to this Master Thesis was obtained from two major processes: a literature review process and a case study done at The Case Company.

2.3.1 Literature review

As explained above, the literature review process was of an iterative nature even for this study. Originally, a framework of four main categories of theory was decided upon serving as main pillars to hold the empirics and analytics in. Keywords were defined and a thorough literature search was made. After a phase of evaluation, one of the four pillars was extracted and the remaining three were reformulated and new keywords were determined. Once again, a new phase of literature collection was done and the theory was evaluated. This iterative process was done and redone until the theory was solid and eligible. The origin of sources was a mix of primary, secondary and tertiary sources.

2.3.2 Statistical data

Statistical data was gathered to better understand transportation from a global perspective. The data was obtained from secondary sources partly provided by The Case Company and partly found through the literature review process. All secondary data was closely examined before used in the study to ensure that the standards for *research credibility* was met.

2.3.3 Interviews

Several interviews were held with a purpose to gather primary and qualitative data to better understand a variety of topics. The interview objects were selected collaboratively with The Case Company and the objects had backgrounds from vehicle manufacturing, academia and the transport industry. Due to competitive reasons, all interviewees and their positions were held anonymous. In addition, several interviews were held with people in the port industry, the logistics industry and manufacturing industry. Here, mostly Operative Managers with strategic horizons were targeted in companies operating in the mentioned industries.

At the end of each interview, the interviewee was also asked to recommend other people in the company or a competitor to interview, to increase the spread and create a nuanced view. The majority of the interviews had a *partly structured* format and a full list of interview objects can be found in *Sources*. Also, the general questions asked can be found in the *Appendix 3*.

2.4 Data Analysis

Once all data is gathered, analysis is needed to understand what it means. Analysis often requires different methods that can be divided into two different main categories; quantitative analysis and qualitative analysis (Höst et. al, 2006). Due to the competitive environment, sensitive variables such as interviewees, market data and company specific information have been anonymized.

2.4.1 Quantitative Analysis

Quantitative analysis means analyzing qualitative data, in other words, data that can be represented in terms of numbers. Within this area it is common to use methods from the world of statistics. There are two main reasons to use statistical methods. The first one is to explore data to create an understanding and the second one is to show relationships and evidence for hypotheses once created (Höst et. al, 2006).

2.4.2 Qualitative Analysis

Analysis of qualitative data is different from the analysis of quantitative analysis, since the data consists of words instead of numbers and values. The data that is analyzed is text documents, either transcribed interviews or archive material, which are documents that from the beginning were created for another purpose. The different methods of qualitative analysis can be grouped into 4 different areas described below.

- *Quasi-static methods:* the methods build upon counting the occurrence of a specific word or groups of words in different texts. By doing that, one can decide how important terms and concepts are for different persons.
- *Template based methods:* this method uses a list of keywords and looks for the occurrence of those words in the qualitative data. The list of keywords is put together from theory and terminology from the subject area. Here, the number of times a word has been used is not important, instead it is the person saying it that is in focus.
- *Editing methods:* Just as the template based methods, this method aims towards creating categories of subjects. The difference is that the editing methods do not have a list of keywords from the start, instead they are searching for keywords in the data material. The interpretation of the person making the analysis is the foundation of the categories.
- *In-depth methods:* This is a strategy where the person conducting the analysis deepens his/hers knowledge in the material and by creativity and intuition.

In the qualitative analysis, the term traceability is important and central. Conclusions drawn from data material must be able to be tracked back to the statements that were the foundation to the conclusion from the beginning. This means that documentation is crucial since it should be possible to follow the reasoning behind a conclusion in the material afterwards (Höst et. al. 2006).

2.5 Research Ethics

According to Denscombe (2010), researchers are expected to approach research with ethical manners and that no findings are *that* important that it justifies pursuing the researchers' own interests over those that are being studied. To ensure that the moral and ethical parts are attained, Denscome presents four major principles that researchers are expected to proceed with their investigations in a way that:

1) protect the interests of the participants;
2) ensure that participation is voluntary and based on informed consent;
3) avoid deception and operates with scientific integrity, and;
4) comply with the laws of the land.

While investigating these four principles further and adapting them to this Master Thesis, two major risks were identified. The first was to ensure that the interests of the participating company were kept protected. To diminish this risk, a close dialogue was held with the client throughout the work and consent was given from them regarding the content of the final publication. The second risk was to balance the client's objectives with the research with scientific integrity to ensure that the findings of the study were unbiased (Denscombe, 2010, p. 331). To mitigate this risk, the validity of data provided by the client was continuously assessed and the stated purpose of the study was always the leading star for the research.

2.6 Research Credibility

As of any research, credibility is of great importance for the relevance of the study. Credibility needs to be demonstrated, hence it can not be taken for granted. There are four main objectives for judging the credibility of research: validity, reliability, generalizability and objectivity (Denscombe, 2010, p 297-298).

Validity is referred to as the precision and accuracy of the data that has been collected. Depending on whether the data is qualitative or quantitative, this issue takes different turns. Regarding qualitative data, this can never be seen as ´completely correct´, although there are tools to state that findings are *reasonably likely* to be accurate. Examples for increasing validity are triangulation (use contrasting data source), respondent validation and grounded data (Denscombe, 2010, p. 299).

Reliability deals with the question: "if the research is done again with the same instrument, will the results be the same on different occasions?" To increase reliability for the research, the readers should be given detailed information regarding methods, analysis and decision-making in the research for others to replicate the study (Denscombe, 2010, p.299-300).

Generalizability, or external validity, describes to what extent the findings of the research may be applicable for other similar situations. This is based on the statistical probability that the same data is shown elsewhere, which often relies on the size of the sample and the representativity of the population in the study. The generalizability can be increased by providing enough information about the cases studied for others to compare with similar cases (Denscombe, 2010, p.300-301).

Objectivity refers to what extent there are biases in the research. Fundamentally, objectivity refers to whether the researcher can produce findings that are free from external influence, even though one can not ever be completely free from influence. The level of objectivity can be increased through openness and willingness to consider competing and alternative explanations (Denscombe, 2010, p.301-302).

To increase the overall credibility of the research, actions were taken to fulfill the four objectives above and the research method was thoroughly explained. Data was gathered through various contrasting data sources from globally accepted institutions and universities. When old sources were used, their relevance in today's environment was discussed before the source was used. To ensure reliability and validity in the material gathered from the interviews, high focus was put to audio recording and transcription. Any unclear details were checked with the interviewee to clarify uncertainties.

As mentioned above, the study contains estimations to fill gaps where no hard data or reliable secondary data sources were found. When estimations have been done, interviews have been used as a proxy to decide upon reasonable assumptions. These estimations are clearly pointed out in the text to ensure reliability and objectivity.

3. Theory

The purpose of this study is to identify, describe and analyse technology shifts and needs within the industry of transportation. Furthermore, to assess the market potential and to explore how a first mover can exploit autonomous solutions. Based on this purpose, the theoretical perspective will consist of three main building blocks; Technology Shifts, Understanding Market Structure and Global Transportation. Starting with theories relating to Technology Shifts including technology cycles, innovation theory and technology strategy states a solid ground to evaluate new technologies. This is followed by theories regarding the Understanding of Market Structure and factors that drive purchase decisions serves as a piece of the puzzle and gives possibilities to effectively seize the market potential. Finally, this is followed by a brief introduction to Global Transportation and its complexity to give an understanding of the environment in which this study will take place.

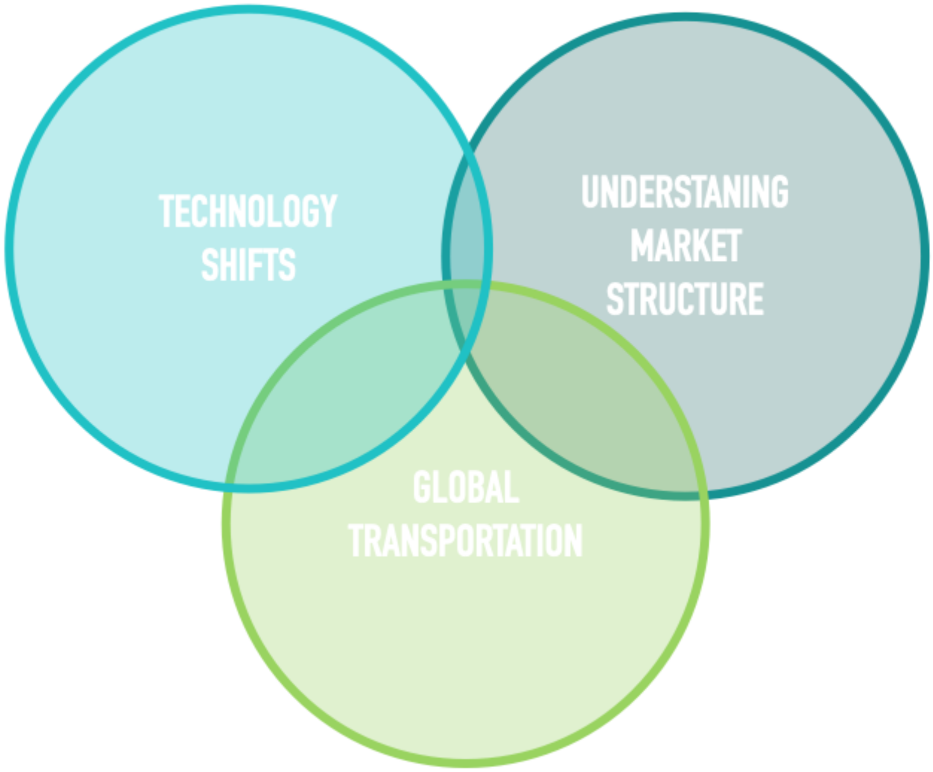


Figure 3.1: The Theoretical Framework

3.1 Technology Shifts

3.1.1 Technology Cycles

Technology shifts present both opportunities and lethal threats to manufacturing companies (Tongur & Engwall, 2014). Introduced by Foster 1986, the S-curves can be used to describe technology shifts. During early stages when new technology is being developed, the rate of progress in terms of product performance compared to the expenditure in R&D is relatively low. Once the technology gains traction and becomes widely understood, the rate of progress increases and new improvements emerge. After a phase of continuous increase in product performance the development pace slowly decreases due to the approach of a natural and physical limitation. Even though more time and money are invested into the technology, only small and incremental findings occur (Christensen, 1992a). When this stage is reached, companies fight to develop the next technology.

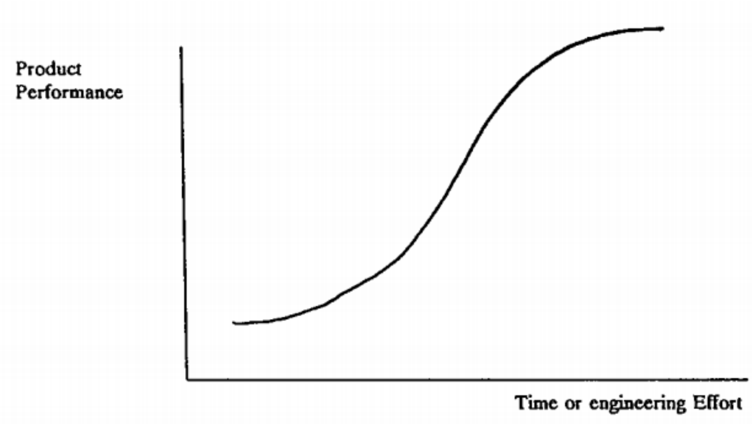


Figure 3.2. The Technology S-Curve (Christensen, 1992a)

Christensen found in his series of papers 1992 where the disk drive industry was examined that the S-curve has different usefulness whether it is adopted on a component or on an architectural level. Once a component technology has reached its full potential there are many ways to evolve (e.g. finding alternative solutions). He also found very few (if any) first mover advantages of aggressively pushing towards adaptation of new component technology. On the contrary, many positive factors were found being a first mover in architectural technologies, where the leading firm could enjoy advantages from driving the architectural change, leading the company towards a position as industry leaders (Christensen, 1992b).

In their work from 1990, Anderson and Tushman further investigate the stages in a technological cycle. It is concluded that the establishment of a new technology on the market starts when a *technological discontinuity* is being introduced. This is some sort of product or process innovation that shakes the foundations and question the existence of the output firm (Anderson & Tushman 1990, p 606-607). An example of this is the invention of the jet engine in the aircraft industry, threatening the previous standard of the rotary engine. Once a new technological discontinuity has been introduced the technological cycle faces an *Era of Ferment*. This period can best be described as a period of fierce design competition where companies fight to develop a new industry standard, or a *Dominant Design*. During this period it is also common with customers substituting the old technology to leave room for the new one. When a broad majority have adopted a certain design of the new technology, the market reaches a phase when a dominant design is decided (Anderson &

Tushman 1990, 606-616). An example of emergence of a dominant design is the fact that a bicycle has two wheels that are (roughly) the same size, air tubed tires and a rear chain. The dominant design is not always the best one from a technical perspective (e.g. JVC's VHS was not the superior alternative for video cassette reproduction on the market). Instead, the emergence of a dominant design is a social and political process (Anderson & Tushman 1990, p 616). Finally, the technological cycle moves into an *Era of Incremental Change*, where the dominant design is being constantly improved by various companies and the focus has shifted from challenging the industry standard to refine the technology in terms of increasing performance, lower costs of production and differentiate by finding new applications. This phase continues until a new technological discontinuity is being invented and presented (Anderson & Tushman 1990, p 617-618).

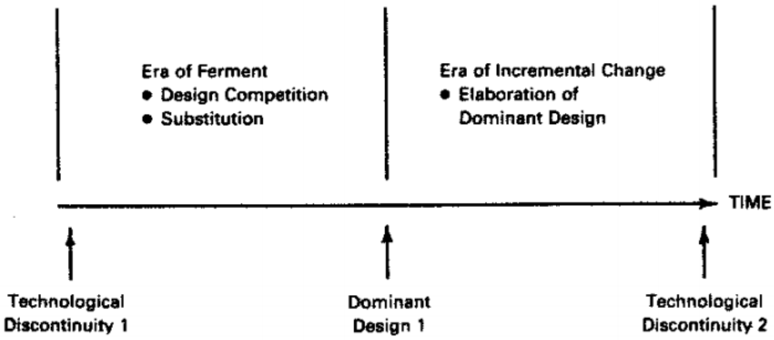


Figure 3.3. The Technology Cycle (Anderson & Tushman 1990)

In a study from 1989, Davis introduces *Technology Acceptance Model* (TAM) as a tool to help study how new IT systems are being adopted in organisations. Relying on theoretical foundations such as *self-efficacy theory, cost-benefit paradigm, adaptation of innovations, etc.* the study examines in detail which forces that drives the acceptance of new IT. Two determinants for a successful implementation are identified, i) Perceived Usefulness and ii) Perceived Ease of Use. The former is defined as "the degree to which a person believes that using a particular system would enhance his or her job performance" (Davis 1989, p 320). The latter is described as "the degree to which a person believes that using a particular system would be free of effort" (Davis 1989, p 320). Davis concludes that the most important factor for usage of a new application is usefulness, even though ease of use also plays a role. If the targeted users sees the potential of the application and the functions it can perform for them, they are driven to adopt the technology, even though the system might be complex to learn (Davis 1989).

3.1.2 Innovation Theory

Innovation is the process where old processes, products or technologies are being replaced by new inventions. Schumpeter discusses the topic of creative destruction in the context of capitalism and socialism as a natural phase when something old is being displaced by new (Schumpeter, 1928). One example of this, described by Darmawa et. al (2019), is the advent of the personal computer industry, driven by Intel and Microsoft, that wiped out old mainframe computer companies. Destructive Construction is unavoidable and a natural phenomena and small companies often adapt faster than large ones to sudden changes, unless the large firm has a good position and competence advantages in the start of the development (Darmawa et.al 2019).

Christensen (1997) builds upon the phenomena of creative destruction with his theory of *disruptive innovation*. Christensen defines disruptive innovation as a process rather than a single event, when a product or process is introduced in the low end of the market, often providing a more accessible and less expensive solution to the customer. Blinded by the needs and wants of today's most profitable customers, industry leaders often miss out on threats presented by new entrants. Once the innovation has established its roots in the low end of the market, it relentlessly moves upwards to finally displace existing competitors (Christensen, 1997).

3.1.3 Technology Strategy

According to Ford (1988), a good starting point to understand Technology Strategy is to affirm that the core of a company is what it knows and can do, not the product it sells or the markets that it serves. Ford states that Technology Strategy is about acquiring knowledge and abilities, managing the knowledge and the abilities as well as exploiting them for a profit. A company's products and production technology can be exploited in more ways than using them in their own products. For instance, they can be licensed-out, used in joint ventures or used to make products for others to their market. Likewise, the company can acquire technology in several different ways, through in-house development, through contracted-out R&D or by licensing from others just to mention a few examples.

Davenport et al, (2003) has a view of Technology Strategy that is more dynamic than the model that Ford developed. Through studies on the evolution of a number of New Zealand firms and Complex Theory, the authors found several positive feedback loops that have driven the technological progression of firms. In addition, Davenport et al, argues that within each of the three aspects that constitute Technology Strategy according to Ford, there are a myriad of other contributing components (Davenport, et al. 2003).

Ford has previously compared Technology Strategy with the task of a farmer. A good farmer wants to extract as much crops as possible from his land, but at the same time he takes great pride in leaving it in a better and more fertile condition compared to when he found it. Just like the farmer who takes what he can from the land in the short-term without a thought for the long-term, a short term product strategy can neglect the longer-term technological issues in a business. Developing a Technology Strategy forces the company to take a step back and analyse the product and production technologies on which the operations are based. Ford also argues that it is very important to ask if the technology base is being fully exploited. The reason is that vast areas of potential exploitation in other companies or applications are being wasted by the company's inability to plan for a combination of product and direct technology sale throughout the full life of the technology (Ford, 1998).

When looking at the contribution of Davenport et al, one major addition is the Firm's "absorptive capacity". A firm needs absorptive capacity to acquire, make use of and learn from technological knowledge and one can see it as the firm's prepared ground and thereby its ability to internalize the new knowledge. The capacity is built up through prior experience and related knowledge within the firm. To explain it in another way, the firm needs a certain level of existing technological knowledge in order to be able to recognize the potential of new technology and information to build upon their existing technology base. The absorptive capacity has to be actively built in order to maximize both the appropriate quantity and quality of technological knowledge acquisition. In addition, the importance of networks and alliances is emphasized. The firm is characterized not only by the configuration of its own technology, but in addition, by its relationships with and linkages to the systems of others. This argues that a meaningful technology strategy is inevitably also a network strategy (Davenport, et al. 2003).

Developing a sound Technology Strategy can be rather complicated and many companies experience it as difficult. One of the problems that are common to arise is known as the “Technology Illiteracy” of many chief executives and managers. An inability or unwillingness to think in terms of the technology basis of products and markets is often a major obstacle on the way towards success. Another problem is referred to as the “High-tech Syndrome” which is divided into smaller parts. Firstly, it is about managers' tendency to think that a Technology Strategy only is relevant for high-tech companies and that it therefore is unnecessary for companies with “regular technology” to get a coherent view of the technology base of the company. High-tech industries might have faster rates of changes, however, that does not mean that companies in industries with a slower rate of change should not assess their acquisition and exploitation of technology (Ford, 1998).

Another problem with developing technology strategy is that it requires special and enhanced communication patterns in the company. It requires a strong connection between those who are responsible for acquiring the technology, like R&D management, and those that are responsible for managing and exploiting this technology. If this connection is not set up, it is likely that money either is wasted on developing wrong technologies, or money being wasted on technology not being exploited (Ford, 1998).

Lastly, one problem is related to management structure and strategy regarding time-scales. The significant time required for a technological change is usually 5-10 years, while corporate or conventional plans usually have a time horizon of 3-5 years. Also, thinking in the long term does not always sit well with managers and their short term horizons due to pressure from factors like quarterly reports for instance (Ford, 1988).

3.2 Understanding Market Structure

3.2.1 Market Sizing

When trying to evaluate the market possibilities linked to a new technology, it is of great importance to understand market needs and how the technology may present a feasible solution to meet these. A firm has to be able to observe its technological competences and their fungibilities together with acquired market knowledge to seize the potential of a new technology. At an early stage there might be a range of opportunities while the initial technological competence around the technology is not widely spread (Gruber et. al 2008). Therefore, many different applications for the technology should be discussed to not miss market opportunities.

At its core, a market size is calculated as the number of opportunities times the selling price for those opportunities in a specific market. There are two different main types of markets, Total Available Market (TAM) and Serviceable Available Market (SAM). TAM is the market that includes all competitive products, while SAM is the specific part of the market that a company can serve as a specialist company or via specific channels. Furthermore, there are three main strategies to decide the market size and it is common to use more than one of them. The first method is called “Top-Down” which is when the calculator is using a bird’s view, using published reports and macro data as often as possible. The second method is called “Supply Side”, where the estimation is based on the size of all the competitors supplying the market. The last one is called “Demand-Side” or “Bottom-Up” and it uses end-user data in combination with the numbers of operators within a market (Marshall, 2020).

A product’s or a company’s penetration rate is a measure of how much a product or service is being used by customers compared to the total estimated market. In other words, the penetration rate is affecting the size of SAM in relation to TAM and there are several factors included in the penetration rate and turning potential customers into customers (Kenton, 2020). This becomes evident when looking at autonomous vehicles, that are predicted by many to be the future of mobility. The technology could potentially increase efficiency, mobility and safety (Beiker 2012). However, the adaptation of the technology is of great importance to actually achieve these perks. In a study with the objective to determine drivers for adopting an autonomous vehicle, Choi and Ji investigated the importance of trust. 552 drivers answered a survey and the answers were analyzed using a partial square method. The authors used the *technology acceptance model*, but extended it to include factors regarding trust for the technology. The results showed that perceived usefulness and trust are two major determinants for the speed of adoption. Furthermore, three constructs affecting trust were determined to have a significant effect, namely, system transparency, technical competence, and situation management. System transparency refers to whether the users can understand and predict the autonomous vehicles’ operations. User’s degree of performance perception describes the technical competence. Finally, a user’s feeling of recovering control over the system if needed is referred to situation management. Just like Davis found in his study from 1989, *perceived usefulness* was found far more important than *perceived ease of use* of the technology (Choi & Ji 2015).

3.2.2 Market Segmentation

Market segmentation is an effective tool for understanding the market structure. Not only does it help the marketing team to understand the needs and wants of their customers, but it also helps management to determine strategic decisions and to choose between different targeting customer groups (Freytag & Højbjerg Clarke 2001). The B2B market is characterized by deep relationships and cooperation which results in more in-depth knowledge for the customers' wants and needs (Freytag & Højbjerg Clarke 2001).

Business-to-business (B2B) markets are different from business-to-consumer (B2C) markets in several different ways. First and foremost, B2B markets have a more complex decision-making unit. In most households, even the most complex decisions are made by the family unit, while a rather simple decision in the B2B segment often includes technical experts, purchasing experts, board members and health and safety experts, just mentioning a few examples. This generally makes the B2B decisions more rational and based on what the company really needs. It is therefore crucial to identify drivers of customer needs, which often is boiled down to relatively simple identifiers such as company size, volume purchase or likewise. These identifiers often enable needs and to segment based on that is therefore often accurately predicted. Adding to this, B2B products are often more complex than B2C products. Also, since even the simplest B2B products often need to be integrated into a larger system, qualified experts need to be involved. This can be compared to more complex B2C purchases like cars, which at the end of the day tend to be chosen on fairly simple criteria (Hauge & Harrison 2020).

This raises the question if segmentation really is possible in such markets, since all customers often have complex and rather different needs. One might argue that every customer therefore needs its own segment. In most B2B markets, a few key customers are so important that they rise above the segmentation and create their own segments in their own right. Beneath these key customers, however, lies an array of companies that have similar and modest enough requirements to be divided into different segments (Hauge & Harrison 2020).

Also, long-term purchases – or at least purchases that are expected to be repeated over a long period of time, are more common in B2B markets. Businesses' repeated purchases will also require ongoing expertise and services in terms of delivery, implementation, installation and maintenance. From one perspective, this makes it easier for B2B segmentation, since segments tend to be less subject to rapid change. The risk of this is that B2B companies can become complacent and pay inadequate attention to the changing needs and characteristics of their customers over time. This is something that can have grave consequences over time (Hauge & Harrison 2020).

B2B has fewer behavioral and needs-based segments, which is in itself a key distinguishing factor of business-to-business markets. Part of the reason for this is the smaller target audience for B2B compared to B2C. In a consumer market with tens of thousand potential customers, it is practical and economical to divide into 10-12 segments, compared to the average B2B company that has 3 to 4 segments. Another reason for this is that a business audience's behavior or needs vary less compared to a consumer audience. The numerous experts and colleagues involved in a B2B buying decision and the company norms established over time, filter out many of the extremes of behavior that would come to surface if the decision was made by one person, responsible for no others (Hauge & Harrison 2020).

A common approach in business-to-business market segmentation is by company size. This is due to the fact that the consumption levels of B2B customers are so different that this often makes sense. Large companies are often thinking and acting differently to small companies. Another approach can be to classify into those who are identified as strategic to the future, those who are important and therefore key, and those who are smaller and therefore considered more of a transactional typology. These segmentations can be referred to as firmographics in B2B markets (Hauge & Harrison 2020).

3.2.2.1 The Nested Approach

One model for segmenting industrial markets is the “Nested Approach” that was presented by Bonoma & Shapiro in an article from 1984. This approach suggests a model with different layers ranging from general factors to specific ones. Factors that are presented are: Demographics, Operating Variables, Purchasing approach, Situational Factors and Personal Characteristics (Bonoma & Shapiro 1984). It should also be added that not all factors are relevant in all cases; some may even be desirable to skip in certain situations (Bonoma & Shapiro 1984).

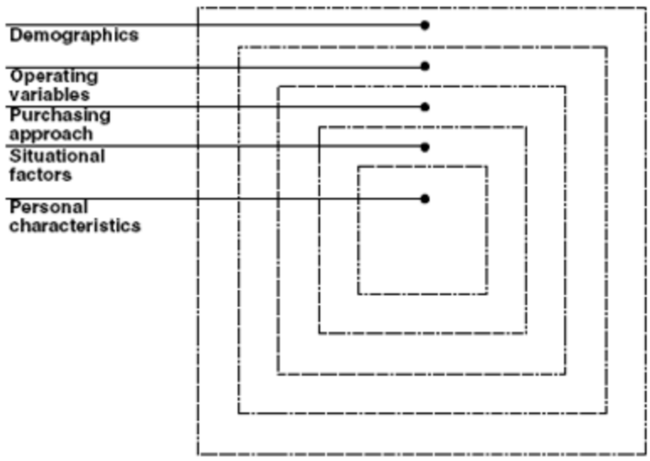


Figure 3.4. Nested Approach for B2B segmentation (Bonoma & Shapiro 1984)

The utmost layer in the Nested approach is *demographics* and it aims to give a generic description and understanding of the customers’ needs and demands. This layer discusses determinants such as general industry knowledge, company size and location. This kind of information is often easily retrieved from statistical information provided by governments and states, industry reports, publications from trade associations, etc. (Bonoma & Shapiro 1984).

The next layer in the hierarchy is *operating variables*. This layer provides a more accurate picture of existing and potential customers within a certain demographic segment. Among the factors for operating variables, company technology, product and brand-use status and customer capabilities are to be found. Data needed to map out these factors can be collected through visits on the customer’s site, through reverse engineering where a customer's product is teared apart by the supplier for it to obtain a better understanding of the technologies upon which the product depends or from financial data from a third party such as a credit rating firm (Bonoma & Shapiro 1984).

The middle layer of the nest describes the *purchasing approach* of a certain firm focusing on factors such as the purchasing function organization, power structures, buyer-seller relationships, general purchasing policies and purchasing criteria. According to Bonoma & Shapiro, this is often a neglected area within industry segmentation, although it's a valuable method if done properly (Bonoma & Shapiro 1984).

Moving deeper into the nest to the second most inner layer, *situational factors* are to be found. Here, general grouping and sorting of companies are left behind and the focus has instead shifted towards the certain purchase situation and considers factors such as product application, order fulfillment and the size of the order. In some cases, situational factors are of greater importance than price itself where companies are willing to pay a premium for receiving e.g. flexibility (Bonoma & Shapiro 1984).

In the center of the nested approach the *Buyer's Personal Characteristics* can be found. Though purchasing decisions are done by people and not corporations, "soft values" such as buyer-seller similarity, buyer motivation and individual perception affects the final decision. This kind of personal data might be hard to retrieve from external sources, hence its often favorable to collect it internally through sales information systems and through the sales force directly (Bonoma & Shapiro 1984).

3.2.3 Customer Drivers

In the context of adapting new technology, a combination of the role of technology limits and the role of customer demand are at play. As previously described, development and integration of new technology is often driven by the fact that the existing technology is approaching its performance limits. A combination of technology-push and demand-pull is likely to drive the development (Tripsas, 2007). Customer demand stands upon the preferences of the customer, which ultimately frames the market.

What appears to be new technology for an industry often origins from other industries, although it may take form in a different shape. Tripsas presents an integrated model of technology transitions in her article from 2007, where customer drivers for adapting new technology are presented. The model stands upon a *technology trajectory,* from which the technology itself is being developed due to performance thresholds in other industries and a *preference trajectory* that changes the dimensions of customers' demand within the industry. Four factors are described to determine the demand namely *relevant attributes, minimum performance requirement for an attribute, maximum valued performance for an attribute* and *relative preference for attributes*. These four dimensions normally undergo periods of incremental change when the customer's preferences are stable and relatively constant. This is followed by periods of preference discontinuity with radical changes in the four demand dimensions (Tripsas 2007).

Several factors might cause the switch of customers' preferences from incremental change to radical change. Constraints related to technological possibilities may limit the thoughts' of customers. Once a barrier is broken, new possibilities arise. Tripsas outlines four drivers of preference discontinuities. First, shifts in the socio-political environment can influence preferences. Such factors can relate to government regulations (e.g. emission regulations), political changes (e.g. trade barriers) or exogenous shocks, e.g. terrorist attacks. Secondly, changes in the overall system can affect parts on lower levels in the system hierarchy. Shifting performance bottlenecks plays an important role, where one technological invention may pave the way for many new innovations (Tripsas 2007). This is what can be considered as 'unlocking values'. Third, customers' preferences change as the company itself evolves. Increase or decrease of company size changes the organization's complexity and hence also its needs. Fourth and finally, producers can, directly or indirectly, change the preferences of their customers through media (e.g. advertising or public relations) or through institutions (Tripsas 2007).

3.3 Global Transportation

A well functioning transportation system is crucial for the economy and society at large. Transportations and logistics lines that are well-organized are key on both international level and local level. In times of globalization, an efficient transportation infrastructure is important for economic and social benefits in developing as well as emerging countries. The transportations sector is looking at some major challenges ahead, especially to adapt to new forms of mobility and new regulations, an increased awareness for environmental sustainability and digital as well as technological innovations that change the settings more quickly than ever (Rodrigue, 2020).

The way goods or passengers are transported is called “transportation mode” and it is usually divided into four main areas; road, rail, air and water (Wengle et al, 2019). To these four areas, pipelines may also be added (Rodrigue 2020). Each mode is characterized by a set of technical, operational and commercial characteristics that relate to different attributes. The technical characteristics relate to attributes such as for instance speed, capacity, and motive technology. Operational characteristics involve the context the mode is operating in including speed limits, safety conditions and operating hours. Since transportation modes are used to support economic activities and generate an income, the demand for transport and the ownership of modes are the dominant commercial characteristics (Rodrigue, 2020).

3.3.1 Transport Industry

3.3.1.1 Road

In order to move passengers and goods, roads are by far the most common mode of transportation. In Europe, passenger cars dominate the passenger transportation with more than $\frac{4}{5}$ of the market share (Wengle et al, 2019). Road infrastructures are large consumers of space with the lowest level of physical constraints among all the transportation modes. Physiographic constraints are however significant in road construction with substantial additional costs to overcome features like rivers and rugged terrain. Road transportation has average operational flexibility since the vehicles can serve different purposes, but they can rarely serve outside roads. In addition, road transport systems have high maintenance costs and low life spans. Road transportation is mainly linked to light industries and freight distribution, where rapid movements of freight in small batches are the most common. Containerization has made road transportation a crucial link in freight distribution between ports and commercial hinterlands (Rodrigue, 2020). When it comes to total freight in ton-kilometers, around 52 % of the inland freight in EU countries is transported by road 2018 (EuroStat, 2020).

3.3.1.2 Rail

Rail transportation has an average level of physical constraints and a low gradient is required especially for freight. Opposite from road transportation, rail transportation systems are more linked to heavy industries and containerization has improved the flexibility of rail transportation by linking it with road and sea modes. Rail is the land transportation mode with the highest capacity. One challenging aspect is however the variation of gauges in the world, making the integration of rail systems complicated (Rodrigue, 2020). From an ecological perspective, rail has some major advantages compared to road, but the share of the inland transportation is significantly smaller. 13 % percent of the total ton-kilometers of freight was carried by train in the EU (EuroStat, 2020). However, there are incentives to increase those numbers in several countries. For instance, in Switzerland, public transport policies strive towards moving as much transalpine freight traffic as possible from road to rail, leading to one third of the total inland freight in Switzerland being transported on trains (Wengle et al, 2019).

3.3.1.3 Air

Possible air routes are almost unlimited but denser over the North Atlantic, North America, Europe and North Pacific. The constraints for air transport are multidimensional and include the landing and take-off site, where a commercial plane needs 3300 meters. Other constraints are the climate, fog and aerial currents for instance. Air transport has long been linked to tertiary and quaternary sectors like finance and tourism, where long distance mobility of people is crucial. However, air transportation has lately been linked to growing quantities of high-value freights and the mode is therefore playing an increasingly important role in the global logistics sector (Rodrigue, 2020). The share of air freight is comparatively low, contributing by 0,4 percent of the total ton-kilometers in the EU (EuroStat, 2020).

3.3.1.4 Sea

Due to physical properties like buoyancy and limited friction, sea transportation, or maritime transportations as it is more known as, is the most effective mode to transport large quantities of cargo over longer distances. Because of the location of economic activities, the maritime circulation takes place on specific parts of the maritime space, namely North Atlantic and the North Pacific. Maritime transportation has high terminal costs, since port infrastructure is among the most expensive to build, but also maintain and operate. These high costs are also related to maritime shipping, since construction, operation, and maintenance of ships is capital intensive. Out of all modes, maritime is the one most linked to heavy industries like steel and petrochemical facilities close to the port sites (Rodrigue, 2020). The shipping industry is divided into transportation on sea and on inland waterways. In comparison to road and rail, inland waterways freight transports 4 % of the total freight. Since the second quarter of 2013, the share of total ton-kilometers of freight transported by maritime has increased to 30 % of the total ton-kilometers in 2018 (EuroStat, 2020). Maritime transportation is mainly linked to four categories of goods namely oil and gas, bulk cargos, containers and general cargo.

Table 3.1 Transportation Medium and the Most Common Mode of Transportation Used

Medium	**Main transportation mode used**
Road	Truck
Rail	Train
Air	Air plane
Sea	Vessel/Boat

3.3.2 Capacity of Different Modes of Transportation

As mentioned above, there are four main modes of transportation, namely air, truck, rail and maritime. Different modes of transportation have different applications, even though they might sometimes be competing with each other (Rodrigue, 2020). While comparing pros and cons of different modal options, freight capacity is of great importance. A standard way of measuring freight is through *twenty-foot equivalent units* (TEU), a shipping container that is 20 feet long and 8 feet tall. One TEU generally has a capacity of 9-11 pallets and two TEUs are the same size as one *forty-foot equivalent unit* (FEU) (Pappas, 2011).

3.3.2.1 Truck

Truck transportation is divided into three subcategories: package delivery, less than truckload (LTL) and truckload (TL). For the latter, a TL means different things regarding what needs to be transported. For example, a TL might be a tank, a dry van or a flat car (Rodrigue, 2020). A semi-trailer truck has a maximum capacity of 26 tons or 2.65 TEUs and this capacity is referred to as a *Truck Equivalent* (Rodrigue, 2020).

3.3.2.2 Train

Transportation using railways is done using either unit trains or carloads. The latter is designed to match truckloads to ease intermodal transportation. Train cars are divided into hopper cars and doublestack rail cars and have a capacity of 100 tons or 4 - 5.3 TEUs. A full car train consisting of 100 train cars hence has a maximum capacity of up to 385 truck equivalents (Rodrigue, 2020).

3.3.2.3 AirPlane

Air freight is divided into either air packages or heavy loads. Air packages are carried using unit load devices through freight planes or on scheduled passenger flights as bellyhold, whereas heavy air freight is carried through specialized airplanes. The maximum capacity of a Boeing 747-400F is 100-125 tons, which is the same as 5 truck equivalents (Rodrigue, 2020).

3.3.2.4 Vessel/boat

Maritime transportation is used for big volumes and long distances. Depending on the type of goods to be transported, different kinds of ships are used. For ocean shipment, Panamax containerships are used to transport containers and very large crude carriers (VLCC) to transport oil. The former has a capacity of 5,000 TEUs (or 2,116 truck equivalents) and the latter can carry up to 300,000 tons of oil (equivalent to 9,320 TLs). For inland and coastal transportation, different kinds of barges in tow are used with a capacity of 50-100 TEUs per barge (Rodrigue, 2020).

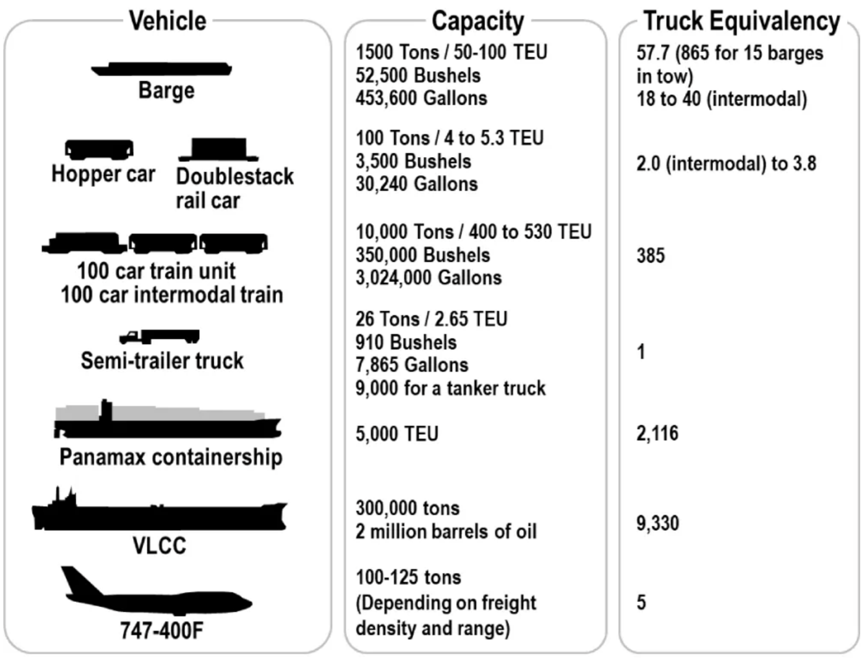


Figure 3.5. Capacity of Selected Transportation Modes (Rodrigue 2020)

3.3.3 Intermodal Transportation

Intermodal transportation is when a minimum of two different modes are used in sequence when transporting something from origin to its destination. It can be applied to passenger movements, but it is in freight transportation that the most significant impacts of intermodalism can be observed. Containerization has been a vector of great importance when it comes to intermodal integration, enabling maritime and land transportation to connect with each other. Although intermodal transportation has created opportunities for complementarity between different modes, transport operators are now starting to compete over many nodes in the transport chain. This represents a growing paradigm involving supply chain competition where the modal competition occurs over three dimensions. The first one is “Modal Usage” which is a competition involving the comparative advantage of using a specific mode or a combination of modes. The other one is “Infrastructure Usage” which is competition resulting from freight and passenger traffic on the same itineraries that link the same nodes. The last one is “Market Area” which is competition between transport terminals for using new locations or capturing new markets (Rodrigue, 2020).

Figure 3.6. Illustration of Intermodal Transportation (DHL, 2021)

The technological evolution in the transport industry aims at adapting transportation infrastructure to the growing demand, needs and requirements. When one transport mode becomes more advantageous than another that is operating on the same route or market, a modal shift is likely to take place. In other words, a modal shift is the growth in demand for one mode on the expense of another. For freight this has implied a shift to faster, more flexible and cost effective modes, mostly trucking and air freight. All modes of transport are affected by the fuel price and its volatility. In the context of higher energy prices and the increased environmental concern, the input costs for transportation is increased which can lead to friction of distance in the future, constraining mobility. In addition, energy costs impact the modes differently and therefore a modal shift can be anticipated where road and air transport are more energy-intensive than rail and sea, which could lead to a shift to the latter two alternatives (Rodrigue, 2020).

3.3.4 Containerization

Containerization was first introduced as a system to increase efficiency in maritime transportation (Hayut, 1981). The concept was first introduced in 1956 in the United States and it was initially only used for domestic transportation. Due to heavy regulations and public ownership, the diffusion of containerization for inland transportation using rail was initially slow. However, it was quickly determined that a standardized concept would bring a positive effect to the maritime transport sector since it was much less regulated (Notteboom & Rodrigue, 2008). By 1977, 68 countries in the world had adopted the technology (Rua, 2014). Main advantages were linked to reducing turnaround times for ships reaching a harbor and cost savings related to loading and unloading cargo (Hayut, 1981).

At the center of the concept stands the container unit, which is also the most visible part of the system. The container is a standardized unit as previously defined; a container unit can be divided into either *twenty-foot-units* (TEU) or *forty-foot-units* (FEU) (Pappas, 2011). Around the container itself is a complex system of intermodal transportation including ships, trucks, specialized cranes and facilities to be found. Every part in the system plays a crucial role for the global supply chain connecting goods with receivers from all around the world (Rua, 2014). Since the advent of the container, a great shift towards intermodal transportation has been made, changing the very foundations of the infrastructure of ports, distribution centers and inland distribution (Hayut, 1981).

As described by Rodrigue and Notteboom: "*The container is thus much more than a box; it is a vector of production and distribution"* (Notteboom & Rodrigue, 2008). No other technical improvement has participated more to the concept of globalization than containerization. Containerization should be considered revolutionary for its impacts on the supply chain, switching from push logistics to pull logistics. Due to economies of scale, costs for transportation could be reduced, serving as an important factor for increased globalization (Notteboom & Rodrigue, 2008).

Containerization has gone through two paradigm shifts and is now in the middle of a third one. The first phase began in the mid 60's with the *introduction of the container and its diffusion within maritime systems*. This phase led to increased efficiency of transhipment with the maritime sector and trucking industry. From that point, diffusion reached its next phase namely *diffusion of containerization within inland transport systems.* Driven by adaptation of the inland rail service for handling of containers, intermodal transport reached the next level during the late 70's in Europe and the United States. Among the drivers of diffusion in Europe, the Port of Rotterdam and the Port of Antwerp served as important players. Currently, containerization is considered to be in the beginning of a third paradigm heading towards *intermodal and transmodal operations and the functional diffusion of containerization within supply chains.* Focus lies on reducing the number of times every container is handled (Notteboom & Rodrigue, 2008).

Among all positive effects related to standardization presented above, the freight industry fights issues regarding "the empty container problem". Once a container reaches its destination and has been unloaded, it has to be handled by the supply chain to serve a new carrying task. Until it is reloaded with new goods, it is a burden for the system and it is taking up valuable space in modal capacity. Although a better integration between inland actors and maritime players lead to some overall performance advantages, the problem is hard to effectively address (Notteboom & Rodrigue, 2008).

3.4 Theoretical Framework

The theory presented above aims to appropriately serve as a theoretical framework upon which the empirics and analysis of the study can rely. The purpose of this study is to identify, describe and analyse technology shifts and needs within the industry of transportation. Furthermore, to assess the market potential and to explore how a first mover can exploit autonomous solutions. Based on this purpose, the theoretical perspective will consist of three main building blocks described above; Technology Shifts, Understanding Market Structure and Global Transportation.

The framework takes off in Technology Shifts and the creation of technology cycles that continuously change our surroundings and assumptions of the new normal. To understand the shifts in technology it is crucial to understand innovation theory since new innovations often are the underlying catalysts for new technology cycles. Henceforth, for companies to survive in the long term in the forever changing reality, a consistent strategy is needed. Technology Strategy is therefore explored to create an understanding of how companies need to develop strategies for acquiring, managing and exploiting technologies now and in the future further away in time than more business related strategies and goals.

Just as new technologies can be innovated and older technologies can be changed for the better, new markets can be created and established markets can be changed. It is therefore important for companies to understand their markets and how they develop. To be able to understand if to enter a new market or not, it is crucial to create a comprehension of the size of the market and the different perspectives that can be used. Once knowing the size of a market, segmentation is needed to know what segment to target. There are several different ways to segment a market, and the methods segmenting a Business-to-Consumer market are different from the methods used in Business-to-Business markets. Regardless of the customer characteristics, knowing the customer drivers is the foundation of knowing the market one is serving.

The transportation industry has experienced several technology cycles which has forced the actors in the market to constantly adapt. The industry can be divided into four main segments with different sizes and customers' drivers. The segments are vehicles traveling on roads, mostly trucks, vehicles traveling on rail, mostly trains, vehicles traveling in the air, mostly airplanes and last but not least vehicles traveling on sea, mostly vessels. Due to the increased globalization, intermodal transportation is common, which is when at least two different modes of transport are used in a chain to travel from point A to point B. To facilitate this process, the container was created making the transition between the modes as efficient as possible all around the world.

The theoretical framework is illustrated in *Figure 3.7* below. In the nave of the wheel we find theories describing the understanding of the market structure. This stands for market size and segments, as well as customer drivers. Around the nave the actual wheel is found, driving the transport industry forward. Driving forces here come from technology shifts challenging the industry standards. In addition, it can be described by theories regarding technology cycles, innovation and technology strategy.

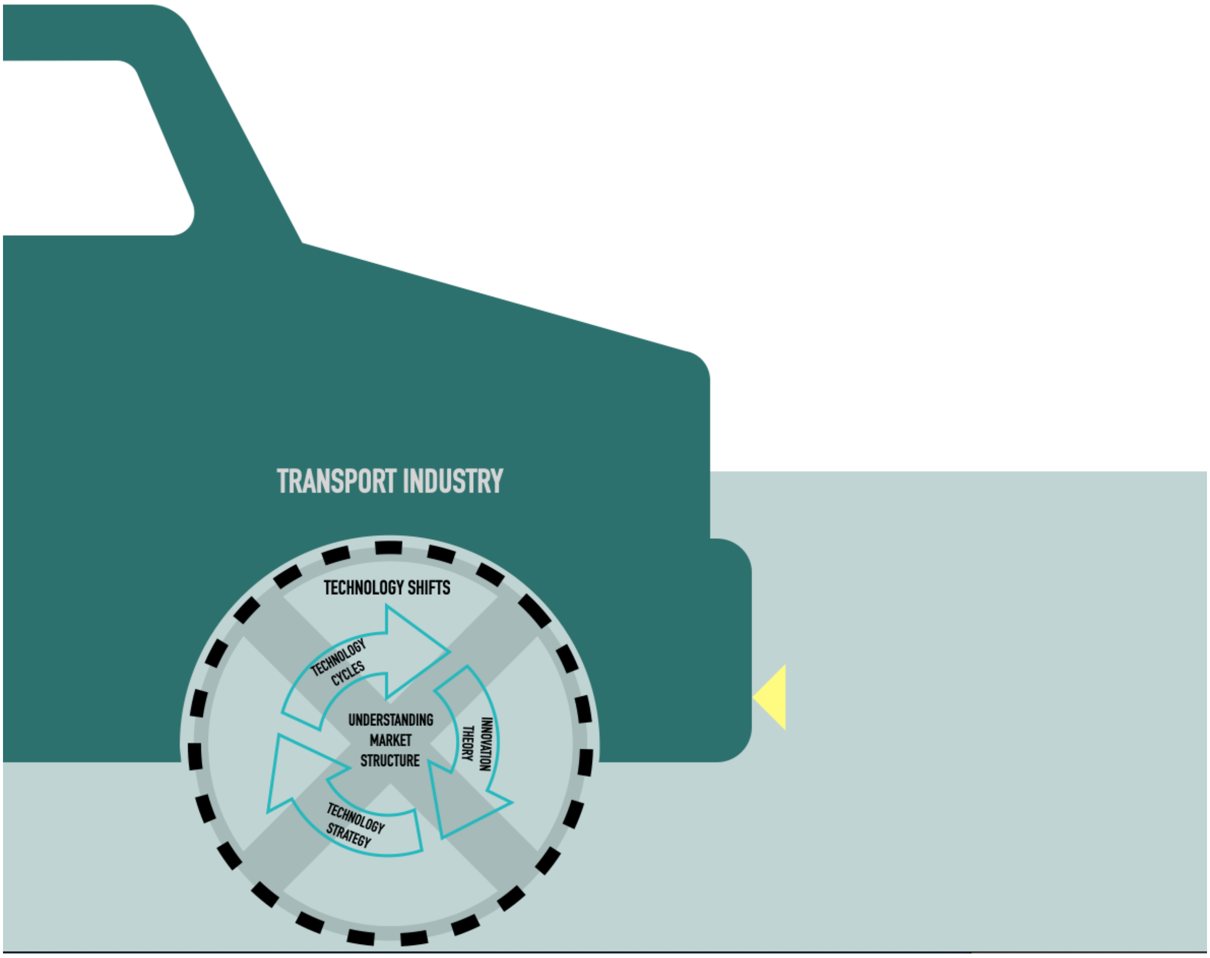


Figure 3.7. Theoretical Framework Illustration

4. Empirics

4.1 Introduction of the Case Company

4.1.1 Introduction

The Case Company is a newly founded company within The Case Company Group. The company is on a mission to further develop and commercialize autonomous solutions to improve safety, radically reduce emissions and to maximise productivity. The company exists in three countries around the world including Sweden, United States and Germany. All in all, hundreds of employees work together towards an autonomous future (Person 8, 2021).

The Case Company is closely linked to The Case Company Group which is a global enterprise. With a global presence and business in over 190 countries around the globe and a total number of approximately 100.000 employees. The Case Company Group serves four main business areas that due to competitive reasons will not be mentioned in this Master Thesis (The Case Company Group, 2019).

4.1.2 Value Proposition

With the introduction of The Case Company, the traditional market rationale for truck sales are questioned. Complex solutions require a deeper collaboration between the supplier and the customer, which has resulted in the introduction of Transport as a Service (TaaS). The principles of TaaS with an offer of a full Autonomous Transport Solution (ATS) is the value proposition offered by the company (The Case Company (1), 2020).

ATS consists of seven components tailored to meet every clients' unique needs, namely: the vehicles/machines, cloud solutions, operations, service and maintenance, payment solutions, infrastructure and virtual driver solutions. Every component is adapted for the specific application or "job to be done". The Case Company has selected three strategic segments to serve including mining and industrial material handling, ports & logistic centers and hub-to-hub/highway. The three strategic segments will be described more in depth further in section *4.1.6 Targeted Markets* (The Case Company (1), 2020).

4.1.3 Relation to The Case Company Group

The Case Company was founded with one focus: to commercialise autonomous vehicles. The initiative was driven by The Case Company Group and The Case Company stands on the same culture and values as The Case Company Group in general. The company is owned by The Case Company Group and is part of a group among several other companies (Person 16, 2021).

The Case Company is considered as a start-up within The Case Company Group, even though they are closely linked to the parent company. They are free to develop new processes and procedures, which gives them more freedom compared to other companies within the group. The Case Company is responsible for developing the virtual driver themselves, but they rely upon other departments within The Case Company Group to deliver the actual truck as well as supporting them with regional sales competence in different markets (Person 8, 2021).

4.1.4 Financial Statement

The company stands on a solid financial ground with The Case Company Group as a parent company. The Case Company has not yet presented any financial data since it was recently founded (Person 8, 2021).

4.1.5 Product Description (with limitations)

The technical solution that this Master Thesis focuses on is a fully autonomous one, tailored for the customer's specific needs. The truck itself is electric, hence it requires a good electric infrastructure to support it. The vehicle is built for on-road applications and every truck is customized for the specific environment it will operate in.

To enable pure autonomous driving, the system uses eight components to create a perception of the environment. One of the main objectives when designing a safe system is to create a good perception redundancy to get the system to make good decisions and have control over the vehicle at every moment. LIDARs, optical measuring instruments, are used to create detailed pictures of objects around the vehicle and together with cameras, high definition maps are generated. To complement this, radars are incorporated. These are mainly used as a complement to support LIDARs and cameras in hard weather conditions, such as heavy rain or darkness. Finally, ultrasonic components and GNSS are incorporated to increase the redundancy even further. At every given moment, the vehicle's computer interprets the surroundings and makes decisions through direct connection with various cloud services (Person 25, 2021).

Possible applications for the technical solution that this Master Thesis evaluates are short and repetitive distance in the range between X meters up to Y kilometers. The environment that the vehicle will operate in should ideally be a restricted/gated area with private roads (Person 16, 2021). However, since the thesis aims to evaluate the business potential on a global level on short and long term, public roads will not be totally excluded.

4.1.6 Targeted Markets

The Case Company works in three different strategic market segments, namely Light Mining and Quarries, Ports and Logistic Centers and lastly Hub-to-Hub/Highway (The Case Company (2), 2020).

4.1.6.1 Light Mining and Quarries

This area includes Mining, quarries and aggregates and industrial material handling. All of these types of applications can both be confined and highly regulated, which makes it easy to separate the autonomous solution from all other processes. Also, the process of loading, transporting and dumping are relatively simple and repetitive, making it very suitable for autonomous solutions. In this area, the Case Company is starting small with less complex use cases and will build additional functionality upon the proven successes. Next steps could be bigger scale applications such as underground mining or tunnel applications, which could assist in the process of removing people from hazardous situations (The Case Company (2), 2020). This segment will not be considered in this Master Thesis .

4.1.6.2 Hub-to-Hub/Highway

Autonomous solutions are also useful for hub-to-hub transportations using dedicated lanes on the highways. With LIDAR and GNSS technology, the vehicle can operate entirely autonomously, continuously reading its surroundings, navigating around fixed and movable obstacles. Simultaneously, the solution gathers data via its on-board transport system to further optimize its route, traffic safety and fuel consumption (The Case Company (2), 2020). This segment will not be considered in this Master Thesis.

4.1.6.3 Ports and Logistic Centers

Autonomous transport with low noise levels and also zero exhaust emissions have an important role to play in the future of logistics and it will benefit both businesses and the society as a whole. Short transports with high precision are common in ports and logistics centers and also well suited for autonomous solutions. The vehicles are designed to locate their current position to within centimeters, monitor in detail and analyze the behaviour of the other objects and road users around, and then respond with very high accuracy. Speed and progress are tailored to increase delivery precision and minimize waste and also increase availability. Also, vehicles that operate on the same route are optimized to create an optimal flow (The Case Company (2), 2020). Within the Logistic Centers segment, traditional logistic companies are represented, as well as internal logistic and material handling in manufacturing companies. This segment will therefore be split into *Ports, Logistic Centers* and *Manufacturing Companies* in this Master Thesis and be analysed separately in the study.

4.2 The Technology Shift

As a result of increased demand for transportation, efficiency and sustainable solutions, automation and autonomous solutions are a significant trend within the transportation industry. McKinsey has outlined in an article from 2018 that automation might reduce logistics costs with as much as 40 percent in the supply chain. With high pressure from the e-commerce industry, automation helps logistics firms to better meet peak demand, handle individual products and move heavier cargo (Chottani et. al, 2018).

In order to standardize terms and definitions around autonomous vehicles on-road, SAE International developed the J3016 standard. First released in 2014, the standard includes “taxonomy and definitions for terms related to driving automation systems for on-road motor vehicles” (SAE (1), 2018).

The standard describes in detail six levels of automation ranging from no automation (level 0) to full driving automation (level 5). The document handles three different actors of the driving process, namely the user (the human being), the driving automation system and other vehicle components and systems. These three players’ relation to the dynamic driving task (DDT) states the level of automation. Active safety systems (e.g. lane keeping assistance) are not included in the definition of driving automation, since they do not account for part or all of the DDT (SAE (1), 2018).

The first three levels of driving automation requires the human driver to physically drive the car, as well as constantly supervise the system. Level 3 - 5 defines states where the human being is not in charge of the driving, but depending on the specific level he/she might still have to supervise the system when it commands the driver to do so. A full definition of the different levels are to be found in the visual chart below (SAE (2), 2018).

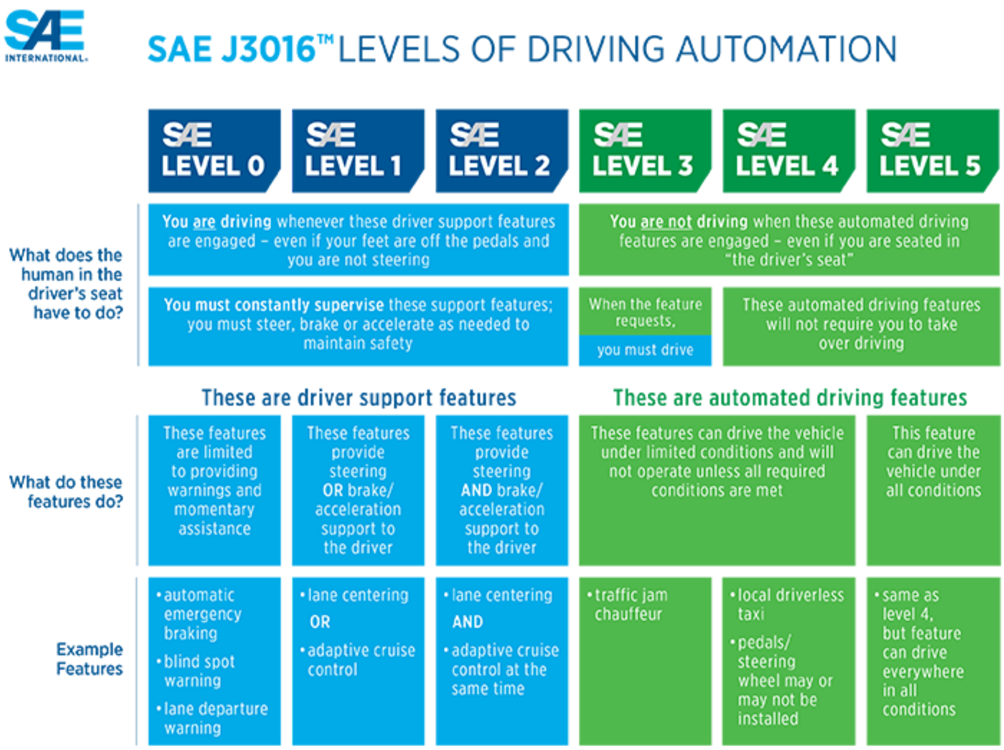


Figure 4.2. SAE Levels of Driving Automation (SAE (1), 2018)

4.2.1 Technology Cycle in the Industry of Transportation

As previously described, the S-curve can be used to evaluate the stage of a product's performance in relation to the amount of time or engineering effort put into further development of the product. The development is slow in the advent of a new technology or product but as the amount of time and resources allocated to the invention increases, the product performance development faces an exponential increase (Christensen, 1992a).

For mining and quarries there have been autonomous solutions in operation for around 10 - 15 years. The vehicles that have been working there are heavy machines weighing up to 300 tons and completely driven by fossil fuels. There has previously not been any truck companies that have presented autonomous solutions for this segment. The factor of electrification gives the new autonomous trucks an additional feature making it even more revolutionary for the mining industry. All in all, autonomous solutions are considered to be somewhere halfway up the S-curve for mining applications (Person 8, 2021).

In ports and logistic centers (including manufacturing companies) autonomous trucks have not been present in the way that The Case Company is working to implement them. There are solutions for container handling on the quay-side, such as AGVs and automatic cranes, but not solutions for trucks. Since these applications often require sections where the truck will operate on public roads, there are not yet solutions in operation. Hence, currently the technology is in the beginning of the S-curve and a lot of product development will occure in the near future as the amount of time and engineering effort increases (Person 8, 2021).

Autonomous trucks in general are in the start phase of a new era. The fact that this is an architectural change in the market and that it eventually will redefine what a truck looks like makes it important to be first to market. There is not yet a dominant design present in the industry and companies fight to be the first ones to present working solutions in order to claim market shares. The Case Company estimates that if they are one among the three first truck manufacturers in the market for autonomous trucks, they have a good chance of acquiring around Q - Z % of the total market share and this share drops dramatically if you are a close follower (Person 8, 2021).

4.2.2 Innovation Theory

The changes towards autonomous solutions in the industry of transportation are to be considered as radical since it changes the very foundations of the industry. Previously, trucks have been designed with the comfort and safety for the driver as a primary focus and once you remove that person you will change the core of the product itself (Person 8, 2021).

Autonomous solutions might also have a huge impact on the business model around how trucks are sold and handled. There is a possibility that truck manufacturers will own the trucks themselves and also to handle the truck operations (Person 21, 2021)

4.2.3 Technology Strategy at The Case Company

The Case Company works with different methods to ensure that they acquire new and innovative technology. The Case Company Group Innovation Center was founded to collaborate with startups together with The Case Company Group. This is also the home for The Case Company, which is one of the most innovative parts in The Case Company Group. In addition, The Case Company Group also has several offices spread out in the world on relevant locations where a lot of technology development happens. Examples of this are offices in Israel, Silicon Valley and China. From there, new technology and knowledge are acquired through observation, partnerships and other types of collaboration. There have recently been changes in structure for product development and today's model is more fluid where there is a complex relationship between subcontractors and the producing firms with different models of revenue sharing. There is a general understanding that today's subcontractors might be tomorrow's competitors and then partners the day after tomorrow. Therefore, there is a close collaboration and partnership between The Case Company and different subcontractors (Person 21, 2021).

Another important factor for acquiring new technology is to have a good HR strategy and this is something The Case Company works hard with. Here, they have a focus on hiring people that are in the forefront of their technical niche, e.g. battery development (Person 21, 2021).

The commercial team works very closely with the technical team to ensure that new knowledge is managed in a good manner internally. New requirements from customers are collected by the commercial side and together with the technical team, The Case Company is setting up new technical solutions based on the wants and needs of the customers. Since knowledge comes from both internal and external sources, it is of great importance to have an open culture where people spread knowledge and ask a lot of questions and that way, the new findings are spread throughout the company. Finally, The Case Company works closely with The Case Company Group's own Venture Capital division, which invests in new startups. The Case Company is involved in the process when a new company is accepted and they work together to obtain knowledge from the new companies (Person 16, 2021).

When new technology has been acquired and spread throughout the organization, it is then exploited to bring value in certain products. This is a process which starts with the creation of a proof-of-concept or proof-of-value for the technology. Once this is done and the company commits to proceed with exploiting the technology, it is rated using a scale from 1 - 9, called TRL - *Technology Readiness Level*. When a technology has been proven to reach a certain point in the scale it is considered ready and valuable to implement on a broader scale in The Case Company's products (Person 16, 2021).

4.3 Strategic Markets

To understand readiness for adoption of autonomous vehicles in different geographical areas, the Autonomous Vehicles Readiness Index (AVRI) report by KPMG is considered. In the report the preparedness of 30 countries and jurisdictions in the race for autonomous vehicles are assessed. The AVRI is a composite index that combines 28 individual measures from different sources into a single score. The different measures are all relevant for assessing how ready the country is for Autonomous Vehicles and they are gathered into four groups shown below (Threlfall, 2020).

The variables within each of the four groups are combined to arrive at an aggregate score for each of the groups. Before the data is combined it is normalized as the variables have different measurement units. This converts the variables to a range between zero and one and the best performing country receives a one and the bottom country receives a 0, on all variables individually. The intended core audience for the index are public sector organizations with responsibility for infrastructure and transport. Below in *Table 4.1,* the scores of the different countries are presented, where Singapore is assessed as the country that is the most ready out of the 30 countries assessed (Threlfall, 2020).

1. **Policy and Legislation**
    a. AV regulations, government-funded AV pilots and AV-focused agency
    b. Government ready for change
    c. Future orientation of government and efficiency of the legal system in challenging regulations
    d. Data-sharing environment
2. **Technology and Innovation**
    a. Industry partnerships
    b. AV technology firm headquarters
    c. AV-related patents
    d. Industry Investments in AV
    e. Availability of the latest technologies
    f. Innovation capability
    g. Cybersecurity
    h. Assessment of cloud computing, artificial intelligence and Internet of Things
    i. Market share of electric cars
3. **Infrastructure**
    a. EV charging stations
    b. 4G coverage
    c. Quality of roads
    d. Technology infrastructure change readiness
    e. Mobile connection speed
    f. Broadband
4. **Consumer acceptance**
    a. Population living near test areas
    b. Civil society technology use
    c. Consumer ICT adoption and digital skills
    d. Individual readiness
    e. Online ride-hailing market penetration

Table 4.1. KPMG Autonomous Vehicle Readiness Index

Country	Ranking 2020	Ranking 2019	Score 2020
Singapore	1	2	25,45
The Netherlands	2	1	25,22
Norway	3	3	24,25
United States	4	4	23,99
Finland	5	6	23,58
Sweden	6	5	23,17
South Korea	7	13	22,71
United Arab Emirates	8	9	22,23
United Kingdom	9	7	21,36
Denmark	10	n/a	21,21
Japan	11	10	20,88
Canada	12	12	20,68
Taiwan	13	n/a	19,97
Germany	14	8	19,88
Australia	15	15	19,70
Israel	16	14	19,40
New Zealand	17	11	19,19
Austria	18	16	19,16
France	19	17	18,59
China	20	20	16,42
Belgium	21	n/a	16,23
Spain	22	18	16,15
Czech Republic	23	19	13,99
Italy	24	n/a	12,70
Hungary	25	21	11,66
Russia	26	22	11,45
Chile	27	n/a	11,28
Mexico	28	23	7,42
India	29	24	6,95
Brazil	30	25	5,49

As outlined above, this Master's Thesis focuses on the market segments for ports and logistics centers. To clarify the segment even further, three different strategic markets have been analyzed namely ports, logistics center for distribution and air freight, and finally internal flows within manufacturing facilities.

4.3.1 Ports

4.3.1.1 Port Operations

4.3.1.1.1 Container Handling Process

Looking at a general perspective, container ports can be described as a system with the purpose to let goods flow between two external interfaces, namely, the sea-/quayside and the landside. The process starts when a container ship calls the port. It is then assigned to a berth spot, where quay cranes are waiting. Quay cranes are used for loading and unloading containers from the vessel to the quay. The cranes drop the containers on vehicles which then move the containers to a stack where they wait for further transportation (Stahlbock et. al, 2004). Here, three main choices for further transportation exist, transportation via truck, transportation via train or transshipment to other vessels. For the case of transshipment, the containers are normally moved from the vessel to the stack and then back to be re-loaded. The loading process for export is handled in the same way, but reversed (Person 6, 2021). The process is illustrated in *Figure 4.3* below.

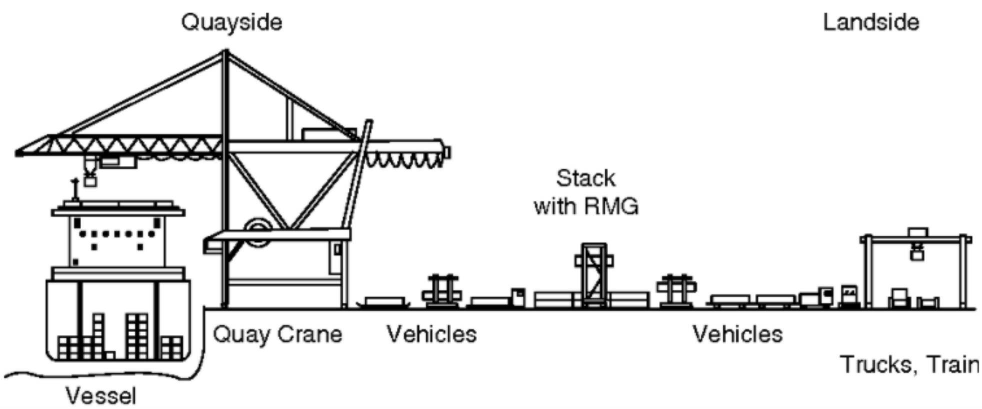


Figure 4.3 Container Handling Process (Stahlbock et. al, 2004)

As previously introduced in the theory section, container ports also need to deal with empty containers. Depending on the country and the rate of import and export, different shares of empty containers are handled by the port. The process for handling empty containers is usually the same as for cargo-carrying containers (Person 5, 2021). In some cases the port accommodates empty depots in the terminal area for storing empty containers (Stahlbock et. al, 2004).

4.3.1.1.2 Vehicles operating in a port

The fleet of vehicles operating in a port is specifically developed to meet the demands of the container handling process.

Quay cranes

The quay cranes handle the loading and unloading of containers between the vessel and the quayside. Quay cranes can typically be divided into two categories, single-trolley cranes and dual-trolley cranes. The former is manual and the latter often use a semi-automatic technique. Modern quay cranes allow moving two 20-foot TEUs simultaneously. Technical capacity varies around 50 - 60 moves per crane and hour, while the performance limitations restricts the capacity to around 20 - 30 moves per crane and hour (Stahlbock et. al, 2004).

Figure 4.4 Quay Cranes (Kalmar (1), 2021)

Stacker cranes

A second category of cranes operates the stacks, meaning the move of a container from an AGV, terminal tractor or truck to a stack. Here, three types of cranes exist, namely *rubber mounted gantry cranes* (RMG), *rubber tired gantries* (RTG) and *overhead bridge cranes* (OBC). One gantry crane normally has the capacity to spread over 8 - 12 rows and reach 4 - 10 containers' heights (Stahlbock et. al 2004).

Figure 4.5 Stacker Cranes (Kalmar (2), 2021)

Automatic Guided Vehicles (AGV)

Automatic Guided Vehicles (AGVs) are used for horizontal transportation between the quay and the stacks. They are classified as 'passive' vehicles, since they do not have the ability to lift the containers by themselves. Instead, they depend on cranes or other vehicles for this type of move. One AGV has the capacity to move one 40-/45-foot equivalent. AGVs are traditionally implemented in areas with high labour costs (Stahlbock et. al 2004).

Figure 4.6 AGVs (Hwee Hwee, 2018)

Terminal Tractor

An alternative to AGVs are terminal tractors, also used for horizontal transportation within the port. Just as AGVs terminal tractors are 'passive' and additionally, they need a human to operate them (Person 5, 2021).

The monthly leasing cost for a Terminal Tractor is 30.000 SEK and the average fuel consumption is 7 liter per hour (Vehicle Company, 2021).

Figure 4.7 Terminal Tractor (Kalmar (3), 2021)

Straddle Carrier

A second category of horizontal moving vehicles for quayside operations are 'active' vehicles, which have the ability to both move and lift containers. Straddle carriers are one such vehicle, which can both move and stack 20- and 40 feet equivalents. Straddle carriers are by nature very flexible and dynamic since they can be used to move containers, stack up to 3-4 containers' heights and directly load containers on trucks. Most straddle carriers are manual, but automatic ones do also exist (Stahlbock et. al, 2004).

Figure 4.8 Straddle Carrier (Kalmar (4), 2021)

Reach Stackers

A reach stacker is, similar to a straddle carrier, an 'active' vehicle with the ability to both move and lift containers. Reach stackers are often used for intermodal operations such as loading containers onto trains or trucks from the stack (Person 13, 2021).

Figure 4.9 Reach Stacker (Kalmar (5), 2021)

Trucks

External over the road trucks are also working in the ports. These are normal trucks coming through the gates to the port to bring containers to or from the port area. These are manual and operated by drivers (Person 5 2021). Generally, 50-80 % of the total share is transported to and from ports with trucks(Person 6, 2021).

Figure 4.10 Truck with container (DAF, 2015)

It is calculated that a common truck has a value of roughly 1.000.000 SEK and a lifetime of 8 years. The residual value then is 10 %. The average yearly cost for service and maintenance is around 50.000 SEK. Finally, the average fuel consumption is 3 liters per 10 kilometer (Person 9, 2021).

Train

Trains are the second most common mode for moving goods out or into a container port. Ports usually have rails going into the port area where they are being loaded with containers from the stack (Person 19, 2021). In ports roughly 20 - 50 % of the total number of containers are transported via train (Person 6, 2021).

Figure 4.11 Freight Train (RailFreight.com, 2019)

4.3.1.2 Markets Size

The global shipping container market size was estimated to be 7,2 trillion USD 2017 (Statista, 2021). During 2019, 811,2 million 20 ft container units and equivalents (TEUs) were handled in ports in the world. This is an increase of 2 % compared to 2018, however, it was the lowest growth in seaborne trade since the financial crisis 2008/2009. The total GDP growth in the world also decreased from 3,1 % the year before to 2,5 % in 2019. UNCTAD forecast's predict that the total seaborne trade volume will have decreased with 4,1 percent during 2020 due to all uncertainty originating from the COVID-19 Pandemic. On the contrary, the forecasts predict a recovery and an increase of seaborne trade with 4,8 % during 2021. Those numbers are strengthened by a forecast made by Clarksons Research Services that predicts a decrease of 4 percent in 2020 and an increase of 4,7 % during 2021 (UNCTAD, 2020).

4.3.1.3 Market Segment

According to the theoretical framework and the Nested Approach, certain *Demographics* of a specific geographic market is presented in the Nested Approach as a valid first layer for B2B-market segmentation (Bonoma & Shapiro, 1984). Therefore, a geographical segmentation and volumes and flows of containerized goods within these regions are studied. Moving deeper into the Nested Approach, *Operating Variables* are to be found, such as customer capabilities including operating, technical and financial factors (Bonoma & Shapiro, 1984).

4.3.1.3.1 Demographics

In the last 50 years there has been a large shift in the share of developing and developed countries when it comes to sending and receiving seaborne cargo. During 1970, 65 percent of seaborne freight was loaded in developing countries, while only 18 percent were unloaded in developing countries. In 2019, those numbers have turned to 60 percent of all cargo being loaded in developing countries and 65 percent unloaded in developing countries (UNCTAD, 2020). In *Diagram 4.1* below the container throughput per region is shown. In Table 4.3 the sending and receiving share of the different continents are shown.

Diagram 4.1. World Container Port Throughput (2019) Divided into Continents (UNCTAD, 2020).

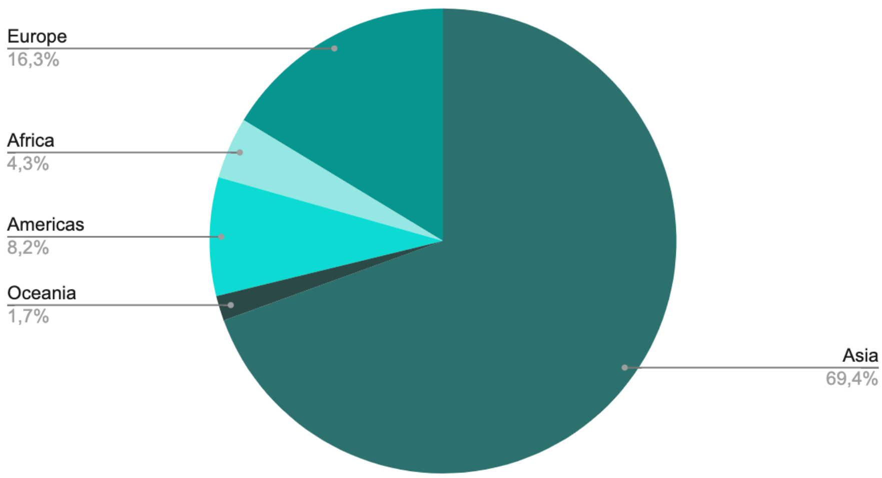


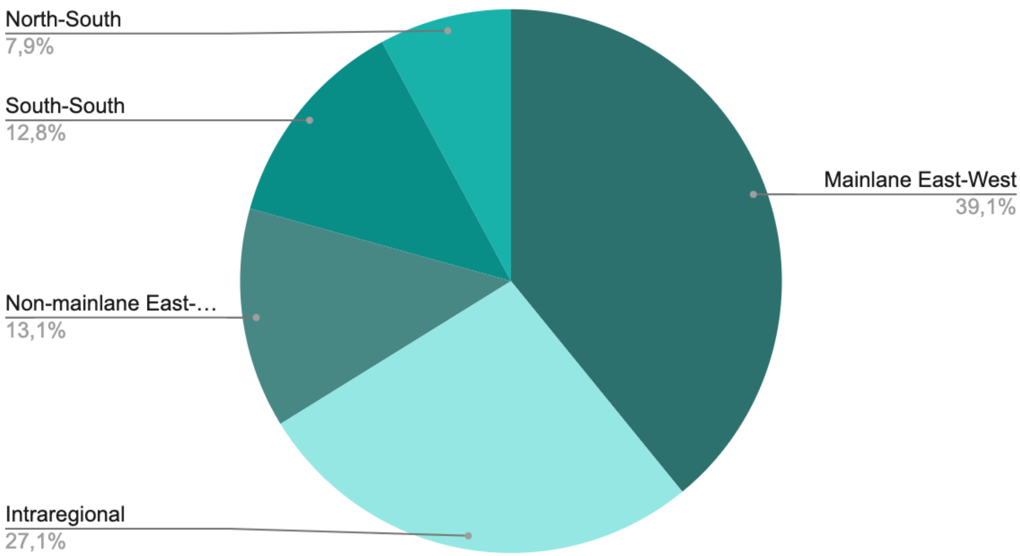
Table 4.2. Container Freight Departing and Arriving (UNCTAD, 2020)

Continent	Percentage of freight departed from here	Percentage of freight received here
Asia	41%	62%
Europe	22%	19%
Americas	16%	13%
Africa	14%	5 %
Oceania	7%	1%

The maritime trade routes can be divided into 5 groups, namely Mainlane East-West, Non-mainlane East-West, Intraregional, South to South and North-South. The Mainlane containerized trade routes, namely Asia-Europe, the Trans-Pacific and the Transatlantic, handled 39,1 percent of the total flow in 2019. Trade on other routes, which involves greater participation from developing countries has gained in importance over time and accounted for 60,9 percent of the trade 2019 (UNCTAD, 2020).

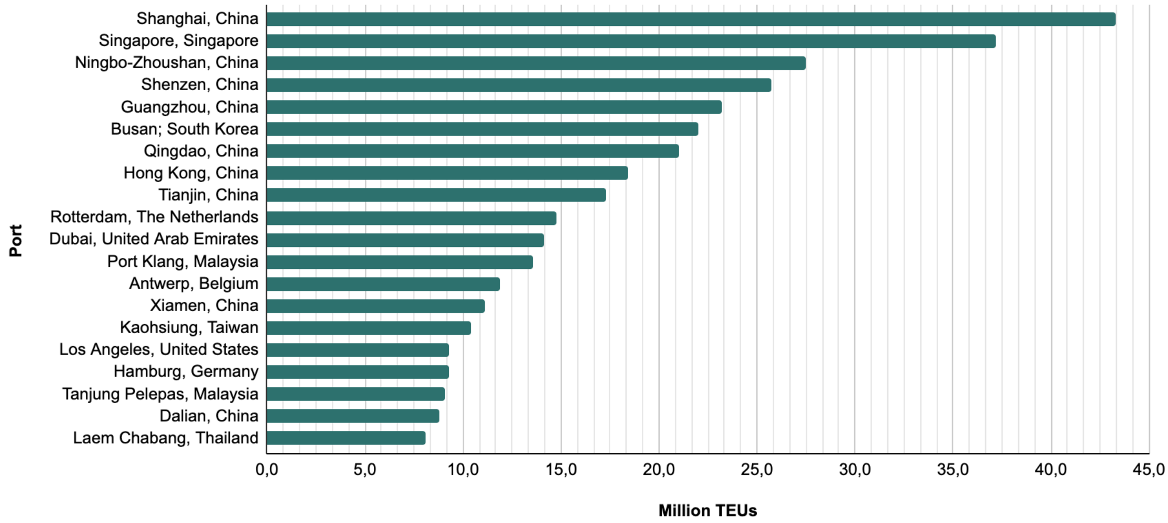
In *Diagram 4.2* the percentage of the containerized trade taking place in the five main route areas are shown for 2019 (UNCTAD, 2020).

Diagram 4.2. The Percentage of the Total Containerized Trade in the Route Areas (UNCTAD, 2020)



Out of the 20 biggest ports in the world in terms of container throughput, 9 of them are located in China. There are only 4 ports on the top 20-list that are located outside Asia. The top 20 list is shown below in *Diagram 4.3*. To gather 80 % of the total container throughput in the world, the throughput in the 109 biggest ports in the world needs to be added up. The last 22 ports on the top 109 list have a throughput that is less than 2 million TEUs per year (UNCTAD, 2020). For a detailed view of the list, see *Appendix 1*.

Diagram 4.3. 20 Biggest Ports in terms of TEUs Handled 2019.



For automation investments in and around ports, one of the major drivers is the cost of labour (Person 14, 2021). At Port Alpha one hour of manpower costs roughly 100 dollars plus 100 dollars for benefits, including health care and retirement (Person 5, 2021). Taking the Port Epsilon as another example, labour costs once again accounts for the biggest share among all costs (Person 13, 2021). Dock labour costs related to port operation stands for around 40 - 75 % of the total operating costs (Nottebom et. al, 2021). A potential variable for demographic segmentation is therefore given by the *Gross National Income* (GNI), since high income countries have greater incitements for reducing labour costs (Person 14, 2021). GNI is represented by the sum of a country's gross domestic product plus the net income, positive or negative, from abroad. GNI gives a more fair picture of a country's economic-well being since it incorporates both domestic and overseas contributions (Bondarenko, 2020). The world bank classifies the world's countries into four different categories depending on their GNI. The classes include low income, low-middle income, middle-high income and high income (Hamadeh & Serajuddin 2020). This is visualized in *Table 4.3* below.

Table 4.3. GNI per Capita Classification Categories (Hamadeh & Serajuddin, 2020)

Group	GNI per capita (in USD by 1 July 2020)
Low income	< 1 036
Low-middle income	1 036 - 4 045
Middle-high income	4 046 - 12 535
High income	> 12 535

With this classification, countries such as Switzerland and Norway are found in the upper end, and in the lower end we find Malawi and Mozambique (World Bank, 2020). A complete list with GNI per capita can be found in the *Appendix 1*.

4.3.1.3.2 Operating Variables

Since autonomous technology is expensive, a certain scale of operations is required for it to be financially viable (Person 16, 2021). For the application of the self driving technique studied in this Master's Thesis, the lower limit for container ports has been set to ports with a minimum throughput of 1 million TEUs per year by the authors.

Up until the late 1980s, both public ownership and public operations were the dominant management models in ports around the world. The forms of governance varied greatly from municipally-owned ports in Northern Europe and the United States, to the state-owned ports in France, Italy and much of the developing world. The institutional entry barriers for port terminal operations were remarkably high and also limited to specific services. This contrasted with the rest of the shipping industry, where private ownership was close to universal. When the containerization started, it underlined how operationally deficient public port authorities added to the increasing time and performance requirements intermodalism imposed on the transport chains. The changes to the industry came from two directions. Firstly, there was a belief that the transport industry as a whole should be divested into the private sector to promote more competition. Ports, as many other sectors, were targeted by economic liberalization policies. Secondly, the World Bank gave a recommendation that developing countries would do well to free their highly controlled port industry by issuing concessions to organizations able to modernize their port industries and manage their operations better (Rodrigue, 2021).

This development helped create what has become a global snowball of port government reforms, known as the port devolution. It made the governments more open to considering a reform of the port governance and also offered better conditions to ensure privatization. The key factors were growing demands for public and private investments in ports, the growth in world trade and the limited ability of the governments to meet these needs because of competing investment priorities. The UK experienced a total privatization of port while many others were willing to consider awarding concessions as an intermediate form of privatization. This has led to the various forms of public-private partnerships (Rodrigue, 2021).

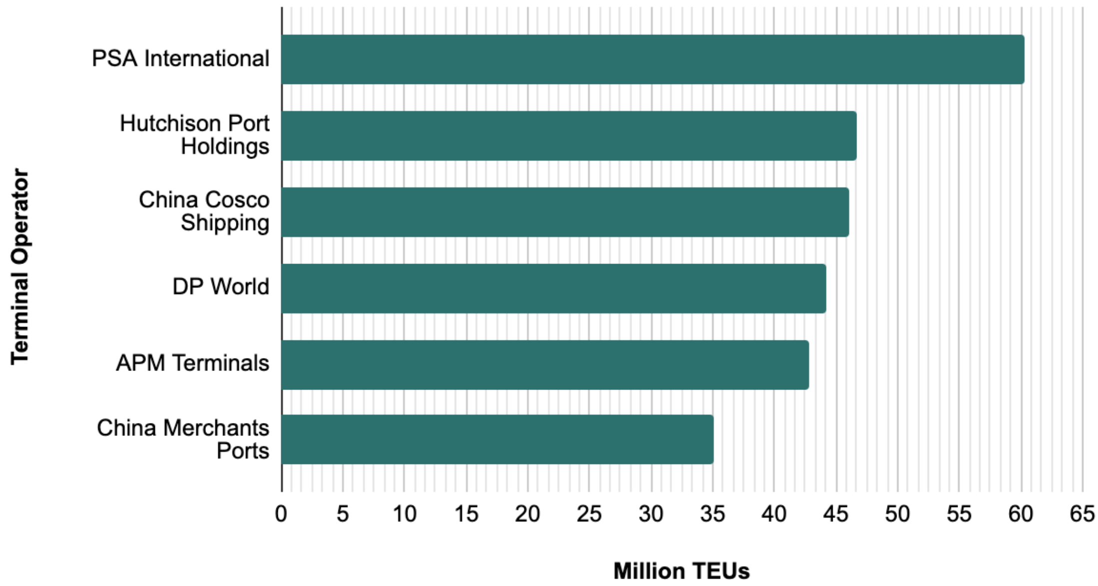
There are five main port management models used around the world, based on the responsibility of the public and private sectors. The five models are the public service port, the tool port, the landlord port, the corporatized port and lastly the private service port. All of these models concern ports that have different characteristics concerning the ownership of the infrastructure, equipment, terminal operations and who provide the port services such as pilotage and towage. Service and tool ports mostly exist to promote public interests, landlord ports attempt to balance public and private interest. At the other end of the spectrum, private service ports are maximizing the interests of the different shareholders (Rodrigue, 2020). For an overview of the different models, see *Table. 4.4.*

Public service ports: In public service ports, the port authority performs the whole range of port related services and they also own all the infrastructure. Often, they are a branch of a government ministry, and most of the employees are civil servants. In some cases, a few ancillary services can be left to private companies. Public service ports are in general less efficient compared to other ports, which has led to a decline in the number of those ports lately (Rodrigue, 2020).

Tool ports: The only difference between a tool port and a public service port is that tool ports have private handling of its cargo operations, although the port authority still owns all the equipment. In many cases, the tool port is a transitional form between a public service port and a landlord port (Rodrigue, 2020).

Landlord ports: This is the most common management model. In a landlord port, infrastructure, particularly terminals, are leased to private operating companies with the port authority retaining the ownership of the land. The lease is often a concession agreement where a private company is granted a long term lease in exchange for rent. The rent is commonly a function of the size of the facility as well as the investment required to build, renovate or expand the terminal. The private operator is also responsible for providing terminal equipment so that operating standards are maintained (Rodrigue, 2020). Below, the 6 biggest port operators are shown in *Diagram 4.4.*

Diagram 4.4. 6 Biggest Terminal Operators in 2018.



Corporatized ports: Ports with this management model have almost entirely been privatized, except that ownership remains public and often assumed as a majority shareholder. The port authority essentially behaves like a private company. This model is unique since it is the only model where ownership and control are separated, decreasing the public good pressures that the landlord port authorities face and the shareholder value pressures that the private service ports are facing (Rodrigue, 2020)

Private service ports: The outcome of complete privatization of the port facility mandates that the facilities retain their maritime role. The port authority is entirely privatized with almost all port functions under private control. The public sector is only retaining a standard regulatory oversight. However, public entities can be shareholders and therefore steer the port towards strategies that are deemed to be of public interest (Rodrigue, 2020).

Table 4.4 Port Management Models (Rodrigue 2020, United Nations ESCA, 2006)

Type	Ownership	Infrastructure	Superstructure	Port Labour	Other Functions
Public service port	Public	Public	Public	Public	Majority Public
Tool port	Public	Public	Public	Private	Public/Private
Landlord port	Public	Public	Private	Private	Public/Private
Corporatized port	Public	Private	Private	Private	Public/Private
Private service port	Private	Private	Private	Private	Majority Private

Ship sizes have increased dramatically during the last decade, which has resulted in the emergence of a hub-and-spoke structure. This has resulted in a network structure with mega ports along main trade routes serving mostly as transshipment hubs where containers are loaded from one ship to another. From these hubs, feeders are used to ship the goods to the final destination. Examples of ports with a high share of transshipment are Shanghai, Singapore and Bremenhaven (Person 6, 2021). The world's main transshipment markets and transhipment shares can be seen in *Figure 4.12*. Transshipment incidences are classified into one of four categories ranging from low (< 25 %) to very high (> 75 %). As can be observed in *Figure 4.12*, a lot of the transshipment hubs can be found in China, in the middle east, along the Suez Canal and in Europe (Notteboom et. al, 2021). A full list with transshipment rates can be found in *Appendix 1*.

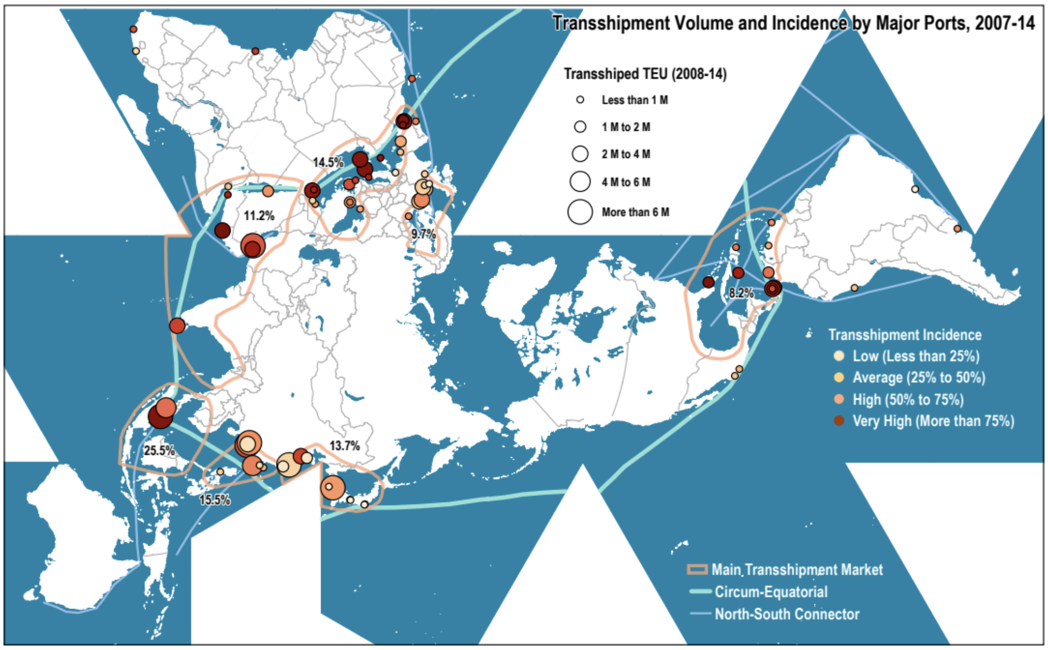


Figure 4.12 Main Transshipment Markets (Notteboom et. al, 2021)

Containers that are not transshipped to other vessels generally have three options for further transportation namely truck, train and barge. The latter is not considered as a real option in most cases, which means that the goods have to leave the port by either truck or train. The share between these two options varies depending on the infrastructure around the port as well as the infrastructure in the country or region where the port is located (Person 6, 2021). Examples of shares are presented in *Table 4.5* below.

Table 4.5 Modal Split for in/out Transportation of TEUs to Ports in Selected Countries (Person 6, 2021)

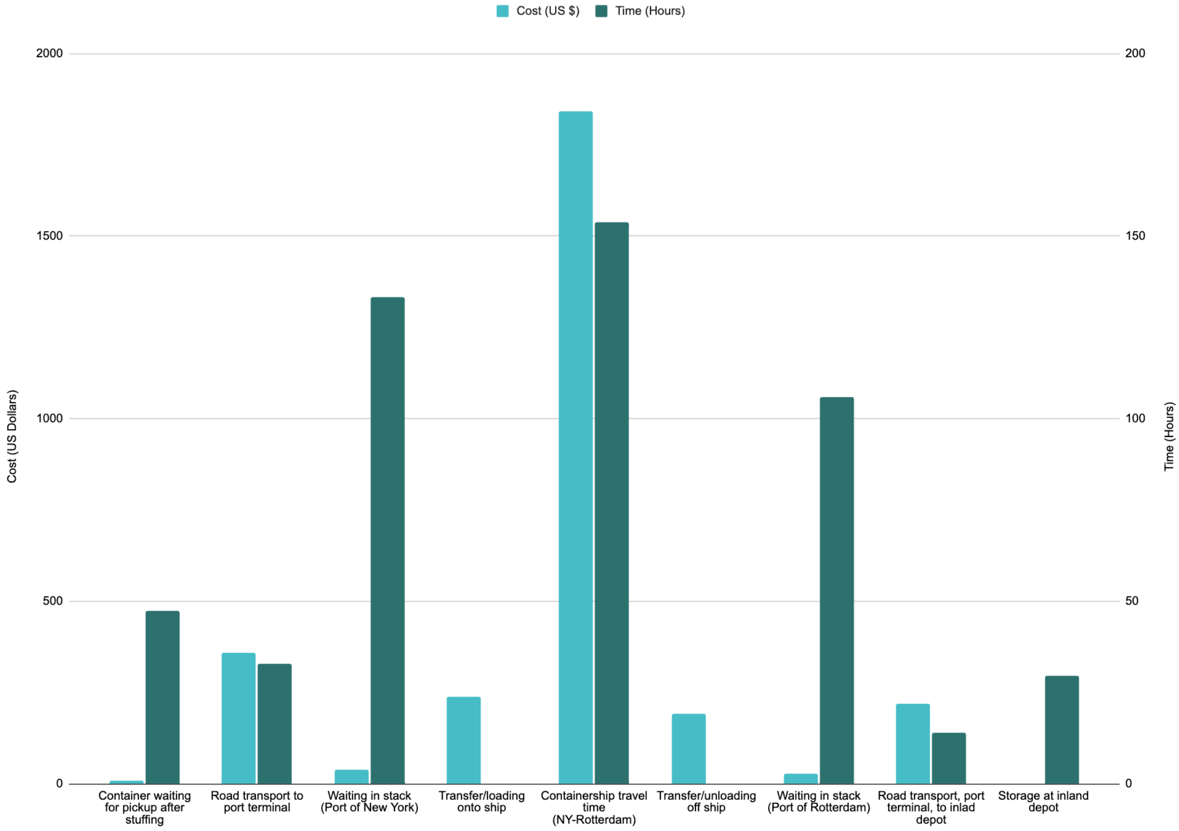
Country	**Truck**	**Train**
China	70 %	30 %
United States	50 %	50 %
United Kingdom	70 %	30 %
France	60 %	40 %
Germany	80 %	20 %

While breaking down the handling cost of containers and the time spent in different stages of the handling process, a better understanding of the operating variables are gained. In a study done by Mr. Jean-Paul Rodrigue, the total cost and time spent in different stages for a forty-footer container transported from New York to Rotterdam in the Netherlands was estimated. The data is collected from a transport done in the late 1990s. The total transportation cost was 3,500 US Dollars and the container spent a total amount of 540 hours in transit (Rodrigue, 2006). In *Table 4.6* a cost and time for certain activities are presented as a share of the total. A graphical presentation can be seen in *Diagram 4.5.*

Table 4.6 Percentage Breakdown of Cost and TIme for the Transportation of a 40-foot Container from New York to Rotterdam (Rodrigue, 2006).

Country	**Share of total cost**	**Share of total time**
Container waiting for pickup after stuffing	0,30 %	8,80 %
Road transport to port terminal	10,30 %	6,10 %
Waiting in stack (Port of New York)	1,10 %	24,70 %
Transfer/loading onto ship	6,80 %	0,00 %
Container ship travel time (NY-Rotterdam)	52,60 %	28,50 %
Transfer/unloading off ship	5,50 %	0,00 %
Waiting in stack (Port of Rotterdam)	0,80 %	19,60 %
Road transport, port terminal, to inlad depot	6,30 %	2,60 %
Storage at inland depot	0,00 %	5,50 %

Diagram 4.5. Breakdown of cost and time for the transportation of a 40-foot container from New York to Rotterdam (Rodrigue, 2006).



4.3.1.4 Customer Drivers

Processes for adaptation of new technology has been described as a combination between technology limits and customer demand (Tripsas, 2007). Looking at the customer demand side in ports there is always a strive towards effectivisation. Operators are focusing on the parts in the process that are incorporating the most expensive equipment of the process. In a port, calling ships are the most valuable asset, together with the quay cranes used for loading and unloading the ships. Therefore, port operators always work to minimize the time in port for the vessels and shorten the ship turnaround time (Person 19, 2021). Other processes in the port serve to make this happen. One example is optimization that is being done in the stack on the quay to make sure that the containers are arranged in the correct order before they are being loaded to the ship (Person 6, 2021). Efficiency is measured by the amount of moves done per hour by the quay crane (Norefelt, 2021).

Port operators are constantly working to eliminate bottlenecks in their operations. According to Person 6, associate professor at The University, the most common bottleneck in the container handling process is the quay crane used for loading and unloading containers to the vessel. Other bottlenecks can be found at the gate where trucks might cause congestion when they are arriving at the port at the same time (Person 6, 2021).

Over the last years, the maritime industry has seen a rapid change in vessel sizes. Looking six or seven years back the largest ships carried around 10.000 - 14.000 TEUs. Today, that number is up to

20.000 TEUs per vessel, which is almost a duplication in size in less than a decade. This has resulted in limitations for carriers, since not all ports have the capacity to accept calls from the new mega ships. Furthermore, this change has driven the network towards a hub-and-spoke structure, with big ports serving as transshipment centers and smaller ports only used for import/export. Looking at the port side, this creates shockwaves in the operations when a mega ship calls (Person 6, 2021). To handle this, ports have to invest in infrastructure on the land side including quay cranes and vehicles together with water preparations, such as increasing the depth in the harbor. There is also a focus towards automation (Norefelt, 2021).

The increase of the batch sizes of containers when a ship calls a port as a result of the increase in vessel sizes has forced port operators to be able to handle greater peaks and container volumes. If the port does not have a constant inflow of big vessels calling the port, this might result in a decrease of utilization (Norefelt, 2021).

Ports have previously been described as complex machineries with many different stakeholders trying to collaboratively work together in an efficient manner to push down ship turnaround times and increase container throughput. One of the most common bottlenecks in the port is the gate where external trucks have to be checked in to either leave or pick up containers to the port (Person 6, 2021). Once a container has reached the stack the ownership and responsibility for the goods is transferred from the shipper to the customer. This customer usually contracts logistics companies to complete the delivery and transport the container from the port to its final destination (Person 13, 2021). Since transportation is done by several different haulage contractors, ports have a hard time optimizing the flow and forcing trucks to bring load both to and from the port to maximise the amount of containers transported for every gate call. To address this problem, Port Alpha has released an initiative to tap into excess capacity and increase efficiency. The solution has been to introduce economic incentives to motivate haulers to bring cargo both ways, meaning they get money from the port everytime they manage to optimize their own routes (Person 5, 2021).

4.3.1.5 Automation Readiness

The very first automated container port was developed in Europe in the beginning of the 1990s. Since then, many ports have installed equipment to automate at least some processes in their terminals. By 2018, close to 40 partly or fully automated ports do businesses in various parts of the world, and an estimated amount of 10 billion dollars has been invested in such projects. From an overview standpoint, container ports seem like an ideal place to automate, since the physical environment is structured and predictable. Furthermore, many activities are repetitive and straightforward. They also generate huge amounts of readily collected and processed data and the value from automation includes not only cost savings, but also performance and safety gains for the ports and the people and companies that do business in the area (Chu et al, 2018).

However, ports are moving more slowly towards full automation compared to other sectors with comparable complexities, partly because the economics of automating them have not lived up to the expectations. In some cases the return on investment has fallen to around one percent while the industry standard is around eight percent. For instance, automation has decreased costs in the mining sector, which also is a process and asset intensive sector, by 20 to 40 percent. In the warehousing business, automation has decreased costs with 10 to 30 percent. Car manufacturing facilities and truck manufacturers have also successfully automated complex processes and many of the equipment they use, for instance automated guided vehicles and materials handling robots, are very relevant for large ports (Chu et al, 2018).

Another obstacle for automation that has affected the port segment harder than other similar industries is the mindset regarding protection from employees losing their jobs to robots and automation. When it comes to ports, this can be a sensitive area since it is a workplace that has been around for several hundred years (Person 4, 2021;Person 3, 2021). Countries have different powered unions which is one reason why the development is quicker in some countries compared to others (Person 14, 2021). Looking at the American market, the automation process of ports has been much slower than the same process for the warehousing industry where Amazon is a great example of a company implementing automation very quickly. One reason could be that warehousing does not have a unionized labour market, while the port industry has a strong union (Person 5, 2021).

The port industry has historically shown thin margins while the upfront investments for automation is huge. Generally speaking, the initiative to automate one container terminal requires at least an investment around 400 - 500 million dollars. Additionally, the daily operations and everyday business has to be shut down to rebuild the terminal, leading to labour that needs to be moved out and ship calls that need to be declined. All in all, this summarizes to a huge upfront cost. Together with thin margins, long payback times and uncertainty regarding the actual efficiency gains, ports have a hard time attracting the required capital for such upfront investments (Person 5, 2021).

Even though the adoption of automation has been slow in general, examples of vehicle automation in ports can be traced back to the beginning of 1993 when the big container terminal in Rotterdam in the Netherlands first incorporated Autonomous Guided Vehicles (AGVs) in their operations. Another example is the port of Singapore (Hock-Guan et. al 2001). AGVs traditionally operate between the quay-cranes and the container stack (Person 6, 2021).

In general, European ports are in front of American ports when it comes to automation. In America, there are four automated facilities in all ports in the country. There are a total of between 70 and 80 terminals in America, making the share that is automated a rather small percentage. In the port of Hamburg only, there are a total of four automated terminals (Person 5, 2021).

4.3.1.6 Port Case Studies

Port Alpha

The Port Alpha handles 9,3 million TEUs/year. In 5 out of 6 cases, the containers are loaded with quay cranes onto yard equipment that are driven by humans. The yard equipment is most often a terminal tractor that drives the container to a container stack in the area. The stacks are usually four containers wide, 3 containers high and 300-400 meters in length. When the stack area is full, it is changed to a delivery area where an over-the-road truck will enter the port area and via a machine get the container loaded onto it. This is the case of 70 % of the containers, and the other 30 percent of the containers are driven with a truck to the train station within the port area. Out of the containers leaving the port with trucks, 30 percent are transported no more than 40 kilometers before they are transloaded in a warehouse. A rather large share of that percentage is eliminated if the distance is decreased to 20 kilometers. Port Alpha has one automated terminal facility as well. Here the process steps are the same but the lifting and the moving are done in an automated environment. When containers are being exported, the process is almost identical but the other way around. Out of the containers entering the port area via sea, no more than 1 % is transshipped (Person 5, 2021).

One facility in the Port Alpha has tried a concept where they have several parking spots outside the port area and a machine will take the container from the stack to the parking lot. 4 - 5 % of the total container flow goes to a local railyard that is situated a couple of kilometers from the terminals. That container flow is repetitive with very few variables (Person 5, 2021).

Figure 4.13 Example Port 1 (Kim, 2016)

Port Beta

Right next to the Port Alpha is the Port Beta that has 6 container terminals, just like the Port Alpha. Port Alpha and Port Beta are two separate authorities, operating in the same zone. All of the operators in the Port Beta except one operate in the same way as the terminals in the Port Alpha. The one that operates in a different way loads off the containers and puts them to a place of rest. From there another truck takes the container and drives them to a dry port facility a few miles inland where it is later picked up by the end user. This way, the truck does not have to enter the port area. However, there are very strict labour restrictions regarding this. For instance, the container needs to stop inside the facilities, go to a place of rest, and then a second carrier can move it. Therefore it is very hard to effectively load a container to a truck and then drive it out from the port. Even in an automated environment, the same steps need to be carried out (Person 5, 2021).

For both Port Beta and Port Alpha, there are a total of 15 000 external over-the-road trucks operating every day, and 9000 of them call more than once a day. There is a big area of warehousing around 15 miles away from the port and another one around 60 miles away. Most of the cargo goes to these areas. This distance to the closest warehousing area in both Port Alpha and Port Beta can be considered a bit longer than usual. This is due to the fact that Port Beta and Port Beta are rather old ports and those tend to be a bit farther away from the urban core where the warehouses are. Many other ports in the US have the warehouses right next to the port. The external over-the-road trucks are allowed to run inside the port 16 hours a day, in both Port Alpha and Beta. In addition, there are around 100 trucks for internal use per terminal in boths ports, making a total of 1200 trucks in total in the area. The total handling process of a container in those ports is around 400 american dollars, out of which the port gets 50 dollars, where at least 50 % of that amount is going to labour (Person 5, 2021).

Port Gamma

The Port Gamma has an annual throughput of around 3 million TEUs/year and the volume is projected to grow up to 8 million TEUs by 2050 (Person 7, 2021). The port follows a landlord structure with Port Gamma Operations Pty Ltd serving as the landlord with the function to provide infrastructure such as wharves, roads, rail, pavements, buildings and cargo yards. The space is then rented out to stevedores, freight companies, trucking companies, etc. (Person 7, 2021).

The main stevedore operations of the port are divided into two precincts for handling containers, one called Dock 1 which is "up-river" and the other named Dock 2 which is "down-river". There are a total of three container terminals and two are located in the up-river precinct and one in the down-river area. The latter is a fully automated container terminal with automated quay cranes, straddle carriers and stacking cranes. When containers are to be moved between the up-river side and the down-river side, trucks are used travelling 6 kilometres on public roads (Person 7, 2021).

There are two main options for transportation of containers to or from the port, namely transportation via truck or via rail. Transportation via truck represents over 90% of the container volume with the remainder on rail (Person 7, 2021). Containers arriving at the port have three days to leave the stevedores. If the cargo owners fail to remove the goods within this time frame, they are obliged to pay demurrage. Imports are typically staged at warehouses and intermodal hubs across Gamma City, 87% of full import containers are delivered to destinations located in the metropolitan Gamma City area. There are currently three metropolitan intermodal hub areas in Gamma City. Metropolitan intermodal hubs are located to the south-east of the port (around 50 kilometres away), to the west (around 15 kilometres away) and to the north (around 25 kilometres away) (Person 7, 2021).

There are approximately 7,000 trucks entering the port each day, many of them carrying up to 4 TEUs (Person 7, 2021). For goods transported via rail there are two on port intermodal terminals and one on dock intermodal terminal. Two intermodal terminals are open access, meaning that any train operator can use these terminals. These intermodal terminals are located within 2 kilometres from the up-river container terminals and the distance between the stevedores to the intermodal terminal is completely within the port area. The other intermodal terminal is on-dock inside an international terminal in the up-river area. This terminal can handle shorter trains up to 550 meters, while the trains arriving to the on port intermodal terminals can be up to 1500 meters long. There is an initiative to build one more on-dock intermodal terminal and this will be up and running in the up-river area in 2023. There is currently no intermodal terminal in the down-river area (Person 7, 2021).

The Port Gamma has a fairly balanced trade of import versus export, even though there is more import. There is roughly 60 % import and 40 % export (Person 7, 2021). Although, there is an imbalance between 20-foot containers and 40-foot containers created by the difference in types of goods exported and imported. Gamma City has a tradition of exporting agricultural products such as grains, tinned fruit, meat and sawn logs and these commodities are freighted in 20-footers because of their higher weights. Looking at the import side, trade such as clothing and electronics are imported from Asia. This is traditionally transported in 40-footers. This imbalance between the different container sizes creates an empty container imbalance. To mitigate this issue, the port is reviewing options for more near port empty container storage (Person 7, 2021).

Port Delta
Port Delta Terminal is the container port within Port Delta. The port is a landlord port with three different terminal operators and a total container throughput of 2,6 million TEUs 2019. The three different terminal operators and their container handling process varies a bit from each other (Person 3, 2021).

They all have the same process when a ship reaches the port, where manual quay cranes empty the vessel. In the case of Terminal 1, an inter terminal vehicle driven by a human, arrives and picks up the container after it has left the vessel. After the container has reached the terminal with the inter terminal vehicle, a rubber tired gantry truck comes and transports the container to the stack. From here, either a truck from outside the port arrives at the stack and picks up its container with help from the rubber tired gantry truck. The other option is for the inter terminal vehicles to transport the container from the stack to the inter terminal rail yard where forklifts are used to load and unload the trains (Person 3, 2021).

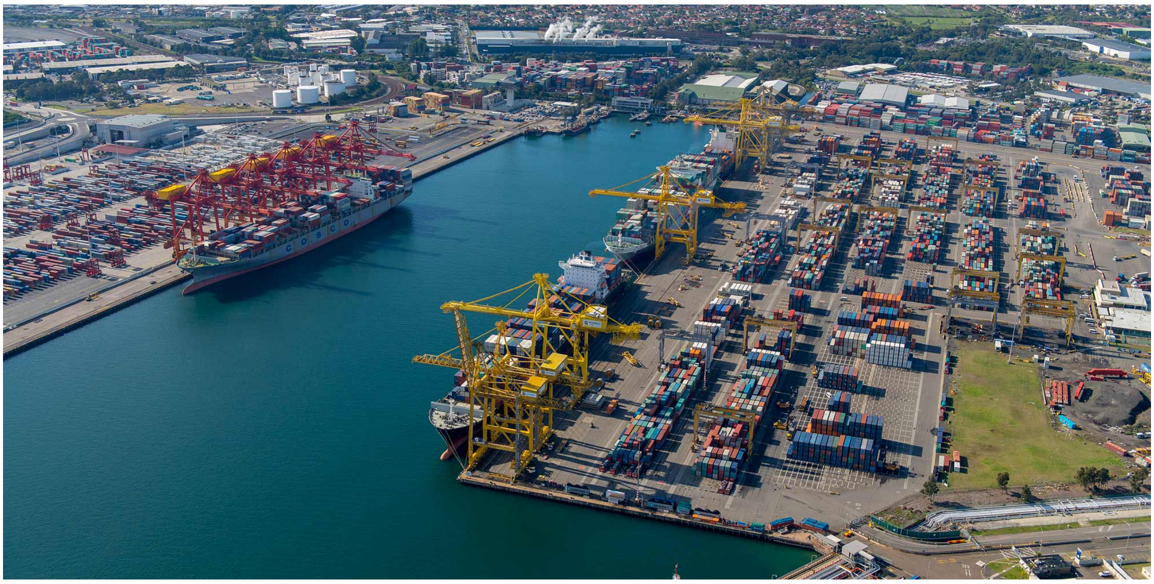


Figure 4.14 Example Port 2 (Coles, 2020)

In the case of Terminal 2, once the container has left the vessel, it is picked up by autonomous straddle carriers that transport the container to the container stack. The autonomous straddle carriers then also transport the containers from the stack to the truck grits and after that they also load and unload the trucks with containers. For the moment the process where containers are loaded and unloaded from the train is carried out by forklifts. However, Terminal 2 is building a new rail terminal that will be fully automated in collaboration with the automated straddle carriers. This is expected to be ready in the near future (Person 3, 2021).

In the case of Terminal 3, manual straddle carriers are used to transport the containers to the stack. However, the stack blocks are automatic with automatic stacking cranes that can stack the containers in blocks that are 5 containers high and 10 wide in a fully automated system.The trucks arrive at the stack block where the stacking cranes then can load and unload the trucks with containers. The containers that are transported out with rail are transported to the rail yard with the manual straddle carriers and loaded onto and off the train with forklifts (Person 3, 2021).

Delta City and The Country in general are import dominant which creates an imbalance between full containers coming in and full containers going out. Of the exported containers, 65 % are emptied. This means that every port in The Country needs empty container parks that can both be owned by the terminal operators, but also be private companies. Port Delta has 10 empty container parks where a majority is located 3-5 kilometers from the port. The road to the majority of the empty container parks are mostly private roads with some parts that are public. To transport the containers back to the port, trucks are used predominantly, but trains are also used to some extent. Every day, shipping lines call the empty container parks and instruct the number of empty containers that they want to pick up when they arrive. A regular case can be 350 containers, where then around 50 trucks are used to transport the containers in 6 laps to the port (Person 3, 2021).

Overall, 16-18 % of all containers leave the port with trains and the rest leaves the port with trucks. Because of the location of The Country, only around 150 000 containers out of 2,6 million are transhiped, mostly to the neighbouring country (Person 3, 2021).

Port Epsilon

The Port Epsilon had a container throughput of 0,8 million TEUs in 2019. After the load off by quay cranes, the container handling process differs from the process in Port Alpha and Port Beta. The containers are transported by straddle carriers to a yard block, manually. As soon as the container reaches the yard block, the responsibility is put on the shipping company again. The shipping line then sends a haulage contractor that collects the container. It is up to a haulage contractor to notify the port when they want to come and pick up the container at the facility. When they notify the port, they get a code instructing them which gate to use to come and pick their container. Port Epsilon has two gates, and depending on where in the terminal the container is located, the haulage contractor will get informed to go to either gate 1 or gate 2, to optimize the driving distance of the internal machines in the port. The gate is today totally automatic and the driver from the haulage contractor needs an ID-code to get past it. When the driver is through the gate, an order is activated for the internal machines to go and get the container and place it on the truck that has parked at a given squared area. The driver can after that leave and the transaction is done. The same goes for the export of containers, but the flow is the opposite direction (Person 13, 2021).

60 % of all containers that reach the Port Epsilon follow the steps described above before leaving the area with a truck, and the other 40 % are leaving the port by train. The transshipment share is very small since Epsilon City is a destination far up north and most often the last destination on a route. The port has a goal to decrease the truck share to 50% and increase the rail share to 50%, creating a 50/50 relationship between the two main ways to exit the port. A large share of the haulage contractors that transport the containers from the port, transport them to Epsilon Suburb which is an area 10 kilometers from the port containing several large warehouses. Epsilon City also has a Container Freight Station (CFS) for paper. For the moment the port uses 6 terminal tractors and wagons transporting containers containing paper to a change area where a straddle crane picks up the container and puts it in park. The distance between the park and the CFS is between 500 and 600 meters. That flow constitutes one fifth of the containers exported from the port every day (Person 13, 2021).

Port Zeta Alliance

The Port Zeta Alliance consists of two ports working together, hereby referred to as “First Port” and “Second Port”. The alliance handles a total of close to 3,8 million TEUs per year and of those, 3 million TEUs comes from the international container trade. The balance between import and export is fairly equal. The port uses a landlord model and the land is leased out to the stevedore companies operating the port and the contracts range from 20 - 50 years (Person 24, 2021).

The First Port has two container terminals and the Second Port has three terminals. Together, these five terminals make 32.000 vessel lifts per week. All kinds of automation are applied to the processes, but the actual equipment (such as vehicles and cranes) are not automated at all. Hence, there are no AGVs working on the quay side. The reason for this is mainly that each terminal is rather small and the huge upfront investment can not be motivated, although they believe that the price of the autonomous technology eventually will reach a level where it is financially defendable to implement it (Person 24, 2021).

Due to the local regulations trucks are allowed to pull trailers larger than 40 feet. Since most of the seaborne trade comes in 40 feet equivalents, transloading is often done close to the port. There are many private companies with warehouses around the port area and a lot of transloading is happening within a 20 kilometers radius and the closest ones are within 1 kilometer away. It is estimated that 70 % of the 15.000 trucks that work around the two ports only work with short distance transportation from the port area to nearby warehouses for transloading. The truck and train ratio has gone from being 50/50 ten years ago to be around 70/30 to the truck advantage. The reason behind this is new policies making it more expensive to take the train in the Country than to transport the goods via a nearby Country by truck (Person 24, 2021).

4.3.2 Logistics Centers

The technical solution studied in this Master's Thesis is suitable for short distance transportation where trucks or terminal tractors are currently used (Person 16, 2021). Therefore, applications for logistic centers where trucks are loaded and unloaded together with hubs for air freight are areas of interest. Hence, one of the focus areas in the empirics section is trying to identify the market for these two sub segments.

4.3.2.1 Layers of logistics

To properly understand the industry of logistics services, it is fundamental to understand the different layers of logistics. There are traditionally four layers of logistics services ranging from First Party Logistics (1PL) to Fourth Party Logistics (4PL). Each layer of service levels requires a certain amount of supply chain integration and as farther up in the hierarchy you reach, a greater amount of integrations is required for creating complex network structures (Rodrigue, 2020).

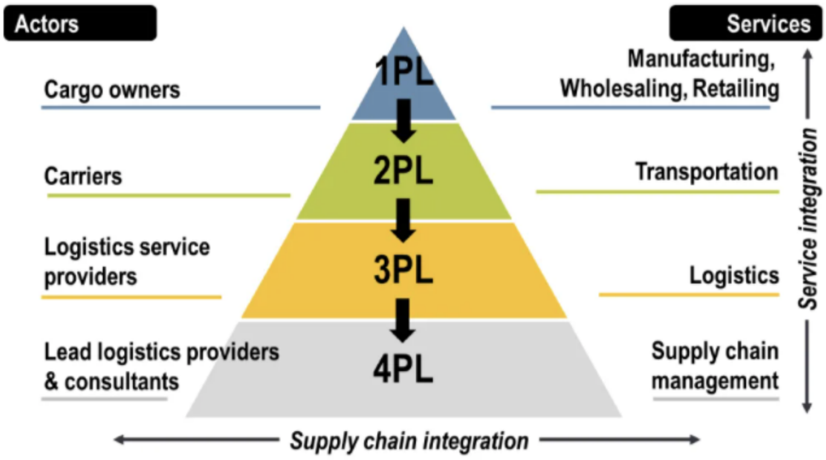


Figure 4.15 Layers to Logistics Services (Rodrigue, 2020)

First Party Logistics (1PL)
First party logistics refer to the cargo owners, which can either be the *shipper*, i.e. the manufacturing firm shipping to its clients or *the consignee*, i.e. a retailer shipping goods from a supplier. The 1PL-part determines the supply and the demand (destination) for the freight that is being transported. Globalization has driven the development towards outsourcing and offshoring of manufacturing, which has resulted in the change for logistics to be handled as an internal function of a company to being outsourced to companies higher up in the freight hierarchy (Rodrigue, 2020).

Second Party Logistics (2PL)
Refers to the function when a company provides transport services on a certain part of the transport chain, e.g. shippers providing maritime transportation from China to Europe or a trucking company which hauls freight from a production facility to a warehouse (Rodrigue, 2020).

Third Party Logistics (3PL)
3PL refers to companies that organize a variety of tasks related to the physical distribution chain and can have a stake in specific transport segments. These companies typically own physical assets and

services can include terminal operations, warehousing, easier labeling or packaging and transloading (Rodrigue, 2020).

Fourth Party Logistics (4PL)
Commonly serving independently as neutral actors companies, 4PL companies orchestrate the complete supply chain structure. These are specialized consultants that help manage other companies' supply chain strategy and their services can include outsourcing decisions, routing of cargo and supplier selection (Rodrigue, 2020).

4.3.2.2 Flows and operations

On a high level, logistics aims to transport freight from point A to point B in the most efficient way possible. Logistics is traditionally focusing on transportation and warehousing, which includes choices of transport modes, terminals and time scheduling (Rodrigue, 2020).

Once the goods are completed in the manufacturing process, it is moved to a warehouse until it is sold. A warehouse is often designed to store products or goods for a longer time period and it is driven by the supply from manufacturers or wholesalers (Rodrigue, 2020).

Moving forward in the chain, distribution centers are to be found. Facilities falling into this category have the objective to consolidate, package or store goods that are sold and are in transit towards their final destination. A distribution center often has one geographical market which it serves and it can be seen as a hub-and-spoke network (Rodrigue, 2020). Depending on the purpose of a distribution center, it can have different designs. For larger regional distribution centers, trucks are commonly docking directly to a dock where workers unload the goods and move it inside for further handling (Person 14, 2021). Another example is centers for international goods that are going to be delivered with planes. For this occasion gateways are used to consolidate goods and deliver to airports for further transportation via big air freight hubs around the world (Person 11, 2021).

4.3.2.3 Market Size

The global freight forwarding industry met its first contraction in 2019 since the financial crisis. The slowdown in the global economy and global trade has been strong factors affecting the industry in this direction. Since the freight forwarding business is non-asset based, the sector is facing high competition from other players in supply chain and other technology based companies. This is disrupting the freight forwarding market (Mordor Intelligence, 2020).

The global road haulage market size was valued at 2811,7 billion USD in 2018 with an expectation to grow at a compound annual growth rate of 5,5 % from 2019 to 2025. There has been a significant rise in the global production of trucks in line with the increasing freight demand from industries such as retailing and manufacturing. However, factors such as massive shortage of heavy vehicle drivers and the high exposure of drivers to road traffic injuries are limiting the growth more and more. Road accidents occur due to factors such as poor road maintenance, rapid motorization, lack of safety features in the vehicles, increasingly crowded roads and a lack of police enforcement. Furthermore, the negative environmental impact diesel engines have and the need to adhere to stringent emission norms are also expected to decrease the market growth (Grand view research, 2019).

In 2020, the global cargo airline industry was valued at 110,8 billion US dollar and the expectation is a growth to 123 billion US dollar in the year of 2021. There has been a great increase in total freight volume the last couple of years and by 2020 the total volume reached a total of 54,2 million metric tonnes (Statista, 2021). Freight is carried in *Unit Load Devices* (ULDs) and one airplane has the capacity to carry 10 - 30 ULDs depending on the types of the ULDs carried (Person 26, 2021). An example of a ULD size is the LD-3 Unit Load Device, which has a maximum net capacity of 1 506 kilograms (Thomson, 2019).

Figure 4.16 Unit Load Devices (ULDs) (Wikimedia Commons, 2008)

4.3.2.4 Market Segmentation

4.3.2.4.1 Demographics

When segmenting on type, the market for road and air freight can be divided into two types, namely international goods transportation and domestic goods transportation. Within the road segment, domestic transport is dominating with more than 60% of the market in 2018 (Grand view research, 2019). The flight distribution is the other way around where international transportation accounted for 87 % in 2019 (IATA, 2020).

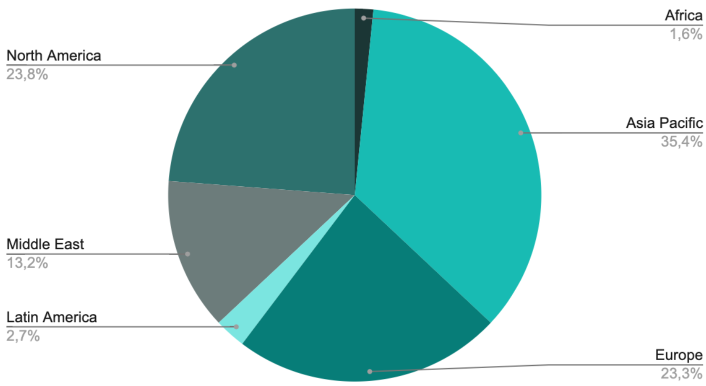
Switching focus to total inland freight in the world, huge differences between countries are observed. In data provided by OECD, the total million tonne-kilometers for inland transportation is summarized. China is the top country in terms of million tonne-kilometers, with a total amount of approximately 15,2 billion tonne-kilometers per year for 2019. The second country on the list is the United States with a total amount of 6,4 billion tonne-kilometers (OECD, 2021). A full list can be seen in *Table 4.7.* below.

Table 4.7. Inland Tonne-Kilometers 2019 (OECD, 2021).

Group	Inland million tonne-kilometers
China	15 249 700,00
USA	6 352 579,80
India	3 094 502,00
Australia	627 430,40
Germany	493 577,00
Poland	469 161,00
Mexico	347 733,00
Turkey	336 524,00
Japan	233 953,00
France	232 406,00
Italy	159 127,00
Netherlands	103 344,00
Lithuania	69 630,00
Sweden	65 366,64
Hungary	58 596,24
Czech Republic	57 858,79
Austria	49 952,80
Slovak Republic	43 305,00
Finland	39 239,00
Portugal	33 917,20
Latvia	31 113,00
Switzerland	29 637,30
Norway	29 614,00
New Zealand	29 202,34
Greece	28 688,00
Ireland	12 475,00
Luxembourg	7 959,15
Slovenia	7 598,00
Estonia	6 950,00
Iceland	1 195,00

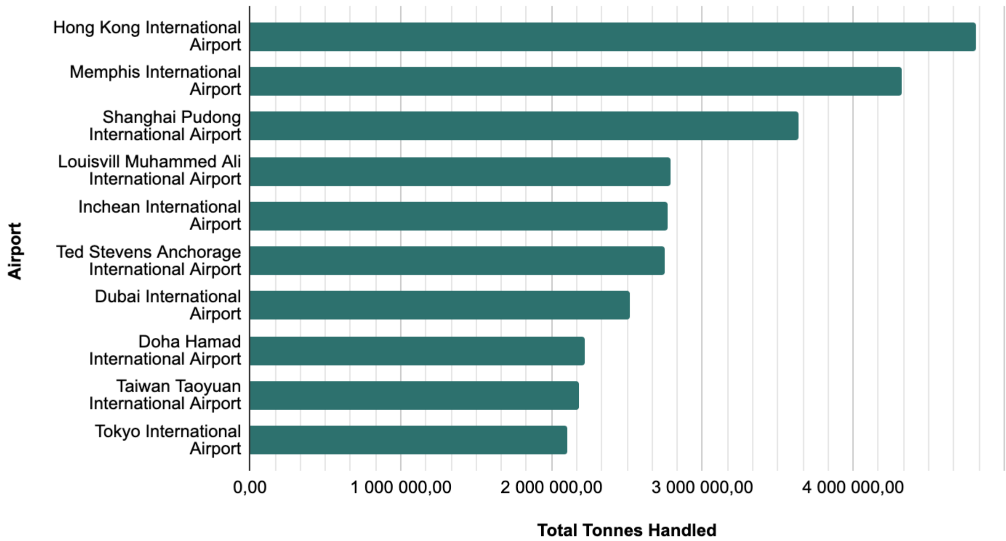
Zooming in to the share of total air freight divided by continent, the Asia Pacific region can be considered to account for the greatest share of freight handled. 35,4 % of all air freight was handled here. In second place with 23,8 % of the global air freight share, North America is to be found. This is followed very closely by Europe with a share of 23,3 % (IATA 2019). A complete summary can be seen in *Diagram 4.6* below.

Diagram 4.6. Share of Total Air Freight (IATA 2019).



As previously mentioned, a hub-and-spoke network is commonly used for air freight logistics. This results in the appearance of hubs which forward great volumes of air freight. The biggest hub for air freight in the world is Hong Kong International Airport with almost 4.8 million metric tonnes handled in 2019. For a complete list of the 10 biggest air freight hubs, see *Diagram 4.7* below (International Airport Review, 2020). A full list can be found in *Appendix 2.*

Diagram 4.7. 10 Biggest Air Freight Hubs (International Airport Review, 2020).

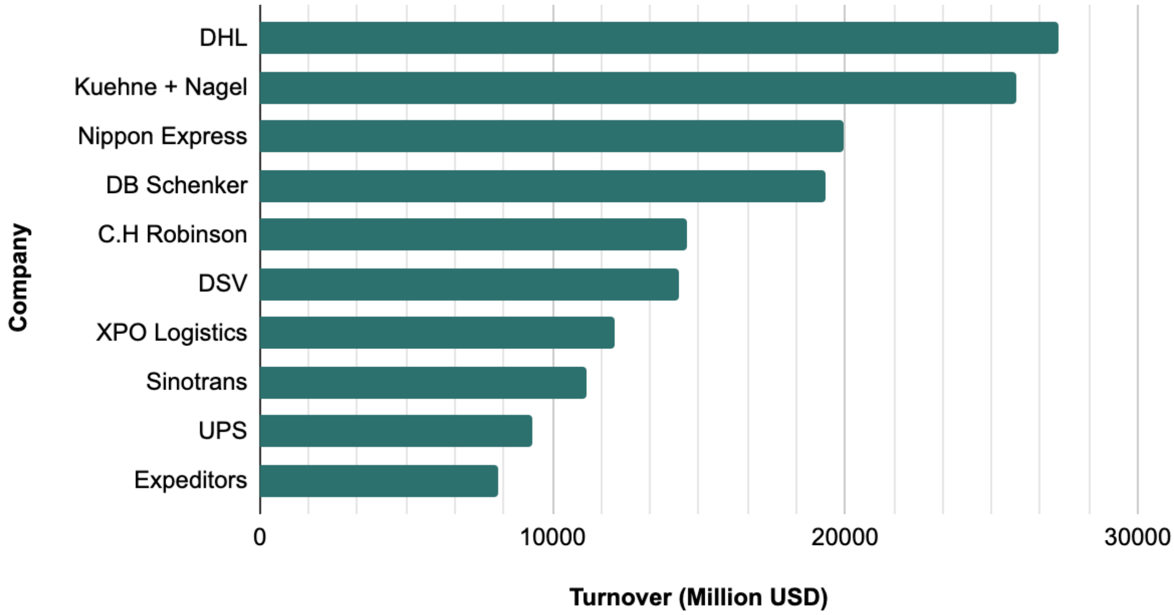


To get an understanding of how an air freight hub is operating, DHL hub in Leipzig will be used as an example. The hub handled 1 147 233 tonnes of cargo in 2019 and the facility is 2 million square meters in size. This freight center includes a network of 120 000 addresses in more than 220 countries. Up to 60 aircrafts start and land here every day and a fully automatic system controls the parking positions which means that the manual guidance of the ramp marshalls is not needed anymore. The apron is covering an area that is 500 000 square meters with parkings spots for 52 aircraft at a time. As soon as the aircraft stands still on its parking spot the ground staff starts unloading the aircraft with high loaders and just a short time later the aircraft will have been loaded with a new freight after which the plane can rise to the sky again. The ULDs are transported to the warehouse with tow trucks and trailers.

4.3.2.4.2 Operating Variables

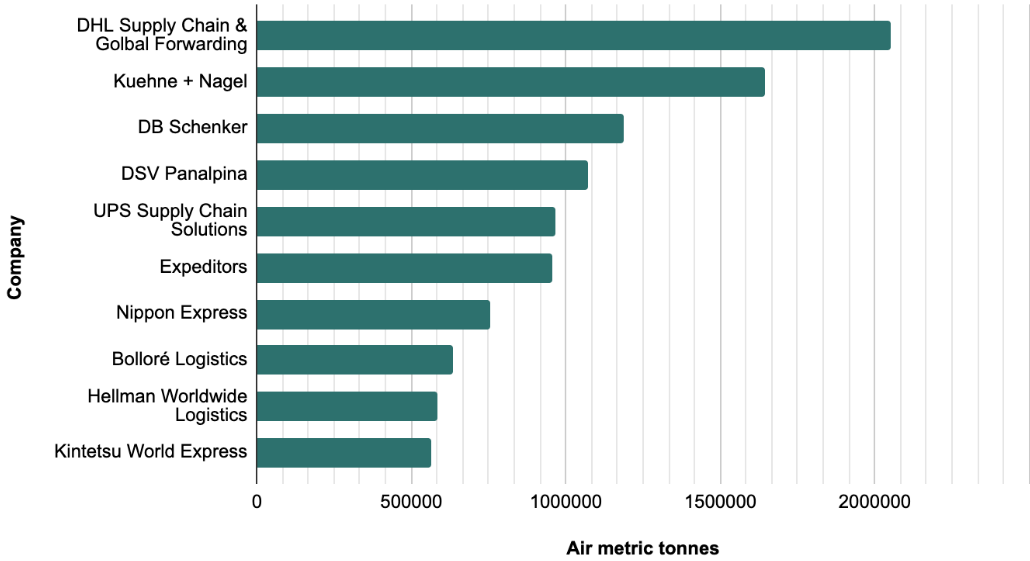
The global freight forwarding market contains a large number of players but the top 20 companies dominate with a combined market share of 50 % (Mordor Intelligence, 2020). In *Diagram 4.8* below the 10 biggest freight forwarding companies are found.

Diagram 4.8. 10 Biggest Freight Forwarders by Turnover (Mordor Intelligence 2020).



Among the leading companies within the air freight industry, DHL Supply Chain & Global Forwarding is found in the top of the list of 2019 with right above 2 million metric tonnes handled. They are followed by Kuehne + Nagel in second place and DB Schenker in third position. The top 25 air freight forwarders faced a total decline of 7,8 % during 2019 (Brett, 2020). A full list of the top 10 companies are shown in *Diagram 4.9* below.

Diagram 4.9. 10 Biggest Air Freight Companies by Volume (Brett, 2020).



4.3.2.5 Customer Drivers

Looking at the distribution and factors influencing the flow of products and goods from manufacturer to end-customer, disintermediation is identified as a trend. As manufacturers seek to find alternative ways to increase their profits, owning their own distribution channels appears to stand out. In a report from 2019 written by McKinsey, 100 senior manufacturing executives in the United States answered a survey. The results showed that direct channels from manufacturers to customers will increase leading to a decreased amount of goods handled by retailers and distributors. The tire manufacturers Bridgestone and Goodyear served as an example with their joint distribution partnership TireHub (Abdelnour et. al, 2019). This changes the traditional distribution chain, by cutting out the middleman.

One main factor driving the development within the industry is environmental sustainability. Both Logistics Beta and Logistics Alpha have implemented delivery with bicycles in larger cities and alternative fuels instead of diesel has been implemented to some extent (Person 11, 2021; Person 12, 2021). Within this area, there is also constant improvement work with increasing the degree of filling, especially on the way back from the delivery location. It is common for customers to require the freight company's actions towards more environmentally friendly and sustainable processes in the RFQs making the sustainability trend of economic interest as well (Person 12, 2021). Logistics Alpha 2 is in the process of replacing their full company car fleet with chargeable hybrids and they also have 10 full-size Mercedes Sprinters that are powered by 100 % electricity to be put into use in Stockholm. The entire Logistics Alpha Group aims to become carbon dioxide free by 2050 (Person 11, 2021).

It is common to measure a freight company's performance by looking at handled shipments per working hour and it is often measured in different parts of the business as well. To balance that measurement it is common to combine it with more qualitative measurements to make sure that the company is keeping up with other softer values like quality for instance (Person 12, 2021). Logistics Alpha 2 has 200 KPIs that can be linked to one single shipment (Person 11, 2021).

In an interview with Max Conrady, senior vice president for Frankfurt Airport in Germany, one of the key drivers towards automation within the air freight industry is the struggle to find competent and experienced people. Mr. Conrady describes that Frankfurt Airport alone lacks 400 - 500 employees per year and automation will be a key driver to maintain productivity and industry growth. (Cargo Airport & Airline Services, 2019).

A key driver for companies within the air freight industry is to reduce costs and one way of doing so is to better optimize the company's fleet of *unit load devices* (ULDs). Initiatives towards a digital system to get control over the positioning of the ULDs is currently driven by Unilode, a company operating 175,000 ULDs around the globe. A better optimization of this fleet can result in 10-15 % cost savings according to the company's CEO Benoit Dumont (Cargo Airport & Airline Services, 2019).

4.3.2.6 Automation Readiness in Logistics Centers

The concept of 'industry 4.0' with an integrated supply chain with all value-adding functions connected through digitalization has laid the foundations for 'logistics 4.0' which presents trends for the future of logistics activities (Ozken-Ozen & Yvas, 2020). Automated Guided Vehicles (AGV) are for instance used in warehouses (Juntamo & Yinbo, 2016). Other types of autonomous vehicles are also predicted to emerge ranging from smart driver assistance functions and platooning where several automatic units follow one lead vehicle driven by a human being, to fully autonomous solutions (Horenberg, 2017). Logistics 4.0 is followed by a broad implementation of all technology to integrate handling management, information management, transportation management and warehouse management in what is called 'logistic center 4.0' (Ozken-Ozen & Yvas, 2020). Steps towards this direction can be found today already, with autonomous systems for container unloading in distribution centers (Bonini et. al, 2015).

The usage of automatic robots have been more common lately in the industry. For instance plastic wrapping robots, cleaning robots and robots doing inventory. The inventory robots have shown to be very efficient since they can operate during the night and perform wall-to-wall counts which is a huge saving compared to having employers doing it during nights or weekends. One great improvement for the industry has been that robots today do not need new infrastructure in terms of loops in the floor and dedicated routes. Instead they now function in the environment that already is present. In general, there is a search for automating low quality work that needs a lot of workforce (Person 20, 2021).

When it comes to terminal traffic, the opportunities for automation have increased largely lately. It is common with standard forklifts that are automated to redistribute the goods inside the terminals to optimize the flows. The level of automation in logistics centers in different countries are very dependent on the costs of personnel, where cheaper workforces decrease the incitement for automation to decrease the salary costs (Person 23, 2021). Looking at warehousing in Sweden, automation has been favourable since it has the potential to decrease injuries, and working in warehouses is seen as an exhausting type of work. In addition, the conversations with the unions have been successful. Although it can vary between countries, almost everything in warehousing is going towards automation consequently. The demand is larger than the technology supply, putting the autonomous solution companies in a favourable position (Person 14, 2021).

In 2018, Frankfurt Airport started the project 'Smart Air Cargo Trailer (SAT)' which is a two-year initiative to increase process efficiency, cut waiting times as well as optimising the resources available. To succeed with the objectives, autonomous vehicles are to be implemented for ground operations and *unit load devices* (ULD) transportation. Using cameras, the system has complete control over cargo units and it can autonomously request a terminal tractor when a ULD is ready to be picked up. The system is cloud-based and accessible all time via smartphone, tablet or computer (Cargo Airport & Airline Services, 2019). Another example of trails of autonomous vehicles in airports are presented by Semcon in collaboration with Örnsköldsviks Airport where an autonomous vehicle has been implemented for keeping the runway clean from snow (Semcon, 2021).

At Toulouse-Blagnac Airport, there is another case of testing autonomous solutions in an airport environment. Using LIDAR, cameras, GNSS and odometer, the vehicle can move cargo (ULDs) around the airport autonomously and the trail aims to increase performance of baggage flow as well as safety. The terminal tractor can drive itself from the baggage sorting area to the aircraft, but once the vehicle approaches the plane it stops and an operator takes over the control of the vehicle (Harper, 2019).

4.3.2.7 Logistics Case Studies

Logistics Alpha 1

Logistics Alpha 1 is one of four companies operating in Sweden within Logistics Alpha Group. Logistics Alpha 1 is first and foremost a 3PL company and the company owns several warehouses in the nordics offering storage solutions, customs services and other services related to warehousing. According to the CEO, the thing that separates Logistics Alpha from the other top tier companies is its details and company culture (Person 20, 2021).

Logistics Alpha 1 is a multinational company with real global presence, which means that they have the power and financial possibility to bring fourth technical solutions at a scale that smaller companies do not have the resources to do. The global presence also means that the company can provide their clients with a global network of 3PL services (Person 20, 2021).

Having five warehousing sites in the middle of Sweden and another four big facilities in the southern parts of the country, Logistics Alpha 1 has a good capacity serving their clients. The company buys haulage services from associated contractors, mostly from their sister company Logistics Alpha Freight (Person 20, 2021).

Freight is coming into the warehouses with trailers from either the continent or via sea from Asia. The truck comes in through the gate and is directly docked to a gate. From there, pallets are unloaded and then brought to shelves inside the warehouse. The process for goods leaving the warehouse is the same, but in a reverse order. In some cases, customers have freight that can be stored in the yard. Although, handling of goods in the yard outside of the warehouses are rare (Person 20, 2021).

Logistics Alpha 1 is currently having a low share of autonomous vehicles operating in their nordic facilities. There are initiatives looking for autonomous forklifts and other types of automation inside the warehouses. There are also projects where short and repetitive flows between warehouses and a terminal are investigated and the possibility for autonomous trucks is evaluated. However, it is estimated that there are a maximum of three to four such cases in total within the Nordics region for Logistics Alpha 1 and a maximum of one truck per location will be needed (Person 20, 2021) .

Logistics Alpha 2
Logistics Apha 2 works in Door-to-Door deliveries, also known as integrated delivery. The company is active in more than 220 countries around the world. Out of the total volume of freighted goods, 50% is business to business and the other 50% is business to consumer. A typical door-to-door process starts with a sender and a contract with Logistics Alpha 2. It is both possible to integrate the customer's own order or inventory software against the Logistics Alpha 2 system, or the customer can use Logistics Alpha 2's system directly. Depending on the volume that the customer wants to send, a booking is made to the system and a fixed daily time is set for recurring pickups or a specific time is set for a one-time pickup. A courier truck then arrives at the location and drives it to a Logistics Alpha 2 gateway or service center where the shipment is processed and prepared for further international transport. For freights outside of Sweden, it is either transported via plane from Arlanda, Landvetter or Örebro or it is transported by truck over the bridge from Malmö to Copenhagen. The next step is a regional hub and from there it is transported by plane or truck to the final destination. Logistics Alpha 2 owns 270 planes and they also have partnered up with several commercial flights (Person 11, 2021).

Logistics Alpha 2 is using a Hub-and-Spoke model with a number of larger facilities which then distribute to local facilities depending on the final destination. At the end of the chain there are service centers with cars for further distribution to the final destination. There are in total 3500-4000 facilities and the company is located in every country in the world where international companies are allowed to enter. There are three global hubs, one located in Hong Kong, one in Leipzig and one in Cincinnati in the USA (Person 11, 2021)

Logistics Alpha 2 truck terminals have very few repetitive transportation routes and therefore small possibilities for transportation automation according to Person 11, Operational Manager in Sweden. The trucks arrive at the facilities early in the morning and after that they are sent out immediately. However, the process looks a bit different in the larger airport hubs. Here, 50-60 planes depart and arrive every day and the goods are retrieved by trucks that transport them between different warehouses and the plane parking spots (Person 11, 2021).

Logistics Gamma 1
Logistics Gamma 1 is a part of the Logistics Gamma Group. The terminal in Gamma Suburb is first and foremost large within domestic goods arriving and departing from the facilities. It is the biggest terminal within Logistics Gamma in Sweden and the fourth biggest terminal in Europe handling 1.000-1.500 shipments every day. The terminal in Gamma Suburb is one of 5 terminals in Sweden for international goods with daily departures to almost all countries in Europe. Apart from truck transports, the terminal is also handling some air and ocean freights. Their main task is to gather goods from Gamma City, making consolidations and controls before sending it to other parts of Sweden. Therefore, the facilities have almost none warehousing (Person 12, 2021).

The flow from ocean freight starts when the terminal gets a notification from the port that their containers soon will arrive in the port. This creates time for Logistics Gamma 1 to prepare before the next notification arrives, indicating that the ocean vessel has left the port. This is the signal for Logistics Gamma 1 to send trucks to go and pick up the containers, deliver them to the facility where they are emptied after being docked. The distance between the terminal and the port is between 10 and 15 kilometers and approximately 10-15 containers are arriving every day although that number varies greatly over the seasons. The road from the terminal to the port is a public road (Person 12, 2021).

Both when trucks arrive with containers from ocean freight and road freight, it is common that the truck leaves after the container has been docked to make it possible for the truck to continue its route while the container is being emptied. This creates a need for transportation of empty containers within the fenced terminal area. For this task the terminal has one tug tractor that is estimated to perform 20-30 container moves per day as an average over one year. The facility has one of those tug tractors operating 24 hours a day, 6 days a week. To put this flow in perspective, between 3 to 5 % of the containers need to be moved within the facilities (Person 12, 2021).

Logistics Gamma 2

Logistics Gamma 2 is a 4PL company within the Logistics Gamma Group. The company is closely linked to Logistics Gamma Group as a company, but at the same time operating as an independent company in terms of which transporters to choose. The company works with a few selected, large clients and are serving as their internal logistics department (Person 23, 2021).

Logistics Gamma 2 does not own any facilities, vehicles or other infrastructure. Instead, the focus is set towards being a network provider tailoring unique solutions for every client. To solve this, Logistics Gamma 2 buys transport services on the market. The company works mostly with cargo routing and supply chain management (Person 23, 2021).

Logistics Gamma 2 has three offices including Gothenburg, Malmö and Germany. Every office serves clients from different industries, where for example Gothenburg is specialised towards customers in the engineering industry. Logistics Gamma 2 works almost only with B2B clients (Person 23, 2021).

Logistics Delta

Logistics Delta is one among three cargo handling companies for air freight at Airport 1. The company normally handles roughly four big transatlantic airplanes per day, together with 40 other airplanes with freight that is carried in regular lines. In total this sums up to around 100 to 150 *unit load devices* (ULDs) handled per day. Due to the pandemic, this number is currently ¼ of what it used to be. One big freightliner has the capacity of carrying 10 to 40 ULDs depending on the type of ULD (Person 26, 2021).

When a plane arrives at the airport it is unloaded by the ground service team, which also handles luggage. This is a process which normally takes 30 minutes. Once the cargo is outside of the airline, it is transported using terminal tractors to the correct terminal for further handling. Terminal tractors are currently limited to pull five separate ULDs at the same time (Person 26, 2021). Terminal tractors from the manufacturer Kalmar are used and they cost roughly 30.000 SEK per month including leasing and service and the fuel consumption is around 7 liters per hour (Vehicle Company, 2021). The transport from the plane to the terminal usually takes around five to fifteen minutes and the distance is in the range of one to two kilometers. The transportation is done completely inside the gated area of the airport. When the freight arrives at the terminal it is dropped by the ground service team and the cargo is then further handled, registered and stored in the waiting for the owner to pick it up (Person 26, 2021).

4.3.3 Manufacturing Companies

4.3.3.1 Manufacturing Company Operations

Manufacturing companies are defined as companies that produce an actual product from raw materials and input components. Since the flows are highly customized based on the specific facility, no general operation will be described (Oberlo, 2021).

4.3.3.2 Market Size

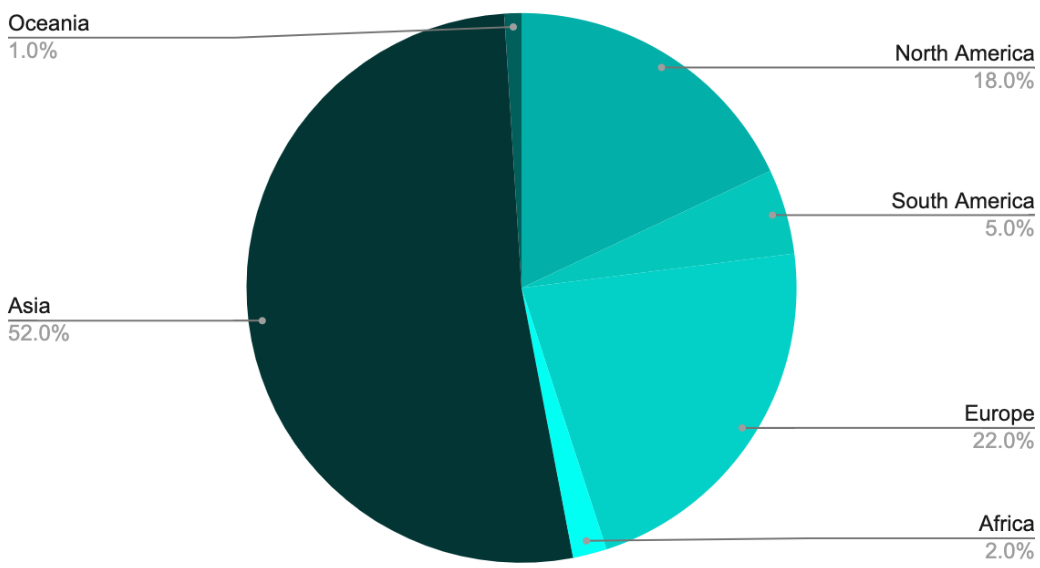
The world manufacturing market size can be estimated to 13,7 trillion USD. The manufacturing industry in Sweden can be estimated to 74 Billion USD (Irena, 2021). It is seen as the backbone of the Swedish economy contributing to 14 % of the total GDP. This can be compared to the United States where the manufacturing industry is 10,5 % of the GDP and the United Kingdom where the percentage is 10 %. The manufacturing industry in Sweden directly employs around 530,000 people which is 11% of the total workforce (Business Sweden, 2018)

4.3.3.3 Market Segment

4.3.3.4.1 Demographics

More than 60 % of the total market value comes from the top five manufacturing countries, namely China, the United States, Japan, Germany and South Korea. Looking at the continents, Asia is being the biggest contributor with 52% of the market size. Europe is on second place with 22 % followed by North America at 18%. Oceania, Africa and South America together constitute the last 8 % (Irena, 2021). A more detailed visualisation of this distribution is shown below in *Diagram 4.10*.

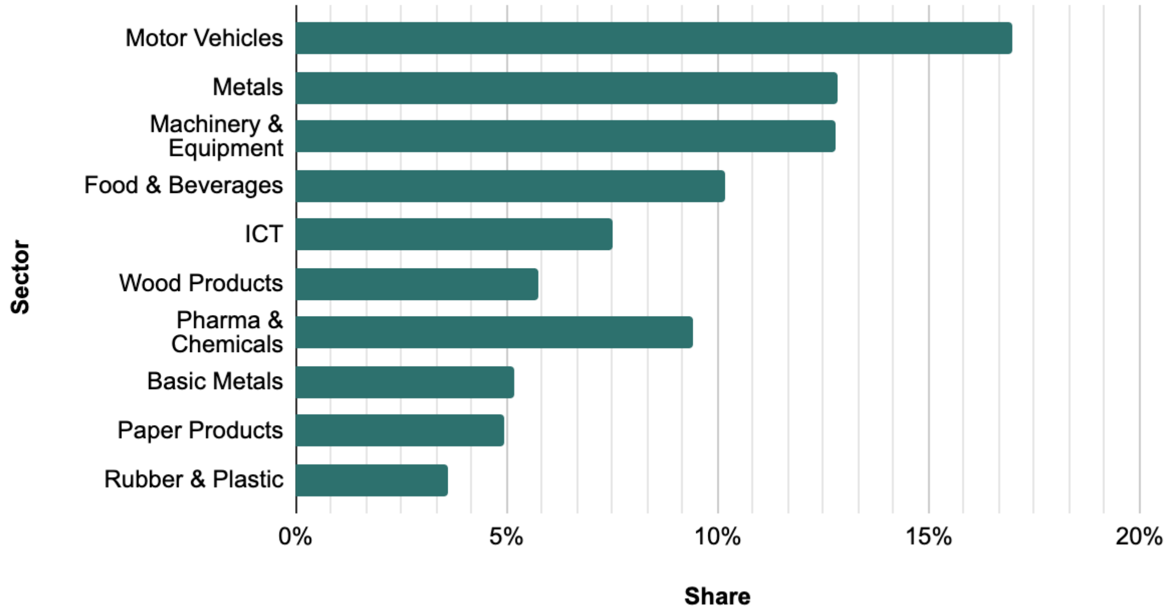
Diagram 4.10. The Continents' Share of the Global Manufacturing Market (Irena, 2021)



4.3.3.4.2 Operational variables

In Sweden, the ten largest sectors within manufacturing make up 89 % of the total market value. The largest sector within this industry is Motor Vehicles, with 17 % of the market value, employing 17 % of the total employment within manufacturing. The second sector on the list is Metals, with 13 % of the market and 12,8 % of the total employment within manufacturing. The Machinery and Equipment sector is in third place, with 13 % of the market value and 12,8 % of the total employment in manufacturing (Business Sweden, 2018). In *Diagram 4.11* below, an overview of the different sectors and their share of the total market value is shown.

Diagram 4.11. 10 Biggest Sectors and Market Shares in Sweden (Business Sweden, 2018)



4.3.3.4 Customer Drivers

Costs are one of the main drivers for the adaptation of new technology and a lot of investment decisions that are made within the industry focus on improving the bottom line (Person 1, 2021). One trend identified is to achieve this is digitalization. With a connected facility, machine learning can be used to let the machines "learn" and mimic previous work routines (Person 1, 2021). Artificial Intelligence (AI) can be used to analyse data from production processes in order to predict maintenance and reduce costly downtime (Person 22, 2021; Person 15, 2021). Better analysis and visualization of data can also help to improve forecasting and optimize productivity and storage (Person 15, 2021).

Sustainability can be considered as another customer driver (Person 0, 2021; Person 10, 2021) (Person 15, 2021). There is focus for both companies and products to be sustainable, or at least not increase the pressure put on the climate (Person 10, 2021). Another reason for focusing on sustainability is to attract new talents, since this is an important variable when younger generations are choosing their future employer (Person 15, 2021). One result of the sustainability driver is electrification (Person 10, 2021). Another example is the work towards sustainable and renewable raw materials, as well as focus towards recyclability (Person 1, 2021).

Younger generations tend to neglect manual labour which puts pressure on the industry towards automation (Person 15, 2021). Incentives towards automation can be found in warehousing (Person 10, 2021), around manufacturing activities (Person 0, 2021; Person 15, 2021) and for internal transport within the facility (Lindblad, 2021; Person 10, 2021; Person 15, 2021).

Competitiveness is one driver influencing investments within companies. Being able to be the first company implementing new technology or new innovations might create an edge over competitors (Person 22, 2021).

4.3.3.5 Automation Readiness

Automation readiness within the manufacturing industry is rather high. Industrial robots have been a topic of discussion since 1960 and different types of automation has helped to improve safety, shorten labour workweek hours, increased efficiency and productivity to name a few advantages. In modern manufacturing facilities, automation can for example, be found in fully automated production lines, automated assembly activities and in material-handling applications (Groover, 2020).

Automation for material handling and internal logistics is rather high. Automatic Guided Vehicles (AGVs) are often used for different flows inside a production facility, for example between two different production activities (Person 10, 2021) (Person 15, 2021). There are also cases where automatic forklifts are used to transport material (Person 1, 2021).

Restrictions for implementing autonomous vehicles are found relating to the physical layout of the facilities. Small areas where machines and labour work alongside each other is one potential barrier for the implementation of autonomous solutions (Person 1, 2021) (Person17, 2021).

4.3.3.6 Case Studies Manufacturing Companies

4.3.3.6.1 Manufacturing Alpha

Alpha City 1

In Manufacturing Alpha's factory in Alpha City 1, one of the products that are manufactured are mechanical pulp. The process is started with timber arriving to the facilities where it is retrieved with a wheel loader from the timber trucks. The trees are laid out in a lumber yard where they are sorted by species. After that it is processed in several ways inside the facilities including both mechanical and chemical procedures before it goes on to become cardboard material. All of those steps are taking place inside the same factory. A total of 450 000 tons of cardboard is produced every year (Person 22, 2021).

When it comes to shorter, repetitive transportations in this facility, there are several. For the internal handling of wood, there are wheel loaders with claws handling most of the processes. The distances are up to a few hundred meters since the lumberyard is rather small in comparison with other facilities within manufacturing Alpha that mostly are located in Finland. The distances in this case are very short, and the precision requirements are very high. Within the production, the distances the material travels is handled by AGVs. The facilities also have rails pulled all the way to the unloading center for train transportation. For the material that leaves with truck, there is a solution where external trucks can dock to the facilities where the loading is handled by forklifts. In addition, there is a transportation flow where trucks come and pick up sludge from the production process. These trucks then drive from Alpha City 1 to a nearby location, a distance of 20-30 kilometers. 45 tonnes are created every year in the process, where some of it is reused in the process which leads to a total volume of 10 tonnes per year that is transported between these locations (Person 22, 2021).

Alpha City 2

Manufacturing Alpha's facility in Alpha City 2 is, just like Alpha City 1, producing pulp from timber. The general process is quite similar, but Alpha City 2 is also producing cardboard paper from the pulp, which is then cut into rolls of paper, which is referred to as "customer rolls". Manufacturing Alpha City 2 produces 932.000 metric tonnes of finished goods per year (Person 1, 2021).

Manufacturing Alpha 2 has a team of 70 employees responsible for the handling process of finished goods. This division has mixed areas of responsibility ranging from transportation from the warehouse to train, packaging goods, loading trucks and delivering finished customer rolls from Manufacturing Beta. Manufacturing Beta rents production facilities within Manufacturing Alpha's production area (Person 1, 2021).

Generally speaking there are three types of flows of goods that are going out from the warehouse. The first option is to leave the facility via train. This is the case for roughly 40 % of all freight. Here, the customer rolls are packaged into "CQ boxes", which is a specialised container made for Manufacturing Alpha. The container is slightly larger than a 40-feet standard container and the distance between the warehouse and the loading area is very short (around 15 meters). The second option is to transport the goods using trucks to the Alpha City Terminal; a nearby distribution center. About 60 % of all produced material is transported this 8 kilometer route and four trucks operate 18 hours per day, everyday to meet the needs of the production facility. In total, 15 people are employed to drive this route. Finally, there is one flow of goods where Manufacturing Alpha moves finished goods internally from Manufacturing Beta's production lane to a warehouse in the very end of the production area. Around 40.000 metric tonnes are driven this internal route within the facility (approximately 500 - 600 meters) every year and for this, terminal tractors are used (Person 1, 2021).

Manufacturing Alpha City 2 has a total of 24 employees working with internal transport in the yard. These people work shifts around the clock in teams with 4 people in every shift. Additionally, there are another 4 people that work daytime. These people share the tasks of driving forklift, terminal tractors and other material handling in the yard (Person 1, 2021).

Autonomous vehicles is something that has been discussed several times at Manufacturing Alpha City 2 and discussions have been held regarding automatic forklifts, AGVs and other autonomous solutions. Although, the conclusion is often that the area is very crowded with people working alongside the vehicles. There is also a perception that the technology is not mature enough yet (Person 1, 2021).

4.3.3.6.2 Manufacturing Beta

Manufacturing Beta in Alpha City 2 gets their raw material from different suppliers where 95 % is coming from the neighbour, Manufacturing Alpha. The material from Manufacturing Alpha is delivered via an AGV solution from Manufacturing Alpha to Manufacturing Beta's warehouse. This distance is around 100 meter and the transport is going inside all the way. The rest of the material arrives with trucks to a loading area before it is driven the last 20 meters to the machines. Inside the facility the main process is to laminate paper rolls with different processes depending on which type of packaging it is going to become. When the paper is laminated it is transported via a conveyor to a loading area where it later is transported via trucks to an intermediate warehouse 500-600 meters away, still within the fenced area. Manufacturing Beta also has a facility in Beta City that makes orders from the same warehouse, and the material is transported via trucks from the middle warehouse to Beta City. The distance between Beta City and Alpha City 2 is 80 km and 10 trucks are used for the transportation.

Globally, Manufacturing Beta has 50 factories and 10 of them are located in Europe. The factories vary in size since they produce products that differ a bit from each other with different demands. Out of the factories, the one in Alpha City 2 is in the lower third when it comes to produced volume. The factories in Beta City and Alpha City 2 together produce 2 billion units every year, which is around 1% of the total units produced in Manufacturing Beta every year. The biggest cost for those factories are by far employee costs, being 80% of the total costs (Person 10, 2021).

4.3.3.6.3 Manufacturing Zeta

At Manufacturing Zeta, goods are arriving at the facilities and stored in an internal warehouse. It is then transported by a truck to the production line where it goes through various processes. When it comes to transportations within the facilities, there is one flow inside where the goods are being transported by a tractor that is pulling a trailer. The distance for this flow is approximately 75 meters. Once the goods are finished, they are transported from the production facility to a warehouse, a distance that is 200 meters. This transport is handled by trucks. The handling of material in the facility yard is all handled by forklifts.

Manufacturing Zeta once tried to automate flows inside the facilities with an AGV, but the initiative failed. The reason was that too many things were going on in the area the AGV was supposed to operate in, with a lot of employees on the ground. The facility in Zeta City is the biggest facility Manufacturing Zeta has, together with a facility in China. The other facilities in Sweden are smaller (Person 17, 2021).

4.3.3.6.4 Manufacturing Delta

Delta City 1

"Rotary" is one out of three production units in Manufacturings Delta's factory in Delta City 1. "Rotary" is a part of the business area "Mining and Rock Solutions". Within "Rotary" at Manufacturing Delta, drill bits in the sizes from 7,8 inches to 16 inches are created. The process starts with a demand from one of the regions that the company serves globally. Some of the drill bits versions are created from scratch while others are created from semi-finalized products, which creates varying lead times depending on what product that is ordered. Most of the processes are made in the same building, however there are some that take place elsewhere. The first process that is not located in the main building is heat treatment that is made in a company located in a town 140 kilometers away on public roads (Person 0, 2021).

Apart from that transportation, Manufacturing Delta, has a whole working unit responsible for all the transports in the garden. The unit "Rotary" is providing a rather small share of the total material that is transported in the garden, with 500-600 drill bits created every month. This can be compared to one of the other business units, "Topphammar korta", that is producing 25 000 drill bits every week (Person 0, 2021). "Topphammar korta" in Delta City 1 stands for 70 % of Manufacturing Delta's total supply and the company as a whole has approximately 50 % of the market share (Person 2, 2021). The raw material will reach the facilities with a truck that empties the material in a specific area. From there, the counterbalanced trucks will transport the goods to the production area 100 meters away. When the products are finished, the goods are transported 300 meters more to an internal warehouse (Person 2, 2021). There are a total of 3-4 forklift trucks operating in the garden for this and then one bigger truck that can handle a weight up to 16 tonnes for special occasions (Person 0, 2021).

For another product, the adapters, the process is the same except that the products are transported around 600 meters for heat treatment before they are transported back to be handled inside the production area. Trucks then arrive at the warehouse to pick up the products and transport them to its end customer (Person 2, 2021).

In addition, there is a supplier, located around 500 meters from the facilities, where a tractor with wagons supplies the drilling steel. The tractors go back and forth 6 times a day, changing an empty wagon to a filled one (Person 0, 2021).

Delta City 2

One production line in Manufacturing Delta in Delta City 2 is producing the drilling needles in volfram and kobalt. The material arrives in powder form and Manufacturing Delta acts as a single source supplier to the Manufacturing Delta Group. Delta City 2 is the smallest of 5 units within Manufacturing Delta producing needles, with 110 employees.

The production starts with supply of metal powder from Austria. The powder is retrieved and driven instantly to the production which starts with electric pressing. A few processing steps later, the material is stored at a middle stocking area. After the material has entered the process again and been finished, it is driven out by a truck to a stall to be controlled by the controlling staff unit. After this step, the process is divided into two. The needles that will be sent to factories within Manufacturing Delta Group will be packed and sent right away since the sharpening process takes place at the ordering factory. For the needles that are going to external customers, the next step in the process will be sharpening before it is put in the warehousing area. From the warehousing area, the delivery time after an order is three days. The processes between the machines inside is at maximum 100 meters and an AGV is used for the transport of material in between. The process for delivery to the customer starts with the transporting truck docking to the building before it is filled with goods and later leaves the facility towards the destination.

4.3.3.6.5 Manufacturing Gamma

Manufacturing Gamma's factory in Gamma City is one out of seven Gamma factories in the world that produce diapers. At the factory, there is a logistics division handling the transportation inside and outside the factory. The logistics division is responsible for handling the material and distributing the finished goods from Gamma City. In addition, the division is responsible for providing Sweden, Denmark, Norway, Finland and the Baltics with products that are produced in any other of the 40 Manufacturing Gamma factories in the world. 70 % of the total volume that the logistics division is handling is produced in the factory in Gamma City, and the last 30 % is produced elsewhere and should be distributed to any other destination in the region the division is responsible for. Approximately one third of the products Manufacturing Gamma in Gamma City is distributing is delivered to Sweden, Norway and Denmark, the second third is going to the UK and lastly one third is going to Germany and Holland. Walmart in the United States is also a large customer (Person 18, 2021).

In total, the logistics division has 26.000 stall spots for finished goods out of which 12 000 are located in the factory. The rest are distributed between 6 external warehouses that are located 400 meters to 3 kilometers away from the factory. Today, Manufacturing Gamma is using 3 terminal tractors for the transportation of goods to the warehouses, fueled by diesel. In addition, one truck is hired via a haulage contractor. 3 of the trucks are operating only daytime, while one of the trucks is operating both night and day. Usually, there are 4-5 drivers on site, and if more workforce is needed for certain occasions, the company hires from staffing companies. The warehouse for raw material is the closest one, 400-500 meters away where the trucks now are operating in a very repetitive way. Because of that, Manufacturing Gamma has been looking at autonomous solutions for that transport. In general, Manufacturing Gamma is looking at updating their truck fleet since the current vehicles are old with increased service costs (Person 18, 2021).

5. Analysis

5.1 The Technology Shift

5.1.1 Technology Cycle in the industry of transportation

The technology cycle in the industry of transportation is slowly shifting focus towards a new era of rapid development in product performance. The old S-curve describing the product performance development over time for fossil fuel driven, non-autonomous trucks is slowly facing physical restrictions and the focus has switched towards autonomous and electric solutions.

Even though the technology within the autonomous trucks themselves are quite similar no matter the application (on a high level), different segments have come to different stages of implementation of autonomous vehicles. The mining and quarries segment have been using autonomous solutions for over a decade, while the technology is just facing it's advent in the segment for ports and logistics centers. On the other side, autonomous trucks for long hauling on public highways are still something for the future to hold. All in all, the technology is believed to be roughly ⅓ up the technology S-curve due to the fact that there are already applications running today. See *Figure 5.1*. At the same time, the product performance development pace is rapid and believed to continue to increase when the time and engineering effort increases.

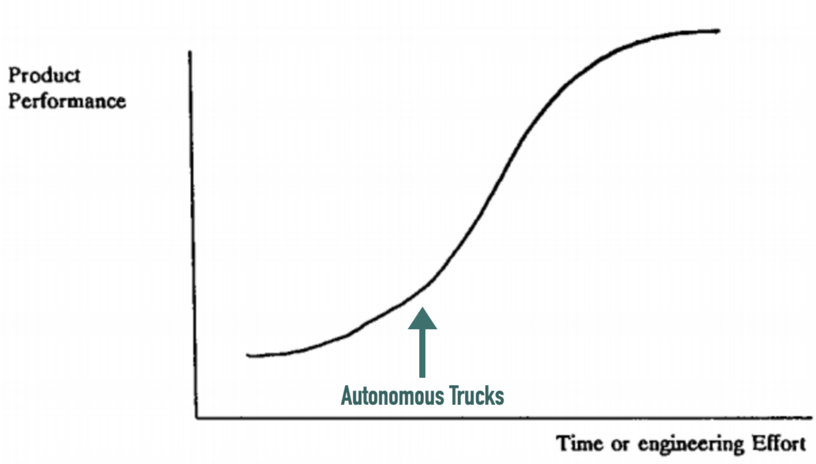


Figure 5.1. Autonomous Trucks in Relation to the S-curve

The entrance of autonomous trucks in the transport industry has created a technological discontinuity since it questions the very foundations of how a truck should look like and how operations should be handled. Companies fight to lead the development towards a dominant design, both in terms of the actual appearance of the truck itself, but also regarding how the business model should be transformed to support the autonomous vehicles. Meanwhile, the first applications in real conditions are taking place in different areas of the market. All in all, the technology cycle for autonomous trucks is considered to be in an era of ferment and it is believed to stay so until there has been a wide adaptation throughout the industry and until the first dominant design has occurred. See *Figure 5.2* below.

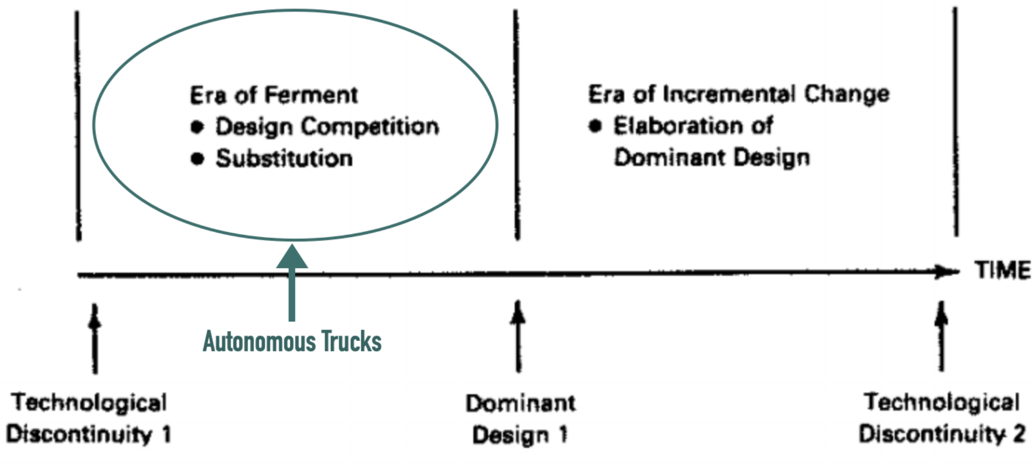


Figure 5.2. Autonomous Trucks in relation to the technology cycles

5.1.2 Innovation Theory

As mentioned in the interviews, people from within the industry consider autonomous trucks as a radical innovation. This can be considered true, since it changes the industry foundations and questions how transport should be handled. A radical innovation challenges the norm of an industry and creates a new standard which can be argued to be true since autonomous vehicles will change not only the vehicle, but also the infrastructure needed to support it. There is also a shift towards transport as a service instead of just selling the truck itself. The result of this is that the traditional structure of the transport industry with up to 4 party logistics partners might change and instead of having freight forwarders carrying the goods, the transportation might be done by the truck manufacturer itself in collaboration with the freight owner. If so, this would result in vertical integration in the industry.

5.1.3 Technology Strategy

It is clear that The Case Company has well developed strategies for all the component parts within the Technology Strategy framework developed by Ford in 1998. In other words, the The Case Company management team knows how to acquire, manage and exploit new technologies even if it is not stated in a structured way.

Starting with the process of acquiring new technologies, it is clear that The Case Company and The Case Company Group are prioritizing this area. In fact, it might be argued that the reason why The Case Company was founded from the beginning was to make sure that The Case Company will have a role to play in the race towards the implementation of autonomous vehicles. By spinning off The Case Company, The Case Company Group will be able to take advantage of the large financial muscles of a big, well established company while at the same time having a start-up's ability to adapt quickly and change according to the progress and change in the industry. In addition, The Case Company Innovation Center in The City which is the headquarter of The Case Company is also another evidence for the large focus on scanning the market to be able to quickly take advantage of new advancements within technology. By being an attractive brand like The Case Company Group and initiating collaboration with smaller start-ups within interesting areas, The Case Company Group and The Case Company are increasing their chances of finding new areas to later exploit and create competitive advantage. This is also a long term strategy since collaboration and partnerships with newly created startups often adds no revenues and large costs the first years. Since a lot of startups in the end turn out to fail, it is clear that The Case Company Group considers it strategically valid to invest time and money in several startups where the majority will fail statistically, just to increase the possibility to find the few that actually turn out to be profitable. Lastly, by having offices in some of the world's most innovative clusters such as Silicon Valley and Israel, The Case Company makes sure to be present in the locations of the world where the chances of finding the next revolutionary technology is the largest.

The Case Company states that their subcontractors of today might be tomorrow's competitors and partners the day after tomorrow. With this view, it is clear they have a close collaboration and partnership with the different subcontractors, and therefore it is evident that The Case Company wants to manage and maintain the skills that are present in their full value chain and network. A company with a weaker technology strategy would focus all resources on the technologies within the company walls and thereby risk missing technology developed elsewhere. Another important aspect here is that with a lot of collaborations and partnerships, the company gets exposed to a broader set of technologies and thereby develops a greater absorptive capacity. Without the absorptive capacity, getting exposed to new attractive technologies will rarely lead anywhere due the lacking ability to either understand its attractiveness or to have the capability to exploit it later. To maximise the potential in this area, The Case Company has a well developed HR strategy. With a focus on hiring the people that are in the forefront of their technical niche, the company is both maximising their absorptive capacity as well as the chances for the next great technology to be developed within the company walls.

As stated in the *Theory* section, a problem with developing technology strategy is that it requires special and enhanced communication between those who are responsible for acquiring the technology, like R&D management and those that are responsible for managing and exploiting this technology. This risk is reduced within The Case Company due to the fact that the commercial team works very close with the technical team to ensure that new knowledge is managed in a good manner internally. Since the new requirements from customers actively will be collected on the commercial side and from there communicated in explicit communication channels to the technical team, The Case Company makes sure that their new technical solutions will be based on the wants and needs of the customers. Judging from the described company culture, it is likely that new knowledge is spread quickly with the open atmosphere and a culture where you are supposed to ask questions. Another example of this is The Case Company's close collaboration with The Case Company Group's own Venture Capital Division and their investments in startups.The Case Company is often involved in the process of which companies to invest in and work together with the VC division to obtain the unique knowledge and make it transpire into The Case Company and The Case Company Group.

Acquiring the technology and spreading it in the company is of little value from a commercial perspective as long as the technology is not exploited later. This can both be done as a component assisting other components in a product or as a main component in a product. This process is however very structured and follows specific steps at The Case Company. The start of the proof-of-concept or proof-of-value for the technology is the initiating part of the process which ends in a commitment to proceed towards exploitment for the technologies that make it through the process. The scoring of a TRL level from 1 to 9 is like a filter between The Case Company and the market, making sure that the product or technology is ready for the judging customers. This full process can be seen as a way to avoid one of the risks a company without a technology strategy can face, namely the risk of spending a lot of money on a technology that will not be exploited in the end.

5.2 Strategic Markets

5.2.1 Ports

5.2.1.1 Market Value

5.2.1.1.1 Total Available Market (TAM)

The fundamentals of the total available market within ports is the number of containers handled in the world's ports, times the cost for the share of the total container transport that is considered interesting for autonomous trucks. As mentioned in the empirics, the total port container throughput was 811 million TEUs in 2019. Since the throughput in a port is increased every time a container is loaded off a vessel and every time a container is loaded onto a vessel, a container on a route from one port to another contributes with at least 2 containers to the total global container throughput. In addition, every container is counted twice in every transshipment port which on average is Λ per container. One can say that a container adds to the total global throughput every time it is lifted with the quay cranes. Since the average is Λ transhipments per container, the average container adds θ counts to the total throughput.

Since the containers rarely are transported further from the quay than to the stack during a transshipment, the handling of the container in the transhipment port is not considered as a potential market for The Case Company. The only time this would be considered is when a container needs to be moved between different terminals, which is rare due to the increased costs. This means that out of the θ times a container adds to the total global throughput, only 2 will be considered as potential areas for The Case Company. This means that there are $\frac{811}{\theta} \times 2$ million potential transportations of containers that can be considered.

Looking at *Diagram 4.5* in *Empirics*, we see that the transportation cost of a container after it has been staffed to the export port terminal was 360,5 US dollars in 1997 for a shipment of a container from Port of New York to Port of Rotterdam. The transport for the container from the stack in the importing port to an inland depot was 220,5 US dollars the same year. This means that the average cost for transporting a container between the stack and the inland depot to be stuffed or unstuffed was 290,5 US dollars. Even though this cost was calculated more than 20 years ago, the number is assumed to be valid today. This assumption is based on the fact that the work with increased efficiency in ports has been slow since the containerization and due to the strong labour unions working against radical efficiency improvements that can reduce the need for employees. However, since the effect of inflation will be large, this needs to be taken into consideration. With a 100 % market share of the interesting transportations in ports around the world, the formula below could be used to calculate the Total Available Market.

The calculations of the *Total Available Market* (TAM) estimation for ports is based on the following assumptions:

- Average cost to/from port with truck was $ 290,5 in 1997 (Rodrigue, 2006)
- Inflation factor from 1997 - 2021 is 1,67 (Smartasset, 2021)

$$\frac{Global\ Throughput}{Avg\ nbr\ quay\ crane\ lifts} \times (considerable\ lifts) \times (avg.\ cost\ per\ transport) \times inflation =$$

$$TAM \Rightarrow \frac{811\,000\,000}{\theta} \times 2 \times 290,5 \times 1,67 = (786\,888\,970\,000)/\theta \approx (786,900)/\theta\ Billion\ USD$$

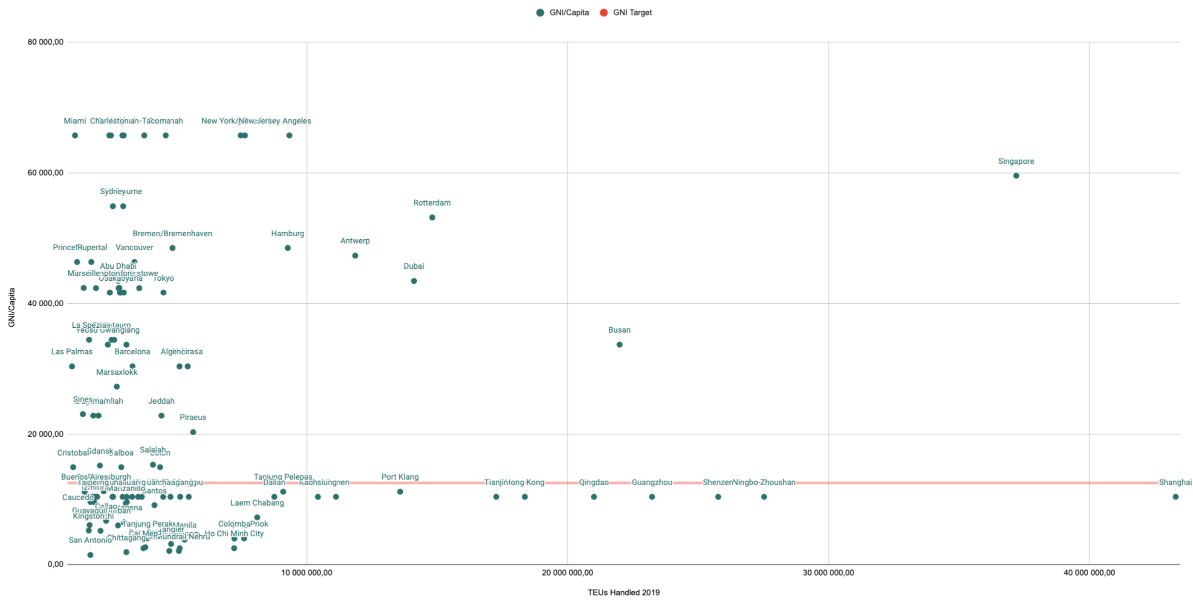
5.2.1.1.2 Factors affecting the Serviceable Available Market (SAM)

When going from Total Available Market (TAM) to Serviceable Available Market (SAM), some limitations need to be taken in consideration. Those limitations can be both operational and demographic, but also of other characteristics. The limitations will together restrict the company to a share of the total available market where it is possible to gain market shares.

A lower limit on the throughput in a port to be more than 1 million TEUs every year, approximately 20 % of the total throughput is not considered as potential market values to capture. As seen in *Appendix 1*, the 109 largest ports in the world together make up 80 % of the total throughput where the ports in the lower end have a total throughput per year just above 1 million TEUs.

In addition, since the main reason why ports consider automation is to decrease the high share of labour costs, the costs of labour needs to be considered as well. Naturally, the lower the labour costs are, the smaller the profit will be in eliminating those costs and replacing them with automation. With labour costs that are too low, automation might be more expensive even in the long run if only labour costs savings are taken into consideration. The higher the labour costs are, the larger the possible profits will be and thereby the shorter the payback period for the large upfront investment will be. Therefore, when deciding the serviceable market, the other requirement after a total throughput of 1 million TEUs will be that the GNI per capita of the country is within the limits of the highest level “High Income”. When applying both restrictions to the TAM, the market goes from 109 ports to 53 and the share of the total container throughput goes from 80 % to 32 % (262 million TEUs). In the diagram below the limitation is visualized with a red line that separates the ports in countries with GNI/capita on the level “High Income” from the rest.

Diagram 5.1. Port Throughput and GNI/Capita per Country



Train and Truck Ratio

The two main ways for a container to be transported to and from the port are as stated in the *Empirics* by train or truck. In general when the container is leaving by train, it is transported with some kind of internal vehicle from the stack to a rail yard within the port. The first option is to transport it with a truck or terminal tractor between the stack and the railyard and use cranes to load the containers onto the truck from the stack and then off the truck to the train. The other option is to use reach stackers or straddle carriers to transport the containers and by doing so the need for cranes are eliminated. The use of straddle carriers or reach stackers are therefore a more efficient way for this transport and therefore ports where this is used are probably not willing to use an autonomous truck instead. The ports that today use terminal tractors and reach stackers are probably also more likely to upgrade to reach stackers or straddle carriers and not autonomous trucks. Lastly, since the railyard often is located in the port area close to the stack, the distance is considered a bit too short in general. This does not mean that there with certainty are no applications for transportations to the railyard in ports globally, but it will not be considered when looking at the generic case.

For the share that leaves with a truck, there are also two main ways. The first process is that an internal port vehicle transports the container to a parking lot outside the port area where the external truck can come and pick up the container. After the interviews that have been conducted in this Thesis, this has been an option in very few ports, and when it is an option, only 1 or 2 of the port terminals use this process. It seems to be much more common for the external truck to enter the port area where an internal machine or vehicle is used to load and load off the truck with a container. Both of the flows will be considered as possible applications for the autonomous truck.

Bearing the above mentioned in mind, the segment sizes will be directly dependent on the truck and train share in the ports. For some of the ports where the truck and train share have not been found on secondary sources or interviews, the closest port with known shares has been used as an approximation. See the values in *Table 5.2 - 5.4* below.

Transshipment Rate

As mentioned earlier, the transshipment rate in a port is of great importance when calculating the total market size for The Case Company, due to the fact that this flow is not applicable. Hence, to adjust for this in the calculations, the share of transhipment is removed from the total throughput for a port. See a total list of transshipment shares in *Table 5.1 - 5.3* below.

Although the ideal scenario is to move the container from the vessel to the stack and then back again, there are situations when that is not possible. According to Person 6, big ports focusing on transshipment do face situations where a lot of TEUs have to be moved from one terminal to another inside the port. Even though this is a minority of the operation, this type of flow still exists and this might be a possible application for The Case Company. However, this type of process is not considered when calculating the market share, due to the fact that this is not part of the standard handling process.

Export and Import Ratio

In general, import and export flows seem to be almost identical but reversed. This means that a container being imported is as likely to be transported by an autonomous truck as a container that is being exported. This means that an imported container will contribute as much as an exported container in the calculation of the market size. In other words, there will be no distinction between these two in the calculation. A container port that is heavily import dominated will have to export many empty containers, and when they are shipped they are handled in the same way as the full containers. Therefore, an empty container being shipped will add as much as a full one to the calculated market size.

The factor to have in mind here is that the ports that are heavily import dominated will have to store the empty containers in empty container parks and be ready to transport empty containers down to vessels that have ordered them for further freight. A great example of this area is what is called a "stack run" in the Port Delta. This is of particular interest for The Case Company since it often results in repetitive flows with short distances, sometimes completely inside of the port area.

Closeness to Inland Warehouse Area

As mentioned by The Case Company, interesting container flows should be between X meters and Y kilometers. That means that flows of containers to warehouses less than Y kilometers from the container ports are of great interest. As soon as the container is on land, it is possible to freight the goods in larger units than a container. Since more goods then can be stuffed into the same unit and therefore more units transported by one single truck, there are economic incentives for the goods owner to have the goods repacked into larger units as soon as possible. This is the reason why there tend to be large warehouse areas in close proximity to the ports. How close those warehouses are is partly dependent on how old the port is. If the Port Gamma is taken as an example, there are two different warehousing areas that are situated around Y kilometers away from the port to which a majority of the containers are transported for transloading. In the Port Zeta Alliance, approximately 70 % of the containers are transported to warehousing areas that are up to Y kilometers away. However, in the case of the Port Alpha, which is seen as an older port in comparison to most other ports in the United States, 30 % of the containers leaving the port area with trucks are transported a distance of less than 40 kilometers. A large share of the percentage is eliminated if you decrease the radius from the port to Y kilometers. In the Port Epsilon, a large share of the containers leaving with a truck are transported to the warehousing area that is located 10 kilometers away from the port. In this case, the exact share is not known but it is reasonable to argue that at least 50 %, a majority, is transported this distance. With the interviews in mind, it seems like at least 50 % of all the cargo that leaves the port by truck is transported less than Y kilometers before it is transloaded, on average. Bearing in mind that the exact share not is known in all of the interviewed ports and the fact that far from all ports in the segments have been interviewed, an average of those shares would not be reasonable to use when calculating the market sizes. A range from under 30 % to 70 % has been detected with more ports in the upper part of the range. However, since the aim is to minimize the risk of using values that lead to a market value bigger than reality, a percentage in the lower end of the interviewed ports range is most reasonable. Therefore, a share of 50 % will be used here.

Private or Public Roads between Port and First Warehouse

As mentioned by The Case Company, interesting container flows should also mostly take place on private roads. Out of the ports interviewed, no port had transportation routes only taking place on private roads to the warehouses. However, this does not mean that there are no application areas. Taking the Port Epsilon as an example, there is a large area of warehousing that is located 10 kilometers away and another flow of containers to an area that is within 20 kilometers away. Both of those flows take place on private and public roads. However, The Case Company classifies the first flow described as not interesting, while the other flow is considered interesting. In other words, it is not possible to decide whether a flow is interesting or not only by answering the question if the routes are private or not. Instead, a close study of the routes needs to be done. Starting with the first flow described in the Port Epsilon case, the route contains highways with heavy traffic which would require a lot of interaction with other vehicles and people. The other flow takes place mostly on private roads but contains parts that are public. However, those parts are not experiencing much traffic at all. In other words, it is not sufficient to only look at if the full distance to the warehouses is on public or private roads. The share of containers that go only on private roads is probably very small and by using that number, a lot of potential flows will be missing out from the calculations. Adding to this, it is reasonable to argue that the legislations regarding autonomous trucks on public roads probably will loosen up in the near future as further technology developments are done and societies around the world will open up for the application. Since the data available in this area is extremely limited, an estimation based on the conducted interviews is the best way forward. Therefore, the share of the transportation routes to warehousing areas less than Y kilometers away from the port that can be operated by an autonomous truck will be estimated to 30 %.

Table 5.1. Parameter description and their effect on market value estimation

Parameter	General/Port Specific	Variable	Effect on Market Value
Truck Share	Port Specific	T	$Adjusted\ Market\ Size\ = T\ *\ Market\ Size$
Transshipment Rate	Port Specific	TS	$Adjusted\ Market\ Size\ = (1 - TS)\ *\ Market\ Si$
Closeness to Inland Warehouse Area	General	C	$Adjusted\ Market\ Size\ = C\ *\ Market\ Size$
Share of Interesting Routes	General	IR	$Adjusted\ Market\ Size\ = IR\ *\ Market\ Size$

Combining all demographic and operational variables and their effect on TAM, the *Serviceable Available Market* (SAM) can be calculated using the following formula

$$SAM\ = \sum_{i=1}^{n} (T_i \times (1 - TS_i) \times C_i \times IR_i) \times\ Throughput_i$$

where i accounts for a specific port. See *Table 5.2 - 5.4* for the calculations for specific ports.

5.2.1.1.3 Market segmentation

Ports in the same country often share many characteristics. For instance, the geographical location of the country often decides whether the share of transshipment in the country is high or low. As mentioned in the *Empirics*, a port at the end of the sea route rarely has large shares of transshipment, while ports in the middle of the route have a much larger share. Another example is that the port unions in the country often has large effects on how far the ports in the country have reached in automation. The same unions protect the workforces in different ports of the same country, which is a balancing force in the development. In addition, as seen in the AVRI-rankings by KPMG, there are several country specific factors that are affecting the automation readiness level, such as the legal system, government flexibility and the data- sharing environment. A good first segmentation model is therefore to divide the SAM into the countries and continents they belong to. In the following four tables, the SAM is therefore divided into countries and grouped into Americas Market, Asian & Oceanian Market and European Market.

Table 5.2. SAM - Americas Market

Country (KPMG AVRI RANKING)	Port	Truck Rate	Transshipment Rate	Throughput (TEUs)	SAM Throughput (TEUs)
Canada (12)	Vancouver	Approx. 50 %	< 25 %	3 398 860	223 050
Canada (12)	Montreal	Approx. 50 %	< 25 %	1 745 244	114 532
Canada (12)	Prince Rupert	Approx. 50 %	< 25 %	1 200 000	78 750
Panama (N/A)	Colon	Approx. 50 %	> 75 %	4 379 477	57 481
Panama (N/A)	Balboa	Approx. 50 %	> 75 %	2 894 654	37 992
Panama (N/A)	Christobal	Approx. 50 %	> 75 %	1 050 000	13 781
The United States (4)	Los Angeles	70 %	< 25 %	9 337 632	857 895
The United States (4)	Long Beach	70 %	< 25 %	7 632 032	701 193
The United States (4)	New York/New Jersey	50 %	< 25 %	7 471 131	490 293
The United States (4)	Savannah	50 %	< 25 %	4 599 177	301 821
The United States (4)	Seattle-Tacoma	70 %	< 25 %	3 775 303	346 856
The United States (4)	Houston	50 %	< 25 %	2 987 291	196 041
The United States (4)	Virgina	50 %	< 25 %	2 937 962	192 804
The United States (4)	Oakland	50 %	< 25 %	2 500 431	164 091
The United States (4)	Charleston	50 %	< 25 %	2 436 185	159 875
The United States (4)	Miami	50 %	< 25 %	1 120 913	73 560
				Tot: 59 466 292	**Tot: 4 010 014**

Table 5.3. SAM - Asian Market

Country	Port	Truck Rate	Transshipment Rate	Throughput (TEUs)	SAM Throughput (TEUs)
Australia (15)	Melbourne	95 %	< 25 %	2 967 315	369 987
Australia (15)	Sydney	83 %	< 25 %	2 572 714	280 2653
Japan (11)	Tokyo	Approx. 70 %	< 25 %	4 510 000	414 356,
Japan (11)	Osaka	Approx. 70 %	< 25 %	2 456 028	225 647
Japan (11)	Yokohama	Approx. 70 %	< 25 %	2 990 000	274 706
Japan (11)	Kobe	Approx. 70 %	< 25 %	2 871 642	263 832
Japan (11)	Nagoya	Approx. 70 %	< 25 %	2 844 004	261 292
Oman (N/A)	Salalah	Approx. 70 %	> 75 %	4 109 000	75 503
Saudi Arabia (N/A)	Jeddah	Approx. 70 %	> 75 %	4 433 991	81 475
Saudi Arabia (N/A)	King Abdullah	Approx. 70 %	> 75 %	2 020 683	37 130
Saudi Arabia (N/A)	Dammam	Approx. 70 %	> 75 %	1 822 642	33 491

Singapore (1)	Singapore	Approx. 70 %	> 75 %	37 195 636	683 470
South Korea (7)	Busan	Approx. 70 %	50 - 75 %	21 992 001	865 935
South Korea (7)	Yeosu Gwangiang	Approx. 70 %	< 25 %	2 378 337	218 510
South Korea (7)	Inchon	Approx. 70 %	< 25 %	3 091 955	284 073
United Arab Emirates (8)	Dubai	Approx. 70 %	> 75 %	14 111 000	259 290
United Arab Emirates (8)	Abu Dhabi	Approx. 70 %	> 75 %	2 780 000	51 083
				Tot: 98 255 948	**Tot: 4 680 046**

Table 5.4. SAM - European Market

Country	**Port**	**Truck Rate**	**Transshipment Rate**	**Throughput (TEUs)**	**SAM Throughput (TEUs)**
Belgium (21)	Antwerp	Approx. 60 %	25 - 50 %	11 860 204	667 136
France (19)	Le Havre	60 %	< 25 %	2 822 910	222 304
France (19)	Marseille	60 %	50 - 75 %	1 455 000	49 106
Germany (14)	Hamburg	80 %	25 - 50 %	9 274 215	695 566
Germany (14)	Bremen/Bremerhaven	80 %	50 - 75 %	4 856 900	218 561
Greece (N/A)	Piraeus	Approx. 60 %	> 75 %	5 648 000	88 956
Italy (24)	Genoa	Approx. 60 %	> 75 %	2 621 470	41 288
Italy (24)	Gioia tauro	Approx. 60 %	> 75 %	2 523 000	39 737
Italy (24)	La Spezia	Approx. 60 %	> 75 %	1 659 000	26 129
Malta (N/A)	Marsaxlokk	Approx. 60 %	> 75 %	2 722 880	42 885
Netherlands (2)	Rotterdam	Approx. 60 %	25 - 50 %	14 810 800	833 108
Poland (N/A)	Gdansk	Approx. 80 %	50 - 75 %	2 073 210	93 294
Portugal (N/A)	Sines	Approx. 60 %	> 75 %	1 423 000	22 412
Spain (22)	Las Palmas	Approx. 60 %	> 75 %	1 007 000	15 860
Spain (22)	Valencia	Approx. 60 %	50 - 75 %	5 439 820	183 594
Spain (22)	Algeciras	Approx. 60 %	> 75 %	5 125 380	80 725
Spain (22)	Barcelona	Approx. 60 %	50 - 75 %	3 324 650	112 207
United Kingdom (9)	Felixstowe	70 %	< 25 %	3 584 300	329 308
United Kingdom (9)	London	70 %	< 25 %	2 790 000	256 331
United Kingdom (9)	Southampton	70 %	< 25 %	1 924 840	176 845
				Tot: 86 946 613	**Tot: 4 195 353**

5.2.1.1.4 Quantifying the Segmented Serviceable Available Market (SAM) Value

When quantifying the Serviceable Market Value, two different approaches will be used to get a value that is as credible as possible. The first approach will be to calculate the cost per container inland transport, and the second one will be to calculate the number of trucks needed to handle the throughput in the different ports.

Approach 1: Cost per Container Inland Transport

The first approach to quantify the serviceable available market size value is derived from the estimation of cost per container inland transport. A total cost per transport can be calculated using assumptions regarding average time for loading, average speed, etc. This is later combined with costs related to running a truck. A full list of assumptions and estimations are presented in *Table 5.5.*

Table 5.5. Assumptions/Estimations for Approach 1 Calculations

Assumption/estimation	**Value**
Monthly salary for transporter (incl. tax and social fees)	45 000 SEK
Number of drivers needed to operate one truck 24 hours a day, 7 days a week	4
Yearly depreciation for a truck (Person 9, 2021)	100 000 SEK
Service and maintenance cost per year for one truck (Person 9, 2021)	50 000 SEK
Truck fuel consumption (Person 9, 2021)	3,0 L/10 km
Fuel price; Diesel	15 SEK/L
Distance between port and logistics center for transloading/round trip distance	10 km/20 km
Average truck speed	40 km/h
Time spent by truck leaving the container at the logistic center	X minutes
Time spent by truck picking up container from port	Y minutes
Round trip time	Z hours

Calculations:

$$\frac{Monthly\ salary \times drivers\ per\ truck}{Rounds\ per\ month} + \frac{Service\ and\ maintenance\ cost\ per\ truck\ and\ month}{Rounds\ per\ month} + \frac{Monthly\ truck\ depriciation}{Rounds\ per\ month}$$

$$+\ Fuel\ consumption \times Fuel\ price \times avg\ distance\ per\ round\ = Avg.\ cost\ per\ transport \Rightarrow$$

$$\frac{45.000 \times 4}{\omega} + \frac{50.0000/12}{\omega} + \frac{100.000/12}{\omega} + 0,3 \times 15 \times 20 = \frac{192.500}{\omega} + 90\ (SEK) \approx \frac{21.295}{\omega} + 9,96\ (USD)$$

$$\Rightarrow (\frac{21.295}{\omega} + 9,96)\ Dollar \times Number\ of\ interesting\ container\ moves\ = SAM$$

Table 5.6. Market Sizes with Approach 1

Market	**SAM Value - Approach 1**
Americas	$ 453 811ω
Asia	$ 529 638ω
Europe	$ 474 786ω
Total market	$ 1 479 210ω

Approach 2: Number of Trucks Needed per Port

By using the data from The Case Company on the average distance traveled by a container truck per day, it is possible to calculate how many containers that one single truck can transport given that the average distance between the port and warehouse is 10 kilometers. Proceeding from that, we can calculate how many trucks that are needed to handle the daily flow of containers between the ports and the warehouse.

Table 5.7. Assumptions/Estimations for Approach 2 Calculations

Assumption/estimation	**Value**
Monthly salary for transporter (incl. tax and social fees)	45 000 SEK
Number of drivers needed to operate one truck 24 hours a day, 7 days a week	4
Yearly depreciation for a truck (Person 9 2021)	100 000
Service and maintenance cost per year for one truck (Person 9, 2021)	50 000 SEK
Truck fuel consumption (Person 9, 2021)	3 L/10 km
Fuel price; Diesel	15 SEK/L
Distance between port and logistics center for transloading/round trip distance	10 km/20 km
Container truck average traveled distance per year	Δ km

Calculations:

$$(1)\ Nbr\ Interesting\ container\ moves \times \frac{Distance\ to\ logistics\ center\ and\ back}{Truck\ traveled\ per\ truck/year} = Number\ of\ trucks\ needed$$

$$(2)\ Trucks\ needed \times ((drivers/truck \times monthly\ salary) \times 12 + (\ service\ and\ maintenance\ cost/truck)$$

$$+ (depreciation/truck) + (Distance\ traveled\ per\ year \times Fuel\ price \times Fuel\ consumption) =$$

$$= Nbr\ Trucks \times \$255\ 543 + 0,03\Delta = SAM$$

Table 5.8. Market Sizes with Approach 2

Market	**SAM Value - Approach 2**
Americas	$ 2 384Δ
Asia	$ 2 782Δ
Europe	$ 2 494Δ
Total market	$ 7 660Δ

5.2.1.2 Customer Drivers

When analysing the customer drivers towards automation in ports in general, it is clear that the main focus for stevedores and port operators is to do everything to minimize the time spent in port for the vessels. To achieve this the operations on the quay side focus on serving the quay crane operators in the best possible way to quickly get the containers out of the way. Since The Case Company's autonomous vehicles do not focus on transportation between the quay crane and the stack, it does not affect the efficiency of this particular part of the process.

Other bottlenecks discussed are the gate where trucks come into the port to collect or leave containers. In most cases today, drivers have to pre-book a pick up or delivery, identify themselves at the gate and then drive the truck into the port area to finish the job. The identification phase at the gate is a bottleneck that often creates congestion. Having an autonomous vehicle in place to handle the transport from the container stack and out from the port area to a nearby location for transloading could help reduce these bottlenecks due to the fact that the identification can be switched to a digital process. Also, data sharing between the port and the vehicle can optimize the flow and avoid peaks.

Finally, the vessel sizes are increasing which has created a need for ports to handle volume peaks with more TEUs with every ship calling the port. This shockwave influences all of the parts in the operation and creates a need for better optimization. The Case Company autonomous trucks could be one piece of the puzzle to solve this, using better allocation of resources via data sharing and operation planning. For this to become an advantage, it requires open data sharing of the handling process in the port as well as for the vehicle itself to be able to prioritize the most effective route at every moment.

5.2.1.3 Automation Readiness

The level of automation in a port is a factor that can make a specific port both more and less suitable for implementing autonomous trucks. On the one hand, that the port has some autonomous parts in the process can be positive since that shows an openness towards automation. This means that the port has had successful discussions with the unions before and also that the port has a strategy to allow large upfront investments for efficiency savings in the future. From this perspective, a port with no automation due to less successful discussion with the unions or another reasoning behind large upfront investments, might be a port that is not worth considering as a possible customer. On the other hand, a port that has implemented many autonomous flows might have less flows that The Case Company can target. A great example of this is the transportation of containers from the quay to the stack which in many ports already is operated by automatic guided vehicles (AGVs). Another example is the transportation with autonomous vehicles of containers to the parking spot outside the port in the autonomous terminal in the Port Alpha. Here, a part of the transportation route that can be operated by The Case Company is already autonomous and therefore not interesting. In other words, there are two situations regarding the level of automation that is favourable. The first one is a port with several autonomous processes but manual handling of the part that The Case Company is interested in. The second one is a port with low levels of automation, as long as the low levels are not a result of resistance towards it from unions, financial perspectives or else.

When applying the *Technology Acceptance Model* (TAM) to autonomous trucks in the Port industry the two determinants for a successful implementation of a new technology are identified to both be beneficial for a full acceptance in the industry. The first determinant, namely the perceived usefulness is high since almost all ports interviewed expressed a large interest in the technology and a belief that it would add many benefits to their operations. This facilitates the process of creating a general acceptance in the industry in the near future. The second determinant, perceived ease of use, is weaker but still classified to be high. A lot of automation is already taking place in the industry and a lot of factors that limit the acceptance are out of control for the ports, like legislations and unions. Since both determinants are favourable, the model argues for autonomous vehicles to be a large part of the port industry in the near future.

5.2.2 Logistic Centers

5.2.2.1 Market Value

5.2.2.1.1 Total Available Market (TAM)

Starting with the interviews conducted with logistic centers where trucks are used, the flow of goods looked roughly the same in the case for Logistics Alpha 1, Logistics Alpha 2, Logistics Beta 1 and Logistics Beta 2. The trucks with goods will reach the warehouse and dock directly to the building where staff will empty the truck into the inhouse flow. When the goods later are ready to leave the building, a truck will enter the area and dock directly into the building where staff can fill the truck with the goods that should be delivered. The average distance that the truck travels to and from the warehouse is far longer than Y kilometers. This means that the regular flow of goods in logistic centers based on the conducted interviews can provide no clear use case for The Case Company.

When looking for flows that are separated from the main flow of goods, two use cases were found. For Logistics Alpha 1in Alpha City, investigations for making flows between the warehouse and close by terminals have been made. They found one of those flows in Alpha City and two more in the Nordics region. Although the facility in Alpha City is the biggest one in Sweden and fourth biggest in Europe, this flow would only require one truck operating per day, which is considered to be a too small number for The Case Company. Another flow that is separated from the main flow is the movement of empty containers in the yard outside the facilities in Alpha Suburb. Here, a tug tractor is operating 24 hours a day 6 days a week. Since only one tug tractor is required here, the volume is also considered too small for The Case Company. Since no applicable use case has been found within this area, the total available market will not be considered here.

Another segment that falls into the market *Logistic Centers* that has a big potential is hubs for air freight. Airports are big, gated areas and the freight has to be moved from the airplanes to terminals for further handling. This transport is done using terminal tractors pulling *Unit Load Devices* (ULDs). The global market for air freight is centered around 20 of the world's biggest airports for air freight, which together accounts for roughly 80 % of the volume.

The calculations of the *Total Available Market* (TAM) estimation for air freight is based on the following assumptions:

Table 5.9. Assumptions/Estimations for Flight Freight Calculations

Assumption/estimation	**Value**
ULD (LD-3) capacity (Thomson, 2019)	1506 kg
Number of ULDs allowed to be pulled by one vehicle (Person 26, 2021)	Γ
Monthly salary for transporter (incl. tax and social fees)	45 000 SEK
Monthly leasing and service cost for a terminal tractor (Vehicle Company, 2021)	30 000 SEK
Terminal tractor fuel consumption (Vehicle Company, 2021)	7 L/hour
Fuel price; Diesel	15 SEK/L

Time for transport to airplane, load off the plane and transport back (Person 26,2021)	1 hour

Calculations:

(1) $Cost\ per\ transport\ =$

$$\frac{Salary\ for\ transporter}{number\ of\ rounds\ per\ month} + \frac{Service\ and\ maintenance\ cost\ per\ terminal\ tractor}{number\ of\ rounds\ per\ month} + \frac{Fuel\ consumption\ per\ hour}{1} \times fuel\ price\ =$$

$$\frac{45.000\ SEK}{(168\ h\ /\ 1\ h)} + \frac{30.000\ SEK}{(168\ h\ /\ 1\ h)} + (7\ liter/h\ \times\ 15\ SEK\ /\ liter)\ =\ 551\ SEK/round \approx 61\ US\ Dollars/round.$$

(2) $TAM\ = \frac{Total\ Volume\ of\ Air\ Freight}{Carrying\ Capacity\ of\ one\ ULD} \times \frac{1}{Pulling\ Capacity\ of\ ULDs} \times (avg.\ cost\ per\ transport)\ =$

$$\frac{61.300.000.000}{1.506} \times \frac{1}{\Gamma} \times 61\ =\ 0,0994\Gamma\ billion\ US\ Dollars$$

5.2.2.1.2 Serviceable Available Market (SAM)

The Serviceable Available Market (SAM) is calculated using similar demographic variables as discussed when the market for ports was examined. Apart from demographic variables, there are operational variables that need to be taken into account. The result is that a SAM value for the market is extracted from TAM.

The technical solution that The Case Company is selling requires a certain amount of freight volume to be financially viable. For ports, this critical volume was determined to be 1 million TEUs handled in one port per year, leading to roughly 80 % of the sea freight volume to be considered interesting for the market size. Using the same share of the air freight market as potential serviceable volume, the market adds up to only the 22 biggest airports for air freight in the world, which together make up 80 % of the air freight market.

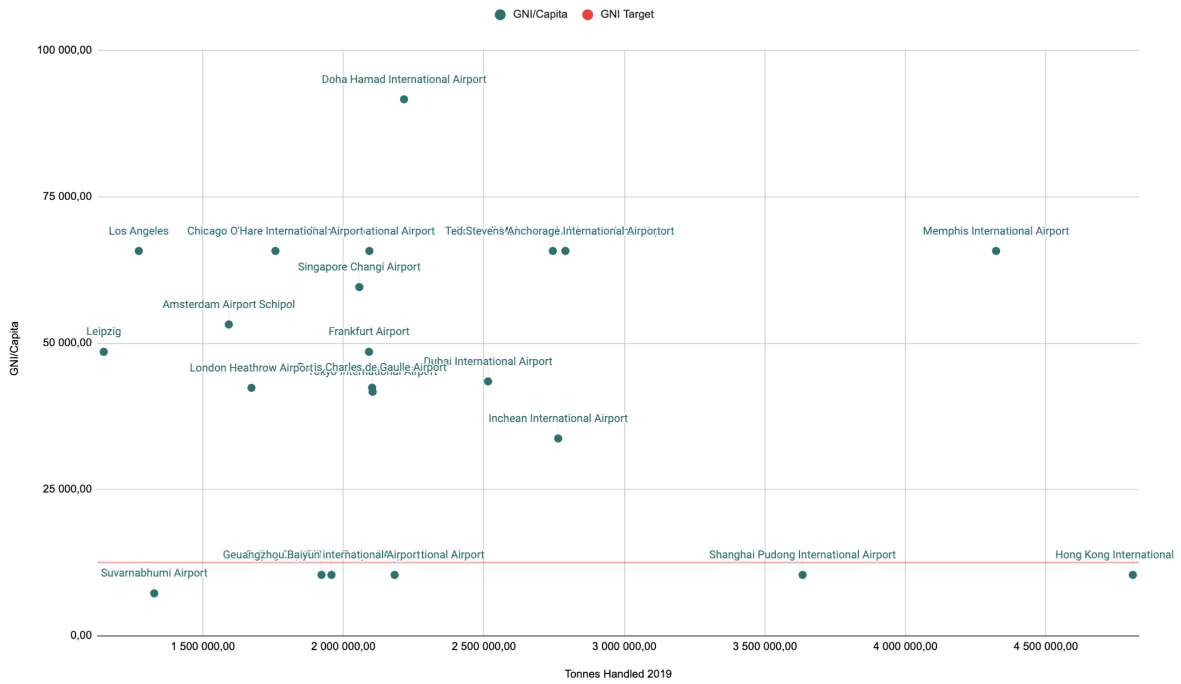
Using the same argument for automation as was used in *5.2.1.1.2 Serviceable Available Market*, one of the major factors for choosing automation is to reduce labor costs. Following this argument, the market size for the logistic centers will also be downsized to only consist of countries falling into the “High Income” criteria for GNI/Capita used by the World Bank. The result when applying this to TAM is that the total volume drops from 80 % to 57,5 % of the total freight volume. A graphical visualisation of this can be seen below in *Diagram 5.2*.

The SAM value is then calculated using updated freight volumes in the formula for market size:

$$SAM\ =\ \frac{Total\ Volume\ of\ Air\ Freight\ for\ SAM\ Market}{Carrying\ Capacity\ in\ one\ ULD} \times \frac{1}{Pulling\ Capacity\ of\ ULDs} \times (avg.\ cost\ per\ transport)\ =$$

$$\frac{35.242.419.000}{1.506} \times \frac{1}{\Gamma} \times 61\ =\ 0,057\Gamma\ Billion\ US\ Dollars$$

Diagram 5.2 Assumptions/Estimations for Approach 2 Calculations



5.2.2.1.3 Market Segmentation

For this thesis, there has not been enough time to further investigate segmentation variables for hubs for air freight. Further investigation of the market could focus on operation variables such as differences in how the freight is handled in different airports, average distance traveled, legal aspects of implementing autonomous solutions and differences in the handling process for different kinds of ULDs.

However, even if no segmentation will be done, the DHL hub in Leipzig can be used as an example with their total volume of 1,15 million tonnes of cargo per year.

DHL Leipzig Hub:

$$Leipzig\ Market\ Value = \frac{Total\ Volume\ freight\ Leipzig\ Hub}{Carrying\ Capacity\ in\ one\ ULD} \times \frac{1}{Pulling\ Capacity\ of\ ULDs} \times (avg.\ cost\ per\ transport)$$

$$= \frac{1147233}{1.506} \times \frac{1}{\Gamma} \times 61 = 0,372\Gamma\ million\ US\ Dollars/Year$$

5.2.2.2 Customer Drivers

When analysing the customer drivers within the segment for logistic centers, two main drivers are found, namely, sustainability and cost reduction. Without going too deep into the subject of sustainability, going from fossil fuel driven vehicles, to electric driven vehicles is of course a step in the correct direction. Therefore The Case Company's solution is addressing this driver in a very natural way. The cost reduction is also reachable in the long run with more efficient operations and the possibility to reduce the large salary costs.

Apart from being efficient and handling as many shipments as possible per hour, another driver identified is to maintain a high quality where few packages are lost or delivered to the wrong address. In this area, the data handling capability in the The Case Company offer is attractive in order to keep track of more processes simultaneously. Finally, removing the driver provides a solution to the competence shortage that was identified. As Conrady described in an interview, Frankfurt Airport has a shortage of 400 - 500 employees per year in their operations. Removing the drivers from vehicles transporting air freight to and from the plane might ease this shortage. However, it is important to further investigate if there is a shortage of employees on a global scale and where in the handling process there is a need for more personnel. If this does not apply for drivers controlling the vehicles, this factor can not be considered as a customer driver for this segment.

5.2.2.3 Automation Readiness

Even though the applications for autonomous trucks in logistic centers for yard operations are limited, the industry has a rather good automation readiness. As discussed above, there are autonomous solutions in place for e.g. wall-to-wall counts within warehouses, AGVs and automatic forklifts operating inside to move pallets and plastic wrapping robots working to ensure that the freight does not get injured during the transportation. This advocates for the fact that the industry is open towards evaluating autonomous solutions and even implementing them when it is economically feasible.

As for any other industry, unions protecting the labor from losing their jobs is one of the major factors restricting the readiness level. From what has been discovered in this study, the unions operating for workers in logistic centers in the nordics region have been accepting a certain amount of automation for the operations within the logistics centers, which is why several examples of automation are present today.

When applying the *Technology Acceptance Model* (TAM) to autonomous trucks in the logistics industry the two determinants for a successful implementation of a new technology are identified to counteract. The first determinant, namely the perceived usefulness is low since almost all companies interviewed had few operations on the outside of the facilities. The second determinant, perceived ease of use, is higher since a lot of processes already have been automated on the inside with for instance AGVs. However, the first determinant is the more important one of the two according to the model and therefore, the model argues for autonomous vehicles being insignificant in the future of logistics centers.

For automation readiness at airports, two interesting cases have been studied. Although this seems to be a very interesting application, there is too little information gathered to analyse the readiness in this segment for airports to implement autonomous vehicles. Looking at the case at Toulouse-Blagnac Airport, an autonomous terminal tractor drives to and from the plane automatically, but once it approaches the plane it is switched to manual mode and overtaken by a human driver. This serves as a great example for the acceptance and willingness within the segment to overcome obstacles for automation. Dividing the task into subtasks where some can be automated and the more riskful parts can still be handled by a human being creates a first step towards a fully autonomous solution.

5.2.3 Manufacturing Companies

Based on the conducted interviews it is clear that manufacturing companies and the flows of goods and raw materials within the facilities are varying greatly. On one side of the spectrum there are facilities where raw materials enter the process via a truck docking to the buildings followed by exclusively indoor handling before finished products are loaded into trucks that dock before they are delivered to the end destination. On the other side there are larger facilities with several buildings and a large flow of goods in the garden and between intermediate warehouses before the products are finished and transported to their destination. Between those ends of the spectrum, there are hybrids as well with a lot of indoor transportation but some handling of goods in an outside yard. Therefore, it has not been possible to decide the general handling flow of goods in producing warehouses.

While interviewing people from organisations in this market with a great overview of the flows that are present, a common pattern was that companies could see the potential gains of automating the flows, both in terms of efficiency gains and sustainability, but they tended to express a doubt that it would be possible to implement. One reason that came up was that the flow rarely was the same all the time and that the skill of improvisation therefore often was needed. Another reason was that internal transportation routes often were occupied by the workforce and that an autonomous vehicle therefore would have a hard time operating without too many interruptions. One third reason was that the vehicles operating in the yard often are used for different flows and processes depending on time of the day and the day of the week. One day it can be used as a transporter of raw material in the yard and another day it can be used to transport semi-finished goods between a production facility and an intermediate warehouse in another part of the facility. When the trucks are used in this way, the flexibility of having a human driver that can adapt instantly to new settings is crucial. In general, the way of thinking about an autonomous solution was that it would be hard to implement it directly into the current solution, compared to other markets where the reasoning about creating an integrated solution came more naturally.

5.2.3.1 Market Value

Two different approaches have been tried in order to scale up the transportation flows identified at the interviewed facilities to the total market size. The first approach was to try to weigh the amount of goods produced in a facility and the transportation needed for the goods, to the total volume of goods produced in the company and from there try to scale it with the company size in relation to other companies. The first obstacle here was that larger companies rarely produce all their product lines in the same facility, instead they have specific facilities for specific product lines. Although the interviewees could answer how large their production volume was in relation to the total production of that specific product, they had limited insights in the total volumes of the company. This means that considerably more interviews would have to be done at one single company and its different parts to use this approach. The other problem here was that even if they knew the volume created in other production lines, they only knew the number of units produced and not how many of those products fitted in a container or one truck.

The second approach was to look at the volume of raw material needed to create the products. In other words, when the volume coming out of the production facilities did not work, the focus was changed to the volume reaching the facilities. The obstacle here was that the volume needed to create a specific volume of products varied in such a way that the number of trucks needed to deliver to products did not say anything about how many trucks that were needed to deliver the finished products or to handle goods in the facility yard. Some products create a lot of waste material that needs to be transported away from the process and other products are more efficient in the volume of raw materials needed for production. Therefore, no correlation could be found here either with the number of interviews made within the given time frame.

In conclusion, the absence of the standardisation of units in manufacturing companies, that is seen in both ports and air freight, makes it hard to scale the applications for autonomous trucks found in the interviews to a global market size. However, this does not make this segment any less attractive for The Case Company. With the vast variation comes more different types of flows and with that more possible applications for an autonomous solution. Therefore, the next sections will not examine the total available market size and the serviceable available market size as in the sections for *Ports* and *Logistics Centers*. Instead it will present 3 of the possible applications found and a calculated market value for the selected cases.

5.2.3.1.1 Market Segmentation

As mentioned in *the Empirics* the market for manufacturing companies are often segmented into ten different segments depending on what they are producing, such as Wood Products or Metals to name a few. After analysing the results from speaking to eight people from different companies in different segments of manufacturing in Sweden, the result points towards the fact that there are few similarities between how the process works and how the internal logistics are handled. Instead, it is more important how the facility is planned and how many separate buildings there are in the yard. Some facilities tend to be incapacious if the company has faced long term growth and has been forced to fit into a small area. One example of this is Manufacturing Alpha's facility in Alpha City 2. Other types of facilities are more well planned and focused on keeping as much of the process under one roof as possible with the raw material coming in at one end of the facility and the refined product leaving in the other end with trucks docking into the same building, minimizing the need for outdoor material handling. Manufacturing Delta is a good example of this. Instead of focusing on segmenting the market after what the company is producing, it is of more interest to look at factors regarding the layout of the facility, the amount of outdoor transportation flows and distances traveled.

Another operational variable that is of interest when trying to determine the market size is how susceptible the company is for autonomous solutions. This is partly dependent on the relationship the company has with the specific union that operates within their area of manufacturing. Hence, it is of interest for this topic to classify companies into the different segments presented in *the Empirics* and from there evaluate the status of each labour union. One way to do so is to see how far companies within each segment have come with automation in general, such as if there are AGVs operating inside the facilities today or if there are other types of automation at play.

5.2.3.2. Selected Cases

5.2.3.2.1. General Assumptions in Selected Cases

In this section, three use cases that were found during the interviews have been selected. These use cases will be more deeply examined and a value for all cases will also be calculated. To decide the value for the companies, the cost for their current solution will be calculated. To calculate this value, three company specific factors will be used, namely the number of vehicles operating in the solution, the number of people who are employed to drive the vehicles and how many hours a day those vehicles are operating. The formula below is a general formula for the calculation.

$$Total\ costs\ =\ (Driver\ salary\ \times\ nbr\ drivers)\ +\ (service\ and\ maintenance)\ \times\ nbr\ of\ vehicles\ +$$

$$Avg.\ fuel\ consumption\ \times\ Avg\ fuel\ price)\ \times\ nbr\ of\ vehicles$$

The calculations of the estimation for each case is based on the following assumptions:

Table 5.10. Assumptions/Estimations for Manufacturing Companies Calculations

Estimates/Assumptions	**Value**
Monthly salary for transporter (including tax and social fees) (Person 26, 2021)	45 000 SEK
Monthly leasing and service costs for a terminal tractor (Vehicle Company, 2021)	30 000 SEK
Fuel consumption for a terminal Tractor (Vehicle Company, 2021)	7 liter/hour
Fuel price; Diesel	15 SEK/liter
Service and maintenance cost per year for one truck (Person 9, 2021)	50 000 SEK
Truck fuel consumption (Person 9, 2021)	3 L/100km

5.2.3.2.2 Manufacturing Gamma; Facility-Warehouses

In the case of Manufacturing Gamma in Gamma City, the lack of sufficient number of storage spots within the facility area forces the company to store more than 50 % of their finished products in warehouses outside the production area. Therefore they have transportation of finished goods to the 6 external warehouses every day, that are situated 400 meters to 6 kilometers away from the location. Manufacturing Gamma has 6 people working with the internal transportation, but also several other employees with the competence to drive the vehicles. Since Manufacturing Gamma expressed that their truck fleet was old and needed to be replaced and that they already have had discussion with one of The Case Company competitors regarding these routes, this case is favourable. The flow on which the raw materials are transported to the production is very suitable since it is between 400 and 500 meters, repetitive, and only on private roads within a fenced area.

Here, a possible approach would be to implement an autonomous solution gradually, starting with replacing the haulage contractor that probably is the largest cost for the moment. To make the repetitive, fenced, flow between the raw materials and the production area autonomous, Manufacturing Gamma and The Case Company will have a perfect pilot project to learn from before continuing with other flows that also will take place partly on public roads. In addition, it can arguably be favourable for the operations to keep at least one manually driven vehicle, in case there are certain parts of the flows that are hard to automate. In the calculations below, we calculate what Manufacturing Gamma spends every year for parts of their transportation solution. What Manufacturing Gamma pays today is seen as the market value for this specific part of their operations. In the table below a summary of the gathered data points is presented.

Table 5.11. Input values for Manufacturing Gamma Calculations

Number of vehicles operating	People employed to drive	Operating hours per day	Routes
3 terminal tractors 1 haulage contractor truck	8	2 terminal tractor 12h/day 1 terminal tractor 24h/day 1 truck 12h/day	Facility to 6 warehouses. 400m-6km kilometers. Public and private roads*

**With 10 minutes to load and 10 minutes to load off and an average speed of 60 km/h and an average distance of 3,4 km, transportation to the warehouses and back takes 10 + (6,8 km)/(50 km/h))*60 min + 10 = 28,16 minutes. This will be rounded to ½ hour for the truck. In 12 hours, this equals a distance of 161 kilometers per day for the haulage contractor truck.*

***An assumption that the terminal tractors are running 30 % of the time has been made. This number has been chosen due to the fact that several sources have stated that these vehicles only drive a minority of the total time. The other part of the time goes to loading/unloading and other activities that do not affect the total fuel consumption.*

1. **Market value for operating 1 truck (12 h/day)**

$Yearly\ cost\ =\ (Distance\ traveled\ per\ month\ \times\ Avg\ fuel\ consumption\ \times\ fuel\ price)\ +\ Driver\ salary)$
$\times\ 12\ +\ service\ and\ maintenance\ cost\ +\ depreciation\ for\ truck\ \Rightarrow$
$((161\ \times\ 30\ \times\ 0,33\ \times\ 15)\ +\ 45\,000\ \times\ 2\ )\ \times\ 12\ +\ 50\,000\ +\ 100\,000\ =$
$1\,516\,902\ SEK\ \approx\ 167\,807\ US\ Dollars$

2. **Market value for 1 terminal tractor (12 h/day) and 1 truck (12 h/day)**

$Yearly\ cost\ =\ (Cost\ for\ 1\ terminal\ tractors\ +\ 2\ drivers)\ +\ (Cost\ for\ 1\ truck\ )\ \Rightarrow$
$(Driver\ salary\ \times\ 2\ (leasing\ and\ service\ terminal\ tractor\ +\ Avg.\ fuel\ consumption\ \times$
$Avg\ fuel\ price\ \times\ run\ time\ share)\ \times\ 12)\ +\ 1\,516\,902\ =$
$(30000\ \times\ 1\ +\ 45000\ \times\ 2\ +\ (7\ liter/h\ \times\ 15\ \times\ 0,3\ \times\ 12\ h\ \times\ 30\ )\ \times\ 12\ +\ 1\,531\,652\ =$
$1\,576\,080 + 1\,531\,652\ =\ 3\,092\,982\ SEK\ \approx\ 343\,792\ US\ Dollars$

3. **Market value for 3 terminal tractors (2x12h/day+1x24h/day) and 1 truck (12h/day)**

$Yearly\ cost\ =\ 4\ \times\ 1\,576\,080\ +\ 1\,531\,652\ =\ 7\,821\,222\ SEK\ \approx\ 865\,221\ US\ Dollars$

5.2.3.2.3 Manufacturing Alpha; Terminal

As described in the empirics, there is a flow of goods from the Manufacturing Alpha Facility in Alpha City 1 to a terminal by the lake of Alpha. 60 % of the finished goods are transported this route, which in numbers equal 560 000 tonnes out of 932 000 tonnes. For this route, Manufacturing Alpha is buying the transport from a company named LBC that uses 4 trucks and 15 people for the transportation. The trucks operate 18 hours a day and the route is on both private and public roads, but the majority of the way is on a public country road.

Trucks might have less problems with precision and flexibility compared to terminal tractors in the yard. However, since there still will be problems with the fact that parts of transportation will take place on public roads, it is a good idea to implement this gradually. In the calculations below, we calculate what Manufacturing Alpha spends every year for their truck transportation. What Manufacturing Alpha pays today is seen as the market value for this specific part of their operations. In the table below a summary of the gathered data points is presented.

Table 5.12. Input values for Manufacturing Alpha Ciy Calculations

Number of vehicles operating	**People employed to drive**	**Operating hours per day**	**Routes**
4 trucks	15 people	18 hours	From facility to terminal. 8 kilometers * Public and private

* With 15 minutes to load and 15 minutes to load off and a average speed of 60 km/h, transportation to the warehouse and back, one round trip, takes 15 + (16km)/(60 km/h)*60 min + 15 = 46 minutes which will be rounded to ¾ hours. In 18 hours, this equals a distance of 384 kilometer per day per truck.

1. **Market value for operating 1 truck (18 h/day)**

$$Yearly\ cost\ =\ (Distance\ traveled\ per\ month\ \times\ Avg\ fuel\ consumption\ \times\ fuel\ price)\ +\ Driver\ salary)\ \times\ 12\ +\ service\ and\ maintenance\ cost\ +\ depreciation\ for\ truck\ \Rightarrow$$
$$((384\ \times\ 30\ \times\ 0,33\ \times\ 15)\ +\ 45\,000\ \times\ 3\,)\ \times\ 12\ +\ 59\,000\ +\ 105\,750\ =$$
$$2\,454\,288\ SEK\ \approx\ 271\,505\ US\ Dollars$$

2. **Market value for operating 4 trucks (18/day)**

$$Yearly\ cost\ =\ 2\,454\,288\ \times\ 4\ =\ 9\,817\,152\ SEK\ \approx\ 1\,086\,020\ US\ Dollars$$

5.2.3.2.4 Manufacturing Alpha-Internal Yard Transportation

Because of the large amount of internal yard transportations that is needed there is a full unit of 24 people working exclusively with transportation. All transport is taking place within fenced areas and both terminal tractors and forklifts are used. Since the transportation unit has several forklifts that are manually manouvered, the unit will keep a lot of precision capacity and flexibility even if both of the terminal tractors in the near future are replaced with autonomous solutions.

There is also a shorter transportation of 500-600 meters within the facility area where Manufacturing Beta's goods are transported to a warehouse by Manufacturing Alpha. For this, Manufacturing Alpha has 2 terminal tractors and 24 people hired. However, the people employed and the terminal tractors are also working with other smaller transportation and tasks in the yard. Because of this, 8 people out of 24 are used in the calculation to exclusively drive the terminal tractors.

From an overview perspective, the situation in Skoghall is suitable from three main perspectives. First of all, all of the transportation done by the terminal tractors are taking place within fenced areas. Secondly, the unit has 2 tractors that can operate 24 hours a day in four shifts which means that there is a really considerable labour share in the total costs calculations. Lastly, since the unit still will have access to several forklifts, the most complex transportations can wait to be automated until the solution in this specific case is fully developed. In the calculations below, we calculate what Manufacturing Alpha spends every year for parts of their transportation solution. What Manufacturing Alpha pays today is seen as the market value for this specific part of their operations. In the table below, a summary of the gathered data points is presented.

Table 5.13. Input values for Manufacturing Alpha Internal Yard Calculations

Number of vehicles operating	People employed to drive	Operating hours per day	Routes
2 terminal tractors	8 people	24 hours	General transportation in the yard. Public and Private

**An assumption that the terminal tractors are running 30 % of the time has been made. This number has been chosen due to the fact that several sources have stated that these vehicles only drive a minority of the total time. The other part of the time goes to loading/unloading and other activities that do not affect the total fuel consumption.*

1. **Market value for operating 1 terminal tractor (24h/day)**

$Yearly\ cost\ = (Cost\ for\ 1\ terminal\ tractors\ +\ 4\ drivers)\ =\ (Driver\ salary\ \times\ 2)\ +$
$leasing\ and\ service\ cost\ +\ Avg.\ fuel\ consumption\ \times\ run\ share\ =$
$(30000\ \times\ 1\ +\ 45000\ \times\ 4\ +\ (7\ liter/h\ \times\ 15\ \times\ 0,3\ \times\ 12\ h)\ \times\ 30)\ \times\ 12\ =$
$2\ 656\ 080\ SEK \approx 293\ 828\ US\ Dollars$

2. **Market value for 2 terminal tractor**

$Yearly\ cost\ =\ 2\ 656\ 080\ \times\ 2\ =\ 5\ 312\ 160\ SEK\ \approx\ 587\ 656\ US\ Dollars$

5.2.3.3. Customer Drivers

The most mentioned customer driver within manufacturing is cutting costs and decreasing the bottom-line together with digitalisation, AI, Machine Learning and Data. Here, implementing an autonomous vehicles service that is built upon machine learning and AI is for sure a step in the right direction. The cloud services that are included will also come in handy when it comes to gathering data from the transportation operations which is something that a manual truck will not do. The important factor here is that cutting costs with autonomous vehicles will be possible over time but probably not from the beginning as the implementation costs will be high. Therefore it is important to calculate the long term savings and also the savings that can be done thanks to the increased amount of information that will be generated. This information will decrease the number of costly wrong decisions and inefficient operations.

Sustainability is the second most mentioned customer driver and as described in the Logistics Part, The Case Company's autonomous vehicles instead of petrol or diesel driven vehicles will be a step in the right direction. An interesting perspective here is the described driver to be sustainable in order to attract the best talents to the company. Being a first mover in using a new technology like autonomous vehicles with all the attention that has been given to the area in the media lately, as a tool to decrease the negative environmental impact, is probably a favourable tactic in attracting the best workforce to the company.

5.2.3.4. Automation Readiness

As mentioned in the empirics, automation inside the facilities in manufacturing companies have been one topic of discussion since the 1960s and has reached far in relation to many other industries as of today. However, the automation outside the facilities have been very low or none at all in all the interviews conducted in this study. Since The Case Company autonomous trucks are more suitable for operating outside, the low automation here can be seen as negative at first sight. However, when looking at the reason mentioned by the interviewees regarding why automation is low on the outside, it is clear that there are some attitude barriers present. The main described reasons why the automation is low on the outside is that the physical layout is too narrow and cramped at some places while it also is occupied by workers. However, in all the interviews where this was mentioned, the same facility would have AGVs or automated forklifts in the inside facility. One can argue that the situation with narrow passages and people on the ground probably was at least as apparent inside the facilities before the automation started there as it is now on the outside. Therefore, a facility with a lot of automation inside is favourable for The Case Company, since they with great certainty have been forced to adjust the layout of their processes to make room for automation before. Probably the changes needed to the inside layout in order to make room for an AGV is more extensive than the changes needed outside for an autonomous truck.

When applying the *Technology Acceptance Model* (TAM) to autonomous trucks in the manufacturing industry the two determinants for a successful implementation of a new technology are identified to counteract. The first determinant, namely the perceived usefulness is high since almost all companies interviewed expressed a large interest in the technology and a belief that it would add many benefits to their operations. This opinion facilitates the process of creating a general acceptance in the industry. The second determinant, perceived ease of use, is weaker since a lot of obstacles such as narrow passages and people on the ground are pointed out by the interviewed companies. However, the first determinant is the more important one of the two according to the model, since a large perceived usefulness can create incentives for the industry to adopt the technology even if the system is complex and requires adaptive measures by the user. Therefore, the model argues for autonomous vehicles to be a large part of the future in the manufacturing industry even if the process of getting there can be slower than other industries.

5.3 Analysis Summary

Autonomous vehicles have reached various states in the technology S-curve in the different segments the technology is targeting. The long history of using autonomous solutions in the mining segment pushes the technology up the S-curve while the limited applications in the long hauling segments suppress it downwards. All sectors considered, the technology reached ⅓ up the curve much due to the fact that there are applications running today. The autonomous trucks have created a technological discontinuity in the transportation industry and companies compete to develop the dominant design, both in terms of physical appearance and the business model needed. Until a wide adaptation is present throughout the industry and the dominant design is set, the technology cycle is considered to be in a era of ferment. Autonomous vehicles challenge the norms of the transportation industry and by questioning not only the vehicles and the business models, but also the supporting infrastructure needed, the technology is seen as a radical innovation.

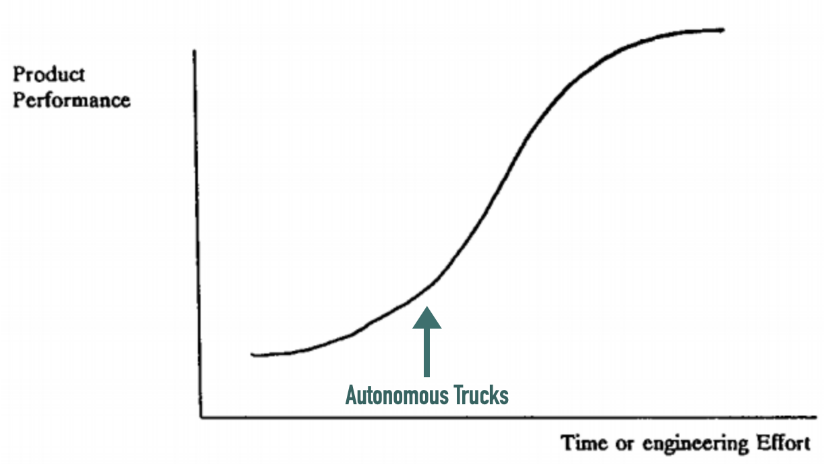


Figure 5.1. Autonomous Trucks in Relation to the S-curve

The Case Company has strategies to overcome the challenges in keeping up with the development of a technology that is not only radical, but also in a ferment era and a fast paced part of the S-curve. The Case Company itself was created by The Case Company Group in order to follow the rapidly changing environment of the technology, not only in Sweden, but also globally by having offices in innovation clusters around the world. With a close relationship with subcontractors as well as a culture that encourages partnerships and collaborations with external parts The Case Company also makes sure to be exposed to a broad set of technologies. In addition, a well developed HR strategy to attract great talents makes sure that new technology is managed in the best way possible once it has reached the company. Lastly, a clear framework for when to exploit a technology with both proof-of-concept and proof-of-value decreases the risk of spending money on technology that creates insufficient revenues in the end.

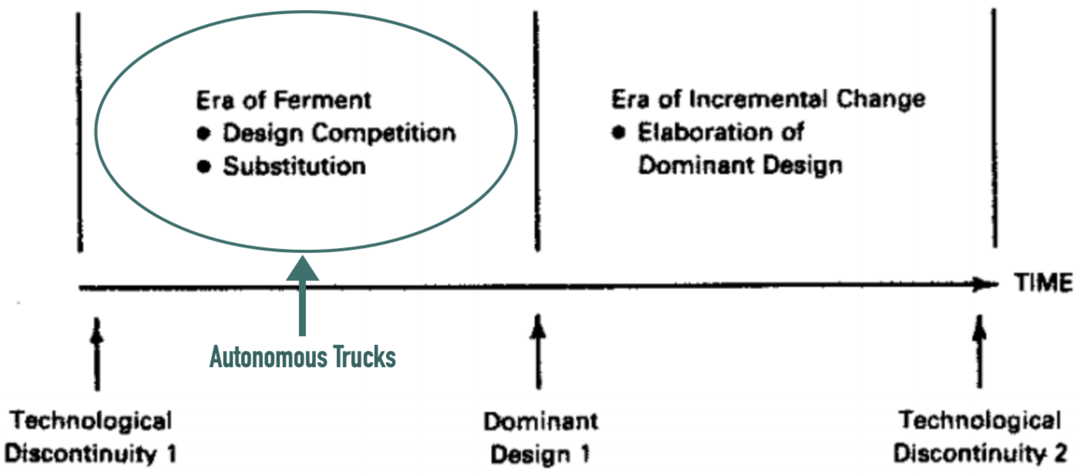


Figure 5.2. Autonomous Trucks in Relation to the Technology Cycles

The total available market for Ports was estimated with a starting point in the total global container throughput with consideration taken to the fact that a container adds to the global throughput first in the exporting port and at the end in the importing port. Transhipment on the way to the end destination is also added to the throughput. With this information, the total number of containers being transported in the world could be extracted from the throughput number. By adding the average cost for transportation from the inland depot to the exporting port and from the importing port to an inland depot, the total available market could be estimated.

The first step in deciding the serviceable available market was to eliminate ports with a throughput less than 1 million TEUs per year and a GNI/capita in the country lower than the highest income level. Thereafter, the containers being transshipped were removed from the total number in order to only consider the containers being exported or imported in the ports. In addition, the containers not leaving the port area with trucks were also removed from the total number. Then, the share of the containers being transported from or to a warehouse within Y kilometers from the port on roads that can be considered as interesting for The Case Company was estimated. Lastly, to calculate the market value for this specific transportation, a supply-side method was used where the cost of the solution used by ports today was estimated with two different approaches.

The Logistic Center segment was divided into centers for air freight and into centers for road freight. After conducting interviews with both segments, only air freight centers were considered interesting for The Case Company. A supply-side approach was used to estimate the total available market by calculating the global cost of ULD transportation within airports by terminal tractors. Just like in the Port market, the serviceable available market was extracted by setting a restriction on the volume handled in the airports and the GNI/capita level of the country.

For the Manufacturing companies segment, no way to generalize the possible applications found in the interviewed companies were identified. The main reason for this is the great operative variation found in the companies and the lack of standardized units used, as the containers used in ports and ULDs in airports. Instead of estimating a total market value, a more meticulous estimation has been made for the interesting application areas found in the interviewed companies. Just like the Air Freight and Port segment, a supply-side approach has been used where the costs for the companies' current solution has been calculated as the targetable value for The Case Company.

6. Conclusion

The conclusion of this Master's Thesis is based on the analysis presented in the previous section, which furthermore is based on the data collected via the interviews as well as from the academic research process. The following section aims to present an analysis regarding the technology shift towards autonomous solutions within the transportation industry as well as giving clear directions regarding how to achieve a competitive strategy for exploiting their solutions within the segments. Finally, it aims to present insights to the industry of transportation regarding autonomous vehicles in general.

The transport industry stands in front of radical change
The technology cycle in the industry of transportation is slowly shifting focus towards a new era of rapid development towards autonomous and electric solutions. There are already applications of autonomous trucks operating in segments such as mining and quarries and it is just a matter of time before they can be found all around the industry. Looking at the S-curve for technology performance development, it has been concluded that it is somewhere around ⅓ up the slope for autonomous solutions for the transportation industry.

Truck manufacturers are currently working to implement their solutions and to claim the dominant design. Exactly what that will look like is for the future to show. Autonomous solutions can therefore be said to be in an era of ferment and a turbulent future in the race towards the dominant design should be expected.

In terms of technology strategy, it is clear that it is a crucial ingredient to stay a competitive company in the rapidly changing transportation industry. The case company in this Master's Thesis had, even if it was not stated as the term "Technology Strategy", clear strategies to acquire, manage and exploit new technologies. Spinning off a part of the company to become a fast moving player with strong financial power, having a clear communication path between the technological development department and the commercial side and a clear framework for deciding when a technology is ready to be exploited, are all typical pieces of a sound technology strategy.

Looking at applications for the autonomous solutions that are present today, it is clear that there are a wide variety of options with short and repetitive flows. Such applications can be found around ports, airports and logistic centers, but also internal flows between different buildings at bigger manufacturing companies' plants to name a few. However, in many cases the surroundings and infrastructure has to be adapted to meet the requirements for the vehicle to operate. This will be a mutual responsibility for both the industry and the truck manufacturers to make autonomous vehicles a reality and a good collaboration between these parties will be a necessity.

Eliminate the illusion that the prerequisites needs to be perfect
Companies in all three sectors concerned in this Master Thesis generally express a large interest in automation. All companies interviewed have examples of autonomous processes within their facilities, varying from short repetitive flows like the AGV transport within several of the manufacturing companies, to the fully autonomous container handling process in one of the terminals in the Port Beta in the United States. Although the interest is high and the fact that all companies have experience in similar technology, the majority of the interviewed companies tend to get stuck on operational obstacles when it comes to the idea of having autonomous trucks in their facilities. Factors

like narrow passages, too little space, complex routes and employees on the ground are often brought up as examples why such a solution would be hard to implement. This is a great example of an illusion that the transportation flows and prerequisites must be perfect from the beginning. This illusion, or way of thinking, is something that needs to be eliminated in order to implement the technology in a broad perspective.

Focus on the relevant customer drivers and mitigate identified obstacles
With the rapid development of technology that is seen in today's society, it is easy for a high-tech company to be blinded by technical improvements and forget about the actual customer outcomes. This is arguably more crucial when what you are selling is not a product, but a service where the customer never really owns the high tech features, only its outcomes. Decreased negative environmental impact and increased operational efficiency and safety are all factors that an autonomous truck can provide. However, when those positive consequences are sidelined by technical buzzwords that are more and more common today, a lot of potential customers can disappear. This can be of extra importance in more conservative industries like the port industry, where a lot of pressure is placed on keeping costs down and improving the bottom line. Therefore, focus must be taken from the up front investments that can be assimilated with high tech products, and instead be placed in the decreased operational costs over time.

Within this area it is also important to take care of the issue with unions, especially in the port segment. All ports interviewed mentioned the power of the unions as one of the main factors making the automation development in ports slower than in many other industries.

Do not allow the legislations of today limit the opportunities of the future
One can argue that the majority of society agrees that autonomous vehicles will be a considerable part of the future even if the usage today is limited. In addition, people are often aware that the technology is in front of the legislation in society. At least, this is arguably the case for the potential customers for this type of technology. If the legislations change and the area of allowed usage for autonomous vehicles are increased, companies that already have started adapting their processes towards automation will have a first mover advantage in exploiting the benefits. By also emphasizing what parts of the company's operations that can be autonomous in the future when the legislations lighten up, an extra incentive is created for the customer in the long run.

7. Contribution and Remarks

7.1 Contribution to Academia

Autonomous trucks are a rather new technology. Even though studies have been done with a focus on determining the possible cost savings, few studies have been done to validate the potential across industries. This Master's Thesis aims to give a brief description of technology shifts in relation to global transportation, focusing on short distance delivery with autonomous trucks. The study aims to give a broad view of possible applications and possibilities for the new technology to inspire to further analysis. The theoretical contribution to academia is the modeling of the interplay of the commercial aspects and technological challenges in the development of new technological solutions in the autonomous area, which is illustrated in *Figure 3.7*.

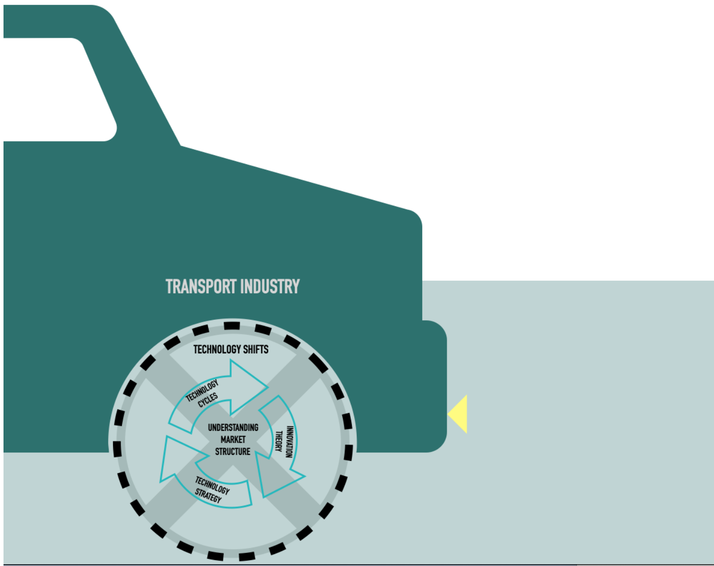


Figure 3.7. Theoretical Framework Illustration

7.2 Contribution to The Case Company

As previously discussed, autonomous trucks are gradually going from being an utopia to becoming reality for certain applications. This study aims to estimate how far the industry has come in accepting the new driverless way of transporting goods for short distances. In addition, it seeks to evaluate the market size for autonomous trucks for first mile delivery within Ports and Logistic Centers (internal flows at Manufacturing Companies included). The results from the analysis will contribute to better stipulate the Go-To-Market Strategy for The Case Company and to focus on relevant customer drivers for their potential customers.

To eliminate the illusion that the prerequisites need to be perfect it is crucial for The Case Company to make it clear that they are not selling only an autonomous truck, but an autonomous solution. The general customer for The Case Company does not have a perfect flow that can be operated by an autonomous truck from day one, which is something that The Case Company needs to make clear. The best way to do this is probably by showing use cases of how other companies' processes looked before they were made autonomous by The Case Company. A large upfront investment is not as intimidating for a company if there are examples of companies that had similar ways of operating before but now have implemented an autonomous solution instead. To do this, The Case Company needs use cases and therefore, the first recommendation is to focus on finding pilot projects and suitable first customers in the Port industry and Manufacturing industry where the solution can be implemented as soon as possible. Here, it might be beneficial to prioritize companies that have expressed interest before companies with suitable flows since The Case Company and the customer will have to collaborate closely to create the best possible outcome. As an example here, the empty stack runs in the Port Delta in the Port segment and Manufacturing Gamma in the Manufacturing segment would be a strategic move. In addition, since The Case Company has the privilege of being part of The Case Company Group, this can be done without worrying too much about being profitable for the moment which is something that the company needs to take advantage of.

In addition, it is important for The Case Company to look at the customer's drivers and adapt their way of communicating accordingly. When looking at the customer drivers mentioned by the companies interviewed in this Master Thesis, almost all of them are perfectly addressable by The Case Company and their service. Therefore, focus must be taken from the up front investments that can be assimilated with high tech products, and instead be placed in the decreased operational costs over time. This is also an area where The Case Company will have a better position to sell as soon as they have use cases from which they can extract actual numbers of improved efficiency and other relevant factors.

To mitigate the problem with unions, it is important for The Case Company to initiate conversations to understand their point of view and their terms of negotiation. Since the unions with certainty will be a large obstacle when the implementations start to become widespread, it is important to have their view in mind to see if there are possible compromises to be made. An idea here is to look at the conversations between unions, stakeholders and companies, in industries where automation has reached higher levels already. By doing so, The Case Company can avoid several mistakes and detours in a process that probably will be time consuming.

Lastly, The Case Company must not let the legislation of today limit their customers' view of the possibilities in the future. Therefore, it will be crucial for The Case Company to not limit their communication to what is possible today and the possible gains of implementing a solution in the near future. Instead, the possibilities today need to be presented only as a start of long collaboration that will unlock new and greater values as time passes by and the legislation loosen up. By always communicating with a horizon far in the future, it will also be clear for the customer that The Case Company sees collaboration as something that will last and evolve over time, rather than a one time purchase. This will also increase the risk that the customers will be ready to automate other parts of their value chain as soon as it is possible, which also is of great value.

7.3 Contribution to Industry of Transportation

The industry of transportation stands in front of one of the biggest shifts in decades when driverless transport solutions become reality. This study seeks to give the industry an understanding of how far the technological shift has come as well as to present possibilities and restrictions. Once again, it is of great importance to point out that today's legal restrictions should not hinder technological development for the future.

7.4 Remarks

This Master’s Thesis is the final deliverable to receive a Master’s Degree in Industrial Engineering and Management at Lund University, which is equivalent to the swedish title “Civilingenjör”. The study has been a joint collaboration between the Production Management Department, Faculty of Engineering, Lund University together with the case company The Case Company.

After initial conversations between the authors and The Case Company, the idea was for the Master Thesis to be executed at the office. However, due to the COVID-19 pandemic and its succeeding restrictions, this has not been possible. Instead, the Thesis has been executed from Lund with weekly online meetings with The Case Company in order to create the best possible outcome with the prevailing circumstances.

Sources:

Abdelnour, Hussein, Malik & Santhanam. (2019). The coming shakeout in industrial distribution McKinsey & Company. Available at: https://www.mckinsey.com/industries/advanced-electronics/our-insights/the-coming-shakeout-in-industrial-distribution [2021-01-05].

Abratt, R. (1993). Market Segmentation Practices of Industrial Marketers. *Industrial Marketing Management*, 22, 79-84. New York, USA: Elsevier Science Publishing Co., Inc.

Anderson, P & Tushman, M.L. (1990). Technological discontinuities and dominant designs: A cyclical model of technological change. Administrative Science Quarterly. 35(4). 604-633. doi: 10.2307/2393511.

Beiker, S. A. (2012). Legal aspects of autonomous driving. *Santa Clara Law Review*, 52(4), Article 1.

Bondarenko, P. 2020. Gross national income. *Encyclopedia Britannica.* Available at: https://www.britannica.com/topic/gross-national-income [2021-02-16].

Bonoma, T. V. & Shapiro, B. P (1984). How to Segment Industrial Markets. *Harvard Business Review* (May 1984). Available at: https://hbr.org/1984/05/how-to-segment-industrial-markets [2020-12-14].

Bonini, Prestini, Urru & Echelmeyer. (2015). Towards the Full Automation of Distribution Centers. *4th IEEE International Conference on Advanced logistics and Transport (ICAl T)*. Available at: https://www.researchgate.net/profile/Marco_Bonini3/publication/308733447_Towards_the_full_automation_of_distribution_centers/links/589318b2aca272f9a55a1030/Towards-the-full-automation-of-distribution-centers.pdf [2021-01-02].

The Editors of Encyclopaedia Britannica. (2021, February 21). *Industrial Revolution*. Encyclopædia Britannica. Available at: https://www.britannica.com/event/Industrial-Revolution [2020-11-24].

Boutan, E. (2020, June 12). *Autonomous driving market overview*. The Startup - Medium. Available at: https://medium.com/swlh/autonomous-driving-market-overview-b8c71d81c072 [2020-12-09]

Business Sweden. (2018). The manufacturing industry in Sweden. Available at: https://fkg.se/wp-content/uploads/2019/05/The-manufacturing-industry-in-Sweden_Final_20180712_PDF.pdf [2021-03-18]

Cargo Airport & Airline Services. (2019, August 15). *Next-level cargo handling*. Available at: https://www.caasint.com/issue-article/next-level-cargo-handling/ [2021-02-25].

Carleton, S (2019, December 9). *What is incremental innovation?.* Northeastern University. Available at: https://www.northeastern.edu/graduate/blog/what-is-incremental-innovation/ [2021-02-28].

Christensen, C. (1992a). Exploring the limits of the technology s‐curve. part i: component technologies. Production and Operations Management, 1: 334-357. doi:10.1111/j.1937-5956.1992.tb00001.x

Christensen, C. (1992b). Exploring the limits of the technology s‐curve. part ii: architectural technologies. *Production and Operations Management, 1*: 358-366. doi:10.1111/j.1937-5956.1992.tb00002.x

Christensen, C. (1997). The Innovator's Dilemma. Boston, USA: Harvard Business Review Press.

Choi, J. K. & Ji, Y. G. (2015). Investigating the Importance of Trust on Adopting an Autonomous Vehicle. *International Journal of Human-Computer Interaction, 31*(10), 692-702. Doi: 10.1080/10447318.2015.1070549

Chottani, Hastings, Murnane & Neuhaus. (2018). Distraction or disruption? Autonomous trucks gain ground in US logistics. McKinsey & Company. Available at: https://www.mckinsey.com/industries/travel-logistics-and-transport-infrastructure/our-insights/distraction-or-disruption-autonomous-trucks-gain-ground-in-us-logistics [2021-01-02].

Chu, F, Gailus, S, Liu, L Ni, L. (2018). The Future of Automated Ports. McKinsey & Company. Available at: https://www.mckinsey.com/industries/travel-logistics-and-transport-infrastructure/our-insights/the-future-of-automated-ports [2021-01-03]

Chui, M et al. (2017). Human + Machine: A New Era of Automation in Manufacturing. McKinsey & Company. Available at: https://www.mckinsey.com/business-functions/operations/our-insights/human-plus-machine-a-new-era-of-automation-in-manufacturing [2020-11-12].

Coles, B. (2020, October 2). *Clearing backlog of thousands of containers underway at Port Botany*. MHD Supply Chain News. Available at: https://mhdsupplychain.com.au/2020/10/02/clearing-the-backlog-of-thousands-of-containers-commences-at-port-botany/ [2021-04-15]

Darmawan, V, Person 6, Y.W & Larasati, A. (2019). Genetic Perspectives on Creative Destruction. *International Conference on Electrical, Electronics and Information Engineering (ICEEIE)*, Denpasar, Bali, Indonesia, 2019, pp. 278-281, doi: 10.1109/ICEEIE47180.2019.8981429.

DAF. 20 percent more cargo volume in intermodal container transport. Available at: https://www.daf.com/en/news-and-media/news-articles/global/2015/q1/18-03-2015-20-percent-more-cargo-volume-in-intermodal-container-transport [2021-05-01]

Davenport, S., Campbell‐Hunt, C., & Solomon, J. (2003). The dynamics of technology strategy: an exploratory study. *R&D Management, 33*(5), 481-499. doi: 10.1016/S0019-8501(99)00103-0

Davis, F. (1989). Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology. *MIS Quarterly, 13*(3), 319-340. doi:10.2307/249008

Denscombe, M. (2010). The Good Research Guide: For small-scale Social Research Projects. 4th ed. Maidenhead: Open University Press.

Dillon, K. (2020, February 4). *Disruption 2020: An Interview With Clayton M. Christensen*. MIT Sloan Management Review. Available at: https://sloanreview.mit.edu/article/an-interview-with-clayton-m-christensen/ [2020-11-24]

Eurostat, (2020) Freight transport statistics - modal split, Statics Explained. Available at: https://ec.europa.eu/eurostat/statistics-explained/index.php/Freight_transport_statistics_-_modal_split#Modal_split_based_on_five_transport_modes:_road_competes_with_maritime_at_intra-EU_level [2021-03-04].

Ford, D. (1988). Develop your technology strategy. *Long range planning, 21*(5), 85-95.

Freytag, P. V. & Højbjerg Clarke, A. (2001). Business to Business Market Segmentation. *Industrial Marketing Management, 30*(6). 473-486.

Grand View Research. (2019). Road Haulage Market Size, Share & Trends Analysis Report By Type (International Road Haulage, Domestic Road Haulage), By Vehicle Type, By Application, By Region, And Segment Forecasts, 2019 - 2025. Available at: https://www.grandviewresearch.com/industry-analysis/global-road-haulage-market [2021-04-15]

Groover, M. (2020, October 22). *Automation*. Encyclopedia Britannica. Available at: https://www.britannica.com/technology/automation [2020-12-09]

Gruber, M , MacMillan, I. C, & Thompson, J. D. (2008). Look Before You Leap: Market Opportunity Identification in Emerging Technology Firms. *Management Science, 54*(9):1652-1665. doi:10.1287/mnsc.1080.0877

Hamadeh, N & Serajuddin, U. (2020). *New World Bank country classifications by income level: 2020-2021.* Available at: https://blogs.worldbank.org/opendata/new-world-bank-country-classifications-income-level-2020-2021 [2021-02-16].

Hancock, P. A., Nourbakhsh, I & Stewart, J. (2018). On the future of transportation in an era of automated and autonomous vehicles. *National Academy of Sciences, 116* (16), 7684-7691. doi: 10.1073/pnas.1805770115

Harper, R. (2019). Autonomous baggage tractor to be tested at Toulouse-Blagnac airport. *International Airport Review*. Available at: https://www.internationalairportreview.com/news/108165/autonomous-baggage-tractor-tested-toulouse-blagnac-airport/ [2021-02-26].

Hauge, P & Harrison, M. (2020). Market Segmentation in B2B Markets. B2B International. Available at: https://www.b2binternational.com/publications/b2b-segmentation-research/?fbclid=IwAR05UP91wg5qJ7_S6413--1Tc8e-vqfTWnbs0oRIrWdifk9DyL1RZKB-iKI
[2021-01-06]

Hayut, Y. (1981). Containerization and the Load Center Concept. *Economic Geography, 57*(2), 160-176. Available at: https://www.jstor.org/stable/pdf/144140.pdf?casa_token=4WXG8XQOg_EAAAAA:P3i2iAGFdaQKzfr9TushgtxJ4upEI81pLtrV3a-DVBUdEJK9sef_q5gOjKY8SdRIXgk8mvO2q5VbStDR15pSayol7-uuPWxIhOJr02avtu1MU2LqiRM [2020-12-17].

Hock-Guan, W, Moorthy R.L, Wing-Cheong, N & Chung-Piw, T. (2001). Cyclic deadlock prediction and avoidance for zone-controlled AGVsystem. *International Journal of production economies.* Available at: https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.552.1476&rep=rep1&type=pdf [2021-02-15].

Horenberg, D. (2017). Applications within Logistics 4.0: A research conducted on the visions of 3PL service providers (Bachelor's Thesis). Available at: http://essay.utwente.nl/72668/1/Horenberg_BA_BMS.pdf [2021-01-02].

Hwee Hwee, T. (2018, February 19). *PSA 'to launch tender for driverless vehicles this year'*. Available at: https://www.businesstimes.com.sg/transport/psa-to-launch-tender-for-driverless-vehicles-this-year [2021-02-19].

Höst, M, Regnell, B & Runeson, P. (2006). Att genomföra examensarbete. Lund, Sweden: Studentlitteratur.

IATA. (2019). Air Freight Market Analysis. Available at: https://www.iata.org/en/iata-repository/publications/economic-reports/air-freight-monthly-analysis-nov-2019/ [2021-02-24]

International Airport Review. (2020, January 20). The top 20 busiest airports in the world by cargo handled. Available at: https://www.internationalairportreview.com/article/107921/top-20-busiest-airports-world-cargo/ [2021-02-24].

Jessop, B. (2020, May 15). *Fordism*. Encyclopædia Britannica. Available at: https://www.britannica.com/topic/Fordism [2020-11-24].

Juntamo, L & Yinbo, M. (2016). Research on Internet of Things Technology Application Status in the Warehouse Operation. *International Journal of Science, Technology and Society, 4*(4), 63-66. Available at: http://www.sciencepublishinggroup.com/journal/paperinfo?journalid=183&doi=10.11648/j.ijsts.20160404.12 [2021-01-02].

Kalmar (1). (2021). Ship-to-shore cranes. Available at: https://www.kalmarglobal.com/equipment-services/ship-to-shore-cranes/ [2021-02-19]

Kalmar (2). (2021). Automatic stacking crane system. Available at: https://www.kalmarglobal.com/equipment-services/automated-stacking-cranes/ [2021-02-19]

Kalmar (3). (2021). Kalmar terminaltraktor. Available at:
https://www.kalmarglobal.se/produkter-service/terminal-tractors/kalmar-t2/ [2021-02-19]

Kalmar (4). (2021). Kalmar Straddle Carrier. Available at:
https://www.kalmarglobal.com/equipment-services/straddle-carriers/diesel-electric/ [2021-02-19]

Kalmar (5). (2021). Gloria, nästa generation av produktivitet. Available at:
https://www.kalmarglobal.se/produkter-service/reachstackers/drg-gloria-container/ [2021-02-19]

Kamara, A & Simcock, A. (2016). Chapter 17. Shipping. United Nations. Available at:
https://www.un.org/Depts/los/global_reporting/WOA_RPROC/Chapter_17.pdf [2020-12-17]

Kenton, W. (2020, September 26). *Market Penetration*. Investopedia. Available at:
https://www.investopedia.com/terms/m/market-penetration.asp [2021-01-12]

Kim, E (2016, November 16). *The old world meets the new world: Port of LA gives big data a try.* Business Insider. Available at:
https://www.businessinsider.com/ge-transportation-and-port-of-la-2016-11?r=US&IR=T [2021-04-15]

Kimmel, A. (2017) What are the most important technologies that led to autonomous transportation? Prescouter. Available at:
https://www.prescouter.com/2017/11/autonomous-technologies-timeline/

Knight, W (2020, January 21). *AI can do great things - if it does not burn the planet.* Wired. Available at: https://www.wired.com/story/ai-great-things-burn-planet/ [2020-12-09]

Littler, C. (1978). Understanding Taylorism. *The British Journal of Sociology, 29*(2), 185-202. doi:10.2307/589888

Marshall, J. (2020). The Secrets of Assessing B2B Market Sizing. *B2B International.* Available at:
https://www.b2binternational.com/publications/the-secrets-of-assessing-b2b-market-sizes/
[2020-12-22]

Mordor Intelligence. (2020). Freight forwarding market - growth, trends, covid-19 impact, and forecasts (2021 - 2026). Available at:
https://www.mordorintelligence.com/industry-reports/freight-forwarding-market [2021-02-23]

Notteboom, T & Rodrigue, J-P. (2008). The geography of containerization: half a century of revolution, adaptation and diffusion. *GeoJournal, 74*, 1-5. Doi: 10.1007/s10708-008-9210-4

Notteboom, T, Pallis, A & Rodrigue, J-P. (2021). Port Economics, Management and Policy. New York: Routledge. Forthcoming.

Nouzil, I et al. (2017). IOP Conf. Ser.: Mater. Sci. Eng. 244 012020. Available at:
https://www.researchgate.net/publication/320439290_Social_aspects_of_automation_Some_critical_insights/fulltext/59e5678b458515250246fe4e/Social-aspects-of-automation-Some-critical-insights.pdf
[2020-12-05]

Oberlo. (2021). Manufacturing. Available at: https://www.oberlo.com/ecommerce-wiki/manufacturing [2021-05-01]

OECD. (2021). Freight transport (indicator). doi: 10.1787/708eda32-en [2021-02-24].

Ozken-Ozen, Y. D. & Yvas, V. (2020). Logistics centers in the new industrial era: A proposed framework for logistics center 4.0. *Transportation Research Part E: Logistics and Transportation Review, 135*. doi: 10.1016/j.tre.2020.101864

Pappas, A. (2011, October 13). *What is a TEU?* Supply Chain Dictionary. Available at: https://dedola.com/2011/10/what-is-a-teu/ [2020-12-08].

RailFreight. (2019, October 17). *New player on Finnish rail freight market.* Available at: https://www.railfreight.com/business/2019/10/17/new-player-on-finnish-rail-freight-market/?gdpr=accept [2021-02-19].

Rodrigue, J-P. (2006). Challenging the Derived Transport-Demand Thesis: Geographical Issues in Freight Distribution. *Environment and Planning A, 38*(8). 1449-1462. doi: 10.1068/a38117

Rodrigue, J-P. (2020). The Geography of Transport Systems. New York, USA: Routledge.

Rua, G. (2014). Diffusion of Containerization. *FEDS Working Paper, 2014*(88). doi:10.2139/ssrn.2520208

SAE International. (2018) (1). SAE J3016™: Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems. Available at: SAE J3016™: Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems [2021-01-24].

SAE International. (2018) (2). SAE International Releases Updated Visual Chart for Its “Levels of Driving Automation” Standard for Self-Driving Vehicles. Available at: https://www.sae.org/news/press-room/2018/12/sae-international-releases-updated-visual-chart-for-its-“levels-of-driving-automation”-standard-for-self-driving-vehicles [2021-01-24]

Saunders, M, Lewis, P & Thornhill, A. (2009). Research Methods for Business Students. 5 th ed. England: Pearson Education Limited.

Schumpeter, J. (1928). The Instability of Capitalism. *The Economic Journal, 38*(151), 361-386

Semcon. (2021). Autonomous solutions tested at airport in unique collaboration project. Available at: https://semcon.com/news-media/avap/ [2021-02-25].

Smartasset. (2021). Inflation Calculator. Available at: https://smartasset.com/investing/inflation-calculator [2021-03-26]

Stahlbock, R., Steenken, D. & Voss, S. (2004). Container terminal operation and operations research - a classification and literature review. *OR Spectrum, 26,* 3-49.

Statista. (2021). Size of global shipping container market size between 2016 and 2025. Available at:

https://www.statista.com/statistics/1097059/global-shipping-containers-market-size/ [2021-03-04]

Threlfall, R 2020. (2020). Autonomous Vehicle Readiness Index. *KPMG*. Available at: https://assets.kpmg/content/dam/kpmg/xx/pdf/2020/07/2020-autonomous-vehicles-readiness-index.pdf [2021-02-12]

Thomson, B. (2019, April 8). *Unit Load Device ULD Air Container Specifications.* Inco Docs. Available at: https://incodocs.com/blog/unit-load-device-uld-air-container-specifications/ [2021-03-17].

Timmermans, S & Tavory, I. (2012). Theory Construction in Qualitative Research: From Grounded Theory to Abductive Analysis. *Sociological Theory, 30*(3) 167-186. https://journals.sagepub.com/doi/pdf/10.1177/0735275112457914

Tipsas, M. (2007). Customer Preference Discontinuities: A Trigger for Radical Technological Change. *Wiley InterScience*. doi: 10.1002/mde.1389

Tongur, S & Engwall, M (2014). The business model dilemma of technology shifts. *Technovation, 34*(9), 525-535. doi:10.1016/j.technovation.2014.02.006

UNCTAD. (2020). Review of Maritime Transport 2020. Available at: https://unctad.org/webflyer/review-maritime-transport-2020 [2021-02-25].

United Nations ESCAP. (2006). Free Trade Zone and Port Hinterland Development. 29-43. Available at: https://www.unescap.org/resources/free-trade-zone-and-port-hinterland-development# [2021-02-18]

Uzialko, A. (2019, February 26). *Workplace automation is everywhere and it's not just about robots.* Business News Daily. Available at: https://www.businessnewsdaily.com/9835-automation-tech-workforce.html [2021-01-12].

The Case Company (1). (2020). Who we are. Available at: XXX [2020-01-19]

The Case Company (2). (2021). Optimizing productivity through complete autonomous solutions. Available at: XXXXXX [2021-03-09]

The Case Company Group. (2019). Company Presentation. Available at: XXXXXX [2021-03-09]

Wengle et al, (2019) Sector Analysis: Transportation. *Inrate*

World Bank. (2020). GNI per capita, Atlas method (current US$). Available at: https://data.worldbank.org/indicator/NY.GNP.PCAP.CD?end=2019&start=1962&view=chart [2021-02-16]

Interviews

Person 26. (2021-03-08) Customs & Procedures, Logistics Delta. (J. Wahl, J. Arnlund, Interviewees)

Person 0. (2021-02-26). Production Manager, Manufacturing Delta AB. (J. Wahl, J. Arnlund, Interviewees)

Person 1. (2021-02-19). Section Manager, Manufacturing Delta AB. (J. Wahl, J. Arnlund, Interviewees)

Person 2. (2021-03-01). Purchase and Logistics Manager, Manufacturing Delta AB. (J. Wahl, J. Arnlund, Interviewees)

Person 3. (2021-03-10). Port Optimization and Logistics Manager, Port Delta (J. Wahl, J. Arnlund, Interviewees)

Person 4. (2021-03-10).Vice President Strategy plus, Innovation Lead Autonomous. (J. Wahl, J. Arnlund, Interviewees)

Person 5. (2021-02-11). Business Development Manager, Port Alpha. (J. Wahl, J. Arnlund, Interviewees)

Person 6. (2021-02-12). Associate Professor, The University. (J. Wahl, J. Arnlund, Interviewees)

Person 7. (2021-03-02). Supply Chain Network Manager & Head of Intermodal, Port Gamma Operations Proprietary Limited. (J. Wahl, J. Arnlund, Interviewees)

Person 8. (2021-03-09). Head Division X, The Case Company. (J. Wahl, J. Arnlund, Interviewees)

Person 9. (2021-03-29). Technology Division, The Case Company Group. (J. Wahl, J. Arnlund, Interviewees)

Person 10. (2021-02-10). Planning and Logistics Manager, Manufacturing Beta AB. (J. Wahl, J. Arnlund, Interviewees)

Person 11. (2021-02-25). Operational Manager Sweden , Logistics Alpha 2 AB. (J. Wahl, J. Arnlund, Interviewees)

Person 12. (2021-02-03). Production Manager, Logistics Gamma 1. (J. Wahl, J. Arnlund, Interviewees)

Person 13. (2021-02-16). Yard Planner, APM Terminals (J. Wahl, J. Arnlund, Interviewees)

Person 14. (2021-02-09). Associate Professor & Director for the Master's Programme in Logistics and Supply Chain Management, Lund University. (J. Wahl, J. Arnlund, Interviewees)

Person 15. (2021-02-17). Production Manager, Manufacturing Delta AB. (J. Wahl, J. Arnlund, Interviewees)

Person 16. (2021-03-19). Head of Sales H2H Ports & Logistics Centers, The Case Company. (J. Wahl, J. Arnlund, Interviewees)

Person 17. (2021-02-16). Team Manager, Manufacturing Zeta AB. (J. Wahl, J. Arnlund, Interviewees)

Person 18. (2021-03-02). Factory Logistics Manager, Manufacturing Gamma AB. (J. Wahl, J. Arnlund, Interviewees)

Person 19. (2021-02-11). Cargo Manager, Port Epsilon. (J. Wahl, J. Arnlund, Interviewees)

Person 20. (2021-02-17). CEO Sweden North and Norway, Logistics Alpha 1 AB. (J. Wahl, J. Arnlund, Interviewees)

Person 21. (2021-02-01). Transport Analyst, The Case Company Group AB.

Person 22. (2021-02-25). Process Engineer, Manufacturing Alpha AB. (J. Wahl, J. Arnlund, Interviewees)

Person 23. (2021-02-23). Operations Manager, Logistics Gamma 2. (J. Wahl, J. Arnlund, Interviewees)

Person 24. (2021-03-05). Director, Port Zeta Alliance (J. Wahl, J. Arnlund, Interviewees)

Person 25. (2021-01-25). Component Owner LIDAR, The Case Company. (J. Wahl, J. Arnlund, Interviewees)

Appendix 1:

Port	Country	TEUs handled (2019)	Transshipment Rate	GNI/Capita
Shanghai	China	43 303 000,00		10 410,00
Singapore	Singapore	37 195 636,00	> 75 %	59 590,00
Ningbo-Zhoushan	China	27 530 000,00		10 410,00
Shenzhen	China	25 770 000,00		10 410,00
Guangzhou	China	23 236 200,00		10 410,00
Busan	South Korea	21 992 001,00	50 - 75 %	33 720,00
Qingdao	China	21 010 000,00		10 410,00
Hong Kong	China	18 361 000,00		10 410,00
Tianjin	China	17 264 000,00		10 410,00
Rotterdam	The Netherlands	14 810 804,00	25 - 50 %	53 200,00
Dubai	United Arab Emirates	14 111 000,00		43 470,00
Port Klang	Malaysia	13 580 717,00		11 200,00
Antwerp	Belgium	11 860 204,00	25 - 50 %	47 350,00
Xiamen	China	11 122 200,00		10 410,00
Kaohsiung	Taiwan	10 428 634,00		10 410,00
Los Angeles	United States	9 337 632,00	< 25 %	65 760,00
Hamburg	Germany	9 274 215,00	25 - 50 %	48 520,00
Tanjung Pelepas	Malaysia	9 100 000,00		11 200,00
Dalian	China	8 760 000,00		10 410,00
Laem Chabang	Thailand	8 106 928,00		7 260,00
Long Beach	United States	7 632 032,00	< 25 %	65 760,00
Tanjung Priok	Indonesia	7 600 000,00		4 050,00
New York/New Jersey	United States	7 471 131,00	< 25 %	65 760,00
Colomba	Sri Lanka	7 228 337,00		4 020,00
Ho Chi Minh City	Vietnam	7 220 377,00		2 540,00
Piraeus	Greece	5 648 000,00	> 75 %	20 320,00
Yingkou	China	5 480 000,00		10 410,00
Valencia	Spain	5 439 827,00	50 - 75 %	30 390,00
Manila	Philippines	5 315 500,00		3 850,00
Talchang	China	5 152 000,00		10 410,00
Hai Phong	Vietnam	5 133 150,00		2 540,00
Algeciras	Spain	5 125 385,00	> 75 %	30 390,00
Jawaharlal Nehru	India	5 100 891,00		2 130,00
Bremen/Bremerhaven	Germany	4 856 900,00	50 - 75 %	48 520,00
Tangier	Morocco	4 801 713,00		3 190,00
Lianyungang	China	4 780 000,00		10 410,00

Mundra	India	4 732 699,00		2 130,00
Savannah	United States	4 599 177,00	< 25 %	65 760,00
Tokyo	Japan	4 510 000,00	< 25 %	41 690,00
Rizhaa	China	4 500 000,00		10 410,00
Jeddah	Saudi Arabia	4 433 991,00	> 75 %	22 850,00
Colon	Panama	4 379 477,00	> 75 %	14 950,00
Santos	Brazil	4 165 248,00		9 130,00
Salalah	Oman	4 109 000,00	> 75 %	15 330,00
Tanjung Perak	Indonesia	3 900 000,00		4 050,00
Port Said	Egypt	3 816 084,00		2 690,00
Seattle-Tacoma	United States	3 775 303,00	< 25 %	65 760,00
Cai Mep	Vietnam	3 742 384,00		2 540,00
Dongguan	China	3 680 000,00		10 410,00
Felixstowe	United Kingdom	3 584 300,00	< 25 %	42 370,00
Fuzhou	China	3 540 000,00		10 410,00
Vancouver	Canada	3 398 860,00	< 25 %	46 370,00
Barcelona	Spain	3 324 650,00	50 - 75 %	30 390,00
Nanjing	China	3 310 000,00		10 410,00
Ambarli	Turkey	3 104 882,00		9 610,00
Yantai	China	3 102 400,00		10 410,00
Inchon	South Korea	3 091 955,00	< 25 %	33 720,00
Chittagang	Bangladesh	3 088 187,00		1 940,00
Manzanillo	Mexico	3 069 189,00		9 430,00
Cartagena	Colombia	2 995 031,00		6 510,00
Yokohama	Japan	2 990 000,00	< 25 %	41 690,00
Houston	United States	2 987 291,00	< 25 %	65 760,00
Melbourne	Australia	2 967 315,00	< 25 %	54 910,00
Tangshan	China	2 944 000,00		10 410,00
Virgina	United States	2 937 962,00	< 25 %	65 760,00
Balboa	Panama	2 894 654,00	> 75 %	14 950,00
Kobe	Japan	2 871 642,00	< 25 %	41 690,00
Nagoya	Japan	2 844 004,00	< 25 %	41 690,00
Le Havre	France	2 822 910,00	< 25 %	42 400,00
London	United Kingdom	2 790 000,00	< 25 %	42 370,00
Abu Dhabi	United Arab Emirates	2 780 000,00	> 75 %	43 470,00
Durban	South Africa	2 769 869,00		6 040,00
Marsaxlokk	Malta	2 722 889,00	> 75 %	27 290,00
Genoa	Italy	2 621 472,00	> 75 %	34 460,00
Quanzhou	China	2 580 000,00		10 410,00
Sydney	Australia	2 572 714,00	< 25 %	54 910,00

Zhuhai	China	2 556 000,00		10 410,00
Gioia tauro	Italy	2 523 000,00	> 75 %	34 460,00
Oakland	United States	2 500 431,00	< 25 %	65 760,00
Osaka	Japan	2 456 028,00	< 25 %	41 690,00
Charleston	United States	2 436 185,00	< 25 %	65 760,00
Yeosu Gwangiang	South Korea	2 378 337,00	< 25 %	33 720,00
Callao	Peru	2 313 907,00		6 740,00
St. Petersburg	Russia	2 221 724,00		11 260,00
Karachi	Pakistan	2 097 855,00		5 210,00
Gdansk	Poland	2 073 210,00	50 - 75 %	15 200,00
King Abdullah	Saudi Arabia	2 020 683,00	> 75 %	22 850,00
Haiku	China	1 970 000,00		10 410,00
Southampton	United Kingdom	1 924 847,00	< 25 %	42 370,00
Jinzhou	China	1 879 000,00		10 410,00
Jiaxing	China	1 865 300,00		10 410,00
Mersin	Turkey	1 854 312,00		9 610,00
Dammam	Saudi Arabia	1 822 642,00	> 75 %	22 850,00
Taichung	Taiwan	1 793 966,00		10 410,00
Montreal	Canada	1 745 244,00	< 25 %	46 370,00
Izmit	Turkey	1 715 193,00		9 610,00
San Antonio	Chile	1 709 639,00		1 510,00
Guayaquil	Ecuador	1 680 751,00		6 080,00
Kingston	Jamaica	1 647 609,00		5 250,00
Taipei	Taiwan	1 620 392,00		10 410,00
Miami	United States	1 120 913,00	< 25 %	65 760,00
Prince Rupert	Canada	1 200 000,00	< 25 %	46 370,00
Buenos Aires	Argentina	1 490 000,00		11 200
Caucedo	Dominican Republic	1 235 801,00		8 090,00
Cristobal	Panama	1 050 000,00	> 75 %	14 950,00
La Spezia	Italy	1 659 000,00	> 75 %	34 460,00
Marseille	France	1 455 000,00	50 - 75 %	42 400,00
Sines	Portugal	1 423 000,00	> 75 %	23 080,00
Las Palmas	Spain	1 007 000,00	> 75 %	30 390,00

Sources:
TEU capacity: https://lloydslist.maritimeintelligence.informa.com/one-hundred-container-ports-2020/Digital%20edition%20ebook
Transshipment Rate: Nottebom et. al 2021
GNI per capita: World Bank 2020

Appendix 2:

Airport	**Country**	**Total Tonnes handled (2019)**	**GNI/Capita**
Hong Kong International Airport	China	4 809 485,00	10 410,00
Memphis International Airport	United States of America	4 322 740,00	65 760,00
Shanghai Pudong International Airport	China	3 634 230,00	10 410,00
Louisville Muhammed Ali International Airport	United States of America	2 790 109,00	65 760,00
Incheon International Airport	South Korea	2 764 369,00	33 720,00
Ted Stevens Anchorage International Airport	United States of America	2 745 348,00	65 760,00
Dubai International Airport	United Arab Emirates	2 514 918,00	43 470,00
Doha Hamad International Airport	Qatar	2 215 804,00	91 670,00
Taiwan Taoyuan International Airport	Taiwan	2 182 342,00	10 410,00
Tokyo International Airport	Japan	2 104 063,00	41 690,00
Paris Charles de Gaulle Airport	France	2 102 268,00	42 400,00
Miami International Airport	United States of America	2 092 472,00	65 760,00
Frankfurt Airport	Germany	2 091 174,00	48 520,00
Singapore Changi Airport	Singapore	2 056 700,00	59 590,00
Beijing Capital International Airport	China	1 957 779,00	10 410,00
Guangzhou Baiyun international Airport	China	1 922 132,00	10 410,00
Chicago O'Hare International Airport	United States of America	1 758 116,00	65 760,00
London Heathrow Airport	United Kingdom	1 672 874,00	42 370,00
Amsterdam Airport Schiphol	The Netherlands	1 592 221,00	53 200,00
Suvarnabhumi Airport	Thailand	1 326 914,00	7 260,00
Los Angeles	United States of America	1 272 010,00	65 760,00
Leipzig	Germany	1 147 233,00	48 520,00

Sources:

Tonnes Handled:
https://www.google.com/url?q=https://www.internationalairportreview.com/article/107921/top-20-busiest-airports-world-cargo/&sa=D&source=editors&ust=1614936315929000&usg=AFQjCNG8FEWYi4IBKcuZtkZ_EvPjppW3aA

GNI per capita: World Bank 2020

Appendix 3:

Question Form Ports

1. Could you please tell us a bit about yourself and your role at Port of XXXX?

2. Are your organisation responsible for the infrastructure in the harbour or the operations in the port? Or are you handling both? Describe your responsibilities.

3. Could you describe the process of handling a container from the point when it enters the port with the ship until it leaves the port area? How does the import/export/transshipment process differ from each other?

4. We are for the moment looking at the possibility for autonomous trucks to operate the transport of containers from the stack to dry ports, railways etc. How would you say the possibilities are for this at your port?

5. How large is the import and export share out of the total container throughput?

6. How large is the share of trailers going to:
   - Transshipment
   - Truck
   - Rail

7. Do you handle empty containers in the same way as you handle full containers?

8. Which part of the handling process in the port is currently the weakest link?

9. How many vehicles are operating the area after the container stack to the next step?

10. How many drivers do you have for that purpose?

11. Do you have an idea of the cost of that process specifically? What is the biggest cost? Labour?

12. Do you see it as a possibility for autonomous trucks to operate in the harbour, transporting the containers from the stack to the next area?

Trends

1. What trends do you see now and in the future in the ports industry?

2. What level of automation do you have in the port for the moment? What do you see as the next step in the automation process for you?

3. Why would you say that the port industry in many ways have been slower than similar industries when it comes to automation?

Question Form Logistics Centers

1. Could you please tell us a bit about yourself and your role at XXXX?

2. Looking at a big distributor as XXXX, how can the typical flow of goods be described on a high level?

3. From a high level point of view how is the network built up (which are the different nodes in a network and what type of transports/modes of transports are used between the nodes)?

4. We are for the moment looking at the possibility for autonomous trucks to operate, how would you say the possibilities are for this at your company?

5. Describe the handling process of goods in a logistic center (a hub).
   - Which steps exist in the process?
   - Are there repetitive steps?
   - Are typical freight networks structured in similar ways as your network?

6. Do you know any specific flows of goods that are short distance within in gated areas, such as logistic hubs? If so, please elaborate.

7. Which part of the handling process is currently the weakest link?

8. What transportation modals do you use in your operations?

9. How do you measure efficiency in your company?

10. Do you have an idea of the cost of that process specifically? What is the biggest cost?

11. Do you see it as a possibility for autonomous trucks to operate in the harbour, transporting the containers from the stack to the next area?

Trends

1. Which trends do you see in the near future in logistics, especially related to transportation? Are autonomous transports such a trend and near future possibility?

2. Are there any forms of automation present in the process right now or in the near future?

3. What role do you think automation will have in the future?

4. Have you discussed automation on the outside of the hub (i.e. in the yard or between buildings)?

5. From a high level point of view and based on your experience, which parts of your network has the short term possibility to introduce automated transports (e.g. at hubs or at larger logistics areas/manufacturing facilities)?

6. What would you say are the main drivers in this industry? Will they change over time?

Question Form Manufacturing Companies

1. Looking at a big producing company, how can the typical flow of goods be described? Please use your production facility as an example.

2. How many production facilities do you have? Are all facilities structured in a similar way?

3. How common do you think that short transports/flows of goods is internally at production facilities?

4. Are there any transports between warehouses, production facilities etc?
   - How are those transports handled today? AGVs/trucks?
   - How many transport vehicles are needed?

5. Are there a lot of yard operations outside or is the truck connecting directly to a gate for loading/reloading?

6. Do you use autonomous vehicles for internal transport within the production area?

7. How is the cost structure for internal transports in the production center?

8. Are there any types of automation incorporated in your production activities today?

Understanding trends in the market for Production Industry

1. Which trends do you see in the near future in manufacturing, especially related to transportation? Are autonomous transports such a trend and near future possibility?

2. Are there any forms of automation present in the process right now or in the near future?

3. What role do you think automation will have in the future, especially regarding automated transports?

4. Have you seen initiatives for automation on the outside of the production facility (i.e. in the yard or between buildings)?

5. From a high level point of view and based on your experience, which parts of your network has the short term possibility to introduce automated transports (e.g. at hubs or at larger logistics areas/manufacturing facilities)?