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SONY

visilion.

Global Supply Chain Optimisation

By Using Sensing Solutions

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Master Thesis in Production Management

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Abstract

Title	Global supply chain optimisation by using sensing solutions
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Supervisor	Bertil I Nilsson, Senior Lecturer, Faculty of Engineering at Lund University
Problem Definition	Internationalisation, higher demand volatility, and faster Supply Chain (SC) speed are factors that are making the global SC more complex. Therefore, organisations strive for a better picture of their SC real-time performance. Hence, a need for a solution that allows a better understanding of the complexity and makes the chain more efficient is required. It is worth mentioning that better visibility itself does not necessarily mean that the SC will become more efficient. It is equally important to consider how the data will be analysed, shared and displayed as well as what actions can be taken.
Purpose	The project's objective is to identify, study, and analyse the opportunities SC visibility offers through adopting sensing solutions. Furthermore, the project aims to provide Visilion with an analysis of the market needs, what opportunities the solution brings, and finally, provides recommendations on future developments.
Method	The research approach of the project is an exploratory single-case study methodology. An abductive approach was applied to obtain the data. The data is collected by reviewing academic and practitioner literature and conducting interviews with field experts. To analyse the data collected, pattern matching and a product-market fit analysis were conducted.
Conclusions	Sensing solutions enable better visibility in the global SC and are mainly impacted by transparency. Transparency is, in turn, interrelated to four other factors, referred to as dimensions by the authors, which are (1) High-quality data, (2) Relationship, (3) Awareness, and (4) Sustainability. Some of the opportunities brought by the dimensions include enhanced decision-making, increased collaboration, optimised route planning, and minimised CO_2 emissions. Further, there is a correlation between the identified factors. Thus, a model has been developed to emphasise the importance of visibility and its interconnection to the factors. The analysis shows that Visilion addresses almost all the identified market needs. However, there are some slight improvements that Visilion could consider.
Keywords	Supply Chain Disruptions, Supply Chain Resilience, Supply Chain Visibility, Supply Chain Transparency, Real-Time Visibility, Internet of Things, Industry 4.0

Abstrakt

Titel	Global supply chain optimisation by using sensing solutions
Författare	Ahmad Belbisi, Maskinteknik, LTH, Lunds universitet Amjad Belbisi, Elektroteknik, LTH, Lunds universitet
Handledare	Bertil I Nilsson, Senior universitetslektor, LTH, Lunds universitet
Problem-formulering	Internationalisering, högre volatilitet på efterfrågan och snabbare försörjningskedjor är faktorer som gör den globala kedjan mer komplex. Därför strävar organisationer efter en bättre bild av deras försörjningskedja realtidsprestanda. Därför behövs en lösning som möjliggör en bättre förståelse av komplexiteten och gör kedjan mer effektiv. Värt att nämna är att bättre synlighet i sig inte nödvändigtvis betyder att försörjningskedja kommer att bli mer effektiv. Det är lika viktigt att överväga hur data analyseras, delas och visas samt vilka åtgärder som kan tas.
Syfte	Projektets mål är att identifiera, studera och analysera möjligheterna för synlighet i den globala försörjningskedjan med hjälp av Sensing Solutions. Projektet syftar också till att ge Visilion en analys av marknadens behov, vilka möjligheter lösningen bidrar med och till slut ge rekommendationer om framtida utvecklingar.
Metod	Forskningsmetoden för projektet är en explorativ enkel fallstudiemetodik. En abduktiv approach har använts för att samla in data. Data samlas in genom att granska akademiska och praktiska litteratur och genom att genomföra intervjuer med fältsexperter. För att analysera den insamlade datan, användes pattern-matching och product-market-fit metoder.
Slutsatser	Sensing Solutions möjliggör en bättre synlighet i den globala försörjnings-kedjan och den påverkas främst av transparens. Transparens är i sin tur relaterad till fyra andra faktorer, refereras till som dimensioner av författarna, vilka är (1) High-quality data, (2) Relationship, (3) Awareness, and (4) Sustain-ability. Några av möjligheterna som dessa faktorer ger inkluderar förbättrad beslutsfattande, ökat samarbete, optimerad rutt-planering och minimerad CO_2-utsläpp. Dessutom finns det en korrelation mellan de identifierade faktorerna. Därför har en modell utvecklats för att betona vikten av synlig-het och dess samband till faktorerna. Analysen visar att Visilion tillgodoser nästan alla identifierade marknadsbehov. Dock finns det vissa förbättringar som Visilion kan överväga.
Nyckelord	Supply Chain Disruptions, Supply Chain Resilience, Supply Chain Visibility, Supply Chain Transparency, Real-Time Visibility, Internet of Things, Industry 4.0

Abbreviations

API	Application Programming Interface
BCG	Boston Consulting Group
CPS	Cyber-physical systems
ETA	Estimated time of arrival
PMF	Product-Market Fit
RFID	Radio frequency identification
ROI	Return On Investment
SC	Supply Chain
SCM	Supply Chain Management
SCRES	Supply Chain Resilience
SCT	Supply Chain Transparency
SCV	Supply Chain Visibility
IoT	Internet of Things

Table of Contents

1. Introduction

This chapter highlights the importance of better visibility in the global SC in a turbulent world of global disruptions. The chapter starts with a brief description of the situation and the company, followed by a description of the problem that organisations are facing. Thereafter, the purpose of the thesis is presented, and the research questions are listed. Finally, the focus and delimitations are delineated, and the chapter ends with the report outline.

1.1. Background

As a result of the uncertainty and the disruptions in the global Supply Chain (SC) due to global and external events, such as COVID-19 and the current conflict in Ukraine, organisations are more than ever concerned about how they can mitigate those disruptions. Boston Consulting Group (BCG) analysis shows that 75 per cent of SC has been disrupted as a result of the pandemic (Close et al., 2020). Organisations are thereby reconsidering how they can manage their SC more effectively. A survey conducted by McKinsey in November 2021 shows that most respondent companies are planning on making their SC more flexible, agile and resilient (Alicke et al., 2021).

The same McKinsey survey also showed that those companies plan to further digitalise SC processes as part of their SC reshaping strategy. The urgency of implementing digital transformation has become more crucial in light of the global crisis. Accomplishing the right digital transformation will not only enhance a single organisation's resilience, agility, and flexibility but also allow for better visibility and transparency across SC stakeholders.

SC resilience (SCRES) refers to an organisation’s readiness, responsiveness, and ability to recover easily. Most global disruptions are inevitable, so having the right adaptive capabilities is crucial to mitigate disruptions’ aftermath (Pettit et al., 2013). One of the factors that enhances SCRES and allows for more agility is having an adequate level of visibility which is allowed by digitalisation (Soni et al., 2014). In some cases, digital readiness is also seen as a barrier to enabling better visibility and transparency.

Francis (2008) defines visibility in the SC as the ability to identify, locate, and measure the status of the entities being transitioned into the SC. This is allowed through data capturing, where actual data, such as time, is compared to the planned one. In order to enable high visibility in the SC, data must be timely, accurate, and usable (Williams et al., 2013). Further, stakeholders need to be transparent, i.e., information sharing between stakeholders needs to exist in the chain, as Parris et al. (2016) emphasise.

The complexity of the SC entails a solution where cargo and assets can be effectively tracked and monitored during transportation. Visilion, a subsidiary of Sony Network Communications, is developing a solution that addresses this need. This solution is referred to as a sensing solution by the authors. It is regarded as a complete solution that helps gather data and instantly turns it into information and insights by analysing it. The information is then presented to SC managers through a platform to help them optimise the SC. As mentioned previously, organisations need better visibility, especially during global crises. However, sensing solutions do not only help during crises but also give value to the entire chain, even in day-to-day operations. Therefore, this thesis will investigate how sensing solutions can optimise the global SC.

1.2. Visilion, Sony

Visilion provides a solution that helps organisations to digitalise their SC and is offered by Sony Network Communications. Visilion is a solution that can help mitigate disruptions in the SC by giving goods owners, transporters, and shipping lines a new level of real-time data for key events during transit. By keeping track of cargo and assets in real-time, Visilion can help provide organisations with better visibility and information sharing.

Visilion's customers exist in several industry sectors, including health care, industrial goods, technology, and consumer goods. Some of these sectors' SCs have more impetus to change than others; according to an analysis made by BCG, they will also differ in the ease of making adjustments to their SCs (Aylor et al., 2020). Visilion's solution tries to solve issues related to visibility, empowering organisations to have control over their deliveries and improving their businesses.

Some benefits of the solution presented on Visilion's webpage are reacting promptly to cargo temperature changes, shocks, and tilts as well as addressing SC interruptions to improve on-time delivery and profitability through better planning. An important factor contributing to the uniqueness of Visilion's solution is its reusability and long-life battery. This makes Visilion an environmentally friendly sensing solution that is well-fitted for organisations looking to become more agile and sustainable in their SC.

1.3. Problem Description

The current global SC is facing a variety of disruptions due to internationalisation, firm interconnection, higher demand volatility, and faster SC speed (Calatayud et al., 2019). The tremendous amount of external factors impacting the chain is making it more complex and is affecting its efficiency. Hence, a need for a solution that allows a better understanding of the complexity and makes the chain more efficient is required. According to a recent survey by McKinsey, organisations are striving for a better picture of their SC real-time performance (Alicke et al., 2021). That being the case, organisations seek solutions that can offer real-time visibility for their SC.

On the other hand, visibility alone does not value the chain. In other words, better visibility does not necessarily mean that the SC will become more efficient. It is just as important to think of how the industry will change with real-time visibility, how the data will be analysed, shared and displayed, and what actions can be taken upon having this information. The opportunities brought by sensing solutions will be explored to allow organisations to understand the value of real-time visibility better. Upon identification of these opportunities, a model is constructed, and product recommendations are proposed to Visilion based on the market needs.

1.4. Purpose

The purpose of the project is to identify and study the opportunities offered by SC visibility (SCV) and how visibility in the chain is optimised with the help of sensing solutions. This is done to understand sensing solutions' effect on the global SC. The project's objective is also to provide Visilion with an analysis of the market needs, what opportunities the solution brings, and finally, to provide recommendations on future developments. Additionally, this project gives other organisations an understanding of what impact visibility and transparency have on the SC. The main topic of the thesis is

Global supply chain optimisation by using sensing solutions

The following three research questions (RQ) will be studied:

RQ1: What are the factors in the SC that are impacted by adopting sensing solutions?

RQ2: What opportunities do these factors bring to the customers?

RQ3: Does Visilion have a product-market fit today?

SQ1: What does Visilion currently offer its customers?
SQ2: What are the recommendations and proposed changes for Visilion?

1.5. Focus and Delimitations

As specified earlier, the SC is complex enough and involves many activities. However, the scope of this thesis is to investigate the cargo and assets' visibility during transportation. The activities that are investigated range from the goods being loaded into a truck or a container till the receiver unloads it. Delivering, handing over, and transit activities are examples of transportation activities discussed in this thesis. As there are several stakeholders involved in SC and transportation activities are plenty, it is challenging to cover all activities in one project. Hence, Business-to-Consumer (B2C) last-mile and tier-two and beyond deliveries are not included in this project's scope. Thereby, the focus is on Business-to-Business (B2B) deliveries.

Sensing solutions can be used in different parts of the SC. However, as is the case for any given research study, this thesis also has certain delimitations. Indoor activities, including tracking, monitoring, warehousing and inventory control, are excluded from the scope of this thesis. This is because Visilion's solution is primarily used in transportation activities.

In total, six interviews have been conducted to build the empirics. As the focus is on B2B deliveries, the selection of companies to interview was oriented toward companies within the industry sector. The interviews were performed with companies from various sectors, including metals, electronics, automotive components, mechanical machinery, shipping, and materials. A further discussion of how these delimitations impact the result can be found in section 6.3, *Validity of Results.*

1.6. Report Outline

The following table gives a brief overview of what is discussed in each chapter of the thesis.

Table 1.1: A brief overview of the thesis chapters

Chapters	Summary
Introduction	Chapter 1 introduces the reader to the topic. Starting with discussing the background, moving to a description of the company, the problem description, the purpose, the focus, and the delimitations. Finally, the report outline is briefly presented.
Methodology	In chapter 2, the procedure used in the project is explained. Initiating with an overview of the method conducted, then discussing the research approach, the research strategy, and the adopted methodology. Finally, the data collection and analysis are explained, and the research credibility tests are explored.
Theoretical Framework	Chapter 3 presents the theoretical framework and is based on the literature review conducted by the authors starting with SC disruptions, SCRES, SC technologies, SCV, and SCT. Finally, the chapter ends by presenting the identified dimensions.
Empirical Findings	In chapter 4, the empirical findings are presented and based on the conducted interviews with companies. It starts with describing the interviewed companies' SC, moving to SC disruptions, SC challenges, and ending with sensing solutions readiness.
Analysis and Discussion	In chapter 5, the analysis of the study is performed. First, the visibility model for the dimensions affecting SCV is presented, then an analysis of SC Challenges is made, and ending with the PMF analysis.
Conclusion and Reflections	Chapter 6 concludes the work done and presents the recommendations. Starting with answering the RQs, and later discussing the recommendations and the validity of the result. Finally, suggesting topics for future research.

2. Methodology

This chapter starts with a research overview to easily allow the reader to grasp the procedure used in this project. The chapter starts with giving an overview of the selected methodology, moving to the research approach to clarify what view is used throughout the research and how data has been obtained. Thereafter, a description of the research strategy is presented to determine the research methodological purpose and the methodology conducted in this project. Later, data collection methods and how the data is analysed are presented. Finally, the research's credibility is discussed.

2.1. Research Overview

The research overview is shortly mentioned here at the beginning of the chapter to clarify what structure is followed throughout the project. Briefly, the methodology followed in this project is a holistic single-case study methodology. Section 2.2 starts with the *Research Approach,* whereas section 2.3 discusses the *Research Strategy*. The methodology's most relevant points are described in section 2.4, *Case Study Methodology* and are based on Yin's process (Yin, 2018). Yin is known for his work on case study research and has a PhD from MIT (SAGE, 2022). In fact, Yin's work is listed as the second most cited methodological work over the past 20 years (Green, 2016).

Initially, defining a perspective to guide the research study is crucial. The project's purpose, as mentioned previously, is to study and analyse how sensing solutions can help optimise the global SC concept. Besides that, it allows Visilion to have a better grasp of its position in the market and what it can do to develop the product further. The SC itself is considered a system with several subsystems; therefore, a systematic view approach is adopted. However, several approaches can be used in a project. Therefore, an actors' view approach is adopted as well when interviewing companies, as the whole is constructed from different views of the interviewees.

The second aspect to consider is what approach the project should apply in order to obtain knowledge. Based on the research questions and from the authors' perspective, the theoretical and empirical findings are essential when collecting data. To put it differently, that includes combining the inductive and deductive approaches mentioned in subsection 2.2.2 *Research Process Approach.* Combining these two approaches means that the project applies an abductive approach to obtaining knowledge. Thirdly, the core purpose of the research is to gain a deep understanding of the opportunities of the global SC. In addition, gaining new insights into how this phenomenon works. That makes the project's exploratory characteristic suitable since a case study methodology is applied.

The data were collected using methods that are explained in section 2.5, *Data Collection*. Both academic and practitioner literature were reviewed as well as interviews. The literature

reviewed includes journals, white paper articles, reports from consultancy firms, magazines and business blogs from field experts. In addition, interviews with field experts were also conducted to collect relevant data. To analyse the data collected, pattern matching and a product-market fit analysis were conducted. The methodological structure used in this project is illustrated in figure 2.1.

Figure 2.1: The methodological structure used in the project adapted from Yin (2018)

2.2. Research Approach

2.2.1. Research Methodological View

To study and adequately research reality, there should be a defined perspective. Data can be seen as relevant for one perspective and irrelevant to another depending on the perspective adopted. Arbnor and Bjerke (2009) inducted three perspectives when creating knowledge in the study area. These views are referred to as methodological views and make ultimate presumptions about reality, which will later guide the research study. Methodological views are needed in order to be able to investigate, examine, and understand the reality and the research topic. The three methodological views of research are—*Analytical, Systems and Actors view* and are illustrated in figure 2.2.

- The **analytical view** assumes that the sum of the different parts equals the whole. This means that the creator of knowledge can understand the total picture by adding the separate parts together. The parts can be considered and analysed separately by verified judgement (Arbnor & Bjerke, 2009).

- The **systems view** assumes that the whole is not equal to the sum of the different parts, in contrast to the analytical view. Understanding the whole consists of explaining the different parts associated with the whole system (Arbnor & Bjerke, 2009). The parts cannot be analysed separately to understand the whole but as mutually dependent components (Arbnor & Bjerke, 2009; Gammelgaard, 2004).

- The **actors' view** assumes that the whole is socially constructed and that reality is not objective (Arbnor & Bjerke, 2009; Gammelgaard, 2004). This is because the actors' reality image accomplishes understanding the social whole.

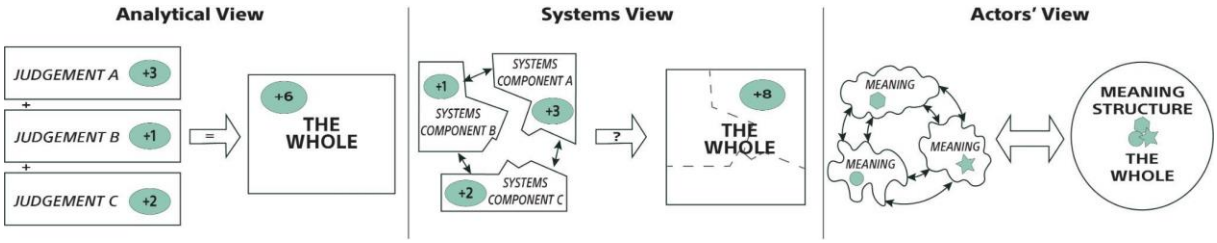

Figure 2.2: Analytical, Systems, and Actors' view adapted from Arbnor and Bjerke (2009)

2.2.2. Research Process Approach

There are three major research approaches when obtaining knowledge; i.e. inductive, deductive, and abductive (Kovács & Spens, 2005). According to Fisher et al. (2002), inductive reasoning moves from a specific collection of data or a specific case to general law. It aims to build an understanding and draw conclusions based on concrete empirical observations; thus, it moves from facts to theory (Kovács & Spens, 2005). In other words, inductive reasoning moves from case to result to rule. On the contrary, deductive reasoning moves from a general law to a specific case (Fisher, 2002; Kovács & Spens, 2005). In other words, deductive reasoning moves from rule to case to result. Figure 2.3 below shows that deductive reasoning derives logical conclusions from existing theories, which are tested in an empirical setting to derive conclusions (Kovács & Spens, 2005).

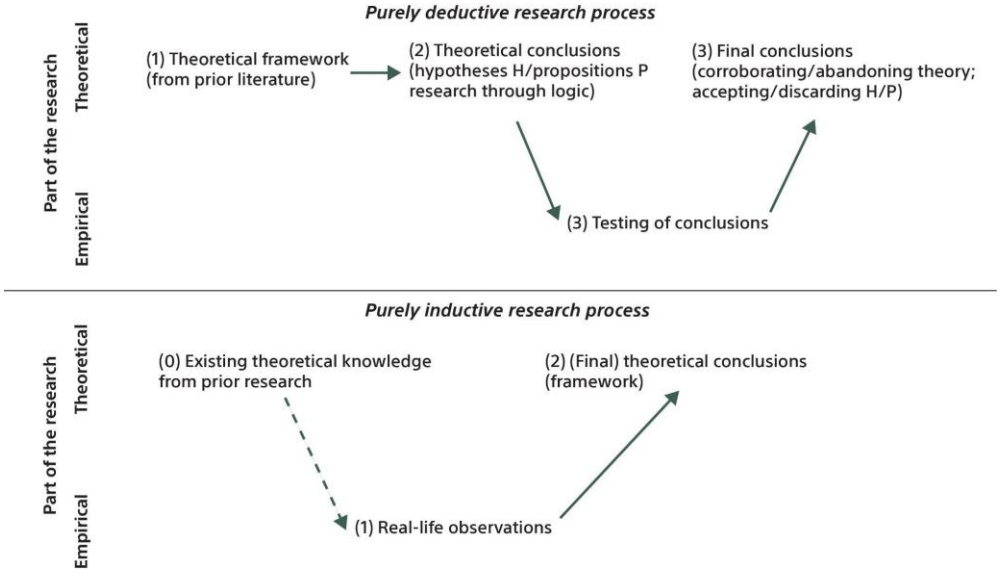

Figure 2.3: Illustration of deductive and inductive research process (Kovács & Spens, 2005)

The third research process approach—the abductive approach—follows a different pattern than the first two, i.e., it moves from rule to result to case (Kovács & Spens, 2005). The abductive approach aims to get a new conceptual understanding from a new perspective by including both inductive and deductive approaches, as seen in figure 2.4 below. Abductive reasoning can be initiated in two ways (Kovács & Spens, 2005). The first way is to apply a new framework to existing observations, while the other way is to make empirical observations that deviate from the previously used theoretical framework.

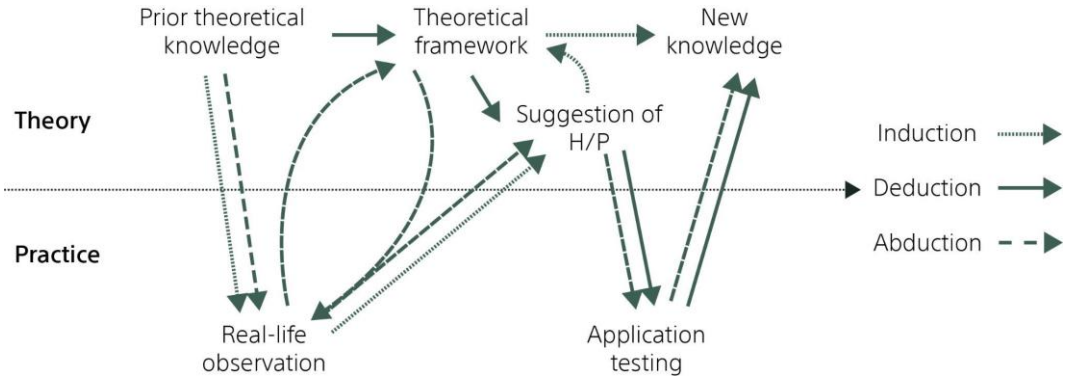

Figure 2.4: Illustration of induction, deduction, and abduction (Kovács and Spens, 2005)

2.3. Research Strategy

2.3.1. Research Methodological Purpose

When doing any research, it is essential to consider its purpose. Choosing a central purpose for the project does not mean that other purposes cannot be considered during research, but there should be one core purpose (Robson & McCartan, 2016). They also mention the importance of considering that even the core purpose can be changed under the study process.

Höst et al. (2006) mention four research purposes:

I. **Descriptive research** aims to portray how a specific situation or phenomenon works.
II. **Exploratory research** aims to deeply understand and find new insights into how a specific phenomenon works.
III. **Explanatory research** aims to find relationships and explanations for how a phenomenon works.
IV. **Improving research** aims to improve and find a solution for an identified problem.

To be able to perform a study, the researcher must choose an appropriate method or a combination of those. In addition, every method has different tools to gather data and later perform analysis on it (Höst et al., 2006).

2.3.2. Research Methodologies

To choose a suitable research methodology, it is vital to understand the project's purpose. According to Runeson and Höst (2008), the primary research methodologies are survey, case study, experiment, and action research. The researcher should assess the four methodologies to be able to decide which one is likely to work best. It is necessary to choose a methodology that is fit for the purpose which needs to be achieved in the research (Denscombe, 2010).

When using **survey** as a method, the purpose is mainly to inspect a particular phenomenon. It is a collection and description of what the phenomenon looks like today. This can be done by collecting information about the target group from a questionnaire or an interview. On the contrary, a **case study** tends to study cases in detail which illuminates the general by focusing on the particular (Denscombe, 2010). A *case study* method can be used if the purpose is to make an in-depth study of one or several cases (Höst et al., 2006). Case studies are, therefore, primarily suitable for an exploratory purpose but may also be used for both a descriptive and an explanatory purpose (Runeson & Höst, 2008).

As for the **experiment** method, the purpose is to isolate specific factors to manipulate one of them. This is done by comparing two or several alternatives (Höst et al., 2006). According to Runeson & Höst (2008), the *experiment* method has an explanatory purpose. Last but not least, **action research** is a method used to "... influence or change some aspect of whatever is the focus of the research" (Robson & McCartan, 2015, p. 199). The difference between this method and the case study method is that the *action research* focuses on and is involved in the change process, unlike a case study's observatory character (Runeson & Höst, 2008). Additionally, action research has an improving purpose.

2.4. Case Study Methodology

The research method conducted in this project, as specified previously, is the case study methodology. Yin (2018) explains the process of this method in detail. The process includes six stages, as shown in figure 2.5 below, i.e. plan, design, prepare, collect, analyse, and share. The process is linear but iterative. The first three stages are explained in the following subsections, while the other two stages—collect and analyse—are explained in the sections thereafter. The last stage, share, is the final stage in the process after several iterations. This stage is done by publishing the final thesis and the popular scientific summary on the university database, which is then shared with the interviewees that contributed to the project.

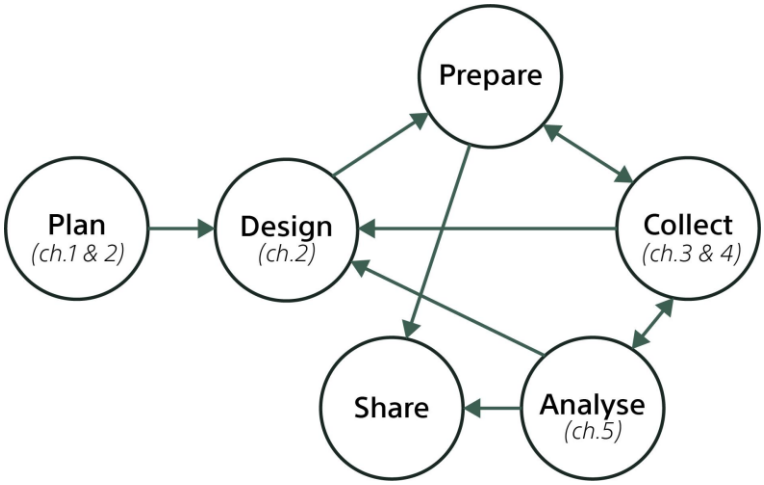

Figure 2.5: Case study methodology's process (Yin, 2018, p.30)

2.4.1. Planning the Case Study

According to Yin (2018), case study research starts with a planning phase. In this phase, Yin highlights three main points. Firstly, *identifying research questions*, which have been identified in chapter 1, *Introduction*. Secondly, *deciding to use the case study compared to other methods* is why the primary research methodologies used in a project have been listed in subsection 2.3.2, *Research Methodologies*. Thirdly, *understanding the method's strengths and weaknesses.* This includes understanding the research strategy and the different approaches when obtaining knowledge. This point is discussed previously in sections 2.2, *Research Approach,* and 2.3, *Research Strategy*.

2.4.2. Designing the Case Study

Yin (2018) states that every empirical study has a research design, whether it is implicit or explicit. Furthermore, the research design is the logic linking the collected data with the initial research questions. Research design could also be seen as a plan for getting from the initial set of questions to a set of conclusions about these questions. According to Yin (2018), this step highlights four points to be covered, which are discussed below.

Firstly, *define the unit of analysis and the likely case(s) to be studied*. A general rule Yin (2018) mentioned in his book is that the unit of analysis is related to the initial research questions. Since our research topic and, thus, questions are related to the global SC, the unit of analysis is the global SC. That makes it a single unit of analysis, also known as a holistic unit. Defining the unit of analysis is essential, especially because it helps determine the scope of the data collection (Yin, 2018).

Secondly, *developing theory, proposition, and issues underlying the anticipated study*. For a solid foundation of the research design, the data collected should be linked to propositions and theories of previous research (Yin, 2018). The scope of the project and research questions were developed to address the global SC issues that can be solved by sensing solutions. These issues were identified through several data collection methods, as presented in section 2.5, *Data Collection*.

Thirdly, *identifying the case study design*. Yin (2018) discusses four types of designs based on a two-by-two matrix, as shown in figure 2.6. The matrix shows, in the vertical axis, the type of unit of analysis whether it is single or multiple. On the horizontal axis, the matrix shows if the case study is of single or multiple characters. To get a deeper understanding of a case, a single case study is preferred, whilst a multiple case study is preferred when comparing two or several cases within the study (Woodside, 2010). The four case study design types are single-case holistic design, single-case embedded design, multiple-case holistic design, and multiple-case embedded design. After identifying the issues and opportunities in the global SC, the project's scope is to connect them with sensing solutions, making the project a holistic single-case design project. Holistic because of the systematic view and single-case because of having one product and one company.

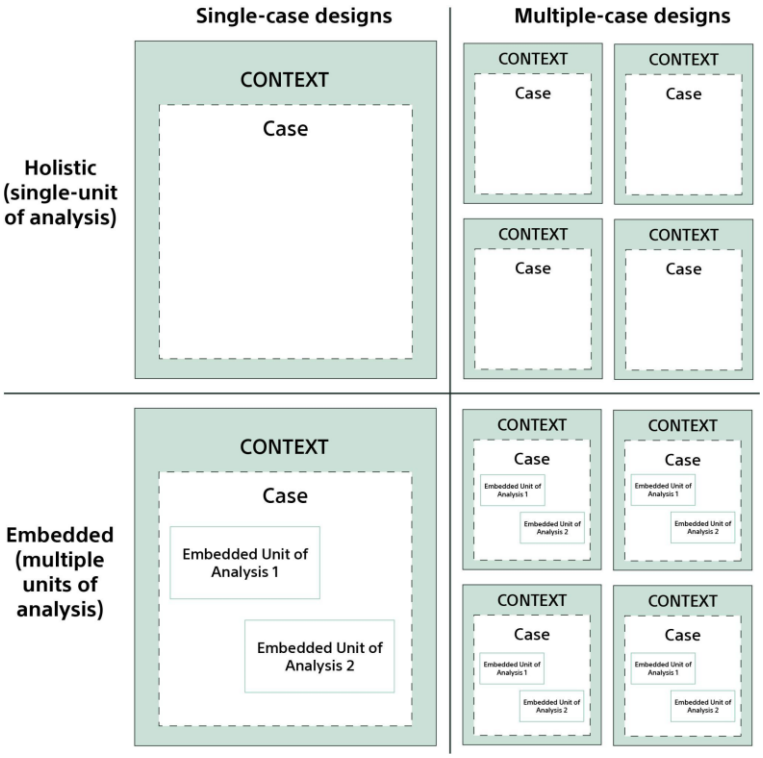

Figure 2.6: Types of designs for case study (Yin, 2018, p.84)

Fourthly, *defining procedures to maintain case study quality*. Very briefly, the quality of a given design can be judged according to specific logical tests (Yin, 2018). Four tests are considered relevant in this context, i.e., construct validity, internal validity, external validity, and reliability (Yin, 2018). More details are discussed in section 2.7, *Research Credibility*.

2.4.3. Preparing the Case Study

In this stage, Yin (2018) explains the importance of the researcher's skills when conducting a case study. Asking good questions is a prerequisite for case study researchers as it is vital to create a rich dialogue with the interviewee; this is followed by being an excellent listener to intercept the answers fairly without bias. Few case studies tend to end just as planned; therefore, it is critical to stay adaptive and see new situations as opportunities rather than threats. However, a skilled researcher should not forget the core purpose of the case study but still be willing to adapt. If an adaptive posture is kept, the results can be invaluable and contribute majorly to the research (Yin, 2018).

Unlike other types of research in a mechanical fashion, the gathered data in a case study is examined continuously, which helps the researcher to decide if there is a need for additional evidence. It also helps the researcher to know if several sources of information contradict one another. Conducting research ethically means being open to contrary evidence, i.e. it is essential that the researcher not only gets swayed towards supportive evidence but also looks at the rival explanations and interpretations (Yin, 2018).

2.5. Data Collection

The fourth stage of the methodology process is critical to the project as it is necessary to determine the suitable data collection sources to perform the case study. Yin discusses the most common sources in a case study, i.e., documents, archival records, interviews, direct observations, participant observation, and physical artefacts (Yin, 2018). Furthermore, he clarifies that it is essential that a case study does not rely on a single data source, as various sources are complementary.

To benefit the most from these data sources, Yin (2018) suggests following four principles of data collection. The first principle is to *use multiple sources of evidence,* and the triangulation rationale can do this. Triangulation means using several methods, several data sources or several researchers to examine an object. This helps get a more comprehensive picture of the case being studied (Höst et al., 2006). The second principle is to *create a case study database*, which increases the reliability of the entire case study. When the collected data is adequately preserved in a retrievable form, it makes it easier for the researcher to own later analysis and serve external readers (Yin, 2018).

As for the third principle, *maintaining a chain of evidence,* it is important to construct the collected data's validity. In addition, the research questions at the earlier stages have to reflect the concepts of the findings at the later stage to increase the quality of the case study. Lastly, the fourth principle is *exercising care when using data from social media sources*. Generally, from critical thinking, it is necessary to be sceptical and cautious when using such a source. In this project, however, the last principle will not be relevant as such sources are not intended to be used. Data will be collected by reviewing literature as secondary data sources and interviewing SC and logistic specialists as primary data sources.

2.5.1. Literature Review

Since the purpose of this study is exploratory, documents were used as a secondary data source as the first approach to collecting data. There are various document types, such as; books, journals, government publications, newspapers, letters and diaries (Denscombe, 2010). In this thesis, however, the sources used in the literature review are from both academic-oriented and practitioner-oriented research. The latter includes white paper articles, reports from consultancy firms, business reports, magazines and business blogs from field experts. The relevant literature is based on this project's research questions and the following keywords; Supply Chain Disruptions, Supply Chain Resilience, Supply Chain Visibility, Supply Chain Transparency, Real-Time Visibility, Internet of Things, and Industry 4.0.

The sources mentioned above have been mainly collected using search engines such as; LUBSearch and Google Scholar. In addition, consultancy firms such as BCG, McKinsey and Gartner own search engines that are used to gather practitioner-oriented reports. Due to the abundance of materials available on these search engines, it is essential not to get lost while reviewing the collected materials and focusing on what is central by sorting them first, as Yin (2018) recommended. A systematic approach was followed to spend more time reading what

is paramount. This was done by first scanning the collected materials and making notes on points that were discussed later between the authors. This also contributes to building the case study database mentioned in the four principles above. Later, if the article seemed to be relevant, it was further read, and more thorough notes were taken. The notes helped with structuring the literature reviewed by extracting the relevant information and elaborating on it under the right headline in the project.

2.5.2. Interview

According to Runeson and Höst (2008), it is important to use interviews in a case study as a data collection source. Interviews help get better direct access to experience and describe things from the interviewees' point of view, as Silverman (2017) puts it. Interviews can be conducted in different forms, namely structured, semi-structured and unstructured interviews. There are also other forms, but these are the major types (Bryman, 2012). He further mentions that the structured form is mainly used in survey research, where the goal is to aggregate the replies by standardising both the questions and the answers. The semi-structured form, however, tends to be more flexible in that the questions are somewhat more general, and the interviewer can ask further questions depending on the interviewee's response. The unstructured form has some similarities with the latter but tends to have a list of topics or issues instead of questions.

In this project, the interviews are of a semi-structured form as the aim is to study the SC and logistics managers' points of view and to have their inputs in the analysis performed later. The questions, seen in the interview guide in Appendix A, were constructed before the interviews to find further evidence on what was found in the literature review. The questions were constructed based on the recommendations of Olsen (2015). As the form is semi-structured, the questions can be changed during the interview depending on the interviewee’s answers.

The approach followed by the authors to perform the interviews is what is suggested by Runeson and Höst (2008). It is good to start the interview with a brief background about the authors, their case study, and the interview's objective. The interviewee should also have the opportunity to present themselves and explain how their background is related to the subject by asking them introductory questions that are simple to answer. Later the main questions of the interview are asked by starting with open questions and moving towards more specific questions in the middle and ending with open questions again. This is known as the *time-glass* model and is followed since it allows a comprehensive interview and gives it a better flow by letting the interviewee contribute with their input (Runeson & Höst, 2008).

Following Runeson and Höst (2008) recommendation of recording the interviews even if notes are taken, both authors have taken notes for all the interviews, recorded or not, and compared them later to ensure better validity and interpretation of the information provided by the interviewee. Recording the interview also allows the authors to be more present during the interview. The interviews lasted approximately 60 minutes and always ended with asking the interviewee if they had any additional points, they would like to add that had not been

mentioned. A follow-up interview was also conducted as a phase two interview, but for those who could not arrange a time for the interview, questions were sent via email as a form of a short survey. Follow-up questions can be seen in Appendix B.

2.6. Data Analysis

Analysing the collected data is essential and includes examining, categorising, testing, or tabulating to draw empirically based conclusions. It is of meaning to display and present the evidence separate from any interpretation (Yin, 2018). It relies on the researcher's style of empirical thinking to provide a clean presentation and, thereafter, a clear understanding of the data (Denscombe, 2010; Yin, 2018). There are several techniques for analysing case study evidence. According to Yin (2018), none of these techniques has been well-defined. Furthermore, Yin adds that even if the techniques are essential, they are not enough on their own, and they are only most helpful if the researcher knows what to look for.

This part of the project is important to consider in advance to know what to do with the evidence once collected. Otherwise, it will be challenging to analyse the collected data properly. The two methods used in this thesis are pattern matching and Product-Market Fit (PMF). These methods complement each other as the pattern-matching method helps link theoretical data to empirical findings. Whilst, the PMF analysis helps with analysing the market from the product perspective, based on the results from the pattern matching analysis. The following subsections describe the two methods thoroughly.

2.6.1. Pattern Matching

Pattern matching is one of the techniques Yin (2018) presented as a method to analyse case study evidence. Above that, it is described as the most desirable technique to be used in case studies. This method is relevant to use in a case study of an explanatory or a descriptive purpose. Before linking the theoretical data with the empirical finding, the answers from the interviews were mapped to sort the similarities and differences in the interviewees' responses. Thereafter, the empirical findings were compared to understand what needs are required from the market side. A table with all the needs identified is presented in chapter 5, *Analysis and Discussion.*

2.6.2. Product-Market Fit Analysis

In order to be able to analyse the market from the product perspective, a PMF analysis was conducted. The concept is defined as creating a minimum feasible product that solves an existing problem or need (Khoironi & Herliana, 2015). Even though there is no specific definition of the PMF concept, several researchers, according to Capovilla (2019), mentioned that the concept is not a discrete and absolute moment and is more than just solving the identified problems. Besides that, the concept is continuous, follows an iterative process, and includes three validation perspectives (Mueller & Thoring, 2012). The validation perspectives are the willingness of the customers to pay for the product, having economically viable ways to acquire customers, and having a large enough market size. Applying PMF analysis, especially in the initial phase of a product, enhances the business' scalability (Mueller &

Thoring, 2012). However, before looking to scale up the business, the company should consider finding a fit for the product in the market (Hokkanen & Leppänen, 2015). Göthensten and Hellström (2017) stated that the main challenge start-ups face is to find product-market fit before they run out of resources, which makes it essential to apply the concept early in the process.

To establish a good PMF, Olsen (2015) developed an actionable framework that is called PMF Pyramid. The framework is illustrated in figure 2.7, which presents five layers divided into the market and product sections (Olsen, 2015; Lopes, 2020). The framework's bottom layer is the target customer upon which all other layers are built. The underserved needs layer is above the target customer layer, as their needs help achieve a PMF. On the other side, the top layer of the PMF Pyramid is the user experience (UX). The UX is what customers see and use, bringing a product's functionality to life. A product's functionality consists of multiple features built to address a market need. Together, these features build a feature set that is the layer below the UX. The features set form the product's value proposition, which is the layer after that.

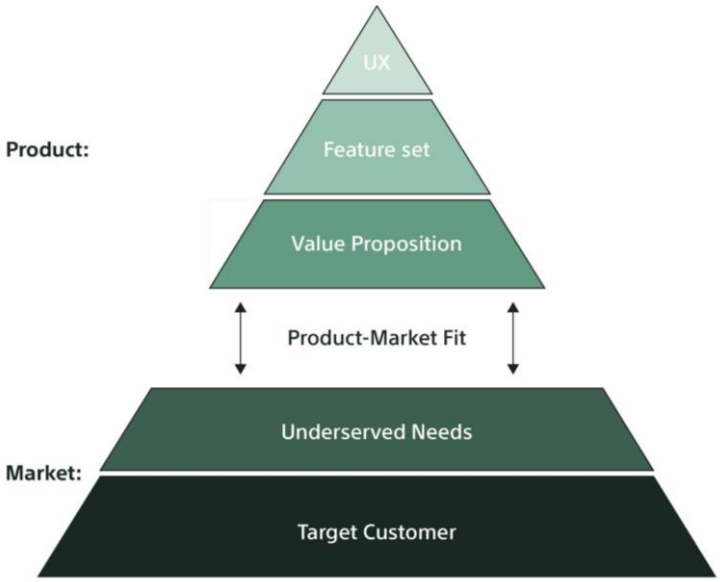

Figure 2.7: The product-market fit pyramid (Olsen, 2015, p.4; Lopes, 2020)

In a PMF, it is essential to ensure that every layer in the pyramid lines up. However, the data collected, by the methods described previously, is analysed to help identify the needs and reach a PMF. The pattern-matching analysis method is conducted to understand the market and to identify its needs. The product's current feature set is compared with the market needs identified from the pattern-matching analysis to identify the underserved needs. The product's features can then be developed to meet the identified underserved needs. This development empowers the company with a better view of the current situation for the product and gives it a competitive advantage.

2.7. Research Credibility

The previously mentioned four tests at the end of subsection 2.4.2, *Designing the Case Study*, namely construct validity, internal validity, external validity and reliability, are commonly used to examine the credibility and quality of the research (Yin, 2018). Three of the tests are for testing validity, and one is for testing reliability. Construct validity and reliability tests are applied when examining the data collection sources. Internal validity is applied when looking into the data analysis, while external validity is used for the research design. The following subsections explain these tests and how they have been implemented in this project. Figure 2.8 below illustrates what validity and reliability mean and how they are connected.

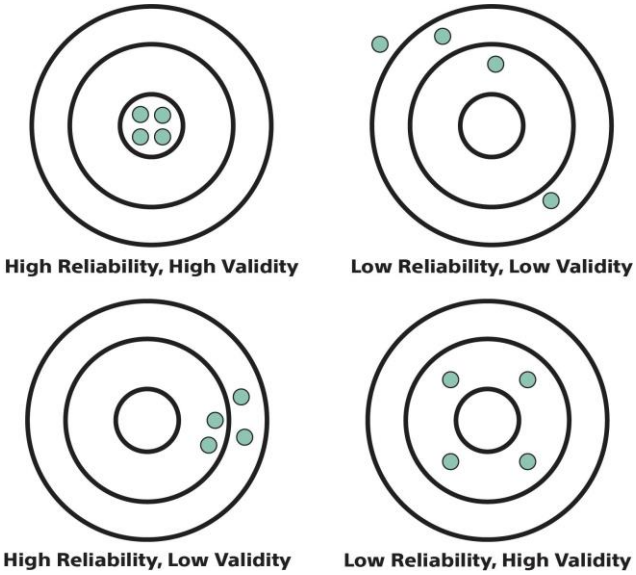

Figure 2.8: Reliability vs validity adapted from Elasy and Gaddy (1998)

2.7.1. Validity

As mentioned above, three types of validity tests can be used to ensure the credibility of empirical research. To start, the construct validity test is used to examine the operational measures for the concept that is being studied. Yin (2018) recommends that multiple evidence sources be used to increase the validity. The authors have therefore gathered data from different sources as mentioned in section 2.5, *Data Collection*, i.e., interviews, academic literature, and practitioner literature in the form of white paper articles and reports from consultancy firms, and even podcasts with vice presidents and executives. Moreover, to examine the construct validity, drafts have been sent and reviewed by the supervisor at *LTH* regularly from the start to the final stage of the project. After that, these drafts were revised based on the comments from the supervisor. To generate validity of the results, the pattern-matching technique was used as it is relevant to the case study context.

Moving on to the next test, namely, internal validity. It is used to find a causal relationship between variables where certain conditions will lead to other conditions. This test, however, is not recommended to be used in an exploratory or descriptive study but rather in an explanatory study (Yin, 2018). Thus, the internal validity test is excluded from this project. On the other hand, external validity is to test if the findings of the research can be generalised and therefore applied to other similar case studies, i.e., it tests the ability of the findings to occur in similar cases rather than being unique to the particular case (Denscombe, 2010).

2.7.2. Reliability

A study must be reliable to minimise errors and biases. This fulfils the objective that Yin (2018) explains in his book that for a study to be reliable, it should be possible to perform the same study by another author with the same procedure as the previous author, and the same results will be obtained. One way of increasing the reliability of a study is to make it clear to the readers how the data were analysed, i.e., it is essential to include a description of how the procedure moving from raw data to findings was done to give the study a better consistency (Denscombe, 2010). Therefore, in this project, authors have thoroughly explained the procedure of the research methodology used and how the collected data were analysed.

3. Theoretical Framework

This chapter introduces the theoretical framework where the research topics are highlighted to build a robust analysis. This is done based on the literature review conducted by the authors. The chapter starts with discussing the recent global disruption events and their impact on the global SC. Then, the importance of SCRES and how digital technology and visibility play an essential role in enabling it are presented. Later, transparency and its relation to SCV are introduced, which leads to the identified dimensions.

3.1. Supply Chain Disruptions

3.1.1. Definition

SC disruptions are unpredictable and challenging to avoid nowadays, making it necessary for companies to have a strategy to deal with the next global SC disruption when it occurs (Gartner, n.d.). A general definition of SC disruptions is

> *an event, whether it is local or global, that has a negative impact on the continuity of the normal supply flow (Xu, 2008; Craighead et al., 2007).*

The commonly known global SC disruptions occurred due to *Black swan events*—events with a low probability of occurring but with no warning and a significant effect (Elston, 2022). In order to mitigate global SC disruptions, it is necessary to have advanced planning in the form of crisis management, as the occurrence of Black swan events is inevitable, and they may become regular in the future (Weber, 2021; Elston, 2022).

3.1.2. Supply Chain Disruption Events

An event in one country can have a domino effect across the globe and thus result in a higher SC disruption level (Roscoe et al., 2020; Liuima, 2020). That is due to the complexity level global SC is approaching, driven by growing internationalisation, higher demand volatility, and faster SC speed (Calatayud et al., 2019). SC disruptions can occur in the event of political uncertainty, economic upheaval, cyber and terrorist attacks, supplier threats, and rapid swings in consumer preferences and demand (Gartner, n.d.). Formerly, organisations could plan and forecast monthly, if not years; however, nowadays, with the high volatility, the time horizon gets shorter, and organisations try to find strategies to become more responsive (Christopher & Holweg, 2017). Below are examples of the main black swan events in SC that affected the global SC flow.

- On September 11, 2001, terrorism had alertly become a new threat and a challenge to SC managers after the attack on the World Trade Center in New York and the Pentagon in Washington DC in the US (Sheffi, 2001). The disruptions in the SC have mainly been caused due to the reaction of the US Government to the attack by closing borders, shutting down air traffic, and evacuating buildings in the country (Sheffi, 2001; Sheffi et al., 2003).

- The financial crisis in 2007-2008 resulted in many companies being starved for liquidity (Mefford, 2009). That led to falling demand and production, thereby boosting the drying up of orders. Back then, many firms relied on a *just-in-time* strategy for their inventory, which led to sudden and large order cuts for fear of the uncertain environment (Mefford, 2009).

- The Japanese earthquake that occurred in March 2011 had a magnitude of 9 degrees and resulted in a tsunami afterwards (Japan Meteorological Agency, 2011). It had a severe impact and caused structural damage in north-eastern Japan. This event caused global production bottlenecks due to the impact on manufacturing industries. The production rate in Japan declined by up to 50 per cent (Arto et al., 2015). Even though this might sound like a local tragedy, Japan only suffered 40 per cent of the total impact compared to the rest of the globe, which bore 60 per cent of the economic damage (Arto et al., 2015). Mostly the damage was in effect of the decreased production rate of key components domestically in Japan, which affected global manufacturing and thus led to global SC disruptions.

- Brexit, or the United Kingdom's decision to leave the European Union, came into force at the beginning of 2020 after a vote in June 2016 (Roscoe et al., 2020). Besides the political challenges that the withdrawal led to, it also impacted and still impacts many aspects of the SC, such as asset positioning, material and information flow, human resources availability, and access to suppliers (Roscoe et al., 2020). The uncertainty of its consequence makes it challenging to prepare and predict the availability of demand and supply, which results in a more vulnerable SC (Hendry et al., 2019).

- The COVID-19 outbreak occurred at the end of 2019, but its real impact was during the coming year. Kähkönen et al. (2021) mentioned that the disruptions of pandemics have a long-term effect on SCs. The pandemic resulted in many disruptions in the global SC, in particular, the impact it had on the healthcare sector (Sharma, 2020). Furthermore, the major challenge associated with COVID-19 was the uncertainty on demand. For some sectors, the demand decreased as people mostly stayed at home, while a sudden spike in demand was noticed for other sectors. Other consequences of the COVID-19 outbreak are shortage of raw materials and supply delays as well as a reduction in the workforce due to, e.g., lockdowns (Kähkönen et al., 2021).

- The ongoing geopolitical conflict in Ukraine severely affects the global SC. Important aspects in SC affected by the conflict are the impact on critical logistics routes, material cost increase and capacity constraints (Hippold, 2022). The major challenges facing the global SC associated with the war in Ukraine can be seen in major sectors, such as agribusiness, automotive, and semiconductors (BCG, 2022). The challenges have mainly been in supply and cost impacts in the form of commodity shortages, components and products sourcing challenges, demand shocks, and the rise of logistics costs as a result of the fuel impact.

These events are only a few examples of black swan events in the SC that had direct or indirect aftermath on the global supply flow. Having recently experienced one disruption after another; Brexit, COVID-19 lockdowns, the Suez Canal obstruction, and the Ukraine conflict, SC managers are shifting their focus from optimising *just-in-time* strategy to preparing for *just-in-case* eventualities (White et al., 2022). Many of these events come with the consequence of having excessive outcomes. Some events resulted in higher global disruptions, while others affected certain industries, as mentioned above. These events are often unpredictable, leading to high uncertainty and volatility. To better manage these disruptions, it is necessary to have a clear picture of each link. This is emphasised in a recent McKinsey survey that shows that visibility is the key to overcoming SC disruptions (Alicke et al., 2022).

Additionally, government regulations are crucial in having a seamless and effective supply flow. In 2022, the US Department of Commerce recently announced new export controls and regulations focusing on the semiconductor sector and related technologies. The new restrictions are technology export controls on China. The restrictions include products, operations, and any technical engineering support from any US personnel for Chinese companies in the semiconductor sector and related industries (EY, 2022). Restricting American expertise from operating in Chinese companies will greatly impact semiconductor manufacturing in China. Both US and non-US companies with a business in China involving semiconductor manufacturing will feel a significant impact. This is a recent example of how new government regulations impact the flow of the chain, as is the case with the regulations applied after the 9/11 attack.

3.1.3. Turbulent and Volatile World

Traditionally, business environments have been more certain where fewer disruptions occurred; this led to a more stable environment where methods like a projection of future demand and relying on a forecast-driven approach were acceptable (Christopher & Holweg, 2017). There is a need today to assess SC structures (Kim et al., 2014) and develop the right bandwidth of flexibility to cope with volatility in the current business environment (Christopher & Holweg, 2017). Thereby the traditional SC structure is no longer fit for purpose in today's turbulent, complex, and volatile world of business.

Christopher and Holweg (2017) state that volatility has become the *new normal* and makes SCs partly more vulnerable to disruptions. Therefore, it is, without a doubt, essential to understand and manage volatility. Managing volatility leads to reducing vulnerability which results in reducing SC disruptions (Sheffi & Rice, 2005), especially nowadays, where globalisation and internationalisation contribute to the increase of vulnerability (Arto et al., 2015). On top of that, resilience in the SC is necessary to manage turbulence and volatility as it gives the ability to bounce back from disruptions and reduce the vulnerability of the SC (Sheffi & Rice, 2005; Kähkönen et al., 2021).

3.2. Supply Chain Resilience

3.2.1. SCRES Definition

SCRES concept has been gaining more awareness in the business environment in recent years (Kamalahmadi & Parast, 2016; Alicke et al., 2022; Hussain et al., 2022). As a fact and as mentioned earlier, the most recent events—the COVID-19 outbreak and the ongoing conflict in Ukraine—have exposed the vulnerabilities of the global SC (Henrich et al., 2022) and, thus, put higher pressure on companies to build a resilient SC to survive (Kim et al., 2014). This is required in order to have effective responses and recover from disruptions (Hendry et al., 2019). Additionally, Pettit et al. (2013) emphasise the importance of firms having the right adaptive capabilities to mitigate the aftermath of disruptions as they are inevitable.

Defining SCRES is difficult as there is no agreed definition by researchers so far, as the theoretical ground is lacking (Kamalahmadi & Parast, 2016). Since the number of publications in this area is low compared to SC Management (SCM), the area of SCRES is therefore considered underexplored (Kochan & Nowicki, 2018). The authors limited themselves to the most comprehensive definition that is relevant and within the scope of the project to ease the understanding of the concept. Kamalahmadi & Parast (2016) define SCRES as:

> *"The adaptive capability of a supply chain to reduce the probability of facing sudden disturbances, resist the spread of disturbances by maintaining control over structures and functions, and recover and respond by immediate and effective reactive plans to transcend the disturbance and restore the supply chain to a robust state of operations."* (Kamalahmadi & Parast, 2016, p.121).

This definition consists of three factors of SCRES. It begins by explaining that a resilient SC should focus on reducing the probability of facing disruption in the first place, also referred to as readiness. Anyhow, if a disruption impacted the SC network, it should be able to respond and limit the damage caused quickly. The last part of the definition considers how fast a reaction should be in order to recover and bounce back easily.

3.2.2. SCRES Enablers

There are several enablers discussed in the academic and practitioner fields that allow organisations to develop their SC network to be resilient. Cristopher and Peck (2004) declare that in order to create a resilient SC, there are four main principles, i.e., re-engineering—building resilience in advance of a disruption—collaboration, agility, and risk management culture. A survey study by Mandal (2012) showed similar results, i.e., re-engineering, agility, collaboration, and risk management are the factors to obtain SCRES. Another survey study conducted by Soni et al. (2014) showed that the five most expected enablers of considering SCRES based on answers from experts are visibility, agility, collaboration, risk management culture, and adaptive capability. It is worth mentioning that the enablers listed in the survey have strong support from the literature, according to Soni et al. (2014).

Furthermore, an interview in the *SC brain* podcast with Mark Balte, senior vice president of product innovation at Logility (Bowman, 2022), emphasised the enablers mentioned above. He added that merely considering internal parameters when forecasting is not enough and that organisations should go global in their planning process. Mark Balte further adds that SC leaders' most adapted behaviour is building inventory buffers or so-called safety stock. This goes in line with a survey conducted on SC leaders by McKinsey, where the majority say that increasing stock levels and applying a dual-sourcing strategy increases their resilience (Alicke et al., 2022).

Pettit et al. (2013) also mention that visibility is a capability that enables an organisation to anticipate and overcome disruptions. Mandal et al. (2016) have also found that visibility positively influences SC which as well leads to a positive influence on SCRES. Based on that, visibility is considered to have a great role in enabling SCRES.

3.2.3. SCRES Benefits

The understanding of the SCRES concept and its enablers enhance organisational learning that could improve future response management and help achieve competitive advantage (Hussain et al., 2022). SCRES not only gives a competitive advantage in the market but also results in several advantageous outcomes (Soni et al., 2014; Carvalho et al., 2012). The benefits of considering SCRES are perceived in daily activities; however, it also allows for achieving market share even during disruptions (Soni et al., 2014; Carvalho et al., 2012).

The current global SC is becoming more complex with unpredictable and continual disruptions. In fact, SC managers identify complexity risk as the highest threat to their firms (Hussain et al., 2022; Pettit et al., 2010). By considering the enablers mentioned above, SC can become more resilient, and SC managers can better grasp the SC's complexity. Traditional risk management does not help prepare for future unknowns, while SCRES prepares for the next disruption by allowing for quicker recovery and mitigating damages (Pettit et al., 2010). Overall, SCRES positively influence SC performance (Mandal et al., 2016).

3.2.4. SCRES Barriers

Besides all the benefits of SCRES, the other side of the coin is that it is costly. According to Christopher and Holweg (2017), SCRES comes at a cost, and the real question is how it benefits the SC. Organisations should weigh the cost against the benefits it brings to their SC. There is no general rule regarding the process of being resilient or the investment amount in achieving SCRES. It basically depends on the need and the complexity of the SC.

Besides the high cost of infrastructure installation, the lack of required knowledge and skills and concerns with data sharing and security could be considered barriers as well (Haddud et al., 2017). Moreover, the maturity of the market is still limited to different geographical and technological areas. This immaturity damps the extension of the sensing environment infrastructure through the whole SC (Haddud et al., 2017; Vábek et al., 2021).

3.3. Supply Chain Technologies

As stated earlier, SCRES is needed as it enables recovery and adoption of the changes in the environment. Digitalisation is an emerging change in firms and society (Ivanov et al., 2021). According to a survey conducted by McKinsey, almost every company plans for further digital investment (Alicke et al., 2021). In light of the latest disruptions, executives regard digital transformation as more urgent (Close et al., 2020). Resilience, or more specifically, SCRES, needs and can be digitally enabled with the help of digital technologies (Close et al., 2020; Ivanov et al., 2021). Furthermore, Alicke et al. (2021) declare that the success of an organisation is strongly connected to its level of adopting digital technologies.

3.3.1. Industry Revolution and Technology Overview

The rapid evolution of information and communication technologies has been hard to miss over the past few years (Ghadge et al., 2020). This resulted in the emergence of Digital technologies in the SC and the digital transformation of the industry. The majority of companies, both in manufacturing and logistics, foresee a positive effect of the digital transformation (World Economic Forum, 2017), which motivated the significant undergoing changes in the SCM (Calatayud et al., 2019).

This digital transformation is known as the fourth industrial revolution, *Industry 4.0,* which drives the new industrial stage by changing the industry's structure, competition rules, and customers' demand (Dalenogare et al., 2018). The steam engine, electricity, and automation influenced the first, second and third industrial revolutions, respectively. As for the fourth revolution, its main feature is the intelligent networks based on Cyber-physical systems (CPS) and the Internet of Things (IoT) (Barreto et al., 2017).

CPS is a technology which allows network interaction with the physical world by so-called network agents. These agents can refer to sensors, actuators, or communication devices that enable operations monitoring, coordination and controlling (Barreto et al., 2017). CPS has been strengthened by IoT technology, and it is considered the key enabler for CPS (Nandhin & Lakshmanan, 2022). IoT is simply the integration of physical objects communicating with

one another through the internet to achieve some useful objectives (Haddud et al., 2017). CPS' main role is to improve the effectiveness and efficiency of the entire industry (Lu, 2017). Therefore, the IoT is critical in the Industry 4.0 revolution (Ghadge et al., 2020). Industry 4.0 is also referred to sometimes as Industrial IoT (IIoT) (Ben-Daya et al., 2017). The main technologies mentioned hereinafter are RFID, cloud technology, IoT, and Big data, and how they can help allow the industry 4.0-adapted SC, or as it will be referred to in this thesis, *SC 4.0*.

3.3.2. The Emerging Technology in Supply Chain

(i) RFID Technology

Applying new technology in order to optimise SCM is not new. Indeed, in 1999, after 30 years of using the barcode in SCs, the MIT Auto-ID Centre was founded, known today as the Auto-ID Labs (Luckett, 2004). The Auto-ID Labs leads the global research network of academic laboratories in the field of IoT and aims to design the merge between the physical and digital worlds (Auto-ID Labs, n.d.). Back then, Radio frequency identification (RFID) technology started bringing attention from practitioners and academics and had the ultimate goal to "... create an 'Internet of things' in which everyday physical items are networked together" (Luckett, 2004, p.50). RFID is "a wireless communication technology that can identify specific targets using radio signals and read and write relevant data without mechanical or optical contact between the system and the target" (Yan et al., 2017, p.524). RFID is considered a subset of CPS (Huebner, 2013). Calatayud et al. (2019) emphasise that RFID is the key technology in enabling IoT systems or even a prerequisite, as Ghadge (2020) puts it. RFID plays an important role in the automation process of IoT and its implementation in SC 4.0 and can be used for object tracking, warehouse inventory control and SCM (Yan et al., 2017).

(ii) Cloud technology and Big Data Analytics

After tracking and gathering information through RFID technology, there raises a need for analysis and information sharing. Cloud technology, together with big data technology, offers such a solution. This is done by storing large amounts of data collected from business systems, devices, and sensors on remote servers known as the cloud (Oztemel & Gursev, 2018). Enhanced data sharing, whether inside the organisational departments or outside the organisational borders, is required; this is enabled by the cloud (Ghadge et al., 2020). "Cloud computing environments are rapidly evolving and driving more data-driven and intelligent SC activities" (Ghadge et al., 2020, p.672). After gathering the data, it is crucial to have a system in place to analyse and handle it; thus, big data analytics is needed. Big data works hand in hand with cloud computing to gather useful insights and empower the analysis at a bigger scale and better performance (Lew et al., 2022).

(iii) IoT technology

As mentioned before, RFID is the key technology in IoT and IoT is the enabling technology for CPS. The connectivity mentioned earlier that IoT allows is done by connecting the information-acquiring devices with cloud computing technology for reliable transmission and

information processing in order to achieve useful objectives (Nandhini & Lakshmanan, 2022). Literature about IoT goes back to the late 1990s, when Kevin Ashton invented the term IoT as a reference to the objects identified by the RFID technology and virtually represented in an internet-like structure (Calatayud et al., 2019; Elder, 2019).

According to Ben-Daya et al. (2017), an IoT network includes four main layers: (1) a *sensing* layer, (2) a *networking* layer, (3) a *service* layer, and (4) an *interface* layer. These four layers enable a complex network to be connected. An IoT network architecture is illustrated in figure 3.1. The first layer consists of RFID tags, sensors or reader tools, and short-distance network connecting technologies that enable efficient communication, e.g., Wi-Fi and Bluetooth (Dweekat et al., 2017). The task of the first layer is to integrate these different types of devices or *things*. Second is the network layer, a gateway that allows devices to connect and transfer information by wired or wireless networks. After that comes the service layer, which is responsible for data storage in the cloud and the interaction amongst multiple devices and processes. Lastly is the interface layer, where collected and transmitted data is analysed with the help of big data analytics. This is later displayed to the users to allow interactions with the system (Calatayud et al., 2019).

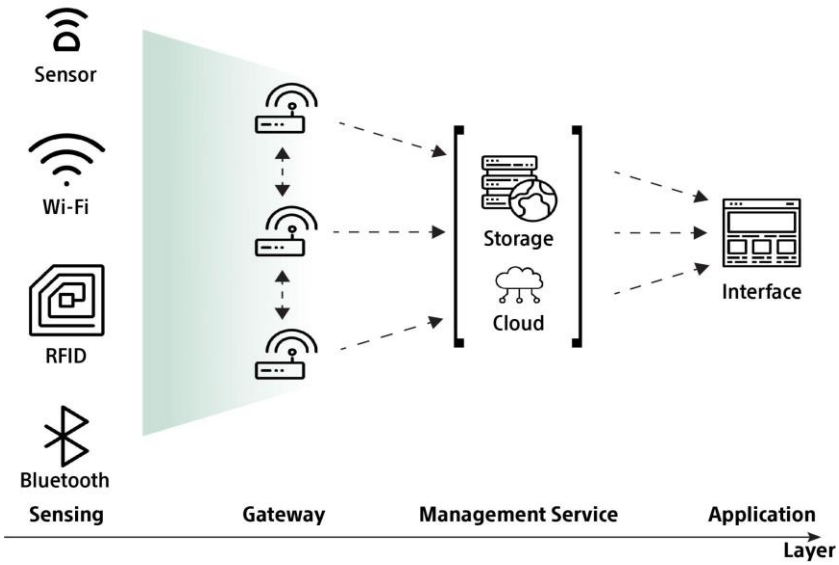

Figure 3.1: IoT network architecture adapted from Calatayud et al. (2019) and Fitzgerald et al. (2018)

3.3.3. Sensing Solutions

Technologies that help optimise the SC have been around since the barcodes started being used as a tracking method. With the increasing global disruption events, new technologies are emerging and helping fasten the adoption of SC 4.0. Sensing solutions technology plays a main role in the SC digital transformation as it transforms the physical world into digital insights by providing data and feedback on the goods and processes of organisations along their SC (Fitzgerald et al., 2018). The IoT network mentioned earlier strengthens the role of sensing solutions as it places it in the first main layer in connecting the network. With the help of sensing solutions, the data can be gathered and later turned into information and insights

that SC managers can use to analyse and optimise their SC. The benefits that IoT brings result in achieving competitive advantages for individual organisations and, thus, their entire SCs (Haddud et al., 2017).

Organisations face several challenges regarding visibility and transparency in their SC due to the lack of high-quality information (Forslund & Johnsson, 2007). With the help of sensing solutions, organisations can take their SCV to a new level by having real-time information flow. Sensing solutions help provide organisations with up-to-date insights and increase the accuracy and reliability of the data (Fitzgerald et al., 2018). Sensing solutions have improved with the help of IoT technology and thus become smarter and more connected. Ben-Daya et al. (2017) define IoT from a digital SC perspective as follows:

> *"A network of physical objects that are digitally connected to sense, monitor and interact within a company and between the company and its supply chain enabling agility, visibility, tracking and information sharing to facilitate timely planning, control and coordination of the supply chain processes."* (Ben-Daya et al., 2017, p.4721).

The enablers mentioned in the definition above improve the connectivity, visibility and integration of the SC with the help of IoT, which in turn helps realise the SC 4.0 (Calatayud et al., 2019; Ben-Daya et al., 2017). The IoT technology can enable great SC connectivity alongside many other applications. However, it requires a ubiquitous connection to the internet, faces security constraints, and an interoperable mobility protocol with today's internet infrastructure (Dweekat et al., 2017).

3.3.4. Traditional Supply Chain

As a result of the industrial revolution and the SCM's ability to cope with the fast transformation, the SC is adapting new digital technologies (Calatayud et al., 2019). The traditional SC was shaped to fit the requirements needed in the industry back then and thus relied on a forecast-driven approach (Christopher & Holweg, 2017). This approach merely counts on historical data as the basis for the planning, which has worked so far.

However, in a rapidly changing environment, this approach could lag. The main challenge in the fourth industrial revolution, besides forecasting, is to become more agile and respond quickly to events as they happen. Further, the traditional SCs are less connected due to poor data sharing, which negatively influences visibility (Calatayud et al., 2019). Moreover, the data collected is manually turned into usable information, resulting in less resource utilisation rate (Calatayud et al., 2019). Just as important, the traditional SC is also less transparent, making it challenging when trying to become more sustainable and aware of what happens along the SC (Ghadge et al., 2020).

3.3.5. Supply Chain 4.0

The authors will use the term SC 4.0 as a reference to the next-generation digital SC. SC 4.0 integrates different digital technologies, such as sensors, IoT, the cloud, and big data analytics, alongside other innovative technologies in the industry into the current SC (Brinken et al., 2022; Barreto et al., 2017; Alicke et al., 2016). Hence, the main characteristics of SC 4.0 are digitisation, connectivity, visualisation, and traceability. Figure 3.2 below illustrates what SC 4.0 looks like and how it is connected.

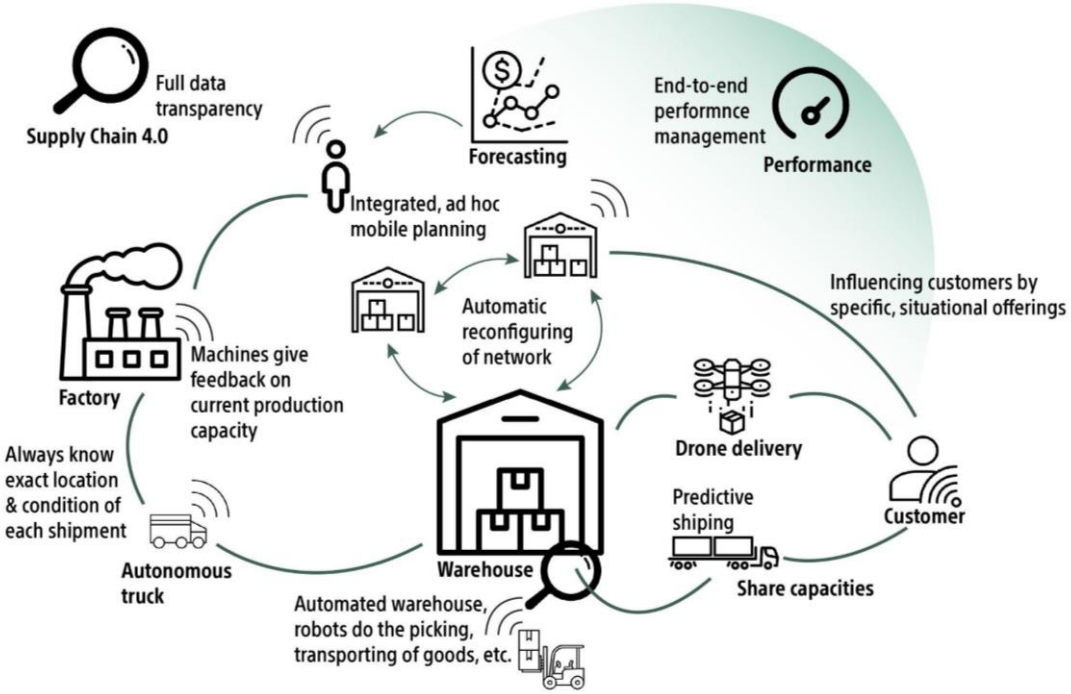

Figure 3.2: Illustration of SC 4.0 adapted from Alicke et al. (2016)

As shown in figure 3.2 above, the information flow is crucial for a functioning SC in the digital era. With the help of SC 4.0, organisations can gain better connectivity, real-time visibility, and understanding to improve their performance and customer satisfaction (Alicke et al., 2016). If implemented correctly, SC 4.0 can help companies get the right product, in the right way with the right quantity and quality, to the right place at the right time, for the right customer at the right cost (Calatayud et al., 2019). According to McKinsey, efforts towards digitisation are mainly focused on visibility as companies aim to get a better picture of their SC real-time performance (Alicke et al., 2021).

3.3.6. Traditional Supply Chain vs Supply Chain 4.0

In the traditional SC, managers work more separately and build their conclusions upon the analysis made at their specific entity and thus cannot capture the entire picture (Ghadge et al., 2020). On the other hand, the analysis made in SC 4.0 takes a holistic view and includes information and feedback from different entities along the SC. This is allowed through constant information flow in the SC network enabled by digital technology (Ben-Daya et al., 2017). The holistic view contributes to making the results from the analysis more rational and accurate.

Figure 3.3 shows what organisations can achieve in their SC with the support of the different technologies mentioned earlier. The rows represent the different areas in logistics and how the gradual implementation of SC 4.0 affects each one. The figure shows that the development of SC 4.0 is gradual and not binary. Figure 3.3 is developed by Brinken et al. (2022).

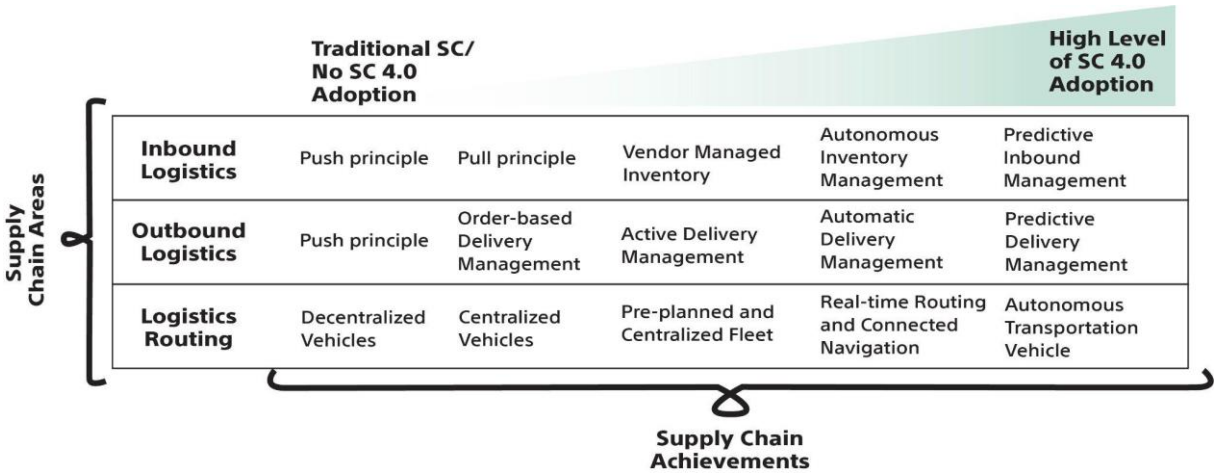

Figure 3.3: Achievements by the support of SC 4.0 adapted from Brinken et al. (2022)

3.4. Supply Chain Visibility

3.4.1. SCV Definition

Enabling SC 4.0 improves the utility of technology and thus enables a better information flow which leads to gaining more visibility on what is happening along the SC. The characteristics of SCV are conceptual, and the term visibility is widely used in SC (Kalaiarasan et al., 2022). Therefore, many definitions exist in the literature. The authors chose to use Francis's (2008) proposed definition of SCV as it is based on his literature review, where he explains the term thoroughly. He defines SCV as:

> *"... the identity, location and status of entities transiting the supply chain, captured in timely messages about events, along with the planned and actual dates/times for these events."*
> (Francis, 2008, p.182).

This definition raises the critical aspects of SCV, starting with a unique identifier of an entity, followed by informing about the entity's location and status. Before sending the information to the receiver, an event is generated with the actual time to be compared with the planned one. Williams et al. (2013) also declare in their definition that the information generated should be of high quality. To achieve that, it must be accurate, timely, complete, and usable. Further, Kalaiarasan et al. (2022) add in their definition of SCV the extent of the visual information that actors within the SC have.

3.4.2. SCV Enablers

According to a survey conducted by McKinsey, companies are striving for a better picture of their SC real-time performance (Alicke et al., 2021). In order to achieve such a picture associated with a higher level of visibility, integration along the SC is needed, namely upstream with suppliers and downstream with customers as well as internally (Wang & Wei, 2007). In addition, to enable such integration, collaboration between organisations is necessary (Swift et al., 2019). Collaboration is enabled by information sharing, which enables connectivity (Soni et al., 2014) and enhances end-to-end visibility (Kalaiarasan et al., 2022).

Connectivity and information sharing enable better visibility (Barrat & Oke, 2007). Information sharing is the most substantial factor in being transparent in SC (Brun et al., 2020). Hence, transparency is considered an enabler for SCV. The SCV is a raw material required to enhance effective and strategic decision-making to mitigate disruptions (Francis, 2008). It is also a way of analysing and putting countermeasures.

Kalaiarasan et al. (2022) divided SCV enablers into three categories, i.e., people, process, and technology. People and processes consider the internal- and external-organisational culture, respectively, which aligns with what is mentioned above. Hence, these two enablers are important in gaining connectivity and, thus, gaining visibility. Based on their division, the third category is technology, referred to as the key enabler in SCV. Digitalisation can enhance the SC's infrastructure by removing constraints related to data that limit the flow of the current SC (Delen et al., 2009).

3.4.3. SCV Benefits

Increasing SCV reveals not only where and when an event occurred but also where the resources and assets are located, where trends are present, and how disruptions are spread throughout the SC (Blackhurst et al., 2011). Furthermore, it helps compare the actual and the planned events to make more accurate decisions at the right time (Francis, 2008). It is realised by Delen et al. (2009) that the most impact of increased visibility is in inventory management and asset utilisation.

When it comes to SCRES, visibility is considered an enabler, as mentioned previously; thus, SCV acts as a support of all benefits related to achieving SCRES (Kamalahmadi & Parast, 2016). Improved agility, flexibility, and analytical ability in improved decision-making are benefits related to increasing SCV (Kalaiarasan et al., 2022). In a high-scale complex SC, visibility significantly affects the SC's performance, while it has less effect on lower-scale complex SC (Brandon-Jones et al., 2014).

3.5. Supply Chain Transparency

3.5.1. SCT Definition

Higher levels of SCV alone are insufficient to improve responsiveness and SC performance (Williams et al., 2013); thus, considering other aspects is important. According to Parris et al. (2016), many authors consider SC Transparency (SCT) as a form of organisation openness in their literature review research. Based on their research, Parris et al. (2016) derived a definition for SCT as:

"The extent to which a stakeholder perceives an organization provides learning opportunities about itself." (Parris et al., 2016, p.233).

This definition takes, in particular, the stakeholders' perception of transparency since transparency is connected to communication interaction between a firm and a stakeholder. This interaction is an event in which the information is shared between these two parties. Further, to obtain a high transparency level, information sharing in the form of providing relevant information and making learning easier for stakeholders is crucial (Parris et al., 2016). In short, it is not about the amount of shared data; instead, it is the relevancy and usage of it to the receiver.

3.5.2. SCT Enablers

One of the most substantial factors required among organisations is enhancing data sharing and the availability of information (Ghadge et al., 2020). Parris et al. (2016) consider information availability the same as being transparent. Being transparent by having a well-designed data-sharing platform is needed to create better SCV, especially in the disruption era (Iakovou & White III, 2022; Caridi et al., 2014). Hudnurkar et al. (2014) add that an integrated information system is required across the SC since information is seen as the glue that holds the business together. The information should not only be shared but also be trustworthy and have value to the receiver (Forssbæck & Oxelheim, 2014). Currently, data is rarely shared across SCs (Iakovou & White III, 2022) and thus leads to reduced levels of visibility. Furthermore, the poor data-sharing capability negatively affects access to accurate and timely information (Caridi et al., 2014), namely high-quality information.

3.5.3. SCT Benefits

To gain improved visibility in the SC, transparency is required as the two influence each other (Bartlett et al., 2007; Brun et al., 2020). According to Hudnurkar et al. (2014), the quality of information sharing is judged by several criteria, i.e., accuracy, timeliness, relevance, and reliability. This goes in line with what is mentioned previously in Williams et al. (2013) definition of SCV; the data must be accurate, timely, complete, and usable, to achieve high-quality data. Organisations can improve their SC by gaining improved SCV, which is obtained by sharing knowledge across the chain (Kamalahmadi & Parast, 2016; Brun et al., 2020).

Iakovou and White III (2022) add that the availability of data across SC members not only speeds up the delivery time but also decreases the total cost. Ghadge et al. (2020) and Hudnurkar et al. (2014) emphasise total cost reduction, where the former adds that increased information sharing increases the efficiency and agility of SCs, whereas the latter emphasises that it leads to achieving competitive advantage. Moreover, better sales (Kaipia & Hartiala, 2006), increased visibility (Hudnurkar et al., 2014), improved inventory management (Kaipia & Hartiala, 2006), and reduction in *bullwhip effect* (Hudnurkar et al., 2014) are also benefits of increasing information sharing. The bullwhip effect occurs when the fluctuation in demand downstream causes higher volatility upstream due to the safety stock accumulation at different downstream stages (Delen et al., 2009).

3.5.4. Transparency Variables

Adopting SC 4.0 can lead to gaining better visibility and transparency along the SC (Haddud et al., 2017). Transparency is considered a latent variable, which means it cannot be measured directly, as Deimel et al. (2008) state. Concerning this and based on the literature review conducted by the authors, four dimensions were identified. These dimensions can be considered as variables to assess how transparent an organisation is in its SC. Further, transparency gets affected if one or more of the four dimensions is neglected due to the correlation between them. Each dimension is inspired by the main issues facing the SC, which are considered opportunities that SC 4.0 contributes to the global SC.

To get a compelling picture of transparency Forssbæck and Oxelheim (2014) concluded that there are two types of transparency, namely ex-ante and ex-post transparency. Where the first type helps in achieving transparency, whilst the latter is the outcome gained by having better transparency. This makes the understanding of the identified dimensions easier and enables a better assessment of transparency. A deeper explanation of the identified dimensions is discussed in the section below. Section 5.1, *Model,* discusses the dimensions identified according to the two types of transparency.

3.6. Dimensions

The four identified dimensions are (1) High-Quality Data, (2) Awareness, (3) Relationship, and (4) Sustainability. These dimensions are identified by considering three main questions; (1) how is better visibility and transparency achieved? (2) what do better visibility and transparency lead to? (3) how better visibility and transparency can benefit organisations and the industry? These questions help identify the dimensions and the opportunities brought to SC.

3.6.1. High-Quality Data

To effectively manage next-generation SCs, companies must manage the increasing data flow (Ghadge et al., 2020). That means SC 4.0 will have a tremendous amount of data, mostly machine-generated, which needs to be effectively managed and processed with a focus on generating high-quality data (Calatayud et al., 2019). To achieve high-quality data, it must be accurate, timely, complete, and usable (Williams et al., 2013). Converting data gathered from different sources into meaningful and valuable information supports decision-making, resource planning, and integration. The opportunities gained by having high-quality data are listed in table 3.1 below for better clarity.

(i) Decision-making

The decisions taken when data is rarely shared and is of poor quality are mostly weak. Even allowing automated decisions is challenging in such an environment. Hence, decision-making based on data and facts possibly leads to improved SC performance (Barrat & Oke, 2007, Ben-Daya et al., 2017). Adopting SC 4.0 will help reduce the time between data capturing and decision-making, enabling SC to react to changes and disruptions in real-time and more accurately (Ben-Daya et al., 2017, Calatayud et al., 2019).

Besides allowing managers to react quickly and take real-time decisions, high-quality data also allow for automated decision-making. The quintillion bytes of data generated need to continuously be processed and analysed to monitor the SC in real-time and automatically take actions to prevent risks before they materialise (Calatayud et al., 2019). Automated decision-making with minimum or no human intervention increases machine and equipment productivity (Lu, 2017). It also allows for material flow optimization, both up- and downstream, to enhance distribution capabilities and satisfy customers (Calatayud et al., 2019).

(ii) Resource Planning

Furthermore, the volatility and disruptions that are facing SC have continually tested the agility of SC planning teams, especially during the last years. According to a recent survey conducted by McKinsey, organisations are implementing more digital technology to improve their resilience. At the same time, around 70 per cent of the respondents reported that the top priority for digital investments is supply planning (Alicke et al., 2022). Having a better planning system and higher data quality would enable connectivity between devices and processes, which helps increase machines' productivity (Calatayud et al., 2019).

One of the issues regarding planning is that organisations merely focus on domestic parameters (Bowman, 2022). This act indicates the urgent need for better planning to mitigate global disruptions. Adopting SC 4.0 would allow for complete global resource planning, which would, e.g., be applicable to enhance transportation and warehouse activities (Brinken et al., 2022).

Adopting SC 4.0 also gives the opportunity for better inventory management and control (Haddud et al., 2017). Better inventory management and control help reduce inventory waste and the lack of product availability as more accurate information is available (Delen et al., 2009). A study pointed out by Delen et al. (2009) shows that better inventory control with the help of visibility reduced inventory fluctuations drastically and helped with a 40-70 per cent reduction in inventory costs. For instance, SC 4.0 can help provide precise data that helps SC managers to plan when to start machines and processes in production. Thus, having a more accurate estimated time of arrival (ETA) allows the managers to know exactly how many miles the delivery is away from the manufacturer. SC 4.0 also helps in connectivity between devices which helps increase machines and processes' productivity (Calatayud et al., 2019).

(iii) Integration

Going a step further, integration is another factor that gets affected by having access to high-quality data. In this context, integration means that all chain members' information and communication systems can seamlessly exchange information and jointly form decisions on activities in the SC (Forslund & Jonsson, 2009). Data sharing, along with enhanced collaboration, are the critical characteristics of SC integration (Haddud et al., 2017). In addition, integration is the primary factor in improving SC performance (Forslund & Jonsson, 2009).

Integration can be regarded in two directions, i.e., vertical- and horizontal integration (Lazzarini et al., 2001; Lotfi & Larmour, 2021), as shown in figure 3.4. Vertical integration is when systems, processes, and information are integrated, shared, and exchanged respectively with stakeholders both up and downstream. While horizontal integration is when organisations operating within the same industry integrate their processes to gain a common purpose and improve SC performance. Horizontal integration is often related to organisations in competition with each other.

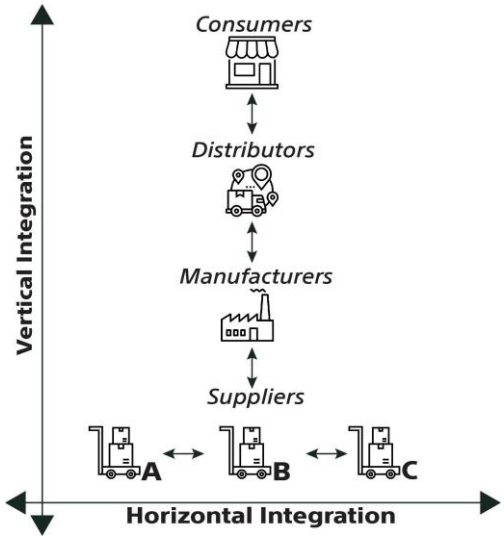

Figure 3.4: Horizontal vs Vertical integration adapted from Lazzarini et al. (2001)

A survey conducted by McKinsey shows that two-thirds of the respondents preferred an integrated end-to-end technology platform instead of having a specialised point solution (Alicke et al., 2022). The survey also showed that companies with an end-to-end solution were twice as likely to avoid SC disruptions caused at the beginning of 2022. Hence, having an integrated SC helps in being synchronised. SC 4.0 helps in connecting physical assets together, which in turn helps in avoiding or quickly resolving process defects and equipment failure (Hahn, 2019), as well as having effective asset employment and optimising the utilisation rate (Barreto et al., 2017).

Table 3.1: High-Quality Data opportunities

#	**Opportunities**	
(i)	Enhanced **Decision Making**	● Improving SC performance ● Allowing real-time decisions ● Reacting more accurately to disruptions ● Automating decision-making ● Increasing machines' productivity ● Optimising material flow ● Having satisfied customers ● Enhancing distribution capabilities
(ii)	Better **Resource Planning**	● Connectivity between devices ● Increasing machines' productivity ● Enhancing transportation ● Enhancing warehouse activities ● Better inventory management ● Reducing inventory waste ● Reducing inventory fluctuations ● Reducing inventory costs ● Better product availability ● More accurate ETA
(iii)	End-to-end **Integration**	● Seamless information exchange ● Jointly formed decisions ● Enhancing collaboration ● Improving SC performance ● Having synchronised SC ● Connecting physical assets ● Effective asset employment ● Optimising the utilisation rate

3.6.2. Relationship

The relationship between chain members is a dimension that is directly affected by transparency (Parris et al., 2016). Besides sharing data, it is important to recognise that sharing understanding and knowledge can easily improve stakeholders' collaboration and communication. Organisations using logistics providers have for years been on the rise. A recent survey conducted by Gartner shows that 74 per cent of logistics leaders anticipate an increase in the logistics outsourcing budget over the upcoming two years (Hippold, 2021). This increase is particularly for organisations not having logistics as a core competency, as stated by Lethbridge and Woodham, two experienced SC PwC consultants (Ashcroft, 2022). Lethbridge and Woodham mean that the increasingly common use of logistics providers can become mission-critical as SC managers face new challenges, especially when it comes to trust (Johnston et al., 2004). Table 3.2 lists the opportunities gained by having a better relationship.

(i) Collaboration

Relationships affect how well SC stakeholders collaborate. Collaboration refers to the cooperative strategy in which one or more organisations join forces toward common goals (Simatupang & Sridharan, 2008). As stated, sharing knowledge across the chain lets the organisation gain more visibility, thus improving its resilience. This statement aligns with Lotfi and Larmour's (2021) findings, which affirm that the more collaboration along the SC, the more resilient it will be. The benefits of collaboration are directly influenced by information sharing (Kaipia & Hartiala, 2006). In hand with that, Simatupang and Sridharan (2008) declare that information sharing is one of five critical elements of collaboration architecture.

According to Johnston et al. (2004), trust is crucial to achieving mutual confidence in other chain members and accelerating the collaboration between two parties. David Gonzalez, the vice president analyst with the Gartner SC practice, emphasised the importance of having a trusting and successful relationship with logistics providers, as it helps with facing disruptions and gives room for future innovation and opportunities (Hippold, 2021). Furthermore, Darko and Vlachos (2022) state that trust is critical for the presence of information sharing. A survey conducted by Gartner in 2022 shows that many organisations' executives are not happy with the exchange of data and information provided by their logistics providers (Johns, 2022). Equally important, the survey shows that organisations feel that there is a lack of transparency, and as a result, they have lost their trust in their providers.

(ii) Communication

Another aspect regarding relationships is to gain better communication, whether it is with customers or with suppliers. Combining upstream data, from the supplier side, with downstream data, from the customer side enables a substantial understanding of customers' needs (Calatayud et al., 2019). By understanding customer needs, there will be better communication, and thus, a more accurate ETA can be provided to the customers. Hence, increasing customer satisfaction and order fulfilment (Ghadge et al., 2020; Barreto et al., 2017).

Transparent communication is essential for companies to maintain credibility with stakeholders (Davies et al., 2022). The relationship with suppliers is enhanced through IoT devices which enable real-time communications between stakeholders (Ahmed et al., 2021). Additionally, sensing solutions give accessibility to data and can be used as an add-on to help with a better rate of information sharing between the different parts.

Table 3.2: Relationship opportunities

#	Opportunities	
(i)	Increased **Collaboration**	● Improving organisational resilience ● Better information sharing ● Helping in facing disruptions ● Enabling future innovation
(ii)	Improved **Communication**	● Substantial understanding of customers' needs ● More accurate ETA ● Increasing customer satisfaction ● Increasing order fulfilment ● Maintaining credibility with stakeholders

3.6.3. Awareness

For organisations to become better aware of their SC activities along the whole chain, transparency and visibility are needed, i.e., a good information flow needs to be existing along the SC (Badia-Melis et al., 2015; He et al., 2009). Organisations can take more immediate actions when they are more aware of their SC due to SCT regarding the flow of products and materials (Min et al., 2005; Hellström, 2008). This awareness, in turn, opens the opportunity for higher traceability of SC activities (Dolgui & Ivanov, 2021), better accountability (Parris et al., 2016), and better route planning (Ghadge et al., 2020). For better clarity, the opportunities gained by being more aware are listed in table 3.3 below.

(i) Traceability

Tracing all SC transition points can bring a new level of awareness to the SC (Ahmed et al., 2021). In addition, traceability allows SC managers to know where and when an event occurs along the SC, thereby having a timeline. Tracing the actual movements of goods from when it is sent until their arrival offers up meaningful insights for organisations (Delen et al., 2009).

Having access to, e.g., the dates and times of movements ensure the goods' arrival in a timely manner. Delen et al. (2009) add that tracing provides a precise indication of how the goods movement was along the SC and how long it took for them to move. Sensing solutions allow better coordination of physical movements along the SC and improve SCT (Haddud et al., 2017; McFarlane & Sheffi, 2003). Better track and trace solutions enable better visibility (Hultman & Axelsson, 2007) and seamless logistics worldwide. Additionally, it minimises missing cargo, reduces backlogs, and increases customer satisfaction (He et al., 2009).

(ii) Accountability

Accountability is a factor that gets influenced by how aware an organisation is of their SC. A lack of accountability may potentially lead to ineffectiveness and illegitimate actions (Kaynak & Avci, 2014). Thereby, having improved accountability helps in verifying the behaviours of other stakeholders (Parris et al., 2016). Kaynak and Avci (2014) state that any progress achieved without first setting an accountable structure would eventually fall. Hence, it allows organisations to establish long-term relations with other stakeholders. Equally important, the perception that an organisation fails to engage in responsible practices will likely lead to untrustworthiness. Moreover, transparency helps create a sense of trustworthiness among stakeholders in the SC and thus influences accountability (Parris et al., 2016).

Accountability today is best reached via contracts; therefore, it is essential to base those contracts on specific terms and conditions. Despite that, contractual accountability is directly related to transparency and trust and becomes hard to have without (Kaynak & Avci, 2014). The results of Kaynak and Avci's study suggest that in order for logistics providers to become more reliable, they should make their systems further accountable and trustworthy. By that, they mean organisations should establish their relationship with logistics providers on the basis of their own rules. Trust, in this case, reflects in reducing transaction costs and promoting cooperative behaviour (Kaynak & Avci, 2014).

(iii) Route Planning

Having more awareness by adopting SC 4.0 allows for another opportunity, namely route planning optimisation (Ghadge et al., 2020). Not having sufficient visibility and, thus, not being aware of what is happening while transporting goods and assets can bring sudden and inevitable consequences. Route planning is an important part of the SC in both inbound and outbound logistics (Košíček et al., 2013).

Awareness can help when managing short-term shipment risks such as terminal capacity and dwell time, caused by, e.g., adverse weather or infrastructure bottlenecks (Hahn, 2019). The immediate reaction to such disruptions enables flexibility and efficiency in logistics operations (Barreto et al., 2017). In addition, adopting sensing solutions empowers SC managers to monitor the progress of individual routes of vehicles and provide insights for possible future developments (Košíček et al., 2013). In time, the data collected by sensing solutions enables a better view of trends during transportation. A recent event that provides an example of the value of having insights is the Suez Canal obstruction. Having insights into future developments could act as a guide for organisations in their planning.

Table 3.3: Awareness opportunities

#	Opportunities	
(i)	More accurate **Traceability**	● Having a timeline of SC activities ● Goods' arrival in a timely manner ● More precise indications of goods movement ● Seamless logistics worldwide ● Minimising missing cargo ● Reducing backlogs ● Increasing customer satisfaction
(ii)	Improved **Accountability**	● Verifying the behaviours of other stakeholders ● Establishing long-term relations ● Having more reliability ● Reducing transaction costs ● Promoting cooperative behaviour
(iii)	Better **Route Planning**	● Managing the short-term shipment risk ● Immediate reaction to disruptions ● Becoming more efficient in logistics operations ● Monitoring the progress of individual routes ● Providing insights for future developments ● Getting a better view of trends

3.6.4. Sustainability

Global climate challenges are on the rise lately, and many organisations focus on sustainability now more than ever. Over the last ten years, stakeholders have increased the demand for transparency in the SC and organisations' actions to have a sustainable SC strategy (Gartner, 2022). SCs have a central role in sustainability transformation and help with global challenges (Henrich et al., 2022), or as Bové & Swartz (2016) phrase it, SC is a missing link for sustainability. Visibility in the SC remains low across various sectors, especially when it comes to monitoring sustainable practices along the SC (Oxford Economics, 2021).

Transparency is key in giving better visibility as executives can use the data gathered through the SC to make more informed decisions and how they impact sustainability goals (Oxford Economics, 2021). For instance, the data can help strengthen decision-making on what routes to be taken, what transport modes to be used, and what suppliers to choose. Emerging technologies can help in achieving real-time visibility and thus help mitigate the climate challenges in the SC (Gartner, 2022; Oxford Economics, 2021). The adoption of SC 4.0 brings two opportunities into the sustainability dimension: minimising CO_2 emissions (Brinken et al., 2022) and eliminating waste (Kusumowardani et al., 2022). The opportunities related to sustainability are presented in table 3.4 below.

(i) CO_2 Emissions

More than 90 per cent of organisations' greenhouse gas emissions often come from their SC (Environmental Protection Agency, 2022). According to BCG analysis, eight global SCs account for more than 50 per cent of annual greenhouse gas emissions, where 25 per cent of those emissions are in the food SC (Burchardt et al., 2021). CO_2 emissions are a critical aspect of the sustainability of the global SC. In 2016, McKinsey presented an analysis in a report that shows that consumer companies are responsible for more than 80 per cent of greenhouse gas emissions in getting the product from the source to the end customer as part of the SC (Henrich et al., 2022). This shows that most of the environmental impact related to the consumer sector is embedded in the SC. In fact, 64 per cent of respondents in the consumer product industry surveyed by Oxford Economics agree that suppliers are the primary contributor to their environmental footprints, i.e., upstream activities (Oxford Economics, 2021).

The adoption of SC 4.0 can improve transparency and sustainability by simultaneously reducing CO2 emissions and costs (Brinken et al., 2022). With better insights into the SC, organisations can understand and analyse their emissions effectively, which helps in mitigating the climate challenges in the SC (Oxford Economics, 2021). Further, adopting SC 4.0 helps influence stakeholders' investments in an organisation.

(ii) Waste

Temperature-sensitive products require more careful management during transportation, production, and storage. Thus they have their own SC system, known as the cold chain (Badia-Melis et al., 2018). The cold chain involves shipping, storing, and distributing goods in a secure, temperature-controlled environment (Cold Chain Federation, n.d.). Energy is consumed for every step in the cold chain, and emissions are therefore produced (Brinken et al., 2022). In fact, 30 per cent of the total world energy consumption is consumed by the current cold chain (Badia-Melis et al., 2018). The cold chain faces several challenges in order to keep modern life possible. Shane Brennan, Chief Executive of the cold chain Federation, states that climate and sustainability are existential challenges for the cold chain (Cold Chain Federation, n.d.). Further, he adds that the cold chain is becoming more necessary in a warming world.

Food and beverages and pharmaceuticals are examples of temperature-sensitive products. Since 40 per cent of all food has refrigerating requirements, they play a big part in waste along the SC (Badia-Melis et al., 2018). The food SC is partly responsible for nearly one-third of the world's total food production lost or wasted across the globe (World Bank, 2020; Badia-Melis et al., 2018). They further explain that the critical contributor factor to this high waste is the inability to monitor and control the temperature in the supply networks. Pharmaceutical goods shipments are often of high value, it is thus important to have a functioning cold chain to prevent costly losses (Hendrik Haan et al., 2013). In fact, it is estimated that 14-35 per cent of international vaccine transport is damaged as a result of temperature deviations. Moreover, understanding where the waste comes from and trying to prevent pollution helps in the longer term to reduce the cost and increase the efficiency of natural resource utilisation (Kusumowardani et al., 2022).

The main purpose of using sensing solutions is to facilitate information exchange between correlated items (Badia-Melis et al., 2018), effectively improving process quality and reducing waste in the cold chain (Hendrik Haan et al., 2013). Hsiao and Huang (2016) state that transparency in the cold chain with time-temperature information exchange in the whole SC would optimise logistics and improve food safety and quality. With the help of sensing solutions, organisations can be provided with the history of the goods' condition, including temperature, humidity, and the presence of certain gases that can affect the shipped goods (Badia-Melis et al., 2015). Dweekat et al. (2017) provided an example of IoT's effect on diary SC where it reduced expiry waste percentage by between 45 and 75 per cent in milk retailing.

Table 3.4: Sustainability opportunities

#	**Opportunities**	
(i)	Minimising **CO_2 emissions**	● Reducing costs ● Understanding and analysing emissions effectively ● Mitigating the climate challenges ● Influencing stakeholders' investments
(ii)	Eliminating **Waste**	● Better monitoring and control of the temperature ● Minimising costs ● Increasing efficiency of natural resource utilisation ● Improving food safety and quality ● Optimising logistics

3.6.5. Summary of Dimensions' Opportunities

In this subsection, the opportunities are illustrated in figure 3.5 to create a comprehensive picture of how they are linked to visibility and transparency. The opportunities are presented and grouped based on the dimension they are related to. The tables in the subsections above list opportunities in more detail, whereas the illustration below only focuses on the more general opportunities for simplicity reasons.

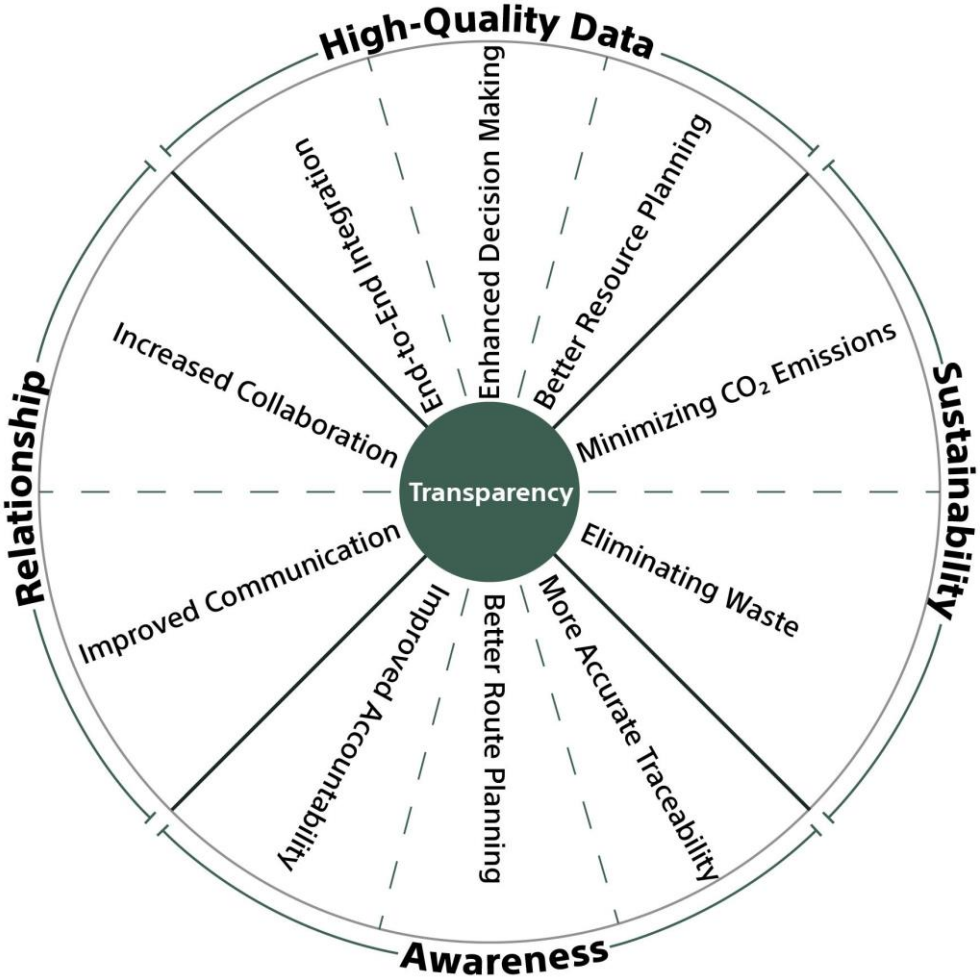

Figure 3.5: Illustration of the opportunities related to each dimension (authors)

4. Empirical Findings

This chapter presents the interviewees' points of view on the recent global SC disruptions, transportation issues they face, and their opinion on the readiness of sensing solutions in the SC. The chapter starts with a description of the interviewed companies SC and then discusses the disruptions and challenges they face. Finally, their opinion on what sensing solutions can help companies with their SC is presented.

4.1. Interviewed Companies' Supply Chain

The interviews were initiated with a general mapping of the companies' SC to get a clearer picture and understanding of their operations. Based on our selection of companies, as mentioned in section 1.5, *Focus and Delimitations*, they operate in the industry sector with B2B activities. The interviewed companies are Axis, Northvolt, Nederman, Tetra Pak, Höganäs, and an anonymous shipping line. Generally, most interviewees mentioned having a global SC, except for some having their primary focus on regional operations, thus operating mainly in Europe.

Despite the location of the companies' facilities, two types of logistics solutions are used by the companies, as the interviewees have explained. While some rely on logistics providers to handle all or some of their logistic activities, others make direct contact with transporters by themselves to have better control of their goods. Companies with a regional SC face different challenges than those with a global SC.

Depending on the interviewee's position at the company, some focused mainly on inbound logistics and its associated challenges. In contrast, others focused on outbound logistics and its associated challenges. Logistics providers handle the transportation at the companies, and neither one of the companies has its own fleet. Most companies did not have any direct connection beyond tier-two suppliers.

4.2. Supply Chain Disruptions

The recent global disruptions that impacted the global SC, presented earlier in theory in section 3.1, *Supply Chain Disruptions*, have been pointed out by most of the interviewees. These events had severe consequences for most of the companies interviewed. The most recent challenge the companies faced due to, e.g., the Ukraine conflict and COVID-19 outbreak, is the lack of components required in their products, particularly semiconductors. However, some companies avoided the disruptions as they operated more on a regional level. As one of the interviewees puts it, they were lucky to avoid the large consequences other companies faced forasmuch as they were operating regionally. For the multinational companies to deal with the disruptions, they tried to benefit from their long-term relationship with other stakeholders.

Furthermore, port congestion and the blockage in the Suez Canal resulted in new challenges. Companies started to choose new routes and other strategies to mitigate the risk. Two interviewees mentioned using air freight to get the right components at the right time, even though this method is costly. One company used air freight to overcome the blocking of the Suez Canal and the port congestion in Shanghai because of lockdowns due to COVID-19. Another mentioned sending goods to customers in China via rail transport to overcome Suez Canal obstruction and deliver on time. This solution did not last long because of Ukraine's conflict, which forced the company to consider different solutions.

Companies mean that real-time visibility in the SC would not only let them react faster and earlier but also reduce disruption. Surely they say these events are unpredictable, but it helps to understand a certain phenomenon at the right time to respond quickly before the situation gets out of hand. As one of the interviewees stated, the sooner one can grasp and understand a situation, the better. One of the companies reached out to their tier-two suppliers to better understand component status during COVID-19. This connection helped them build insights into the level of disruptions ahead. Other companies improved their visibility by improving their integration in investing in new SCM systems that integrate easily with their ERP system.

Several interviewees mentioned that they consider their SC to be, to some extent, resilient, even though it is not easy to measure resilience. However, they also see a big potential in improving their SCRES strategy in the coming years by conducting more technological solutions and becoming more digitalised. On the other hand, they add that there are other ways of improving SCRES, e.g., having a bigger safety stock for unreliable suppliers or considering other transportation modes alternatives. Despite what is mentioned, one interviewee states that there is no one way to achieve a resilient SC.

4.3. Supply Chain Challenges

All interviewees have brought up visibility as the main challenge facing SC today. They added that most of the issues that came along with global SC disruptions were due to a lack of visibility and low capacity. The interviewee from the shipping line mentioned that there is no one definition for visibility and that it is intercepted in different ways depending on the customer. He means that for some, it can mean the location of the cargo being shipped, while for others, even the condition is considered part of visibility. In fact, some of the interviewed companies addressed visibility as only knowing what day and time they will receive their cargo, while others even considered the cargo's condition along the way as part of visibility. The shipping line interviewee defined visibility as: *The availability, accessibility and flow of information.* Even though some have been working on implementing better visibility in their SC for years, one of the interviewees mentioned they have been working on this since 2008. However, there still is a lack of good enough visibility due to **poor-quality data**. According to several interviewees, one of the main benefits of having better visibility is minimising the risk along the SC. It also helps in being more **aware** and informed early about certain events to take action and mitigate the risks. Visibility even helps in correct planning, operational optimisation, and an integrated SC workflow.

Moreover, they state that the insufficient level of visibility given by their logistics providers affects the **relationship** between them and the company. It also affects how organisations assess **sustainability** goals and present them. This negative impact is because they lose direct insights and status about their goods along the SC. A solution shipping line is working on developing an end-to-end solution where information automatically flows into the customer's system. Further, they are even working on taking responsibility during transportation and, at the same time, providing the company with the right and required information without them requiring it. This allows for better transparency and trust and enables long-term relationships as well as meeting sustainable goals.

As a matter of fact, the interviewees agreed that most of their issues in the SC occur during transportation. Transportation issues lead to, among other things, lower customer satisfaction. One interviewee even specified that 20 per cent of all received customer complaints are related to transportation in one way or another, e.g., a product arrives damaged or never arrives to the customer. He adds that freight forwarders lose 30 to 40 shipments per year, and even though they compensate for the losses, it affects the company not being informed at the right time. Another interviewee mentioned that real-time visibility could contribute to having better-satisfied customers by being aware of what is happening along the SC at the right time.

He further adds that, for instance, if certain transportation is going to arrive late, they see if there is a nearby facility for the customer that has the same goods and can deliver them on time. Later, they relocate the late delivery to the nearby facility to compensate for the backup. This solution aligns with a benefit mentioned in several interviews: real-time visibility allows companies to become more proactive and agile since such decisions require quick actions at the right time. One company has clarified that they wished they had better visibility when large disruption events hit the SC. They could easily reallocate resources and hence minimise any additional costs.

Furthermore, one of the interviewees gave an example of an event that he described as a *horrific scenario* where low visibility was one of the main reasons for them losing a large fortune. A delay of 4 months for one of their shipments left them with no choice but to use air transport to deliver the goods to the customer at the right time. The main issue was that they first learned about the delay from their freight forwarder on the day of arrival. The delay made him and his coworker panic, and he had to devise a quick solution. If they had real-time visibility, he states it would have been clear to them earlier that the goods were sitting still at one of the ports and were not moving, allowing them to take action earlier to save time and money.

The challenges and issues associated with having a low level of visibility brought up during the interviews have been divided according to the dimensions identified earlier in the theoretical framework in section 3.6, *Dimensions,* namely high-quality data, relationship, awareness, and sustainability. The division coordinates the challenges with the opportunities identified earlier based on the literature.

4.3.1. High-quality Data

One frequently mentioned issue during the interviews is the problem of having poor-quality data, i.e., inaccurate, unreliable, and untimely data. According to the interviewees, poor-quality data affects upstream or downstream planning and decision-making. Transportation disruptions occur approximately weekly for one of the companies operating on a regional level, directly affecting the production rate. They further mention that the disruptions occur mostly due to inaccuracy in the logistics providers' information-providing process. This inaccuracy, in turn, affects the ETA. As a result, companies are faced with unsynchronised planning, affecting material flow in particular and leading to time-consuming and costly decisions. According to one interviewee, short decision-making paths are essential if the company wants to act quicker on disruptions. Companies could achieve these short paths by having high-quality data and being more transparent.

To mitigate the effects of the issues above, some companies consider planning with inventory buffers and including some time buffers. This way, they can reduce some of the effects on production when a transportation issue occurs. Two companies have a fixed route from their suppliers to the manufacturer, so they follow a *Milk Run* strategy along these routes. Firstly, to eliminate the partial truckload and minimise the time and travel. Secondly, which is more important to the company, is ensuring uninterrupted inventory replenishment for raw materials and semi-finished products. In addition to these strategies, the regional operating companies mostly choose local suppliers to mitigate disruptions from global events. Worth mentioning that even though they chose local suppliers, they were to some extent affected indirectly by some of the inevitable global disruptions.

Two interviewees specifically mentioned the lack of integration between the different systems they use in their SCM. This lack of integration makes it difficult for the team to interact with all systems and grasp all the different data provided. In particular, this becomes a challenge for companies offering services for their customers besides the product assortment, as it requires them to deal with many systems. An interviewee gave an example of an issue they face when dealing with different transportation modes from different forwarders, as they need to bring the data together from different systems manually. As stated by the interviewee, this challenge is not easy to handle as it is hard and costly to make IT investments. Additionally, and as mentioned by an interviewee, several stakeholders want to have their own end-to-end systems, making the situation even more challenging since there are many service providers along the SC. Consequently, this leads to an insufficient level of integration between systems and thus impacts the SC. According to the interviewee from the shipping line, trust is needed to address this challenge.

Another related issue highlighted several times is that information is sometimes not directly available from the logistics providers. To get the data, the company has to make an effort to seek the information by contacting the provider. This issue is mostly associated with large transporters prioritising their biggest customers above others. Some of the interviewed companies feel they are not large enough for the transporters to prioritise them, although they are big enough in their industry. On the other hand, when it comes to local transporters, the

case is different since often the route is shorter and the shipments only contain goods for one or few companies. The interviewed managers mentioned that the information provided by local transporters is, to some extent, more reliable, accurate, and timely than that from global transporters and shipping lines.

4.3.2. Relationship

The majority of the interviewees declared that the relationship between their company and the logistics providers is related to providing truthful information. Some companies trust their freight forwarders and count on the information provided, while others doubt the information's reliability. It becomes even more concerning when there is an ongoing crisis. The ones who trust the information provided count on their freight forwarders to do their job of coordinating the goods along the SC.

The interviewee from the shipping line explained that their vision is to free customers from thinking about every step in the SC. He means they take the burden from companies and are responsible for filling their warehouses at a predetermined time. In addition, he mentions that the shipping line is accountable for events happening during transportation on their behalf. The main goal is to reduce customer complexity by providing a complete transportation service.

Accountability can also improve collaboration with the company's customers if no logistics providers are involved. One company that offers delivery service takes full responsibility until their product reaches the end customer's warehouse. They are thus responsible for any delays or damages that occur during transportation. To take this responsibility, the customer must deliver some forecasted numbers each night via mail to allow the company to deliver the right quantity. The interviewee further clarifies that this is a way of having a better relationship with the customer and gaining their trust.

The quality of communication differs between a domestic and a global provider. As mentioned above, some interviewees face a sort of prioritisation from their transporters. A prioritisation in the form of not caring about providing correct and timely data. Sometimes the information does not reach them, which forces the companies to contact the transporters themselves and ask for the information; even in this case, the information is sometimes not satisfying. The manner is different when it comes to domestic providers. Companies with regional operations feel that communication with their domestic providers is good enough. One interviewee explains communication to be easier when only one company's goods are onboard and with regular transports between two locations. Additionally, one of the interviewees mentioned that there are usually fewer issues when dealing with local transporters due to easy communication and shared understanding. An example mentioned during the interview is if a driver becomes ill, they get to know it in good time to devise an alternative plan.

Some interviewees have mentioned that sensing solutions allow a better understanding of the data and give better accessibility, contributing to better communication with the stakeholders in the SC. They added that a complete solution, including a platform, can reduce miscommunication and unnecessary time wasted constantly contacting the logistics providers and asking for the information. One of the companies is seeking a solution of having only one primary system when it comes to communicating with other stakeholders.

4.3.3. Awareness

Most interviewees agreed upon the need to improve their awareness as they have limited information about their goods during transportation due to low visibility, as mentioned previously. The majority of the companies are using logistics providers to put their efforts into the company's core business, and they mentioned how dependent they are on them to perform well. The dependency and trust thus lead to being less aware of transportation activities. Regarding that, several interviewees mentioned that they are limited to the information shared with them by the logistics providers. The interviewees do not consider the information provided insightful; they believe it lacks quality and is thus inaccurate and unreliable.

Another challenge mentioned by a different interviewee is that their SCV is limited to what standardised parameters their freight forwarder is providing on their systems. He adds that it mainly depends on how the forwarder perceives and interprets visibility; thus, different forwarders provide different information. On the other hand, another interviewee is not considering awareness to be an issue when dealing with low-volume production. He means that when a few goods are being transported, it is easier to track them manually and thus become aware of their condition. According to several interviewees, not being aware of the goods along the SC can sometimes be challenging. Companies can be more proactive than reactive in their decisions by having better awareness. They further explained that it would be helpful to know when a certain event happened and where it happened. They mean that a better timeline for activities along the SC can give them better traceability and allow them to determine who is accountable for certain events.

An interviewee gave an example of a situation during COVID-19 where, at the time, there was no capacity in the main ports in the US which resulted in several delays in their shipments. At that time, they had an offer from an agent to buy some space onboard on a smaller ship. With all the risks associated with the offer, it allowed a faster transportation time. The goods were delivered within 12 days compared to the usual 24 days rate in normal situations and even a longer rate during COVID-19. The noticeable difference for them was their level of awareness, as the shipper had been continuously informative and had personal contact with them. This situation changed the company's perspective on awareness, and they appreciated the personal contact and the flow of information they had with the agent.

Some interviewed companies relied completely on their contractual accountability with their logistics providers. While others had to worry about the events during transportation. The ones that relied on it did not question the information they got from the provider because they

were satisfied and believed they were getting trustworthy information. If anything were to happen, they would receive compensation. On the other hand, some relied on the providers but were not satisfied due to the delay in information which cost them a lot. However, they were compensated for the losses, even though the events still affected their reputation and production. There are different concerns for accountability depending on the company's business model and what they are offering its customers.

4.3.4. Sustainability

Some interviewees rely, even regarding sustainability, on reports they get from their freight forwarders or logistics providers. It is mentioned that they are good at doing these reports and meeting the companies' expectations. The most crucial factors for one of the companies are knowing the proportion of flight transportation and the percentage of damaged goods besides CO_2 emissions. Sensing solutions can also be utilised to get some of the required factors to meet sustainable goals.

Another interviewee mentioned an initiative they have where they started using high-capacity transportation to optimise their transport and minimise CO_2 emissions. Their long-term plan is to use electric vehicles and a combination of multimodal transports where, e.g., they let the train drive as close to the customer as possible. Sensing solutions could be beneficial in measuring CO_2 emissions during transport and also in analysing the most effective route to take.

The impression that most interviewees had is that there is no added value in changing the logistics providers since the options in the market are limited. Even if they are not satisfied with the service provided, they are limited in their choices of alternatives. An interviewee is confused about how transportation prices are rising even though freight forwarders are not performing well. Despite the issue a company faces, the data provided needs to be analysed to be able to take action. Implementing real-time visibility is a costly investment, according to what is mentioned during several interviews. The most noteworthy fact is to know what value visibility brings with it and how the information will be analysed and used to optimise the SC.

4.4. Sensing Solutions Readiness

Sensing solutions are regarded with different opinions among the interviewees. Some are positive about how sensing solutions can help optimise the SC, while others doubt a business case exists. According to the interviewee from the shipping line, there still is a need to crack the solution of having better visibility for all shipping modes. Moreover, markets are fragmented and global, which creates a challenge in adopting technology as the maturity of markets is different in different parts of the world. Despite that, several interviewees emphasised the importance of technology in having better visibility along their SC to be more proactive and aware. Two interviewed companies have made several initiatives using the technology but were only applied on a one-time analysis to examine and understand a certain phenomenon along the SC or the risks associated with choosing a new route.

One of the interviewees provided an example of a situation where they used sensing solutions to make a one-time analysis when they started using a new transportation mode, namely, rail transportation. The one-time analysis was conducted in 2017 on goods transported from Sweden to South Korea. As it was their first time doing that, they installed single-use sensors in their containers to monitor the goods along the way. They were worried about the safety of the train's route and thus installed light indicators to know if someone had opened the containers along the way. The goods transported were sensitive to shocks, tilts, vibrations and temperature; therefore, they thought using the train as a transportation mode may not be the optimal solution. The data showed that the route had little slight damage to the goods, which was acceptable, and they have continued transporting their goods on rails since then. In this case, they no longer needed to use the sensors after analysing the data and knowing that the new route was efficient.

In the example above, the one-time analysis helped in one particular situation for the company. However, this manager and the others see several potential uses and values in having sensing solutions in their SC. The valuable parameters to have data on, mentioned by the interviewees, are location, temperature, shocks, tilts, vibrations and humidity. Furthermore, most managers appreciate a solution with analytical capabilities to facilitate the presentation of meaningful insights. Another appreciated feature by the interviewees is how different events affect different parameters, for instance, how a peak in the temperature impacts the shelf life of a product. Moreover, getting better updates on the location of the goods during transportation has been agreed upon by most interviewees as valuable, particularly when handling time-sensitive products.

Having up-to-date information on the location contributes to having better ETAs; hence, it helps in giving customers a heads up about the arrival time of their goods and, thus, creates better customer satisfaction, as some interviewees mentioned. It is worth mentioning that one interviewee does not consider the location parameter bringing a critical value as their products have a flexible schedule. One of the transportation issues that was repeatedly mentioned is missing goods. Therefore, one of the interviewees believes that sensing solutions can help in knowing the location of the missing product and help impede the problem from happening in the future. Another value of knowing the location, added by the same interviewee, is ensuring that the goods are moving since sometimes the logistics providers' system lags or shows wrong information.

Some interviewees consider sensing solutions more appropriate when having a high-volume production, while others deem it appropriate when dealing with high-value products. The latter often deals with low-volume production and sees a value in real-time tracking and condition monitoring to react quickly when an undesirable event occurs along the transportation in order to mitigate any losses and damages. Otherwise, it becomes costly. Companies dealing with high-volume production, often being products of low value, find real-time tracking valuable. One of the interviewees mentioned that real-time tracking gives value to automating frequent flows and replenishment orders. By having an automated

decision-making process, companies will have more time to optimise other functions in the SC instead of having to worry about frequently placing orders. Once an odd event happens, they expect to be notified and can accordingly take action.

When considering downstream activities in the SC, another interviewee brought up automation and how real-time tracking can help inform customers about their shipments. The solution might be more relevant for companies offering transportation services besides the product assortment. The interviewee gave an example of automatically notifying the customer once the goods have left the warehouse and other valuable information along the way. Moreover, notifying the customer when the goods are approaching the final destination allows them to be prepared when it arrives. According to the interviewee, this will optimise the resource utilisation rate and increase customer satisfaction. Likewise, using sensing solutions on express transportation enables real-time visibility, which gives customers better updates, increasing customer satisfaction.

The interviewees had different levels of doubt about using the technology in their case, but the cost is the one aspect they all agreed on. The Return On Investment (ROI) has been brought up in nearly all the interviews; the interviewees are mainly worried about how expensive the implementation of sensing solutions will be. This is confirmed by the shipping line interviewee, who stated that sensors are needed to create visibility, but it all depends on the will of the customers to pay. An alternative and more affordable solution than having real-time sensors that the shipping line is working on is using the capabilities already implemented in the market—for instance, getting location data from already installed GPS devices on vessels and vehicles. One interviewee even shared his worries about the time it will consume and the resources that need to be allocated. A similar opinion shared by another interviewee is the doubt that there would be a need for real-time sensors, as having timely data on all parameters is unnecessary. Two of the other interviewees believe that freight forwarders should be responsible for providing real-time and reliable data to their customers and filling up that need. Furthermore, one went even further and calculated how much they were willing to pay for such a solution. He stated that they are willing to invest as much as the cost of their missing goods per year since the technology could help them eliminate this cost.

5. Analysis and Discussion

This chapter is aimed to analyse the data collected to form an understanding of the market needs and the status of Visilion's product. The chapter starts with presenting a model for the identified dimensions that affects SCV. Then a comparison of the theoretical framework with the empirical findings is performed which leads to a list containing market needs. Finally, the market needs are compared with the product feature set to give Visilion proposals on improvements to consider in order to meet the market needs better.

5.1. Model

After considering the information gathered, the authors constructed a model that illustrates the importance of visibility and its relation to transparency, as well as the interconnection with the identified dimensions. The construction of the visibility model mainly connects visibility with tangible factors to facilitate a better understanding of the dimensions identified and to clarify their correlation with visibility, transparency, and each other. The outcome of this connection is the model shown in figure 5.1 below.

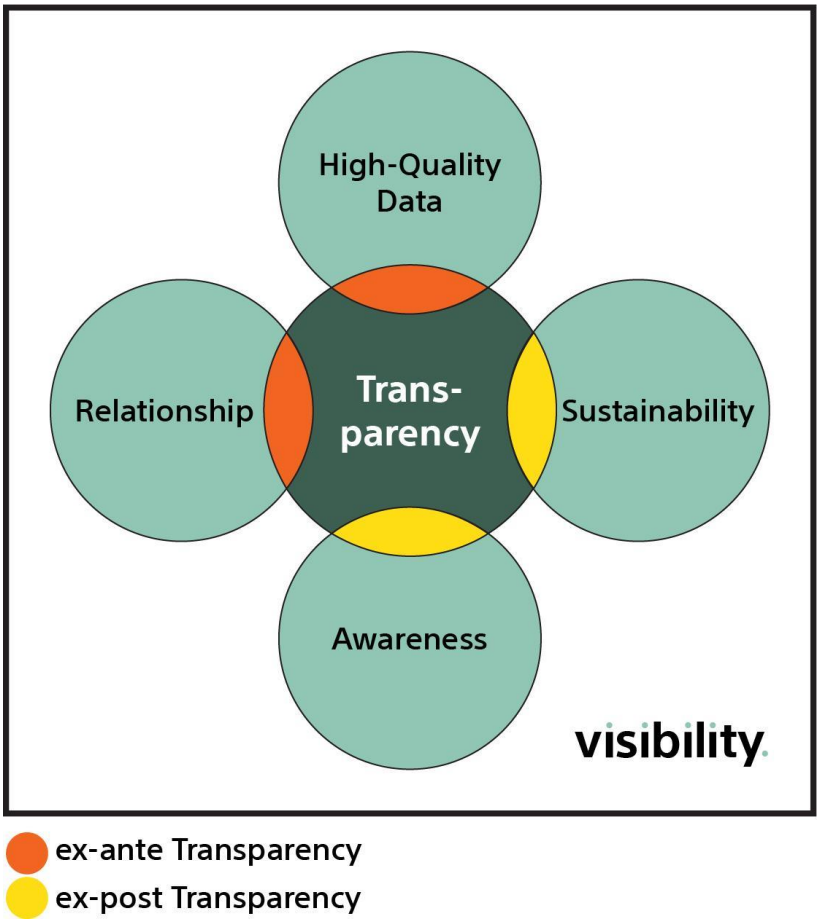

Figure 5.1: The visibility model (authors)

As shown in the figure above, visibility is considered the main frame for containing transparency and the dimensions. Based on what is mentioned in section 3.4, *Supply Chain Visibility*, visibility is considered conceptual; therefore, the identified dimensions help make it more tangible. Due to the correlation between the factors, both visibility and transparency get affected if one or more of the four dimensions is neglected and the other way around. Transparency is placed in the middle as it is considered the core and plays a crucial role in visibility and the four dimensions. The dimensions are distributed consciously equally to the core since this model does not consider how much each dimension affects transparency or gets affected by it. In other words, high-quality data is, to some extent, affected more by transparency than sustainability, as the theory and empirics show. However, this is not illustrated in the figure.

Further, the four dimensions are attached to the core, i.e., transparency. Transparency, as mentioned in subsection 3.5.4, *Transparency Variables,* has two types, according to Forssbæck and Oxelheim (2014). The two types are ex-ante and ex-post transparency; thus, the dimensions are marked in the model figure depending on their type. The high-quality data dimension is considered an ex-ante type as it is the base for transparency. Without sufficient data quality, it is challenging to build transparency. The relationship dimension is also considered to be of ex-ante characteristics as it helps achieve better transparency. The connection to the remaining two dimensions, awareness and sustainability, is considered an ex-post type. The ex-post type is the outcome gained by having better transparency. Therefore, these two dimensions are enabled by better transparency, which means they require high-quality data and strong relationships. The two types are marked in each dimension of the model.

The placement of the dimensions in the model is based on their effect on each other. Indeed, each dimension enables and supports at least the following dimension in an anti-clockwise order. As mentioned earlier, two dimensions need to be considered in an earlier stage to achieve better visibility and transparency. At the same time, the other two come as a result afterwards. To start with, high-quality data with the opportunities it brings allows for stronger relationships with other stakeholders. Reaching a sufficient level of data quality and an improved relationship leads to enhanced awareness. These three dimensions, in turn, lead to reliable and accurate data, thereby making achieving sustainability goals easier. The visibility model can be further developed and is discussed in section 6.5, *Further Studies*.

5.2. Analysis of Supply Chain Challenges

As previously mentioned in the theoretical framework, visibility is a term that is widely used in SC. Hence, there is no one unified definition agreed on. However, the interviewees agreed that SC's main challenge today is visibility. The interviewee from the shipping line stressed that their customers interpret visibility differently, which aligns with the literature. He mentioned that from a customer point of view, visibility could be merely seen as the location of the cargo during transportation. In contrast, for others, it could include condition monitoring of the cargo.

Several theoretical SCV benefits, mentioned earlier in subsection 3.4.3, *SCV Benefits,* have been brought up by the interviewees. It has been mentioned in the theory that SCV helps in making accurate decisions at the right time. It also improves inventory management and resource and asset utilisation. As per the interviewees, generally, they agreed upon the importance of having better SCV; in some cases, due to allocating resources and assets more efficiently, while in others, getting access to the information once it is available. Despite the reason why better SCV is needed, they agreed that having meaningful insights along the SC allows companies to take proactive decisions which are inexpensive and take less time. This concludes that there is a need in the market for more proactive decision-making that is based on facts rather than estimations.

According to the theory and empirics, sensing solutions are a key contributor to achieving an SC 4.0. The next generation of SC differs from the traditional SC as it transforms the physical world into digital insights by providing data and feedback on the goods and processes of organisations along their SC. Additionally, IoT leads organisations to achieve a competitive advantage. However, it comes with several challenges, such as a high investment cost, and it requires a sufficient level of technological capabilities in the market. The maturity of SC technology differs in different parts of the world. Therefore, the market needs in different countries may not be the same.

The interviewees agreed upon the opportunities brought by the identified dimensions in the theoretical framework. They even added more opportunities that they consider achievable by having better visibility. Thereby real-time visibility brings better data quality, more awareness, stronger relationships with other stakeholders, and finally helps achieve sustainable goals. The following subsections compare the theoretical framework and empirical findings by following the pattern-matching method introduced in section 2.6, *Data Analysis*. The result of the analysis is presented in table 5.1 at the end of this section, which lists the market needs.

5.2.1. High-Quality Data

Data quality is a crucial factor affecting many aspects, from planning and decision-making to having a shared understanding as a result of accuracy and availability. According to Alicke et al. (2022), most organisations prioritise supply planning for their digital investments, as mentioned in section 3.6, *Dimensions*. This phenomenon is also seen among the interviewees. They mentioned different issues they are facing today and want a solution for. Among these issues is, for instance, unsynchronised planning due to poor-quality data from logistics providers that affect, among other things, material flow. Another issue related to planning is the availability of the information once they are needed. In hand with this, companies sometimes struggle with gathering important information even manually.

According to the empirical findings, ETA is affected by the quality of data. Thus understanding what different events have for impact on the ETA is valuable. It is encouraged that organisations include external parameters besides the domestic and internal ones. This, according to (Bowman, 2022), will allow for better planning. There is also a need for the interviewed companies to get notified once an undesirable event happens along the SC. Interviewees also mentioned that having several systems to deal with is frustrating, especially when there is a system for each transportation mode. Hence having an integrated end-to-end platform for all transportation modes instead of a specialised point solution helps with considering the larger picture when analysing and allows quick access to the information. Thereby enabling short decision-making paths and helping in avoiding disruptions.

In short, to have better quality data, it is required to have synchronised data flowing into one end-to-end platform where this data is automatically generated and shared as well as being timely and is one click away from being reached. Furthermore, an updated ETA once an undesired event occurs is a requirement. Organisations prefer to have customised parameters to choose the most relevant ones for their operations. These different parameters allow for effective and comprehensive planning and decision-making.

5.2.2. Relationship

Relationships between stakeholders are directly influenced by transparency and collaboration. This becomes more important as more organisations use logistics providers, and the rate is estimated to increase further in the upcoming years (Hippold, 2021). This reflects why most of the interviewed companies are relying on logistics providers to handle their logistics and to provide them with the required data. Thus, SC managers face many challenges, including trust (Ashcroft, 2022; Johnston et al., 2004). Trust is considered, by the interviewees, to be essential in relationships between stakeholders.

Trust leads to more collaboration which increases the exchange of data and information between the two parties (Darko & Vlachos, 2022). When logistics providers do not share enough information or are not transparent, it becomes challenging to have a successful relationship. Compared with what was stated by the interviewees, they get the feeling of being left out and not prioritised by some of the large transporters as they are considered small compared with other customers. They further explained that the information they get is inaccurate and often delayed. This aligns with the survey conducted by Gartner, where organisations feel a lack of transparency and thereby lose trust in their SC partners (Johns, 2022).

To have a better relationship with SC stakeholders, whether they are partners or customers, there is a need for better communication. Furthermore, better data flow is needed to understand customer needs better (Calatayud et al., 2019). In fact, most dissatisfaction in the relationship between the interviewees and their logistics providers is mainly due to insufficient communication. One of the interviewees noticed a great difference in communication when dealing with domestic providers, where communication is substantially better.

What Ahmed et al. (2021) mentioned about sensing solutions and how they can enhance communication between stakeholders in the SC aligns with what the interviewees mentioned. They see a potential for the technology in having better communication with their logistics providers as they will have access to real-time data and can avoid any possible miscommunications by the provider. They mean that they will save the time wasted on communicating with the providers today to get access to correct data. Companies that offer delivery services also mentioned that a complete solution, including holding communications through a platform, could facilitate information sharing between the transporters and their customers. This way, trust can be built and the relationship enhanced.

5.2.3. Awareness

According to Blackhurst et al. (2011), SCV provides organisations with a timeline for both the status and location of their assets. Visibility and transparency provide better awareness and allows managers to take immediate action regarding their SC (Hellström, 2008). According to this project's empirical findings, organisations find it beneficial to know where and when a certain event happened, and they agree on having low awareness of their goods during transportation today. This aligns with what Ahmed et al. (2021) mention about organisations not having a timeline and cannot trace all SC transition points today.

Without traceability, it becomes hard to determine who is accountable for certain events. Therefore, organisations depend on contractual accountability today, but it is still challenging to have it without transparency and trust, according to Kaynak and Avci (2014). The companies hiring logistics providers have mentioned that they mainly depend on contractual accountability. Even though the responsibility of goods during the transportation is on the logistics providers, companies feel that only financial compensation in case of disruption is not enough because the company's entire operations get affected. Therefore, the best way is to try to eliminate the disruptions during transport since all parties involved are affected in some way.

To avoid sudden inevitable consequences in the transportation routes chosen, better planning is needed. As mentioned in section 3.6, *Dimensions,* awareness can optimise route planning and help manage risks related to adverse weather or infrastructure bottlenecks. According to the empirics, having available data can help one become more aware of certain events, even if they are not usually necessary. Being able to adopt new technology into SC will enable progress monitoring of individual routes, provide insights for future developments and have a better view of trends, according to Košíček et al. (2013). Adopting more technology and having good integration strategies helps companies to shift from taking reactions to being proactive in their decision-making.

Comparing theory to empirics, it is apparent that for companies to become more aware of their activities along the SC, it is required to have a timeline for when and where events occur. This will allow better traceability when needed. As it is hard today to determine who is accountable sometimes, there is a need in the market for better traceability of transition points during transportation. For companies to be able to optimise their route planning, they need better awareness. In other words, it is required to have monitoring of individual routes to get insights and to have a better view of trends. Another requirement is including global and external factors affecting the transportation in the platform. External factors include port congestion, pandemics and endemics, and natural disasters that could have affected a specific area.

5.2.4. Sustainability

As climate change has brought more and more awareness towards sustainability in the SC, it is becoming crucial for organisations to meet stakeholders' demands and have a sustainable SC strategy in place (Gartner, 2022). Still, organisations have a low level of visibility regarding monitoring sustainable practices along the SC (Oxford Economics, 2021). Aligned with that, interviewees consider sensing solutions to provide them with better insights about sustainable practices. Additionally, one interviewee means that sensing solutions can help optimise the routes taken by determining the most effective one. Besides that, it can help analyse CO_2 emissions by knowing the type of vehicle used and which route is taken.

Suppose SCT is present and better information is shared. In that case, it will be easier for organisations to understand how they impact sustainability goals regarding what routes to take and what suppliers to collaborate with (Gartner, 2022; Oxford Economics, 2021). They can, for instance, influence their CO_2 emissions and waste management along the SC. According to some interviewees, knowing the CO_2 emissions, the amount of missing goods, and the proportion of air transportation is crucial to meet sustainability goals. Whether the company is hiring logistics providers or handling the transportation activities themselves, it is essential to consider sustainability data. This is to meet sustainability goals and determine the transportation mode as well as better planning and determining what routes to take.

Table 5.1: Market needs based on analysis of the theoretical framework and empirical findings.

#	Market Needs
High-quality data	
1	Timely and synchronised data
2	Condition monitoring
3	Immediate notifications in case of an undesirable event
4	Importing data from other transportation systems
5	Integrated end-to-end system for all transportation modes
6	Include external factors to the platform
7	Updated ETA
8	Being able to customise parameters depending on the need
Relationship	
9	Better information exchange between partners and stakeholders
10	Holding communications with other stakeholders through the platform
Awareness	
11	Timeline of when and where things happened along the SC
12	Individual routes monitoring, and insights on route trends
13	Insights of common trends shared between all platform users
Sustainability	
14	CO_2 emission detection
15	Supporting and assessing sustainability goals

5.3. Product-Market Fit Analysis

To perform the PMF analysis, it is essential to line up the product features and understand the market needs. Based on the pattern-matching analysis, the market needs were identified in section 5.2, *Analysis of Supply Chain Challenges.* These needs are compared, in this section, with the product's feature set to identify the underserved needs. After that, and based on the PMF analysis, recommendations for future development are presented in section 6.2, *Recommendations based on Product-Market Fit.*

5.3.1. Product Introduction

The IoT architecture has been explained earlier in subsection 3.3.2, *The Emerging Technology in Supply Chain,* and can be applied to Visilion as it has four layers in an IoT architecture, starting with the sensing layer and finishing with the interface layer. Visilion uses IoT, cloud, and data analysis technologies and has a high potential to contribute to adopting SC 4.0. It basically starts by letting the trackers send the data to a cloud service, which is later analysed. A map with the recent events is displayed on a user interface, besides an overview with other parameters. The user interface of Visilion can be seen in Appendix C.

The technology used in Visilion gives it several advantages to meet the market needs. For instance, the product has real-time technology to track assets and cargo, uses GPS, and has a long-life battery. Furthermore, it could be remotely controlled and accessed. Choosing among parameters and choosing the upload frequency are two settings that could be changed remotely. The device also includes Firmware Over The Air updates (FOTA) to send updates that were gathered offline when the device is reconnected to the network. This is used, for instance, when the device is on an aeroplane; all data collected is later sent when the device is on the ground or is reconnected. The product even has integration capabilities to import data from other systems via Application Programming Interface (API). API is a cloud-based intermediary that enables data exchange among applications with different designs and codes.

A challenge for the product to succeed is that it can be costly, as most interviewees stated. The interviewed companies mean that they need to know what value the investment brings to them compared to existing solutions that are less costly. Indeed, most organisations are considering further investments in digitalisation based on the theoretical framework. Therefore, many companies may come across this solution, which means Visilion needs to consider how they promote the product and how its cost is justified.

5.3.2. Product's Feature Set

Based on the information provided by Visilion, table 5.2 has been constructed. This information is gathered through several meetings with *Visilion, Sony* and by the provided product information sheet. To be able to perform the PMF analysis, the current product's features are listed in the table below. The order of the features listed is according to the identified dimensions.

Table 5.2: Presents the product's features provided by Visilion

#	Product's Features
High-quality data	
1	Real-time cargo and asset positioning
2	Condition monitoring (temperature, humidity, shock, tilt, and light)
3	Modify what parameters to monitor
4	Instant notifications for predefined events and geofence, i.e., waypoints
5	Fully multi-modal functionality (air, ocean, rail, and road)
6	Integration capabilities with other systems via APIs
7	Data augmentation from third parties (e.g., ocean)
8	Dynamic ETA
9	Remote device control
Relationship	
10	Uncomplicated interface that is accessible from any connected device
11	Information exchange between partners and stakeholders
Awareness	
12	Transportation overview and analysis of all transition points
13	Route deviation detection
14	Re-routing suggestions
15	Auto detection of transportation mode
16	Kiosk mode that allows an overall status of all moving trackers
Sustainability	
17	Rechargeable and reusable device

5.3.3. Underserved Needs

The underserved needs are the result of the PMF analysis conducted. This analysis is performed by comparing the market needs with the feature set identified earlier. Table 5.3 below is constructed by comparing the previously presented tables in chapter 5, *Analysis and Discussion*. The table includes market needs that the product addresses, market needs required but not yet addressed by Visilion, and the product features unarticulated—those that are not expressed by the market.

The listed needs in table 5.1 are presented slightly differently from the features listed in table 5.2, depending on how they are expressed by Visilion and the market. The market needs already addressed by the product are marked under both *Visilion* and *Market* columns in the table below. Whereas the underserved needs that potentially could be addressed are only marked under the *Market* column. Lastly, the unarticulated needs are only marked under the *Visilion* column.

Table 5.3: A comparison between market needs and product's feature set

#	Market Needs and Product Features	Visilion	Market
High-quality data			
1	Timely and synchronised data	✓	✓
2	Condition monitoring	✓	✓
3	Immediate notifications in case of an undesirable event	✓	✓
4	Importing data from other transportation systems	*	✓
5	Integration capabilities with other systems via APIs	✓	
6	Integrated end-to-end system for all transportation modes	✓	✓
7	Include external factors to the platform	*	✓
8	Updated ETA	✓	✓
9	Being able to customise parameters depending on the need	✓	✓
10	Remote device control	✓	
Relationship			
11	Better information exchange between partners and stakeholders	✓	✓
12	Holding communications with other stakeholders through the platform		✓
13	Uncomplicated interface that is accessible from any connected device	✓	
Awareness			
14	Timeline of when and where things happened along the SC	✓	✓
15	Individual routes monitoring and insights on route trends	✓	✓
16	Insights of common trends occurring for all users of the platform		✓
17	Auto detection of transportation mode	✓	
18	Kiosk mode that allows an overall status of all moving trackers	✓	
Sustainability			
19	Rechargeable and reusable device	✓	
20	CO_2 emission calculation		✓
21	Supporting and assessing sustainability goals		✓

** Features that Visilion can address based on the customer requirement*

As the table above shows, Visilion addresses the majority of market needs. However, there still are some needs that are yet to be fulfilled. For instance, the real-time data feature fulfils the need of having timely and synchronised data and thus is considered to be addressed by Visilion. An example of an underserved need is communicating with stakeholders through the platform. The unarticulated needs that Visilion offers today but has not been expressed by the market are still necessary to have. This could be for different reasons; either the market presumes that the product addresses the need, or the authors did not specifically ask about it. Some examples of these are having an uncomplicated user interface, a kiosk mode, and a rechargeable and reusable product.

Some needs are, to some extent, addressed by Visilion on a case-to-case basis. For instance, *importing data from other transportation systems* is the ability to import data into Visilion's platform from other companies' transportation management systems to enable an end-to-end solution. Another example is *including external factors to the platform*, which is also fulfilled depending on the factors customers desire to include. The product imports data from third parties, especially data regarding ocean events. This feature is referred to as *data augmentation* by Visilion. Other factors like natural disasters occurring in the area of the customers' operations and port congestions are examples that could further be considered. For instance, if a company uses a particular route to transport its cargo from Europe to Asia and there is a current unforeseen weather disturbance in the region, it would be helpful to be notified early to use a different route.

The underserved needs are explained in detail in section 6.2, *Recommendations based on Product-Market Fit*, where the authors provide recommendations for future developments to Visilion.

6. Conclusion and Reflections

This chapter concludes the work done in this study and gives recommendations based on the analysis with final remarks and reflections. The chapter starts with answering the research questions presented in section 1.4, Purpose. It is then followed by the recommendations given for Visilion based on the analysis. Later comes a reflection on the validity of the results, and the research contribution to both academia and industry is presented. Finally, suggestions for future studies are presented.

6.1. Conclusion

The purpose of this project is to identify and study the opportunities offered by visibility and how sensing solutions optimise SCV. The results show that there is a correlation between the identified factors, therefore, the visibility model has been developed. The model illustrates the importance and the interconnection between visibility, transparency, and the identified dimensions. It allows for a better understanding of visibility and transparency as well as the identified dimensions.

The purpose is also to assess Visilion in analysing the market needs and what opportunities the solution brings. The PMF analysis conducted resulted in table 5.3 above, where a comparison between the product's feature set and the market needs has been made. The result shows that Visilion addresses almost all the identified market needs. However, there are some slight improvements that Visilion could consider in order to meet even more needs required in the market. Thereby, recommendations that help assess the product development for Visilion are presented below in section 6.2, *Recommendations based on Product-Market Fit.* Furthermore, the theoretical framework and the visibility model have contributed to developing the research area within the SCV.

The answers to the research questions are presented below.

RQ1: What are the factors in the SC that are impacted by adopting sensing solutions?

To identify these factors, the authors started by looking at the main reason behind adopting sensing solutions, namely, to get better visibility in the SC. SCV has been considered by organisations for a while. However, in order to deeply understand how visibility is affected, several factors were identified by the authors. The core factor that impacts visibility is transparency, according to the theoretical and empirical findings. Transparency is, in turn, interrelated to four other factors, referred to as dimensions by the authors, which are (1) High-quality data, (2) Relationship, (3) Awareness, and (4) Sustainability, see figure 6.1 below.

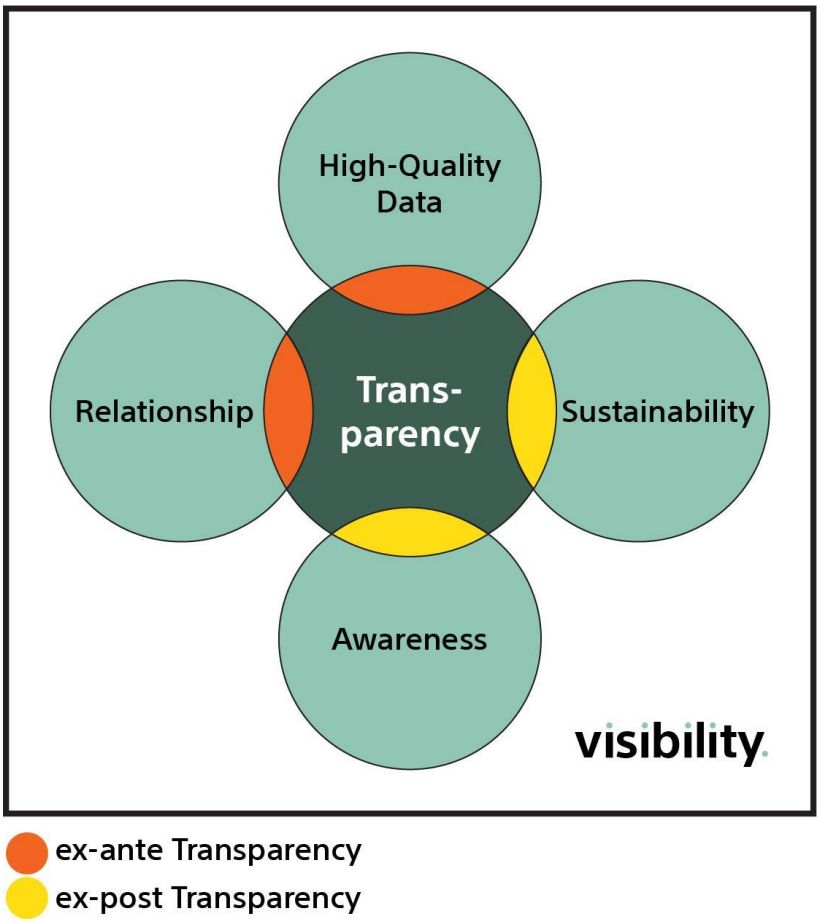

Figure 6.1: The visibility model (authors)

RQ2: What opportunities do these factors bring to the customers?

Each of the identified dimensions has its own opportunities that they bring to the customer when adopting sensing solutions. Based on the theoretical framework, the authors identified various opportunities. Besides bringing better SCV and SCT, they also allow for, e.g., enhanced decision-making, increased collaboration, optimised route planning, and minimised CO_2 emissions. The opportunities are explained in detail in section 3.6, *Dimensions*, where each subsection ends with a table presenting the comprehensive opportunities related to the particular dimension. Figure 6.2 below shows the general opportunities for the identified dimensions.

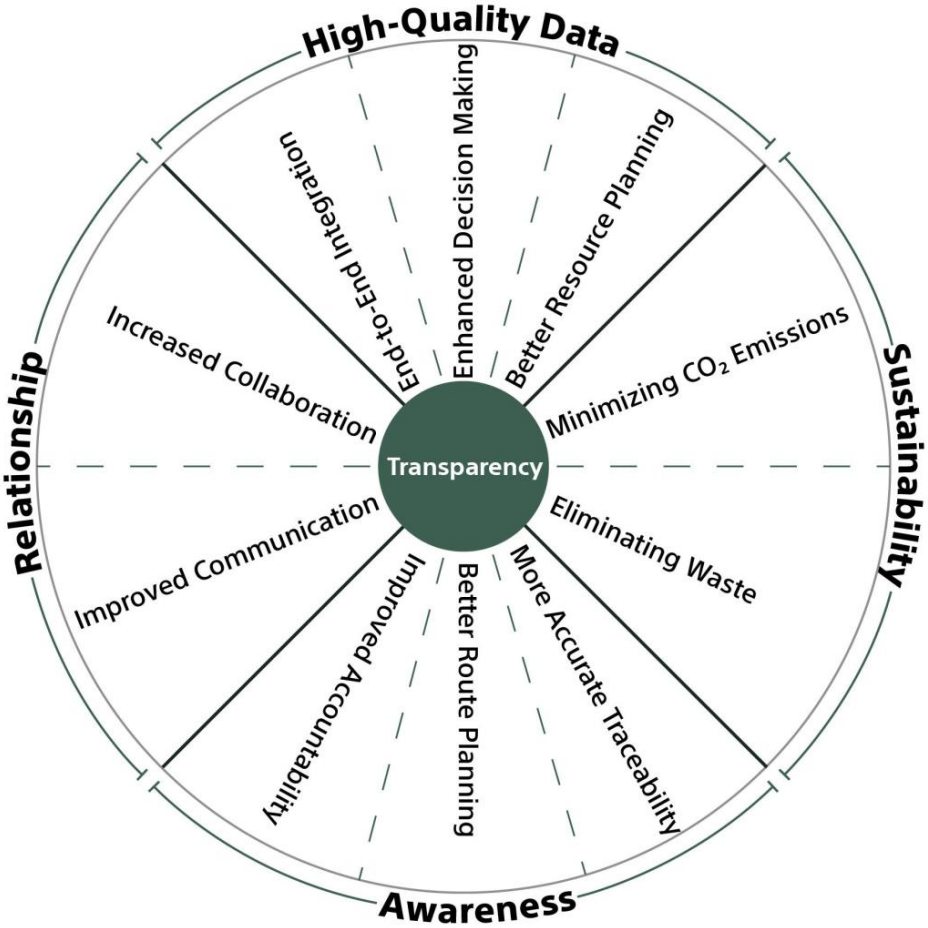

Figure 6.2: Illustration of the opportunities related to each dimension (authors)

RQ3: Does Visilion have a product-market fit today?

In order to answer this question and the two subquestions below, a PMF analysis was conducted, considering the market needs and comparing them with what features the product offers today. The purpose of the PMF analysis is to fill the gap between the market and the product. According to the answers of the two subquestions below Visilion has a product-market fit.

SQ1: What does Visilion currently offer its customers?

To ensure an accurate answer, the authors first identified what Visilion currently offers by the provided product information sheet and then had several meetings with *Visilion, Sony* to confirm and adjust the features identified. These features are presented in subsection 5.3.2, *Product's Feature Set.*

SQ2: What are the recommendations and proposed changes for Visilion?

The recommendations for Visilion are based on the PMF analysis taking into consideration the scope of the project. After answering SQ1, the identified product's features are compared with the market needs in subsection 5.3.3, *Underserved Needs.* As a result, the authors identified the underserved needs in the market and provided recommendations for future developments. The recommendations are presented in the section below.

6.2. Recommendations based on Product-Market Fit

Based on the PMF analysis, the following recommendations are suggested to be considered by Visilion:

- Providing insights into common trends that are shared among the users of the platform.
- The ability to communicate between stakeholders through the platform.
- The ability to calculate CO_2 emissions.
- Supporting and assessing sustainability goals.

Providing insights into common trends shared among the platform users is one of the recommendations for Visilion to consider. It means that the insights gained over time on a certain route can be shared between the different users for them to consider when planning. The insights can come from a trend where one user runs into several problems along its transportation route. The trend can then be shared anonymously among the users using the same route to help avoid facing the same problem.

Visilion imports, to some extent, data from systems that customer use, which helps organisations to interact with fewer systems. Another feature that Visilion has developed is the ability to share shipment information with other stakeholders to get instant updates. A feature that can be recommended to develop information sharing further is to include a communication feature. The feature can be used with transporters in the form of getting updates and holding communications to get more detailed information. Moreover, the communication feature can make an organisation's customers more satisfied by being supportive and close to them. Thereby, this feature helps smoother communications and information sharing between stakeholders. In addition, it gives Visilion a more comprehensive solution that gives the product a competitive advantage.

Moreover, sustainability practices are gaining great attention in the SC, and in fact, most emissions for organisations occur in their SC. It would be beneficial if Visilion could also calculate CO_2 emissions and analyse their occurrence along the SC. This can attract more organisations that are willing to build a more sustainable SC. Thus, a recommendation is to include a CO_2 calculator in the product.

As SC plays an important role in most emissions for organisations, Visilion can help impact organisations to meet their sustainability goals. A recommendation is, therefore, to allow organisations to register certain parameters and requirements they want to meet, to the platform. Visilion can then track and assess the parameters to give the users indications of their progress and how to meet these criteria better. The parameters that could be measured are, e.g., energy consumption, food and medicine waste, and the effect of using different transportation modes on sustainability. The determination of the parameters depends on the sector of the organisation.

6.3. Further Proposals

Based on the theory and empirics and after considering a more holistic image of the product and the market, some proposals for Visilion are presented below.

- Since Visilion is an independent solution that gathers, analyses, and displays the information by itself, the solution could be a non-biased third-party quality solution. This means neither the company nor the provider influences the data, but the solution is there only to ensure quality and trust in the information shared. This solution's benefit is improving the relations between stakeholders by ensuring that data can be trusted. The challenging barrier for this proposal is who owns the process and who is responsible for the quality of the information shared. The data could be either owned by Visilion or by the focal company. Moreover, Visilion could partner with some quality organisations and other organisations for standardisation to ensure the honesty of data presentation or to have some kind of stamp on approved data. This could allow for a new target group and a new market share. This area of research is promising as it allows dynamic and real-time quality control. It is referred to as quality-controlled logistics by Ben-Daya et al. (2017).

- As communication between stakeholders needs to improve in the SC, the Visilion platform could be a solution for companies to get access to data and facilitate operations easily. Companies could, for instance, suggest that their customers hold their communication via the platform. This saves time for both partners since all information is communicated through one system. Furthermore, the customers should be able to predetermine the factors communicated, allowing shared understanding.

- An area that can be explored is to investigate if Visilion’s sensors can be attached to other devices to be powered instead of having their own battery. This can open a new opportunity for Visilion, which is, to some extent, different from what they are currently working on. By attaching Visilion’s sensors to other devices, a new relationship with customers can be built and thus aiming for a long-term relationship. In this way, Visilion will skip worrying about battery life and can improve its analytical capabilities regarding its platform.

6.4. Validity of Results

The limitation of only including B2B deliveries in the scope of the thesis among the different SC activities is not considered to affect the conclusion and the final recommendations. This conclusion is drawn because of the great importance of B2B transportation in the SC. However, considering more activities, such as B2C and last-mile deliveries, could allow for more opportunities to be included and thus have more recommendations and proposals for Visilion. Another aspect that could also have the same effect is considering indoor activities, such as warehousing, material handling, inventory control, and yard management. Considering these two aspects could continue building on the findings of this thesis. Hence these are brought up as an area for further research.

There has been a variation in the choice of companies to interview by the authors mainly to get different aspects and understanding from different sectors. However, the authors did not cover all industries, and it would help to have more variation. Additionally, only two companies are not totally outsourcing the logistics activities and are partially responsible for their logistics. Due to time restraints, the authors could not perform other interviews with companies fully responsible for their logistics. Nor with companies in other sectors, such as food and beverages, where the cold chain is involved, and products are more sensitive. Nevertheless, this is also brought up in future studies.

Another aspect that can be considered is how the result is affected if another analysis method is conducted. Other methods may consider different perspectives, meaning the analysis result might take another turn if pattern matching and product market fit were changed with other methods. For instance, a technology audit would have considered more technical aspects of the product. A business model canvas may also result in more business-oriented recommendations.

6.5. Contribution

This project contributes to academia by conducting a literature review where different factors of visibility are connected, and their need in the SC is investigated. Starting with an overview of disruption events to indicate the need for SCRES and how it enables better SCV and SCT. The project also connected the need for better SCV with the technology used in the SC. All these areas were considered from the fourth industrial revolution perspective and how real-time visibility enables a quicker revolution in the SC. The main contribution to academia is to have these factors connected and related to the topic in one place.

Another contribution to academia is the visibility model that is illustrated in figure 5.1. The model creates a strong connection between the four dimensions that should be considered when looking at visibility. Furthermore, the model is based on theoretical and empirical findings and could be further developed to add additional perspectives or even connect more dimensions to it. This model can be used to illustrate the interdependence and the correlation between the different dimensions of visibility and transparency.

This project also contributes to having a better view of Visilion regarding the market fit. Hence, from the scope of the thesis, it is confirmed that the product meets the market needs from both a practitioner and an academic perspective. Additionally, this project confirmed for Visilion that there is a need for real-time visibility in the market, which Visilion provides. What is more, the project provides Visilion recommendations and further proposals to consider to help with the future development of the product development.

6.6. Future Studies

The developed model considers the correlation between visibility, transparency, and the dimensions, not taking into consideration any ranking between the dimensions. Thereby, a recommendation for a future study could be to conduct broad market surveys, which would help rank the identified dimensions. Ranking the dimensions would allow an understanding of the value of adopting sensing solutions and which dimension has the most significant effect. Conducting market surveys can help evaluate market needs and identify the most important ones.

Additionally, due to the limited time, there are certain business sectors included in the scope of the research, and thus interviews have been performed with companies in these sectors. When conducting future studies, additional sectors can be looked at, and more interviews can be performed to understand each company's SC better and its needs. Thus giving tailored proposals for each sector. In addition, ROI could also be investigated to get the financial aspect of the solution, including both hard and soft values.

The scope of the project is to investigate visibility during transportation and even study other stakeholders' activities. Therefore, future studies could investigate internal visibility and transparency by adopting sensing solutions. In other words, investigate how Visilion's solution makes a company operate more cross-functionally by eliminating internal silos.

In the area of adopting sensing solutions, several aspects have been identified as interesting to study further. The following are recommendations on questions for further research:

1. What would indoor sensing solutions contribute to optimising the global SC?
2. What would be different in the analysis if last-mile or B2C delivery were to be included? How would SCV affect these activities?
3. How can sensing solutions benefit and optimise the cold chain?
4. Can data ownership become an issue for Visilion in the future?
5. How can sensing solutions break internal silos?
6. What is the ROI when adopting sensing solutions?
7. Can Visilion's sensors be attached to another device and be powered by its battery? How will this solution strengthen the long-term relationship with Visilion's customers?

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Interviewees

Anton Gustavsson, Director of Operations Development & Digitalization, Axis
Axel Brundin - Supply Chain Digitization Manager, Northvolt
Fredrik Clausson, Managing Director at AB Ph. Nederman & Co
Michael Hultberg, Global Planning Manager, Tetra Pak
Johan Walter, Supply Chain Manager, Höganäs
Representative of Shipping Line Company

Appendices

Appendix A: Interview Guide

Part 1: Background & general information

- A brief description of our project and our research questions
    - The aim of the project.
    - How the information will be used and contribute to the project.
- A brief description of the interviewee and their experience.
- Interview agenda
    - What will be discussed in the interview?
    - How long the interview will last.

1. Visibility: Could you start with generally mapping your SC?

Part 2: Transportation issues

2. What are the most transportation issues your company faces?
    a. How do you handle them?
3. Are there any specific issues when handing over the shipment between different stakeholders?
    a. How is that managed?
4. How do you track and monitor your products during transportation?
    a. Do you have any tracking devices attached to your shipments? If yes, how do you manage/analyse the data?
    b. Is the data provided in real time?
    c. Do you consider the information provided trustworthy to build your decision upon?

Part 3: Disruptions

5. How did SC disruptions impact your SC (e.g., Covid-19, Brexit, port congestions, shipping costs, lack of containers, Russia-Ukraine war)?
    a. What procedure did you take to mitigate the impact?
    b. How flexible were you in your reaction to dealing with this effect?
    c. Would you describe your SC as visible enough? If yes, how did you achieve that? If not, what could be done in order to have better visibility?

Part 4: Sensing Solutions

- Introduction to what we mean by “sensing solutions”.

6. Based on your experience, what will sensing solutions contribute to the SC?
7. What is your opinion on sensing technology?

Appendix B: Follow-up Questions

Part 1: Transparency:

1. How would you evaluate the transparency you have today in the form of information sharing? Does better transparency between stakeholders contribute to better visibility?
2. How do you think sensing solutions can contribute to allowing better transparency in the SC?

Part 2: Relationship

3. How would you describe your communication with your customers/suppliers today?
4. How more accurate ETA will affect your relationship and communication with
    a. Suppliers.
    b. Customers.
5. What are the relationship challenges with your logistics providers and transporters?
    a. How collaborative are they regarding information sharing etc.?
    b. How do you manage trust between you and your logistics providers and transporters?

Part 3: Sustainability

6. How do you deal with your sustainability goals in the SC? Would transparency and a better view of data help in having a better impact on sustainability goals? How?
7. Which parameters are important when considering sustainability, especially during transportation? Besides CO_2 emissions.
8. How would you describe your process of monitoring sustainable practices along the SC?
9. Do you have good monitoring practices for CO_2 emissions? How do you think digital technologies can improve it?

Part 4: Awareness

10. Would you consider contractual accountability enough to determine who is accountable and responsible? How is that done today?
    a. What does transparency have for an impact on accountability?
11. What do you do as a company when adverse weather or road bottlenecks occur along your transportation way? What about the dwell time and port capacity? Do you know about it in advance?
12. Would you consider sensing solutions as a tool to give you better insights into future developments on your chosen transportation routes? How?

Part 5: High-quality data

13. How do you think SCV affects resource utilisation, resource planning, and productivity in the form of (material flow, resource allocation etc.)?
14. What value does real-time information bring to you as a manager? How will it allow you to take actions/countermeasures?

Part 6: Sensing Solutions

15. What expectations do you have of such a solution to invest in it?
16. What other important functions should be included in such a solution?

Appendix C: The user interface

Screenshot of Visilion's platform.