KTH ROYAL INSTITUTE
OF TECHNOLOGY

Licential Thesis in Production Engineering

Supply chain visibility in the manufacturing industry: conditions and realisation

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Stockholm, Sweden 2022

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Academic Dissertation which, with due permission of the KTH Royal Institute of Technology, is submitted for public defence for the Degree of Licentiate of Engineering on Friday the 7th October 2022, at 10:00 a.m. in C1, Kvarnbergagatan 12, Södertälje.

Licentiate Thesis in Production Engineering
KTH Royal Institute of Technology
Stockholm, Sweden 2022

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ISBN 978-91-8040-338-2
TRITA-ITM-AVL 2022:25

Printed by: Universitetsservice US-AB, Sweden 2022

Abstract

Supply chain visibility (SCV) has been gaining attention as a key for supply chain performance. The key characteristics of SCV are information accessibility, accuracy, timeliness, completeness and usage, all of which aid in the enhancement of operational and strategic supply chain activities. Despite the increasing acceptance of the importance of SCV, knowledge regarding SCV is scattered. There is a need for knowledge regarding the conditions affecting the realisation of SCV, which motivates this thesis.

The thesis contains three research questions. First, it identifies and categorises the conditions affecting SCV to provide a holistic view of SCV. Second, given the role of SCV in decision making, it investigates what supply chain information is important for SCV from a supply practitioner's point of view. Third, it explores the possibilities and challenges of implementing technologies to improve SCV in practice.

The findings include a holistic framework on SCV based on the literature and empirical research. The framework categorises the factors affecting SCV and its outcome as antecedents, barriers and challenges and drivers and effects. Among the identified essential supply chain information for SCV, there is a consensus that data regarding deliveries, deviations, supplier capabilities, inventories and capacities are the most important. In terms of approaching SCV in practice, this thesis identifies the steps for translating SCV problem areas into technological solutions to enhance supply chain performance. However, the full SCV effort will require a focus on people, processes and technology. Given its role in decision making and performance, SCV is difficult yet important to implement.

This thesis outlines four main academic contributions: i) adding to the academic research and detailing the need for more research on SCV, ii) a state-of-the-art understanding of SCV, iii) empirically exploring the factors influencing SCV and iv) confirming and adding to previous research on the technologies for SCV. For supply chain practitioners, the present thesis offers guidance and insights to plan, implement and further enhance SCV to attain increased levels of supply chain performance.

Keywords: supply chains, supply chain visibility, technologies, supply chain management

Sammanfattning

Synlighet i försörjningskedjor, s.k. Supply Chain Visibility (SCV), har fått ökad uppmärksamhet för sin betydelse för försörjningskedjors prestanda. För att nå SCV har olika egenskaper hos information mellan försörjningsleden pekats ut: tillgänglighet, noggrannhet, aktualitet, fullständighet och användbarhet. Alla dessa egenskaper stödjer förbättring av både operativa och strategiska aktiviteter i försörjningskedjor. Även om värdet av SCV generellt sett är oomtvistat, är kunskapen kring SCV inte samlad. Det finns ett ökat behov av kunskap om förutsättningar och förhållanden som påverkar hur vi kan nå synlighet i försörjningskedjor, vilket är motivet till denna avhandling.

Avhandlingen bygger på tre forskningsfrågor. Den första identifierar och kategoriserar förhållanden som påverkar SCV med avsikt att ge en holistisk syn. Den andra frågan undersöker, utgående från relaterade beslut som ska fattas, vilken information för SCV som är viktig för försörjningskedjors intressenter. Den tredje utforskar möjligheterna och utmaningarna med att implementera teknologier för att förbättra SCV i praktiken.

Resultaten inkluderar ett holistiskt ramverk av SCV baserat på litteratur och empirisk forskning. Ramverket kategoriserar de faktorer som påverkar SCV och dess utfall, som förutsättningar, barriärer och utmaningar, drivkrafter och effekter. Rörande den information som är viktig vid SCV, är bilden att leverans, avvikelse, leverantörskapacitet, lager och kapacitetsrelaterade data är viktigast. För att förverkliga SCV i praktiken, introduceras steg för att översätta problemområden relaterad till SCV till tekniska lösningar, allt i syfte att stimulera försörjningskedjors prestanda. Dock kräver SCV en gedigen insats med fokus på människor, processer och teknologier.

Denna avhandling tillför i huvudsak fyra akademiska bidrag: i) ett bidrag till den akademiska forskningen och detaljerat behov rörande fortsatt forskning inom SCV, ii) en övergripande sammanställning av kunskapsfronten rörande SCV, iii) ett empiriskt utforskande av faktorer som påverkar SCV och iv) en bekräftelse och ett bidrag till tidigare forskning om teknologierna för SCV. För industriella aktörer, tillför denna avhandling vägledning och insikter för att planera, etablera, implementera och ytterligare förbättra SCV.

Nyckelord: försörjningskedjor, synlighet i försörjningskedjor, teknologier, supply chain management

Acknowledgements

I would like to thank and express my sincere gratitude to all the people whose support and guidance were vital in the completion of this licentiate thesis.

First, I would like to thank my main supervisor, Professor Magnus Wiktorsson, for his continuous support, encouragement and positivity. His timely guidance and constructive feedback have helped me enormously in completing this milestone. I would also like to sincerely thank my cosupervisor, Associate Professor Jannicke Baalsrud Hauge, for the constructive feedback and sharing of her knowledge. Her continuous support and assistance have been vital in achieving this milestone. I want to thank my industrial supervisor, Patrik Johansson, for his continuous support and help in ensuring the industrial relevance of my research. His interest and encouragement have been important motivators for me.

I would also like to thank my colleagues at Scania and KTH for the interesting and fruitful discussions that helped me a great deal. Special thanks to the LOVIS project team and the case companies for the opportunity to collaborate and conduct research. I want to thank Professor Jan Olhager for sharing immensely valuable knowledge while writing the appended papers. I also want to thank Dr Tarun Kumar Agrawal for the support and collaboration while conducting the studies and writing the appended papers.

Being an industrial Ph.D. student has required me to balance research with my industrial commitments. I would like to thank my manager, Dr Anders Berglund, for supporting me to prioritise research. This helped me put in the hours needed to complete this thesis.

I want to also thank my family. The continuous support and love from my parents have been invaluable sources of motivation in my life. I send my love to my son, Naavin, who reminds me of the true value of life. Last but not least, I want to thank my wife, Arrabi, for her unconditional love, which I take for granted. This thesis would never have seen the light of day without her continuous support and encouragement.

Ravi Kalaiarasan
Stockholm, 2022

List of appended papers

Paper 1.
Kalaiarasan, R., Olhager, J., Agrawal, T.K., Wiktorsson, M., 2022. "The ABCDE of supply chain visibility: Systematic literature review and framework." *International Journal of Production Economics*, *248*: 108464. doi:10.1016/j.ijpe.2022.108464.

Contribution in paper 1: The research was carried out in the project LOVIS – Production Logistics Visibility. The scope and aim were defined by the coauthors and the PhD student. The PhD student performed the literature search in the database based on criteria set by the PhD student and coauthors. Screening of abstracts and titles, followed by analysis, was performed by the PhD student. Writing the original draft was carried out by the PhD student while receiving continuous comments and feedback from the coauthors. Complementary text was added by the coauthors.

Paper 2.
Agrawal, T.K., Kalaiarasan, R., Olhager, J., Wiktorsson, M., 2022. "Supply Chain visibility: A Delphi study on managerial perspectives and priorities." *International Journal of Production Research*. doi: 10.1080/00207543.2022.2098873

Contribution in paper 2: The research was carried out in the project LOVIS – Production Logistics Visibility. The PhD student was part of selecting the experts for the study. The PhD student participated throughout the study by working closely with the first author to coordinate the study and conduct an analysis of the data collected. The PhD student contributed to the manuscript by writing a significant amount of the manuscript by receiving and integrating feedback from coauthors.

Paper 3.
Kalaiarasan, R., Agrawal, T.K., Olhager, J., Wiktorsson, M., Baalsrud Hauge, J., 2022, "Supply chain visibility for improving *inbound logistics: A design science approach." International Journal of Production Research*. doi: 10.1080/00207543.2022.2099321

Contribution in paper 3: The research was carried out in the project LOVIS – Production Logistics Visibility. The scope and goal of the paper was set by the PhD student and coauthors. The data collection consisted of interviews, participation in project meetings at the case company and analysis of project documents was performed by the PhD student. Writing the original draft was performed by the PhD student, with the integration of comments and feedback coming from the coauthors.

Additional publications in reverse chronological order

Kalaiarasan, R., Agrawal, T.K., Wiktorsson, M., Hauge, J.B., Olhager, J., 2021. "Requirements on supply chain visibility: A case on inbound logistics." In: Dolgui, A., Bernard, A., Lemoine, D., von Cieminski, G., and Romero, D. *(eds) Advances in Production Management Systems. Artificial Intelligence for Sustainable and Resilient Production Systems. APMS 2021. IFIP Advances in Information and Communication Technology, vol 631.* Springer, Cham. doi:10.1007/978-3-030-85902-2_13.

Agrawal, T.K., Angelis, J., Khilji, W.A., Kalaiarasan, R, Wiktorsson, M., 2022. "Demonstration of a blockchain-based framework using smart contracts for supply chain collaboration." *International Journal of Production Research* 0: 1–20. doi:10.1080/00207543.2022.2039413.

Agrawal, T.K., Kalaiarasan, R., Olhager, J., Wiktorsson, M., 2021. "Understanding supply chain visibility through experts' perspective: A Delphi based approach." In: Dolgui, A., Bernard, A., Lemoine, D., von Cieminski, G., Romero, D. *(eds) Advances in Production Management Systems. Artificial Intelligence for Sustainable and Resilient Production Systems. APMS 2021. IFIP Advances in Information and Communication Technology, vol 633.* Springer, Cham. doi:10.1007/978-3-030-85910-7_20

Kalaiarasan, R., Olhager, J., Wiktorsson, M., Jeong, Y. 2020. "Production logistics visibility – Perspectives, principles and prospects." In Säfsten, K. and Elgh, F. *(eds) Advances in Transdisciplinary Engineering*. IOS Press, vol 13: SPS2020, 501-510. doi: 10.3233/ATDE200188.

Agrawal, T.K., Kalaiarasan, R., Wiktorsson, M., 2020. "Blockchain based secured collaborative model for supply chain resource sharing and visibility." In Lalic, B., Majstorovic, V., Marjanovic, U., von Cieminski, G., Romero, D. *(eds)* E *Advances in Production Management Systems. The Path to Digital Transformation and Innovation of Production Management Systems, 259–266*. IFIP Advances in Information and Communication Technology. Cham: Springer International Publishing. doi:10.1007/978-3-030-57993-7_30

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Paper 1

Paper 2

Paper 3

List of acronyms and abbreviations

CEO	Chief executive officer
CIMO	Context intervention mechanism outcome
CTO	Chief technology officer
ETA	Estimated time of arrival
LOVIS	Production logistics visibility
QFD	Quality function deployment
RQ	Research questions
SC	Supply chain
SCM	Supply chain management
SCOR	Supply chain operations reference
SCV	Supply chain visibility
SLR	Systematic literature review
SME	Small- and medium-sized enterprises
S& OP	Sales and operations planning
SOTA	State of the art
VP	Vice president
WEF	World Economic Forum

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1 Introduction

This chapter introduces the present research work. First, the related background is presented, followed by the problem statement, objectives and research questions. Then, the scope and limitations are described.

1.1 Background

In recent times, supply chain visibility (SCV) has been gaining attention as essential for supply chain performance (Catalayud et al., 2019; Bechtsis et al., 2021). There are a few key characteristics of SCV. First is the *accessibility* of information for stakeholders across the supply chain (Barratt and Oke, 2007; Caridi et al., 2014). Second is the *accuracy* of the information (Williams et al., 2013). Third is the timely *availability* of information (Francis, 2008). Finally, fourth is the *usefulness* of information in terms of maintaining and improving business and operational performances (Brandon-Jones et al., 2015). These characteristics make SCV crucial for decision making and supply chain operations. In particular, SCV has become important for manufacturing supply chains that are increasingly operating in competitive and volatile markets (Sodhi and Tang, 2019). It has been revealed that manufacturing companies suffer from a lack of SCV, which inhibits the performance of their supply chains (Srinivasan and Swink, 2018). Indeed, a low SCV can be related to the inability to promptly handle disruptions (Choi et al., 2020; Mubarik et al., 2021). Specifically, the consequences of a low or even lack of SCV include manufacturers experiencing supply disruptions in material supplies, deliveries and revenue (Caridi et al., 2014; Yu and Goh, 2014; Swift et al., 2019). Global economic prospects reported that the supply network disruption costs in 2020 because of COVID-19 was 4 trillion dollars (Chauhan et al., 2021). Furthermore, the COVID-19 pandemic brought to light the consequences that manufacturing companies face when there are lower levels of SCV. In addition, other recent events, such as the incident at the Suez Canal, have further revealed the vulnerabilities of supply chains today. As a result, manufacturers have felt pressure to improve performance and, at the same time, promptly handle disruptions. Accordingly, the leaders in manufacturing companies have emphasised the need to focus on SCV to successfully manage their supply chains (Sodhi and Tang, 2019). In this sense, SCV is regarded to be an integral part of improving decision making for both current and future supply chain performances (Finkenstadst and Handfield, 2021; Modgil et al., 2021).

Along with globalisation, the need for competitive intelligence and performance enhancements has been pushing the boundaries of SCV (Srinivasan and Swink, 2018). SCV is expected to support supply chains and facilitate

companies in achieving dynamic capabilities (Catalayud et al., 2019; Sanders and Swink, 2019). In addition, the emergence and development of various technologies have been identified as the enablers of SCV. In general, these include technologies for data generation, handling and usage. Recent studies have acknowledged that SCV will be demanded from companies to fulfil certain obligations. In fact, the COVID-19 pandemic has resulted in regulations that have forced companies to prioritise SCV (Loske, 2020), for example, by ensuring responsible sourcing and human rights (Swift et al., 2019; Dolgui and Ivanov, 2021). In addition, the material supply disruptions faced by several companies worldwide have revealed that low SCV make companies and their supply chains vulnerable (Sharma et al., 2020; Bechtsis et al., 2021).

Despite the need for SCV, the realisation of SCV is difficult to achieve because of the complex nature of supply chains and their conditions. Today, supply chains consist of several factors, such as different actors, processes and locations. Hence, realising SCV requires a comprehensive understanding of the conditions affecting SCV and its realisation to achieve the desired performance outcome (Somapa et al., 2018; Swift et al., 2019).

1.2 Problem statement

Previous studies have identified the implications of improving SCV. For instance, SCV is expected to enable agility (Suh and Lee, 2018), analytical abilities (Srinivasan and Swink, 2018), risk management (Sarker et al., 2016), and planning (Ghasemy Yaghin and Goh, 2020). Improved SCV is also stated as being able to enhance performance in areas such as inventory cost (Srinivasan and Swink, 2018; Handfield et al., 2019), lead time (Srinivasan and Swink, 2018) and sustainability (Brun et al., 2020). Despite the growing attention given to SCV by both practitioners and researchers, a comprehensive view of SCV is missing (Somapa et al., 2018; Swift et al., 2019), motivating further research to develop a deeper understanding of the conditions and factors affecting SCV.

Several studies have stated that technologies are key for SCV. This includes technologies for real-time data generation (Guo et al., 2015; Papert et al., 2016; van Hoek, 2019), connectivity (Dubey et al., 2018, 2019) and data-analytics (Catalayud et al., 2019). When established through technologies, SCV can turn data into meaningful information for decision making (de Oliveira and Handfield, 2019; Yang et al., 2021). Although previous studies indicated that SCV is key for informed decision making (Handfield et al., 2019), there is still a lack of clarity regarding what supply chain information those decisions should be based on (de Olivera and Handfield, 2019). Given its importance for supply chain performance, it is vital to develop an understanding of SCV information for decision making.

Despite the importance of technologies for SCV, few studies have empirically explored the implication of testing technologies for improving SCV in practice (Yang et al., 2021). Neglecting the practical aspects of SCV is likely to cause

insufficient implementation of SCV, leading to both financial and reputational losses (Swift et al., 2019). Hence, understanding the practical dimension of SCV is essential in identifying both the possibilities and challenges while contemplating the realisation of SCV.

Overall, the literature has indicated that the need for SCV is increasing at a rapid phase (Bechtsis et al. 2021). Yet there is a lack of empirical studies that provide an extensive understanding of SCV that not only incorporates technologies and perceived benefits of SCV, but also the potential challenges and drivers to plan, implement and improve SCV. As a result, realising SCV is likely to require understanding beyond the enabling technologies found in the literature. Hence, given the importance of SCV for supply chain performance, acquiring knowledge regarding the conditions affecting the realisation of SCV is crucial for successful implementation of SCV (Somapa et al., 2018; Swift et al., 2019).

1.3 Objective and research questions

The realisation of SCV requires both a holistic and deeper understanding of how SCV can be planned, implemented and further improved. Hence, the objective of the current research is to *develop an understanding of the conditions affecting SCV and its realisation in the manufacturing industry*. In terms of scientific contributions, the present thesis aims to advance knowledge in the area of SCV through industrial cases. The purpose is to support decision-makers and researchers in developing holistic and deeper insights into SCV and support the realisation and further enhancement of SCV. The results are expected to both detail and extend the existing knowledge regarding the conditions affecting SCV. To achieve this objective, the present thesis seeks to answer the following research questions, as applied to the manufacturing industry:

RQ1: How can the conditions affecting visibility in supply chains be categorised?

To benefit from SCV, it is crucial to identify and categorise the conditions and factors affecting SCV. Although previous studies have addressed certain conditions and factors, most are scattered, with a comprehensive understanding missing.

RQ2: What supply chain information is considered important for supply chain visibility?

Although researchers have acknowledged the importance of SCV, there is a lack of what type of supply chain information is considered crucial by supply chain practitioners. Hence, identifying useful information that should be made visible is key to implementing SCV in practice. This research question aims to identify critical SCV information and data elements conveyed by practitioners through industrial cases, here based on the current state-of-the-art in the literature.

RQ3: What are the possibilities and challenges of implementing technologies to improve visibility in supply chains?

Although previous studies have mentioned certain implications of SCV, there is still a need for empirical studies focusing on the implications of technologies on SCV. Thus, this research question aims to deepen the understanding of implementing technologies for improving SCV in practice and acquiring additional insights through industrial cases. Successful implementation, improvement and management of SCV requires an understanding of both the possibilities and challenges of technology implementation.

Figure 1 illustrates the initial framework for the present thesis. SCV is affected by a set of factors and conditions that can be identified and categorised by answering RQ1. Then, the aim is to find important information and data elements for SCV that are expected by manufacturing companies to be visible for them to improve decision making and enhance performance. This is primarily investigated through RQ2. However, while attempting to improve SCV in practice by implementing technologies, manufacturing companies are likely to face potential possibilities and challenges. This is mainly explored through RQ3.

Figure 1. Framework for the thesis

1.4 Scope and limitations

First, the present thesis primarily focuses on large manufacturing companies, which affect the generalisability of small- and medium-sized enterprises (SMEs). Second, among the studied cases, one is based on a single company, which makes it prone to the limitations associated with single case studies. In addition, the single case study focused on technology implementation for SCV, excluding organisational and process-related factors. Third, while having a supply chain focus, the present study did not cover visibility beyond first-tier suppliers.

1.5 Outline of this thesis

In total, the current thesis consists of six chapters, which are structured as follows:

Chapter 1. Introduction: presents the background, problem statement, objective and research questions, scope and limitations of the thesis.
Chapter 2. Frame of reference: covers an overview of SCV, including the characteristics and related topics.

Chapter 3. Research methodology: includes the applied research approach and strategy, research process, research methods and quality assessment
Chapter 4. Results from appended papers: provides summaries of all three appended papers.
Chapter 5. Analysis and discussion: answers the three research questions based on the results from the appended papers.
Chapter 6. Conclusion, contributions and future directions: presents the key findings of the current thesis, along with academic contributions, practical contributions and future research directions.

2 Frame of reference

The frame of reference for the current thesis is presented in this chapter; it covers the definitions of SCV and addresses its characteristics. This chapter also presents the conditions and aspects for the realisation of SCV identified in the literature.

2.1 Definitions of SCV

SCV lacks an unanimously accepted definition, and the literature provides numerous definitions of it. Table 1 lists five common definitions adopted by the literature.

Table 1. Common definitions of SCV identified in literature

Definition of SCV	Source	Referred to by
'The extent to which actors within a supply chain have access to or share information which they consider as key or useful to their operations and which they consider will be of mutual benefit'.	Barratt and Oke (2007)	Klueber and O'Keefe (2013), Papert et al. (2016), Somapa et al. (2018), Timmer and Kaufmann (2017), Wang et al. (2017), de Oliveira and Handfield (2019), Dubey et al. (2019), Torres et al. (2019), Wichmann et al. (2020)
'Access to high quality information that describes various factors of demand and supply. In order for information to be of high quality, it must be accurate, timely, complete and in usable forms'.	Williams et al. (2013)	Somapa et al. (2018), Srinivasan and Swink (2019), Morgan et al. (2018), de Oliveira and Handfield (2019),
'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)	Klueber and O'Keefe (2013), Papert et al. (2016), Somapa et al. (2018)
'Greater visibility, created through improved knowledge and	Brandon-Jones et al. (2014)	Somapa et al. (2018), Wang et al. (2017), Dubey et al. (2018)

understanding of inventory and demand levels, allows organisations to proactively manage potential risks in their supply chain'.		
'The ability of the focal company, i.e. the supply chain leader, to access/share information related to the SC strategy and the operations of SC partners'.	Caridi et al. (2014)	Somapa et al. (2018), Suh and Lee (2018), Calatayud et al. (2019)

Certain similarities and differences can be noted in the definitions of SCV listed in Table 1. Barratt and Oke (2007) emphasised the focus on visibility throughout the supply chain and mentioned that information sharing is not enough to form good SCV. Rather, the 'extent' of information that is shared is relevant. In addition, it is important for the information to be useful, timely and in an adequate format. Barratt and Oke further stated that there are levels of SCV that are characterised by 'amount of useful that is shared across the supply chain' (2007, p. 1218). The definition by Williams et al. (2013) also acknowledged visibility across the supply chain. Williams et al. (2013, p. 545) also suggested having timely and accurate information as key for visibility. However, unlike the other definitions, they mentioned the importance of information regarding both demand and supply, which, in turn, entails that visibility is key both down and upstream in the supply chain. The definition by Francis (2008, p. 183) revolves around an entity, stating that visibility does not require more information than 'identity, location and statues'. Like Williams et al. (2013), Francis (2008) also highlighted timeliness as a key characteristic of visibility. Compared with the other definitions, Francis (2008) captured the importance of visibility for understanding those events affecting the entities transiting the supply chain. Unlike the other definitions, the definition by Brandon-Jones et al. (2014, p. 6907) for SCV focused on inventory and related demand levels. Improved risk management was presented as the key outcome of improved levels of visibility. Compared with the definition by Barratt and Oke (2007), which suggests visibility is an outcome of information sharing, Brandon-Jones et al. (2014) stated that visibility is an outcome of improved knowledge and understanding. Although most of the definitions have a supply chain perspective, the definition by Caridi et al. (2014, p. 2) zeroed in on the focal company; this definition also distinctly indicates that visibility must support both strategic and operational activities. However, the definition by Caridi et al. (2014) also identified sharing and access to information as key for visibility. In the current thesis, SCV is defined in chapter 5.2.1. The key characteristics of SCV include having visual access

to demand and supply information that is timely, accurate and useful or key for operations and supply chains.

2.2 Conditions for SCV

In the present thesis, the conditions for SCV refer to the circumstances and factors affecting the planning, implementation and enhancement of SCV. In general, the conditions in previous studies are based on nontechnological and technological factors (Sodhi and Tang, 2019).

In terms of nontechnological factors, *information sharing* has been described as a key precondition for SCV (Barratt and Oke, 2007; Brandon-Jones et al., 2014; Dubey et al., 2020; Wang et al., 2020). Based on their case studies in the retail industry, Barratt and Oke (2007) argued that information sharing is key to achieving SCV. Here, *trust* between supply chain actors is mentioned as key for SCV (Wang et al., 2020). Lee et al. (2014) stated that trust generated from the conviction of good intentions in interorganisational collaboration leads to SCV. *Interorganisational collaboration* has also been stated as enabling SCV between actors in the supply chain. Wang and Wei (2007) argued that collaborations concerning common processes will support the establishment of SCV. Lee et al. (2014) mentioned that the circumstances in which there is joint governance have the potential to increase SCV. Srinivasan and Swink (2018) stated that companies aiming to improve SCV will be required to *invest*, which is likely to initially add cost. Potential *conflicts of interest* can affect the possibility of improving SCV (Cho et al., 2017). Jüttner and Maklan (2011) stated that companies might be reluctant to share information because of the *risk of losing business*. *Compliance* also affects SCV and the ability to share information across the supply chain (Brun et al., 2020). *Privacy* concerns have also been reported as influencing the possibility of establishing SCV (Kaipia and Hartiala, 2006).

Both recent and past studies have identified technologies as important in establishing SCV. In general, SCV is supported by technologies for data generation, management and usage (Srinivasan and Swink, 2019). Kim et al. (2011) noted the importance of *integration* and *IT compatibility* for SCV. Brandon-Jones et al. (2014) stated that *connectivity* in the supply chain is crucial for SCV. In line with this, Dubey et al. (2018, 2020) also stated that supply chain connectivity is a prerequisite for SCV. Data generation for SCV can also be collected through *sensor-based technologies* (Dolgui and Ivanov, 2021). *Collaborative planning systems* have been mentioned as ways to facilitate SCV in real time (Barratt and Barratt, 2011). Similarly, a recent study by Giannakis et al. (2019) identified that technologies enabling cloud-based collaboration are required to improve SCV. Data usage can improve SCV by applying technologies such as *AI* (Kosasih and Brintrup, 2021). Predictive abilities can be gained from SCV supported by AI (Calatayud et al., 2019). The study by Dubey et al. (2018) indicated that *Big Data* impacts data

usage and, thereby, SCV. A summary of the conditions for SCV is presented in Table 2.

Table 2. Conditions for SCV

Conditions for SCV	**Source**
Information sharing	Barratt and Oke (2007); Brandon-Jones et al. (2014); Dubey et al., (2020); Wang et al. (2020)
Trust	Lee et al. (2014); Wang et al. (2020)
Interorganisational collaborations	Wang and Wei (2007); Lee et al. (2014)
Investment	Srinivasan and Swink (2018)
Conflict of interest	Cho et al. (2017)
Risk of losing business	Jüttner and Maklan (2011)
Compliance	Brun et al. (2020)
Privacy	Kaipia and Hartiala (2006)
IT infrastructure	Kim et al. (2011)
Connectivity	Bradon-Jones et al. (2014), Dubey et al. (2018); Dubey et al. (2020)
Sensor-based technologies	Dolgui and Ivanov (2021)
Collaborative planning systems	Barratt and Barratt (2011)
AI	Calatayud et al. (2019); Kosasih and Brintrup (2021)
Big data	Dubey et al. (2018)

2.3 Potential outcomes of improving SCV

Although few studies have focused on a holistic understanding of SCV, the results from previous studies have given evidence regarding the potential benefits of improving SCV, as presented in Table 3. Several potential benefits can be related to the performance attributes within the supply chain operation (Supply Chain Council, 2010) (SCOR) model. First, in terms of *reliability* and *responsiveness*, the study by Srinivasan and Swink (2018), which is based on survey data from 191 global firms, highlighted that SCV can improve on-time deliveries, which then improves on the time taken to move products to customers. Next, in terms of *agility*, Barratt and Oke (2007) argued that SCV will enable companies to improve supply chain performance, leading to a competitive advantage. Based on data collected from 232 manufacturing companies in South Korea, Suh and Lee (2018) stated that SCV will provide both agility and flexibility. The next performance attribute, *costs*, has been mentioned as being improved by establishing SCV (Srinivasan and Swink, 2018). Based on data from 124 intermediate component

manufacturers, Lee et al. (2014) stated that cost management is an outcome of improving SCV. Finally, in relation to *assets*, Swift et al. (2019) argued that SCV will be important in supporting outsourcing sourcing activities. Related to sustainable SCOR (Supply Chain Council, 2008), the improvement of environmental performance in terms of emission handling can be supported by realising SCV (Dubey et al., 2020; Wang et al., 2020). Swift et al. (2019) argued that SCV is important to ensure responsible sourcing activities. Lately, studies have acknowledged that SCV will play a key role in ensuring the right working conditions (Brun et al., 2020). In fact, regulations to ensure human rights conditions demand that companies realise a certain level of SCV (Dolgui and Ivanov, 2021). Table 3 summarises the outcomes of improving SCV in practice.

Table 3. Outcomes based on SCOR performance attribute

Source	**Outcome**	**SCOR performance attribute**
Srinivasan and Swink (2018)	Improve on-time delivery	Reliability
Srinivasan and Swink (2018)	Improve time to customer	Responsiveness
Barratt and Oke (2007); Suh and Lee (2018)	Attain competitive advantage, increase of flexibility	Agility
Lee et al. (2014); Srinivasan and Swink (2018)	Improve cost management	Costs
Swift et al. (2019)	Improve outsourcing activity	Assets

3 Research methodology

This chapter presents the research methodology used. First, the research approach and strategy are described. The research process and methods are then detailed. Finally, the procedures for the quality assessment of the research are described.

3.1 Research approach and strategy

It is important that research is conducted in a way in which it can be understandable and reproducible and that an evaluation of its quality is possible (Trochim et al., 2016). SCV is complex, consisting of multiple aspects. This complexity is added by several dimensions, such as the number of actors in the supply chain, type of industry, operations, globalisation and systems involved. The primary question of the current thesis aims to understand how various conditions affect SCV and its realisation. To achieve this, a mixed methods approach was chosen. The research concerning SCV is scattered, and an extensive study on SCV is missing. Thus, RQ1 focuses on a comprehensive understanding of SCV by aiming to categorise the conditions that affect SCV. To fulfil this, a systematic literature review within SCV was considered appropriate. In addition, by providing a state-of-the-art (SOTA) understanding of SCV, an SLR will help in developing a multifaceted view on SCV and providing future research directions (Rowley and Slack, 2004; Denyer and Tranfield, 2009; Seuring and Gold, 2012).

RQ2 addresses practitioners' views of SCV. Given this, an apt approach would be a Delphi-based industrial study involving multiple supply chain practitioners. This approach is relevant for understanding and analysing a relatively new research area, such as SCV (Melnyk et al. 2009; Kembro et al. 2017). Applying the Delphi method in an industrial study can help capture perspectives on SCV from supply chain practitioners. As an alternative, a survey study was considered because it is suitable for gaining knowledge of relatively new or unknown research areas. However, the Delphi approach was chosen because it supports reaching a consensus in relatively new research areas, such as SCV (Dalkey and Helmer, 1963; Kembro et al., 2017).

RQ3 aims to provide deeper insights into realising SCV in practice. For this purpose, a case study approach was selected. Besides supporting the building of in-depth knowledge, case studies are suitable when there is limited knowledge regarding a research area. However, one relevant question related to the case study method is whether to choose a single-or multiple-case study. Each method provides certain advantages and possible challenges. Multiple cases provided the opportunity to compare the cases. In turn, this elevates the generalisability, external validity and robustness (Rowley, 2002; Eisenhardt and Graebner, 2007; Yin, 2009). This can be difficult to achieve with a single-case study approach (Voss

et al., 2002). However, it is also important to contemplate the advantages of single-case studies, which can provide the ability to develop in-depth knowledge in complex situations and further identify unique conditions (Voss et al., 2002; Yin, 2009). Because this was the focus of study RQ3, a single-case study method was chosen.

Overall, the current thesis has been built on three papers (paper 1, paper 2 and paper 3) derived from one SLR and two empirical studies (A and B). This enabled an in-depth understanding of the conditions affecting SCV and its realisation in practice (Eisenhardt, 1989; Yin, 2009). Figure 2 illustrates the relationships between the research questions, the conducted studies and the appended papers.

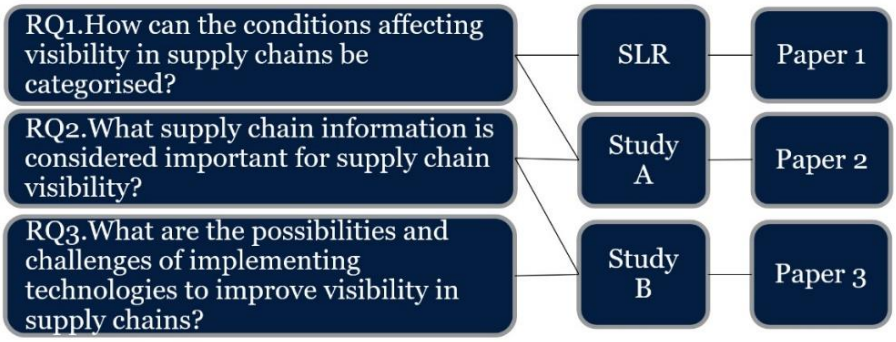

Figure 2. Relationship between research questions, SLR, empirical studies and appended papers

3.2 Research process

A research process involves the steps supporting the achievement of the aim of the study. Increased understanding between practice and theory can be achieved through an iterative process (Dubois and Gadde, 2002). Here, several steps and activities are involved when conducting research. Existing practice and theory influence the identification of areas of knowledge, including the SOTA understanding, identification of the problem area and gap and scope of research. In turn, this will determine the design of the study and its execution while enabling the gathering of empirical results for analysis and then synthesising the results. Finally, the discussion and conclusion derived from the results are likely to contribute to both academia and practice (Säfsten et al., 2020, p. 58).

The current research was conducted within an industry/academia research project LOVIS, which included two universities, two OEMs and one standardisation organisation. As illustrated in Figure 3, the research began in 2020 with the SLR. Prior to the SLR, a brief literature review was conducted, which resulted in a conference paper (Kalaiarasan et al., 2020). This paper motivated a more extensive SOTA understanding of SCV; this was further motivated by Somapa et al.'s (2018) review of the SLR on SCV, which helped identify the scope for an SLR focusing on

the conditions affecting SCV. Then, RQ1 was developed, and the SLR was planned and conducted, which resulted in paper 1. Based on the SLR, the author could identify the further scope of the research. This motivated the development of both RQ2 and RQ3. The author then discussed potential studies with the research team and project partners. This led to study A, in which the motivation was to provide a thorough understanding of practitioners' views on SCV, resulting in paper 2. During this time, the author also held discussions with one of the LOVIS project partners regarding RQ3, which resulted in study B and paper 3, respectively. The collaboration provided the author with the opportunity to be part of a pilot study at the case company. The study also provided a deeper understanding of developing requirements and testing technologies for improving SCV in practice.

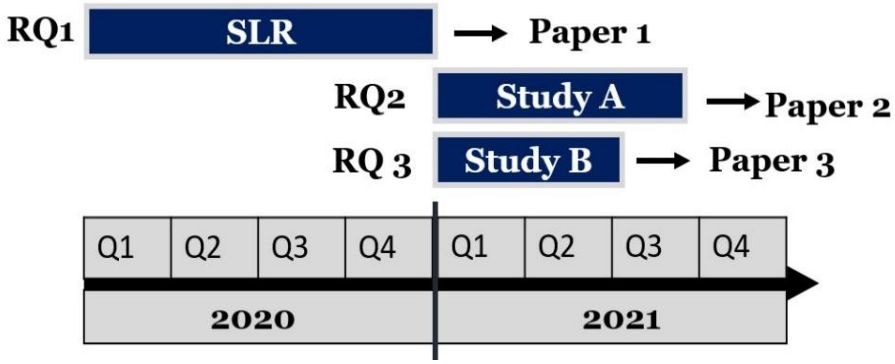

Figure 3. Timeline of the research process

3.3 Systematic literature review

A novel and SOTA understanding of a subject can be established by conducting a systematic literature review (SLR). In addition, it can support the identification of future research areas (Rowley and Slack, 2004; Denyer and Tranfield, 2009; Seuring and Gold, 2012). Hence, the present thesis was started with an SLR, which followed the four-step model suggested by Seuring and Gold (2012): i) collection of the material, ii) conducting a descriptive review, iii) selection of categories, and iv) evaluation of material. To collect the data, the author collaborated with one postdoc and two professors to develop a search strategy (further explained in paper 1); this included the development of the following key words: 'supply chain', 'logistics', 'operations', 'manufacturing', 'production' and 'visibility'. The search was conducted in Scopus and resulted in 975 papers. The author stored the identified articles in common databases to make them available to the coauthors. This was followed by a screening process. The focus was on identifying the empirical research on SCV from peer-reviewed papers. This left 109 papers for further analysis. Then, the author created an Excel spreadsheet where information (authors, title, year, journal, research questions, findings, contribution and future

research) were documented. The focus was on empirical research on SCV. Papers that did not explicitly mention SCV were excluded, leaving 43 papers for content analysis. This was followed by forward-tracking and back-tracking, which identified an additional four papers, resulting in the final number of papers being 47. Figure 4 illustrates the SLR process.

Next, as suggested by Bresling and Gatrell (2020), a content analysis was conducted to identify, combine, organise and categorise the perspectives on SCV. This added four columns to the Excel sheet: definitions of SCV, perspectives and factors on SCV, research methodology and theories used. Then, cross-tabulations of the data sheet led to the emergence of categories and factors (Figure 2 in paper 1). Finally, the results were analysed and discussed, and the manuscript for paper 1 was written.

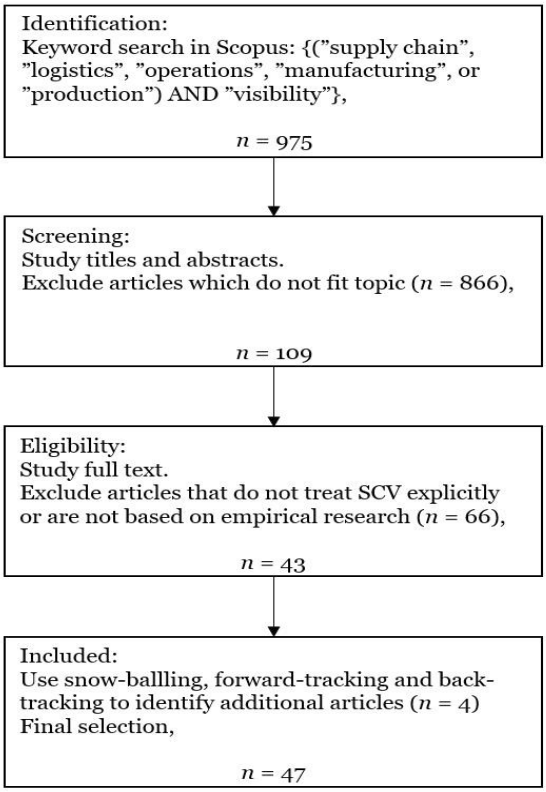

Figure 4. Systematic literature review process

3.4 Delphi-based industrial study

3.4.1 Selection of the participants

Extensive experience of work in global supply chains, SCV-related challenges, willingness to share SCV-related knowledge and an ambition to increase SCV in their supply chains were key criteria when selecting the participants for study A. The researchers followed the general guidelines for Delphi studies (Melnyk et al., 2009; Kembro et al., 2017) to set up an appropriate panel to ensure the validity of the results. To overcome individual biases, a minimum of 20 participants and maximum of 30 participants is ideal (Ogden et al., 2005; Agrawal and Pal, 2019). The researchers within the LOVIS project invited some 34 senior supply chain executives with a minimum of 10 years of work experience from industrial firms in Sweden with global supply chains. These experts were primarily drawn from, or recommended by, industry contacts and research partners. All invited executives had extensive experience in global supply chain management. Overall, 26 individuals representing a variety of industries agreed to participate in the Delphi expert panel, as illustrated in Table 4.

Table 4. Overview of participants in study B

Expert	Position	Industry	Years of work experience
1	Global Development Manager	Automotive	30+
2	Logistics Manager	Energy equipment & solutions	22
3	Senior Excellence Manager	Automotive	12
4	CEO & Business Development	Cable production	15+
5	S&OP Development Manager	Outdoor power products	17+
6	Supply Chain Analyst	Dairy & farming machinery	15
7	VP and CTO	Steel	10+
8	Supply Chain Manager	HVAC products	15
9	Project Manager Logistics	Automotive	15+
10	Director of Production Technology Tools	Cutting tools	25+
11	Plant Manager	Automotive	10+
12	Supplier Development Manager	Automotive	22
13	CEO	Automotive	30+
14	VP, Operations	Optoelectronics	20
15	Material Management Director	Security systems	25+
16	Director, Operations Development	Heavy equipment	20+
17	Logistics Specialist	Aerospace	20
18	Senior Director, SC Strategy	Forest & Garden	25
19	Operations Development Manager	Energy systems	20
20	Solution Architect	Candy	30
21	SC Development Manager	Heat transfer	11
22	Director, SCM Strategy	Automotive	15
23	Global Purchasing & Logistics Manager	Furniture	25
24	Global SC Manager	Packaging solutions	13
25	Business Development Manager	Furniture	25+
26	Senior Business Architect	Telecom	30+

3.4.2 Data collection

For study A, data collection occurred from February to June 2021. Following the Delphi technique (Melnyk et al., 2009; Kembro et al., 2017), empirical data were collected from expert senior supply chain practitioners from 26 companies belonging to different industries. In essence, the study consisted of five steps, which is described in more detail in paper 2. The first step consisted of expert selection based on recommendations, industrial contacts and research partners. As described in chapter 3.4.1, senior supply chain practitioners based in Sweden were invited. The second step focused on the first round of the Delphi study by sending our four open-ended questions to collect perspectives on SCV from the participants. The questions were sent via email, and three weeks were provided to the participants to answer. The results were analysed individually by the researchers to find themes and categories that were late compared. During the third step, the results were validated to locate the important factors that needed to be further explored. In the second round of the Delphi study, the participants were asked to highlight each factor as either 'important' or 'not important'. Again, a three-week response time was given. The results were analysed, and an understanding of the important factors was reached. The fourth step aimed to rank the factors from the previous step on a 7-point Likert scale. As in previous rounds, a three-week response period was given. Calculation of the mean and standard deviation was performed for the result. In the fifth step (the last step), two seminar sessions were organised in which the participants were invited. This was done to acquire additional insights and clarify the results. The sessions were recorded and transcribed. An overview of the key steps is illustrated in Table 5.

Table 5. Key steps for data collection in Delphi method

Step	**Purpose**
1. Expert selection	Establish panel with experts with extensive work experience and representation of manufacturing companies.
2. First round	Explore SCV issues through open-ended questions and create an extensive list of SCV-related factors.
3. Second round	Reach an understanding by validating the findings and selecting factors for further studies.
4. Third round	Quantify and rank the impact of different factors on a numeric scale.
5. Fourth round	Conduct seminar involving panel experts to clarify the results and gather additional insights.

3.4.3 Analysis

The data from the first round were compiled and stored in spreadsheets made available to the rest of the research team. This was followed by individual analysis, in which each researcher coded the results to generate themes and categories. These themes and categories were later discussed and interpreted by the research team to resolve differences and reach the consensus required for the second round.

To analyse the results of the second round, two researchers calculated the importance of each factor for SCV by counting the number of times each expert marked a factor as 'important' or 'not important'. This enabled the team to later reach a conclusion regarding which factors were important, hence eliminating the ones with low scores. This was later developed into a Likert scale and provided the data to quantify the impact of the factor for SCV in the third round. During the third round, the results of the Likert scale were analysed by calculating the mean and standard deviations for each factor. In turn, this enabled the team to rank the factors for SCV, which could be ranked from high to low. This analysis facilitated round four of the group seminar sessions. The sessions, which were recorded and transcribed, were used to confirm, clarify and develop arguments for those factors impacting SCV. The study yielded paper 2, which had a distinct purpose of providing prioritised managerial perspectives on SCV.

3.5 Case study

3.5.1 Case selection

Study B was initiated by collaboration between the research team and the case company in the LOVIS project. The study was motivated by the challenges experienced by the case company because of a lack of visibility in their inbound flow. The company is a global manufacturer of transportation systems, has approximately 50,000 employees in 100 countries and is constantly ranked among the top three in their industry. However, the disruptions experienced during the COVID-19 pandemic, combined with their ambitions for the future of their supply chain, motivated the company to enhance its SCV. Hence, they can be regarded as a representative of companies on the digitalisation journey facing numerous SCV challenges. In addition, the accessibility to the company also enabled a deeper understanding of SCV-related conditions in practice (Voss et al., 2002; Yin, 2009).

3.5.2 Data collection

For study B, data collection was carried out from January to June 2021, in which the researcher was part of the project team. The data came from a pilot study focusing on increasing visibility in inbound logistics at the case company. The author collaborated with the company's project team to develop requirements and test the technologies for a potential visibility system that was initially aimed at inbound logistics. To achieve this, a design science approach was applied through context-intervention-mechanism-outcome (CIMO) logic (Denyer et al., 2008). The study process is described in detail in paper 3. The first step mapped the current state of inbound logistics and challenges because of lack of visibility by collecting data from project presentations and mapping IT systems. This was followed by a semistructured interview with the project member from inbound logistics, that is, a project manager in supply chain development, to identify the relationship between the challenges and business requirements (including short-term and long-term

goals). The third step included the identification of functional requirements followed by technological solutions based on business requirements. This was performed by the researcher with support from the research team and was later verified with the project team using semistructured interviews. In the last part, data were collected during the pilot study, which occurred in June and in which four sensor-based technologies were tested to improve the visibility of inbound logistics. This included semistructured interviews, observations, review of project documents and documentation of pilot results. An overview of the data collection for study B is presented in Table 1 in paper 3.

3.5.3 Analysis

For study B, the primary aim was to contribute to solving a real problem experienced by the case company: the lack of visibility in their inbound logistics flow. This was initiated by an analysis of the data collected concerning the current state, as described in chapter 3.5.2 (first step data collection). Analysis of the current state revealed constraints that had to be addressed to develop solutions. The following aspects were identified for SCV: IT systems, process steps, packaging and internal and external actors in inbound logistics. Visualising their interrelationships (Figure 2 in paper 3) enabled us to locate the lack of visibility in the inbound flow and related challenges. By adopting the ideas from the quality function deployment (QFD) methodology (Hauser and Clausing, 1988; Akao, 1990), the challenges were analysed and translated before being mapped into technological solutions via business and functional requirements. This supported the project team in selecting and evaluating technologies in a pilot study in which the inbound flow was simplified and emulated. During the pilot, each technology was tested in terms of connectivity and tracking precision. The results were later analysed by the project team to determine suitable technologies for further testing the real inbound flow. The current study resulted in paper 3, which provides a deeper understanding of SCV-related conditions and technologies in practice.

3.6 Quality assessment

3.6.1 Construct validity

The construct of validity normally refers to the identification and development of adequate measures and indicators for a study (Yin, 2009; Saunders et al., 2016), and the use of multiple sources to collect data enhances the construct of validity (Meredith, 1998; Yin, 2009). In line with this, both empirical studies included in the current thesis incorporate data from multiple sources, interviews, observations, surveys, content review of project documents and participation in pilot projects. In addition, the collected data were reviewed, discussed and interpreted by the research team, project partners and industrial partners, which improved the construct validity of the study.

In study A, data were collected from multiple companies to establish links of evidence. However, there was a challenge in ensuring that the participants understood the interview questions and could connect them to the purpose of the study (Flyvjerb, 2006; Rowley, 2002). Therefore, the answers were verified with the participants and later further discussed during the seminar sessions. This reduced the bias and one-sidedness. The seminar sessions were recorded and transcribed and later verified by the research team, which contributed to strengthening the validity.

Study B was prone to the limitations of a single case study and deviation of purpose (Yin, 2009; Voss et al., 2002). However, this was handled mainly by two measures. One was the choice of case, which was discussed by the research team and aligned with the literature. Second, multiple sources were used to collect data: project documents, semistructured interviews, project meetings and active participation in the pilot study (Yin, 2009).

3.6.2 Internal validity

Internal validity refers to the extent to which a study attains trustworthy cause-and-effect relationships between different sets of conditions (Yin, 2009). The studies in the present thesis created internal validity through pattern matching (Yin, 2009). The SLR and specific literature reviewed for both empirical studies generated patterns consisting of the conditions and factors affecting SCV and its outcomes. In several instances, both studies confirmed what was found in the literature. However, some new and novel insights into SCV could also be identified from all three studies. This was expected because the literature underlined the need for empirical studies of SCV.

3.6.3 External validity

External validity concerns the degree to which a study's results can be generalised to a broader context (Yin, 2009). For study A, which was based on multiple sources, replication logic was applied to support external validity (Yin, 2009). Study B, which was based on a single case, faced the challenge of a limited scope for generalisation (Yin, 2009; Voss et al., 2002). To support the generalisability of study B, the design of the study was matched with the literature (Yin, 2009). In line with this, the SLR and frame of reference in both studies supplemented the generalisability. The SLR and frame of reference supported the development of the Delphi study in study A and selection of technologies in study B.

3.6.4 Reliability

Reliability concerns the degree to which a study's procedures can be repeated to produce the same results (Yin, 2009). Saunders et al. (2016) further stated that researchers' process for data collection must be documented to enable others to replicate the study. For study A, a database was established to document, maintain and analyse the data. To reduce bias, the interpretations made by the research team

were verified and discussed with the participants between rounds and during both seminar sessions. The sessions were recorded, transcribed and made available for the participants. The same approach was applied in study B, where the results were discussed and verified with the project team at the case company.

4 Results from appended papers

This chapter presents the main findings from the SLR (paper 1), study A (paper 2) and study B (paper 3). Section 4.1 covers the conditions affecting SCV and is related to RQ1. Section 4.2 presents the managerial and practitioner perspectives on SCV, which relates to RQ2. Finally, related to RQ3, chapter 4.3 targets the improvement of SCV in practice. The findings are further elaborated on in the appended papers.

4.1 Conditions affecting SCV (SLR)

Paper 1 covers the findings from the SLR of 47 peer-reviewed journal papers (Appendix 2 in paper 1). To facilitate understanding of the development and implications of SCV, the SLR provided deeper insights into the conditions and factors affecting SCV. First, the SLR distinguished SCV from two related terms: traceability and transparency. Transparency is related to information disclosure about compliance and expected norms. On the other hand, traceability is a particular aspect of visibility used to ensure provenance (Sodhi and Tang, 2019). Then, by incorporating the key characteristics from previous definitions, the SLR proposed a new definition for SCV (presented in chapter 3.1 in paper 1 and further discussed in chapter 5.2.1).

The key findings from the SLR are the identified factors affecting SCV. Broadly, the factors, which are described in detail in paper 1, could be grouped into four themes: antecedents, barriers and challenges, drivers and effects. As described in paper 1, the antecedents refer to those factors that must be in place to achieve SCV (also referred to as enablers). In turn, the antecedents contain three subcategories: people-, process- and technology-related factors (Table 6).

Table 6. Antecedents for SCV (paper 1)

Subcategory	**Factor**
People	Culture Interorganisational collaboration Trust
Process	Business alignment Information sharing Information quality Integration
Technology	Blockchain Collaborative planning system Connectivity RFID

Next, although related, the barriers and challenges are different. Although barriers refer to the factors that are not possible to overcome to implement SCV, challenges are the factors that are possible to be addressed to implement SCV. The factors

belonging to barriers and challenges could be grouped into the subcategories of internal operations, customer-related, supplier-related and factors common for the entire supply chain (see Table 7).

Table 7. Barriers and challenges for SCV (paper 1)

Subcategory	**Factor**
Internal	Budget constraints Poor data quality
Customers	Reluctance to provide data
Suppliers	Budget constraints Limited to/by first tier Risk of losing business
Supply chain	Conflict of interest Disparate sources of information Lack of standardisation Lack of skills and knowledge Supply chain complexity

The third theme—drivers—contained those factors that motivate the implementation of SCV. Drivers could be grouped in the same way as barriers and challengers: internal operations, customer related, supplier related and factors common to the entire supply chain (see Table 8).

Table 8. Drivers for SCV (paper 1)

Subcategory	**Factor**
Internal	Price advantage Purchasing power
Customers	Compliance Customer service Mark intelligence Modular design
Suppliers	Responsible sourcing Supply-based management
Supply chain	Intelligence Risk management Sustainability

Finally, Table 9 presents the identified effects of SCV. These include two interrelated subcategories: capabilities and performance. Capabilities have been typically described as the direct outcome of SCV, hence leading to improvement in one or several performance areas.

Table 9. Effects of SCV (paper 1)

Subcategory	Factor
Capabilities	Agility (including flexibility) Analytical ability Decision-making support Planning Risk management
Performance	Cost (including inventory cost) Customer service (including delivery lead time, responsiveness, and sales) Profitability Quality and safety Sustainability

4.2 Managerial perspectives on SCV (study A)

Based on RQ2, study A sheds light on the managerial perspective on SCV. As mentioned in chapter 3 and further detailed in paper 2, the study applied the Delphi method to reach a consensus based on data collected from experts who had extensive experience in a particular field (Dalkey and Helmer, 1963; Melnyk et al. 2009; Kembro et al. 2017) (see Table 4). The Delphi study contained four rounds. Overall, the study focused on identifying and understanding data elements to be made visible in the supply chain, the factors affecting the implementation of SCV and the implications of SCV. The results were based on the four open-ended questions targeting i) what SCV means to the participants, ii) the importance of SCV to their company and supply chain, iii) the factors affecting the implementation of SCV and iv) additional insights in the context of SCV to add. The results could be categorised as data elements, drivers, enablers, challenges, contingencies, capabilities and performance effects of SCV.

Responding to the first question, the participants defined what SCV means to them and their supply chains. After examining the definitions, the data elements for SCV could be identified. These can be categorised as belonging to: i) customer-related factors, ii) internal factors and iii) supplier-related factors (see Table 10).

Table 10. SCV data elements (paper 2)

Customer-related	**Internal related**	**Supplier-related**
Deliveries	Inventory levels	Purchasing plans
Deviations	Capacity	Supplier capabilities
Orders	Lead times	Supply
Demand	Production plan	Supplier location
Forecast	Safety stocks	Track and trace
Country of origin		

Related to drivers, in total, eight factors were ranked the highest. In terms of enablers, eight factors were also prioritised as key to implementing SCV. Then, seven factors were identified as functioning as major challenges to establishing SCV. Finally, the performance effects included six prioritised factors mentioned by the participants (see Table 11).

Table 11. Factors affecting SCV

Drivers	- Managing deviations - SC control - Customer service - Decision-making support - Sustainability: Economic - Risk management - Sustainability: Environmental - Sustainability: Social
Enablers	- Data quality - Information sharing - Top management support - Trust - Interorganisational collaboration - Common SC master data - Connected/integrated systems - Standardisation
Challenges	- Standardisation (lack of …) - SC complexity - IT infrastructure (lack of …) - Willingness to share data (lack of …) - Data from multiple sources - SC competence (lack of …) - Organisational culture
Effects	- *Capabilities* - Predictive capability - Decision-making support - SC control - Planning capability - Risk management - Traceability - Optimisation and simulation - Forecasting - *Performance* - Customer service - Sustainability: Economic - Flexibility - Lead-time reliability - Sustainability: Environmental - Sustainability: Social

4.3 Possibilities and challenges to improving SCV in practice

Based on RQ3, study B provides deeper insights into implementing technologies for improving SCV in practice. As described in chapter 3.5, the study was conducted at a global manufacturing company seeking to improve visibility in the inbound flow because of the disruptions caused by the COVID-19 pandemic and that wanted to

prepare their supply chains for the future. By applying the CIMO logic, the material and information flow was mapped to identify current visibility-related problem areas in the inbound flow (further elaborated and illustrated in paper 3). Overall, six major SCV-related problem areas can be identified for the inbound flow. Together, they formed the motivation for the case company to improve visibility in its inbound flow. The problem areas are summarised in Table 12.

Table 12. Current SCV challenges in the inbound flow

SCV problem areas	**Description**
Speed transports	No real-time information causes speed transports
Additional inventory levels	The complexity of the supply base forces the company to keep additional stock to ensure material availability for production
Blind spots	Lack of SCV causes difficulties in identifying spots of deviations in the flow
Additional investments	Additional investments in storage capacity because of the lack of SCV
Lack of unified view	No unified visualisation of article number, pallets, truck and hub
Limited proactivity	Difficulties to identify deviations in time and take appropriate actions

Next, as illustrated in Figure 5, the problem areas were translated into technological solutions via business requirements and functional requirements. This approach enabled the possibilities to test and implement technologies for improving SCV in the pilot study at the case company. The possibilities were further supported by ensuring that the technological solutions were derived from current problem areas and business requirements. The functional requirements, which were translated from business requirements, supported the project team in selecting and testing the technologies (detailed in Table 4 in paper 3). The results indicated that improving SCV in practice using technologies will demand technological solutions for *data connectivity, real-time data collection, data management, data analytics and data integration*. As detailed in paper 3, the pilot study emulated a typical inbound flow at the case company, which helped the project team evaluate four sensor-based technologies for *connectivity* and *real-time data collection*. In terms of challenges, stable connectivity and tracking precision levels were revealed as challenges, especially for potential large-scale implementations. As detailed in Table 6 in paper 3, low levels of tracking precision and/or connectivity can affect the possibility of improving SCV. In addition, it was revealed that network dependency can affect the implementation of technologies.

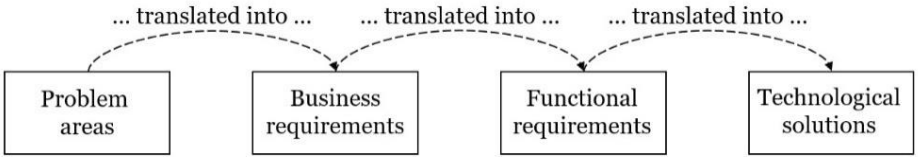

Figure 5. Approach for successive translation of problem areas into technological solutions

5 Analysis and discussion

This chapter presents the analysis and discussions of the SLR and studies A and B in relation to the research questions. In addition, cross-study perspectives are analysed and discussed.

5.1 Categorisation of conditions affecting SCV (RQ1)

5.1.1 The ABCDE framework of SCV

As presented in chapter 4.1 and further discussed in paper 1, the SLR revealed that the literature on SCV has covered a multifaced view of SCV consisting of four main dimensions: antecedents (11 factors), barriers and challenges (11 factors), drivers (11 factors) and effects (10 factors). Combined, these four dimensions provide a holistic view of SCV, which was referred to as the *ABCDE framework for SCV* in paper 1 (see Figure 6).

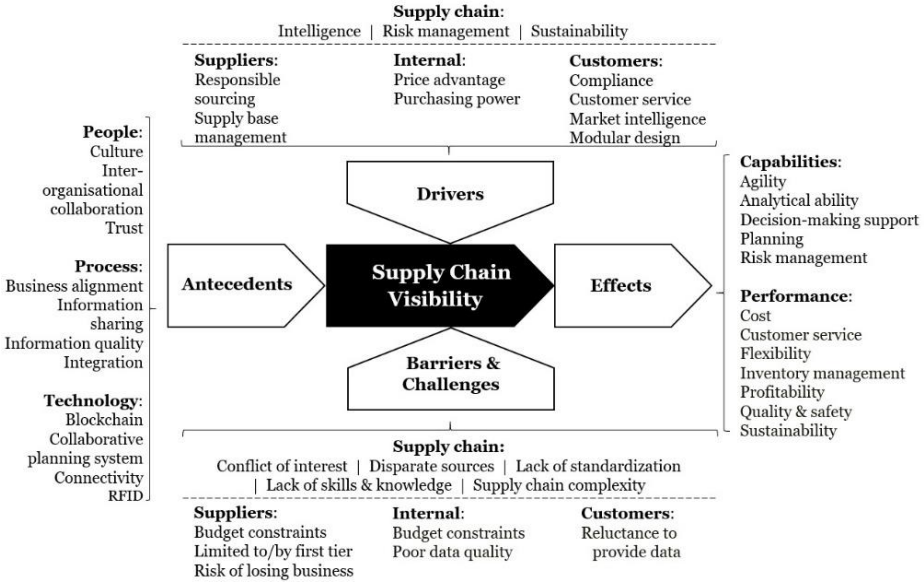

Figure 6. The ABCDE of supply chain visibility

Note: A=antecedents, B=barriers, C = challenges, D=drivers, E=Effects

The ABCDE framework captures the scattered perspectives and implies that SCV is difficult yet important to implement because of its benefits in terms of effects (both capabilities and performance). Furthermore, the framework acknowledges that SCV needs to be addressed both holistically and in detail. The findings suggested that ignoring factors in one or more dimensions is likely to lead to improper implementation of SCV, leading to unwanted results. At the same time, not all

factors may be relevant in every case. Related to this, the interrelationships between the identified factors for SCV were unclear. In a few instances, it could be noted that certain factors appeared in more than one dimension. For instance, risk management was found to be both a driver and effect of SCV. Similarly, information sharing (antecedent) versus reluctance to provide data (barriers and challenges) were identified to be related. Thus, it could be understood that tensions exist between certain factors. The dominant factor in each case is likely to affect the possibility of implementing or improving SCV. For instance, if a driver is perceived as highly important, companies are likely to focus on handling barriers and challenges.

5.1.2 Cross-study perspective – SLR and study A

The ABCDE framework, which emerged from the SLR, shares similarities and differences with the results from the Delphi study, which covers those factors affecting SCV, SCV content and the implications of SCV (see Figure 7). Overall, the SCV model, which was created from the results of the Delphi study and presented in Figure 7, complements the ABCDE framework. Here, as described in paper 2, it is worth mentioning that the participants for study B were not provided with any framework for SCV (i.e., including the ABCDE framework).

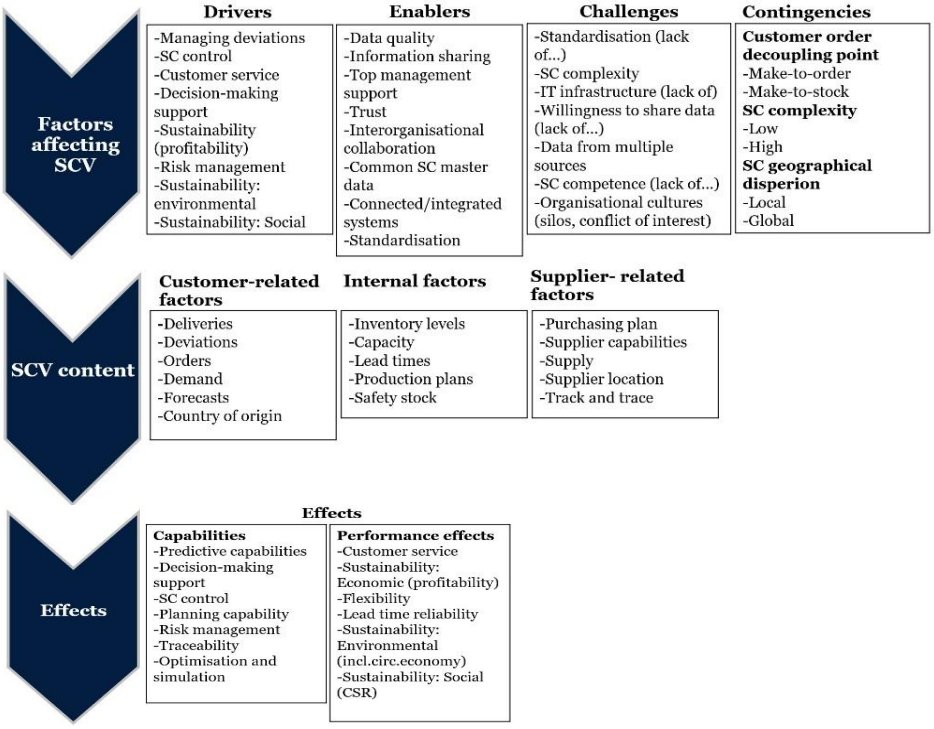

Figure 7. SCV model based on the Delphi study.

Comparing the ABCDE framework with the findings from study A, several of the factors belonging to each dimension in the ABCDE framework can be found in the corresponding category in Figure 7. For instance, trust and interorganisational collaborations can be identified both in the ABCDE framework (under antecedents) and in Figure 7 (under enablers). Similar observations can be made for each category. These similarities in factors can be noted, despite the fact that the SLR captured empirical results on SCV across the globe and that study A primarily included participants working in Sweden.

Although the factors for SCV captured in study A study do not contradict the factors in the ABCDE framework, certain differences can be noted. Although the SLR identified several technologies as key for achieving SCV (Barratt and Oke, 2007; Kim et al., 2011; Guo et al., 2015; van Hoek, 2019; Dubey et al., 2020, Dolgui and Ivanov, 2021), the Delphi study identified and ranked several nontechnological factors as being important. In fact, information sharing (Barratt and Oke, 2007; Dubey et al., 2020), top management support and trust (Dubey et al., 2018; Brun et al., 2020) were ranked higher than the only technological factor, which is connected/integrated system (Dubey et al., 2018). It can be argued that this could be the result of the participants in the Delphi study having managerial positions in their supply chains.

5.2 Information and data elements for visibility (RQ2)

5.2.1 Defining SCV—comparing SLR and Delphi study

As identified in the SLR, there is no unanimously accepted definition of SCV. Although the definition by Barratt and Oke (2007) is adopted and referred to by several studies (Jüttner and Maklan, 2011; Klueber and O'Keefe, 2013; Papert et al., 2016; Somapa et al., 2018; De Oliveira and Handfield, 2019), the SLR also identified four more definitions from Francis et al. (2008), Williams et al. (2013), Brandon-Jones et al. (2014) and Caridi et al. (2014).

Each definition emphasised certain characteristics incorporated into a new definition proposed in paper 1: *'the extent to which actors within a supply chain have visual access to the timely and accurate demand and supply information that they consider to be key or useful to their operations and supply chains'*. The key characteristics of this definition are presented in Figure 8.

Figure 8. Characteristics of the definition of SCV

Study A identified the definitions for SCV provided by the participants, detailed in appendix 1. In line with the definitions identified in the SLR, the definitions provided by the participants have both similarities and differences. As mentioned

in the literature, a few participants used SCV interchangeably with the term transparency. Participants 1 and 29 associated SCV with transparency. Then, further insights were gained by comparing the characteristics presented in Figure 8 with the definitions provided by the participants.

In terms of *information* for SCV, the definitions by the participants confirmed that both demand and supply information are important for SCV. However, some participants focused on information upstream, some downstream and some in both directions. For example, participant 2 focused on the deliveries of 'material flow/incoming transport' to production, participant 27 focused on delivery towards customers, and participant 24 mentioned that SCV covers both up and downstream, stating that SCV includes seeing what 'customers are asking' but also seeing this as the 'suppliers' ability to meet' demands.

The participants also mentioned having *access* to information and data when defining SCV. For instance, participant 3 stated that SCV includes having 'access to data' regarding information related to customer 'needs, suppliers' location, capacity and lead time, logistics suppliers' flows, capacity and lead time'. Participant 28 stated that SCV means key figures are 'accessible'.

Timely available information was also considered an important aspect of SCV. Participant 30 noted the importance of having end-to-end SCV 'at any given time'. Participant 3 accentuated the importance of having 'real-time' data for SCV.

In terms of *accurate* information, none of the participants explicitly mentioned this facet. However, they referred to a related term, namely, *correct* information. Participant 23 commented that SCV is 'correct' and fact-based for decision making. Similarly, participant 26 stated that SCV involves having a 'correct picture' of the situations for decision making and actions.

None of the participants explicitly used the terms key/useful while defining or describing what SCV meant to their operations and supply chains. However, most of the participants found SCV to be beneficial for their operations and/or strategic activities in their supply chain.

Overall, it can be understood that, to fully benefit from SCV, all of the characteristics have to be in place. Ignoring one or several of the key characteristics of SCV in Figure 8 is likely to restrict actors in the supply chain from performing. For instance, in the case of a delivery deviation, it is important to have information that is accurate, accessible and useful. However, if the information is not available in a timely manner, the handling of the deviation is likely to be reactive rather than proactive.

5.2.2 Data elements

As presented in chapter 4.2, study A captured the expected data elements for SCV, here as categorised into three main categories: customer related (6 factors), internal related (5 factors) and supplier related (5 factors). As discussed in paper 2, in terms of customer-related data, deliveries and deviations were ranked the highest. This is understandable because study B was conducted during the time of

the COVID-19 pandemic when ensuring deliveries of material were a key priority for companies. This is also related to data concerning internal operations, where inventory levels and capacity were the most important. In terms of supplier-related data, purchasing plans and supplier capabilities ranked high. As discussed in paper 2, worldwide events, such as the semiconductor crisis, could have affected the perspectives on SCV in this category.

It can be argued that how the participants in study A defined SCV influenced the identified data elements for SCV. However, it is important to consider that several factors were dropped (see section 3.4 in paper 2). Only the data elements ranked high were included, indicating that, overall, these data elements are important for SCV. Still, the standard deviation (see Table 3 in paper 2) indicated that there was a variation among the participants regarding the importance of the data elements for SCV. As discussed in paper 2, this is likely because of the nature of the supply chain to which the participants belong. Although supply chain actors might rank certain data elements as more important than others, they likely depend on information across the entire supply chain. In fact, the participants in study A acknowledged that information sharing across the supply chain is important because events happening in one area of the supply chain affect others. For instance, both supplier-and customer-related information is needed in real time to handle deviations in a timely manner. Study A further revealed that visual access to information was preferred. The information is expected to be displayed interactively in the form of dashboards. A similar finding was identified in study B, which added insights regarding the supply and internal related information needed to be displayed in a potential SCV system (Yang et al., 2021; Kähkönen et al., 2021). In particular, study B identified data visualised in an SCV system as being related to real-time monitoring of deliveries from suppliers, forecasting accuracy, planning and virtual stock. Supply-related information focuses on: 1. digital view of articles and packaging, 2. providing real-time estimated time of arrival (ETA); and 3. track and trace capability for displaying inventory and registrations of events (arrival, departure, loading and unloading and alarms at the point of deviation).

Together, studies A and B provide a detailed understanding of supply chain information needed for SCV as conveyed by stakeholders (de Oliveira and Handfield, 2019). In particular, study B illustrated how SCV information has the potential to improve decision making and performance (Somapa et al., 2018).

5.3 Possibilities and challenges of implementing technologies to improving SCV in practice (RQ3)

The results from study B showed the possibilities and challenges of improving SCV in practice at the inbound logistics department at a global manufacturer. In terms of possibilities, study B developed an approach to translate and map SCV problem areas into technological solutions. The approach supports the improvement of SCV in practice by supporting companies in developing technological solutions via

business and functional requirements for a potential SCV system. In turn, technological solutions can support manufacturing companies in solving current SCV problem areas and supporting the future transition of supply chains.

It was found that improving SCV in practice requires mapping current problem areas and understanding their consequences. Next, business requirements containing both short-term and long-term goals must be established by involving the relevant stakeholders of the supply chain. In turn, functional requirements should be established for an SCV system, which then have to be translated into technological solutions. Then, based on technological solutions, the technologies for improving SCV can be selected, tested and evaluated. The technologies tested in study B revealed that improving SCV in practice helps companies handle several problem areas in supply chains. This structural approach addresses the ambiguity of increasing SCV in practice, despite the existence of research regarding technologies (Lee and Rim 2016). Furthermore, although study B was conducted in the scope of inbound logistics, some of the SCV problem areas, such as speed transports, additional inventory, supply chain blind spots and limited proactivity, are likely to be relevant to other areas, such as internal and outbound flow. Hence, it is likely that the structural approach presented in Figure 5 can be applied in other areas of the supply chain.

Study B further identified the challenges of improving SCV in practice. One area of challenge is related to the actors involved in the flow. Numerous actors both internally and externally must collaborate to improve SCV. In the case of study B, suppliers, various transport solution providers, cross-docks and logistics centres must be synchronised to improve SCV. Potential conflicts of interest and unwillingness to share information limit the possibility of establishing SCV. The second challenge is found in the processes involved. The case revealed that ownership of the trailer can be a limiting factor because the company was not allowed to mount technologies on the trailer wall. Furthermore, the results of the tested technologies revealed that connectivity and tracking precision might be a limiting factor when trying to improve SCV in practice. This is because none of the other requirements will work properly unless connectivity and tracking precision are sufficient. Furthermore, study B confirmed that, beyond first-tier suppliers, SCV is a challenge. This confirms previous studies stating that supply chains of manufacturing companies suffer from a lack of visibility beyond first-tier suppliers (Choi et al., 2021). Study A also identified additional challenges in improving SCV in practice. The participants in study A stated that standardisation for data sharing and technology integration is difficult to achieve in practice.

5.4 Overall discussion

Figure 9 ties the three studies in relation to the objective of the current thesis. First, the SLR (paper 1) suggested a new definition for SCV by reviewing and combining the key characteristics of SCV identified in past studies. These characteristics of

SCV include both downstream and upstream supply chain information that is timely, useful, accurate and visually accessible to stakeholders. Then, the SLR investigated how the conditions and factors affecting SCV could be categorised. This was done by identifying four main categories, each containing numerous factors affecting SCV and its outcome. Then, the SLR also identified that there is a lack of multidimensional models or frameworks on SCV. Thus, the SLR presented a holistic framework on SCV containing four categories: antecedents, barriers and challenges, drivers and effects of SCV. This ABCDE framework can be regarded as a meta-analysis of the empirical research on SCV. Overall, the findings from the SLR highlighted that a multitude of factors must be addressed to establish SCV. In general, this correlated with the findings from study A, which focused on the managerial perspectives on SCV. Similar to the SLR, study A identified enablers, drivers, challenges and implications of SCV. Overall, the SLR and study A complemented each other regarding the conditions and factors affecting SCV. As illustrated in Figure 9, factors function as the prerequisites for SCV. These factors, which are related to *people*, *process*es and *technology*, require attention to implement SCV. Second, a set of *barriers* and *challenges* are likely to be encountered by companies seeking to improve SCV. These factors can be expected to occur within and outside their organisations. Third, multiple *drivers* demand that companies focus on SCV. Certain drivers are likely to be driven by companies, while others are likely to be demanded by events and external parties. However, both scenarios demand SCV from companies. Fourth, the direct *effect* of SCV is a set of capabilities that will help handle expected and unexpected events related to current operations. Furthermore, these capabilities will help companies transition their supply chains to be more intelligent, predictive and partly or fully autonomous.

After identifying and categorising the factors affecting SCV, the current thesis focused on understanding what supply chain information and data elements are considered important for improving SCV in practice. Study A addressed this by collecting expected supply chain information for SCV from several managers working in Swedish manufacturing supply chains. The findings identified that, to improve SCV in practice, a set of *suppliers, internal operations* and customer-related data must be visible to actors across supply chains. To make informed decisions, supply chain actors need to have visibility in other areas of the supply chain and visualise adequate supply chain information. This was investigated further in study B, which focused on improving inbound logistics visibility through technological solutions. Study B revealed the essential information a potential SCV system is expected to display. In addition, study B showed that technological solutions for improving SCV are expected to analyse and present SCV information in useful ways for supporting decision-making and performance enhancement.

Finally, the current thesis investigated the possibilities and challenges of improving SCV in practice. This was primarily done through study B. Overall, the

possibilities to improve SCV in practice can be achieved by successive translation and mapping of current SCV problem areas into technological solutions for SCV that incorporate both short-term and long-term solutions. Potential SCV systems that are enabled by technological solutions should have built-in functions (such as the ones identified in study B) supporting both current operations and future transitions of supply chains.

Although technology currently is—and will continue to be—a key enabler of SCV, it is important to consider and select technologies based on their specific purposes. SCV demands technologies for data generation (connectivity and collection), data management (handling and storing), and data usage (for current operations and predictive abilities). Paper 3 stated that covering all these aspects in practice, which involves internal flows, external flows, a multitude of processes and stakeholders, can be a limiting factor for SCV. Hence, in addition to technology, improving SCV in practice requires a focus on people- and process-related factors as well. In fact, many of the challenges of improving SCV in practice are associated with people- and process-related factors, as emphasised in study A.

Figure 9. Conditions for and content of SCV, as summarised by the results from the SLR, study A and study B.

6 Conclusions, contributions and future directions

This chapter concludes the current thesis. First, it briefly answers the research questions, which is followed by contributions to academia and practitioners. Finally, the present thesis is concluded by stating the limitations of the research, and future research is then offered.

6.1 Answers to the research questions

RQ1: How can the conditions affecting visibility in supply chains be categorised?
The current thesis identified and categorised several factors affecting SCV, which together provide a multifaceted view of SCV. Primarily presented and discussed through the ABCDE framework in paper 1 and chapter 5, these factors can be categorised into antecedents (A), barriers and challenges (BC), drivers (D) and effects (E). Antecedents consist of people, processes and technology-related factors. Barriers and challenges, as well as drivers, contain the following subcategories: internal operations, customer and market, supplier and supply base and supply chain factors. Finally, effects are broadly divided into capabilities and performance effects; these are interrelated, such that the capabilities contribute to performance effects. An implication of the present thesis, here considering the many antecedents, barriers and challenges, is that SCV seems to be difficult to implement. Simultaneously, the literature has suggested that there are many positive effects of the successful implementation of SCV. Consequently, SCV is important but can be difficult to implement.

RQ2: What supply chain information is considered important for supply chain visibility?
As discussed in chapter 5, the current thesis identified crucial data that are considered important for SCV. The data can be categorised into customer-, internal- and supplier-related data. Regarding customers, deliveries and deviations were ranked the highest. In terms of internal factors, inventory levels and capacity were ranked the highest. Finally, as related to suppliers, purchasing plans and supplier capabilities were considered to be the most important. However, as discussed in chapter 5, it is important to consider that the importance of certain factors will vary depending on the nature of the supply chain and its operations. In addition, SCV demands information and data that are *accessible*, *timely available*, *accurate* and *key or useful* to operations and supply chains.

RQ3: What are the possibilities and challenges of implementing technologies to improve visibility in supply chains?
The current thesis identified that the possibility of implementing technologies for enhancing SCV can be executed by translating current SCV problem areas into technological solutions via business and functional requirements. Mapping SCV

challenges includes mapping problem areas and understanding their consequences. Next, translating SCV problem areas into business requirements includes short-term goals (focus on solving current SCV challenges) and long-term goals (supporting future transition of supply chain). Stakeholders should be involved in both cases. Then, the functional requirements for a potential SCV system should be developed based on business requirements. Finally, the technological solutions fulfilling the functional requirements must be mapped and tested.

The challenges of implementing technologies for improving SCV in practice are, in general, marked by the challenge of synchronising and integrating people, processes and technologies both internally and across supply chains. The present thesis has shown that improving SCV upstream poses challenges to the collaboration of suppliers, various transport solution providers, cross-docks and logistic centres. Related to processes, ownership and conflicting procedures are limiting factors for improving SCV in practice. Finally, identifying technologies providing adequate connectivity and tracking precision in various processes and environments are limiting factors when improving SCV in practice.

6.2 Contributions

The current thesis has confirmed and contributed to the literature on SCV in various ways. First, during a period when SCV has become a key concern for companies and organisations for managing deviations and improving supply chain performance, the current thesis adds to the academic research on supply chains and addresses the need for more research in the area of SCV (Somapa et al., 2018; Swift et al., 2019; Yang et al., 2021; Kähkönen et al., 2021). Second, it contributes to the literature by providing a SOTA understanding of SCV by presenting a framework of factors functioning as enablers, drivers, barriers and effects of SCV. Driven by the content analysis, the framework serves as a meta-analysis of SCV and aids in approaching SCV both holistically and in detail. The findings convey that improving SCV in practice is important yet difficult to achieve. Incorporating many factors is needed to benefit from SCV, leading to both operational and strategic performance. Third, the present thesis confirms and adds to previous research on the technologies for SCV by: i) testing the technologies for improving SCV in a new supply chain setting and ii) enclosing one of the few first studies of introducing alternative technologies for improving SCV. Fourth, the current thesis is among the few empirically exploring those factors influencing SCV, hence generating new insights into why barriers can be difficult to overcome in complex supply chain settings.

The present thesis guides managers and supply chain practitioners seeking to improve SCV in different ways. First, the proposed framework, which contains factors considered enablers, drivers, barriers and effects of SCV, can aid managers with perspectives and factors to consider when discussing, implementing and improving SCV, hence providing researchers with a SOTA review of SCV. The

factors can be used by managers to aid in the discussion, planning and successful implementation of SCV. The results stress the importance of managerial and organisational factors, such as information sharing and interorganisational collaboration, for SCV. Second, the current thesis has provided the supply, internal and customer-related data necessary for SCV. This supports managers in visualising SCV in both the internal and external parts of their supply chains. Third, the current thesis has presented the possible implications of SCV in terms of both capabilities and performance effects. This enables managers to determine how SCV can be used to improve both the operational and strategic performance of their supply chains. Fourth, the current thesis guides manufacturing companies seeking to enhance visibility in their inbound flow, potentially extending visibility in other areas, such as internal and outbound flows.

6.3 Limitations and future research directions

The studies in the current thesis had a number of limitations that must be acknowledged. First, because of the fact that the research was conducted during the COVID-19 pandemic, the author faced numerous challenges. First, some interviews and seminars that were initially planned to be person had to be rescheduled as Zoom and Microsoft Teams meetings. Although the author constantly aimed to double-check and verify the data, it is possible that this affected the quality.

The current thesis has built on the ongoing academic debate on SCV by exploring and structuring the conditions affecting the realisation of SCV. Despite the studies included in the thesis being planned based on the research directions provided by scholars, it is worth mentioning that SCV is still a relatively new research area. Hence, it can be argued that SCV is still under-researched, which then calls for further research.

Paper 1 provided a SOTA summary of the empirical research on SCV by giving insights into the conditions and factors affecting SCV. This was primarily done by developing a framework for SCV that covered four main categories capturing the i) antecedents, ii) drivers, iii) barriers and challenges and iv) effects of SCV. Still, it is important to highlight that the framework itself lacks empirical testing. Therefore, it is possible that potential factors are not represented. This direction is further strengthened by the findings from paper 2, which identified the enablers, drivers, challenges and implications of SCV. Although paper 2 identified factors similar to paper 1, it was not a study aiming to test the ABCDE framework. Furthermore, paper 1 identified certain tensions and interrelationships between drivers and barriers and challenges. Testing the framework can reveal the interrelationships between the factors, such as identifying if a certain driver acts as a stronger motivator than others. Hence, future interview studies addressing all categories are likely to provide more insights and strengthen the reliability and generalisability of the framework. In addition, it is worth mentioning that paper 1 presented a research agenda for future research in the area of SCV.

Both papers 2 and 3 involved the participating managers and project team in considering factors that affect their supply chain, respectively. Paper 2 provided managerial perspectives on SCV, while paper 3 provided the insights of a pilot study at a global manufacturer of transportation systems. However, the scope of both studies was limited to first-tier suppliers. In fact, paper 1 identified the limitation of first-tier suppliers as a barrier and challenge to fully benefit from SCV. Hence, all three papers together motivate further research on the extended supply chain. This is especially important in further identifying the role of SCV in sustainability. In particular, the transition towards circular production is likely to require end-to-end visibility. Therefore, understanding the impact of SCV-based decision making on circularity is vital in supporting the processes in the extended supply chain.

Although paper 3 tested and evaluated technologies for improving SCV in practice, the testing itself was conducted in a controlled environment located at the company site. However, testing the technologies in a real flow is recommended; this will enable further insights regarding the possibilities and challenges of improving SCV in practice. For instance, more research is warranted for ensuring data security while contemplating improving SCV. Study B, which resulted in paper 3, focused on the testing of technologies in response to increased SCV. It must be emphasised that organisational and process aspects are also vital. In particular, both papers 1 and 3 identified that SCV demands a focus on people, processes and technologies. Therefore, testing in a real flow will bring together several supply chain actors, processes and technologies, revealing how these are interrelated and together influence improving SCV in practice.

Altogether, the three papers found that establishing and further improving SCV is likely to depend on an SCV system. Although paper 1 mapped and discussed the theoretical lens applied by previous studies, it is worth mentioning that none of them applied systems theory. Adapting a systems approach can support the further testing of technologies for real-time access to data and create models that cover a multitude of supply variables. Exploring and understanding the dependencies and potential correlations between variables can aid in further developing SCV. In turn, such models can support decision making for supply chain performance.

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Appendix 1

	Question 1
Participant number	**Please describe in your own words what supply chain visibility means to you, your company, and your supply chains. Please provide examples.**
1	To have a high degree of transparency, both map information and physical movements of products, which are shared by all / relevant parties in the current process. When it comes to data, forecasts, order boards and production plans are good to share as much as possible, from both supplier and customer, in one or more stages.
2	What I first think of is the importance of visibility in the material supply / incoming transports with components to our Production. Partly because in some cases we have long lead times of up to 6 months and partly the importance of knowing in the short term what is coming so that we can, if necessary, adjust our production plans accordingly.
3	Visibility In supply chains, then you have access (so not good that it exists) to data on Customers' needs, suppliers' location, capacity and lead time, logistics suppliers' flows, capacity and lead time and all mapped risks available in real time, visually so you can act, plan , customize and wing up in real time. Example: Connection to customers' future real needs breeds material plans / forecasts and is linked to these, so in case of problems you would know which customers would first be affected, e.g. Everything can be planned strategically, tactically and dynamically for maximum resource utilization. Then you see through e.g. event management, real time telematics data or similar always where goods are and what steps are passed, e.g. arrival at terminal or repacked, loaded on ship etc. Everything is monitored automatically and with the help of Advanced analytics and flags deviations or predicts deviations that may happen and like for example. A Control tower or the like can act on.
4	a. For me, this mainly means the ability to connect the stakeholders in a supply chain more deeply than in official business transactions (order, delivery, payment). Seeing needs, changes in needs and inventory levels is a fantastic opportunity that is almost completely unexplored in many parts of the industry. b. For KPRO, close cooperation with customers and suppliers is a key to creating competitiveness as a Swedish contract manufacturer. The ability to set up and maintain systems that

	connect the supply chain can be the USP that cannot be copied or priced easily. The service that the customer experiences is invaluable and a very strong reason to collaborate with KPRO. We have raised this with customers who immediately like the idea but who are not systemically mature enough to closely connect business systems. Instead, it will be forecasts and manual SharePoints that will be an intermediate solution but which also create great value.
5	Supply Chain Visibility is a visualization of the supply chain status with alerts on supply chain issues, primary issues that impact inventory availability or supply chain performance (say, delays in warehouse operations or transportation). This is typically done through solutions that are currently called as "Control Tower". Those solutions would show the existing supply chain networks and visualize the inventory projection situation in all related locations, alerting cases of out of stock. Those solutions will also show cases where, say, deliveries got a new ETA due to delays in transshipment. There are two types of visibility: analytical where the status and issues are being visualized and alerted; or actionable – where the issues might be resolved by modelling solutions, picking the right solution and then sending this solutions to the execution systems. As an example, Australia gets a customer order that is alerted as delayed. The goods are sourced directly from a factory in China, with a specific production and transportation lead time. Analytical visibility will give a view that the order is delayed, possibly – where else this inventory is available so we could relocate it to Australia. Actional visibility - on top of what analytical visibility can do – could also provide a chance to model a situation how this would change in case we, say, add additional shift in production in China, as well as costs associated with such change. In the best of the cases, the visibility would include not only the main supply chain of the organization, but also supply of components (visibility into supply) and existing order stock or inventory at dealers (visibility into point of sales data).
6	For us it mainly means to "connect the islands" in our company. What I mean by that is that our different DCs and factories operate rather independently towards each other (more like a customer-supplier relationship). We are striving to automate and enhance the information sharing and ordering between the internal entities. In practice this means connecting the MRP systems so that if DC A buys from DC B the plan of DC A is directly linked into the input of the MRP for DC B. We regularly share planned purchase quantities with our suppliers to enable them to plan and procure raw materials.

7	To know that the delivery will come as agreed and to receive prompt information about deviations, their nature and when and how the delivery will take place in the event of deviations. I personally see no value in being able to go in and see where in a supplier's flow our order is located. It is a waste to have to spend time on such things.
8	To have a forward-looking process where we steer towards the most probable scenario and through visibility as early as possible identify deviations and problems in order to maintain a good decision-making process with relevant facts and consequences for the alternatives that exist. We work actively and proactively towards the most suitable solution where we actively choose the path and understand the consequences that it entails. For us, it is about capital efficiency, customer value, and risk mitigation.
9	Visibility for us at Scania is a tool for optimization and decision-making. It is also a prerequisite for being able to have autonomous vehicles in our supply chain in the future. With full visibility, we could potentially avoid investments in new warehouses and optimize the surfaces we have today. We would use the information to increase the degree of filling of our transports and thereby reduce our CO2 emissions.
10	Visibility for me is the possibility to e.g. be able to follow delivery times. We must be able to let customers go in and see where their orders are in our manufacturing chain. Another way to show visibility is to show the measurement value and process parameters and the product that the customer has ordered. It creates a sense of security for the customer, they know what they are getting and when they are getting it. This also applies to our suppliers
11	Visibility I see mainly as knowing status vs plan, ie does the flow follow the plan? In the event of a deviation within a given framework, "Andon" is created. We have this at Volvo Cars for collection from suppliers, however, this is unfortunately missing on the remaining flow before it reaches the factory.
12	Visibility is important for Volvo CE, both downstream and upstream. We have worked hard with the life cycle aspect and then good visibility is needed in the supply chain. Upstream, we want control of the supply chain as we place strict demands on our Tier 1 suppliers and we expect them to pass on the same requirements to Tier 2, tier 3, etc. There are also legal aspects to this, such as conflict minerals and want them to fill in CRT and CMRT templates. Material origin is important for Volvo CE and we would like to have control over this and what material we use. In these cases, we are involved beyond tier 1. Downstream, it is very much about customers and the use phase of the products as well as recycling.

13	1. As responsible for an organization that standardizes and develops best practice for the automotive industry, my answers are general assumptions and some findings from experience regarding, in particular, supplier contacts for about 20 years. 2. Around the year 2000, a survey was initiated by several European OEMs, about how long it takes for needs information from OEM to reach Tier 5 and the answer was 5-.8 weeks. Should a deficiency occur at Tier-5 level, it would probably take the same amount of time for the information to reach OEM again, ie 10-16 weeks. Right now, all manufacturers in Europe are suffering from a shortage of semiconductors and this comes as a pretty big surprise to the industry, even when it should be obvious that the increase in sales of smartphones, toads and computers could have predicted the problem. The automotive industry has historically always trusted that you get the material you called for and there is really no warning system when shortcomings occur. The shortage has created production disruptions or even stops throughout Europe. A good example of how lack of visibility (or laziness to find out reality) quickly creates problems. 3. As more or less all vehicles are now tailored to the customer's order, the total number of components is constantly increasing and as the automotive industry insists on using its own (buyer's) part numbers, problems of item confusion often arise, either on the part number itself or on the revision mode of an article. This could be improved by OEMs sharing the configuration of each vehicle in a better way. 4. Visibility and sharing of article data and component composition will be a requirement in a circular economy, as components such as EV batteries (Traction batteries) will be recycled or go to second life. Regardless, it will require information about the battery's composition, content, capacity, etc. We also see that other components such as plastic parts will be recycled to a greater extent in the future and thus that these details are marked with information for recycling / scrapping. These scenarios will also require increased visibility between parties.
21	Visibility for me is the ability to review the status, plans, and trends in the supply chain and trends and changes that affect the supply chain, both upstream to multi-level manufacturing partners and suppliers, and downstream to distributors and system integrators. For me, it is also visibility in what e.g. US

	authorities are planning for changes in regulations that affect the global supply chain.
22	Visibility in supply chains is largely about the control of supply chains itself being about controlling material, information and payment flows from supplier to final consumer. To improve control, in most cases you need to replace layers with information. Information about, for example, future demand, capacity, order volume, inventory development or order status. Part of visibility in supply chains is about making information about demand, capacity, order volume and inventory development visible by creating better processes for demand planning, capacity planning, phasing in and phasing out, etc. Much of this visibility is about making the information visible internally within the company and that everyone functions share the same information in order to make better decisions about the material supply. Another dimension of visibility in supply chains is about making information available / visible to other stakeholders in the supply chain, e.g. suppliers, carriers, etc. In this case, it is often a matter of making information in, for example, the process from order to delivery that an interested party has, for example, the status of a delivery at the carrier visible to other parties, such as customer service or the customer himself. Correspondingly, information on, for example, inventory levels, sales and forecasts can be shared with a company's suppliers in order to improve material supply, for example through supplier-controlled inventories.
23	It is crucial. Strategic: Correct, fact-based decision basis. Limited visibility leads to assumptions. Critical for defining production locations (footprint), insourcing / outsourcing / subcontracting (make or buy) and changes in capacities. Tactical: Allocation decision for above, better forecasting (divide it along the entire supply chain, "not in steps"). Operational: To manage order flows, avoid bullwhip effects, and reduce lead times. We have long purchasing, production and transport lead times, which means that it is critical that we can see end-customer demand at all stages of the chain.
24	For me, visibility means the ability to see what our customers are asking for (volumes of different products), but also to have a picture of our suppliers' ability to meet our needs. Here I refer to factors such as being able to deliver according to an agreed plan, but also to handle volume changes. Knowledge of the suppliers' technical capability is also to some extent part of visibility, i.e. the ability to handle technical challenges such as avoiding / resolving

	quality problems, etc. Also within the company, it is important to have good visibility / control of the situation in order to be able to use the internal resources as efficiently as possible and deliver to the customer as well as possible.
25	Track goods to have control over accessibility from a risk perspective. Wants to be able to consider goods in transit for stock and order planning. Identify possible dependencies in the supply chains, (bottlenecks or "hot-spots") to support strategy decisions regarding redundancy needs etc.
26	Visibility in supply chains is about being able to have a correct picture of and be able to understand the current situation in order to be able to make the right decision about priorities and where changes need to be implemented. The ability to simulate different options - this requires visibility Be able to give everyone in the organization the same opportunity to understand the current situation and the alternatives.
27	The most important thing is to know if we can produce enough finished goods to be able to deliver to our customers. This means that the entire supply chain needs to function, everything from the delivery of raw materials and packaging materials, production capacity in the factories to the delivery to our finished goods warehouses. We currently have three types of finished goods: 1. We produce in our own factories = Here we have visibility in our business system from the delivery of raw materials and packaging materials to the delivery to the customer. We have also started VMI with some packing material suppliers, so we have better visibility there. 2. We buy finished goods = Here we currently have the visibility divided into two systems, a supplier portal where suppliers approve a delivery plan and then purchase orders are registered in the business system when we are informed of the exact deliveries (we are moving to a new system that can send the delivery plans to the business system) 3. We buy finished goods that are our products packed by the supplier = Here we have a gap in visibility, the supplier approves a delivery plan in the supplier portal (same as in point 2) and then they send us an EXCEL file with the need for input materials to be able to pack the plan. We have no idea how much stock or security stock they have.

28	Visibility means that it is possible to see the status of key figures in the supply chain in a clear, correct and easily accessible way (preferably in the form of interactive "dash-boards" and reports) and that in the event of deviations or changes it is easy to "drill down" in current area to make an analysis and identify corrective actions. For example: Scheduled production start of a production order. This has consequences for the entire supply chain, including on purchased material (which is to be postponed or perhaps postponed) and on the delivery of the order. This must be discovered so that information and corrective action can be taken.
29	Transparency & visualization. Using digitalization to establish visual management of the full value chain. Integrated sales, inventory and operations planning to establish reliable and dynamic forecasts. Gaining insight into to the full tier-x supply chain, all the way to “the mine”. Utilizing Transport Management System to track & trace logistics and optimize the network.
30	Supply Chain Visibility is the ability to trace and connect data, information and goods across our end-to-end supply chain, at any given time.

Appended Papers