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Supply chain visibility: A Delphi study on managerial perspectives and priorities

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ABSTRACT

Visibility across supply chains has been a key concern for organisations for many years, but the tools and information systems to achieve real-time visibility have not been available until recently. In response to uncertainty and complexity, advanced information and communication technologies have been explored for supply chain visibility (SCV). However, managerial perspectives are largely absent from the current literature. In response, this paper systematically documents managerial factors influencing SCV and information that should be collected and shared among supply chain partners for better visibility. A multi-stage Delphi analysis was conducted with 26 supply chain experts from various globally recognised enterprises with manufacturing units located worldwide. The results provide details on prioritised managerial perspectives and experiences within (1) factors affecting SCV (drivers, enablers, challenges and contingencies), (2) SCV content (supplier, internal and customer information) and (3) implications of SCV (capabilities and performance effects). One observation was that forecasting is not deemed as important due to severe disruptions in supply chains. Real-time visibility for better predictability emerged as the top priority. This study is among the few that empirically explores factors influencing supply chain visibility and generates new insights into why barriers can be difficult to overcome in complex supply chain settings.

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1. Introduction

In any crisis: decision, speed and accuracy are of the utmost importance for coping with changing realities and can be the difference between success and failure (Handfield and Linton 2017). The pandemic has shown that visibility is required to enable critical decision-making accuracy (Finkenstadt and Handfield 2021; Modgil, Singh and Hannibal 2021). In a study on conflict material disclosures, Swift et al. (2019) found that firms can attain operational and market benefits by improving visibility in their supply chains. If supply chain visibility (SCV) is limited, the supply chain actors must act on incomplete, inaccurate and outdated information that can potentially lead to forecast errors, bullwhip effects, inventories of the wrong size and supply chain disruptions. Such unexpected events can lead to delays in deliveries and reduced materials, productivity and revenue for manufacturing companies across the globe (Yu and Goh 2014).

SCV refers to '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). Organisations find it challenging to prepare the

internal logistics and to quickly respond to unexpected events, due to low inter- and intra-site visibility (Srinivasan and Swink 2018). Collecting and sharing real-time data related to the order process, inventory, delivery and potential supply chain disruptions is not a well-adopted practice in production units (Bregman, Peng and Chin 2015). Additionally, because of low SCV, focal firms find it difficult to monitor all the actors involved in an efficient way. Thus, the visibility of the extended supply chain requires visibility of internal as well as external operations.

Hence, visibility is important for efficient decision-making, but difficult to achieve in practice, making SCV a key concern for organisations. Much of the extant literature on SCV focuses on technological advances, and digital technologies such as artificial intelligence (Modgil, Singh and Hannibal 2021), blockchain (Wang, Chen and Zghari-Sales 2021), cloud-based systems (Giannakis, Spanaki and Dubey 2019) and RFID (van Hoek 2019) have been proposed as important for achieving enhanced visibility through out the supply chain. Though previous studies have contributed to the understanding of SCV on a general level, the managerial perspectives are largely

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absent in the available literature (Somapa, Cools and Dullaert 2018; Calatayud, Mangan and Christopher 2019). To better understand the practitioners' view on SCV, a multi-stage study was designed to address the following research questions (RQs):

RQ1: Which information is crucial to be made visible in a supply chain?

RQ2: What factors affect the implementation of SCV?

RQ3: What are the implications of SCV?

We employed an extensive Delphi study with 26 industry professionals from a variety of manufacturing industries as panel experts to seek their perspectives about SCV. The study contributes to the understanding of SCV by providing broad managerial perspectives. Based on the outcome of the Delphi study, we present a model that links factors affecting SCV, SCV content and implications of SCV. The model captures multiple aspects of SCV that can guide supply chain managers in planning, implementing and improving SCV in manufacturing supply chains. For researchers, it provides an overview of the practical aspects of managing SCV, highlighting the complexity of SCV.

This paper is structured as follows: First, we review the related literature. Second, we describe the Delphi methodology and the approach used in this research. We then present the results of the Delphi study, followed by the discussion section, where we present the SCV model that is based on the inputs from the Delphi study. Finally, in the conclusion section, we answer the research questions, present managerial and research implications, discuss limitations and suggestions for further research.

2. Related literature

Although the area of SCV is relatively new, three latest systematic literature reviews are available: Somapa, Cools and Dullaert (2018), Calatayud, Mangan and Christopher (2019) and Kalaiarasan et al. (2022). Somapa et al. (2018) include articles up to 2016 that focus on the characteristics and effectiveness of SCV. They found that SCV can be grouped into three main characteristics: automational, informational and transformational. Automational characteristics refer to the ability to automatically collect information and transfer it to business partners. Informational characteristics are based on the quality of information in terms of accuracy, timeliness and completeness. Transformational characteristics refer to the use of the information exchanged to enhance the operational and strategic activities of companies. They concluded that most previous studies have focused on either automational and/or informational characteristics,

only a handful incorporating SCV effectiveness into their transformational characteristics.

Calatayud et al. (2019) include articles up to 2018. They propose a supply chain model referred to as the 'self-thinking supply chain'. This was predominantly enabled by Internet of things (IoT) and 'artificial intelligence' (AI) technologies, which make supply chains autonomous and increase predictive capacities. Based on their results, they further claim that IoT and AI are mostly associated with handling future supply chain challenges, supporting businesses in attaining higher levels of visibility.

Kalaiarasan et al. (2022) include articles up to 2020 and propose a holistic framework for SCV driven by the insights from the content analysis of 47 empirical research papers. The framework covered a multitude of factors that either affect or were affected by SCV. In addition, they proposed an agenda for future research directions.

All these reviews call for more research on the managerial and organisational perspectives of SCV. Based on their literature review, Somapa et al. (2018) claimed that challenges to establishing SCV are more related to organisational factors than technological factors. In line with this, Calatayud et al. (2019) encouraged research investigating managerial perspectives on how self-thinking supply chains enabled by SCV might affect aspects of supply chains, such as power, balance and policies. Kalaiarasan et al. (2022) proposed multiple-case or Delphi studies, involving a variety of firms, focusing on understanding which type of data are crucial to be managed for SCV.

2.1. Data elements of SCV

Supply chain visibility (SCV) requires management efforts to collect information about operations upstream, downstream and internally (within business processes) throughout the supply chains (Sodhi and Tang 2019). The extant literature includes a variety of data elements that are considered essential to make visible in the supply chain. These data elements can be divided into two broad areas: internal visibility and external visibility. Internal visibility refers to the collecting, recording and sharing of data within a business' processes. It includes all the means, procedures and elements needed to record and share data along the internal supply chain. Internal tracking takes place when products or raw materials arrive, are stored in inventory and are processed internally in potentially various stages; the end product is then delivered to the customer or an inventory position in the distribution system. It involves an intra-site, real-time visualisation system for material management with tracking

and tracing functionality. External visibility, on the other hand, refers to the products or goods outside of a business entity in the upstream and downstream supply chain; it concerns dynamic status information and the prediction of supply network status among supply chain partners and across different geographical areas. For external SCV to be effective, it relies on the existence and appropriate design of internal visibility in each entity (Somapa, Cools and Dullaert 2018).

2.2. Factors affecting SCV

Previous studies have provided factors to consider when developing and implementing SCV. In essence, these can be divided into two main categories: managerial- and technical/technological-related factors. One factor that demands a managerial perspective is inter-organisational collaboration. Previous studies have accentuated that inter-organisational collaboration is key to increasing SCV (Srinivasan and Swink 2018; Swift, Guide and Muthulingam 2019). Brun, Karaosman and Barresi (2020) indicated that SCV can be achieved through increased collaboration amongst supply chain partners. With regards to inter-organisational collaboration, trust is another major factor affecting the establishment and further improvement of SCV (Dubey et al. 2020). Brun, Karaosman and Barresi (2020) claim that there is a direct correlation between the level of trust and the established SCV. Studies have also pointed out that information sharing is a factor leading to increased levels of SCV. For example, Dubey et al. (2019, 2020) found that investing in and gathering resources to share information can enhance SCV. Furthermore, Barratt and Oke (2007) indicated that the quality of information is important for SCV. It has also been stated that work cultures encouraging information sharing function as a prerequisite to attaining SCV (Doetzer 2020).

Technical and technological factors have been mentioned in both older and more recently published studies. Munir et al. (2020) noted that SCV can be enhanced by external integration collecting reliable and accurate information. Collaborative systems are also presented as technological factors in aiding real-time visibility (Barratt and Oke 2007; Barratt and Barratt 2011). For example, Giannakis et al. (2019) highlighted that cloud-based collaborative systems are key to enabling end-to-end SCV. Technological infrastructure supporting connectivity is another factor considered to be a prerequisite for achieving SCV (Dubey et al. 2019, 2020). The compatibility of IT infrastructure amongst supply chain partners is crucial to ensuring visibility through out the supply chain (Kyu Kim, Yul Ryoo and Dug Jung 2011). In the past, several studies have identified RFID as a key technology

for attaining SCV. Specifically, RFID is key to attaining visibility as goods move along the supply chain (Caridi, Perego and Tumino 2013; Pero and Rossi 2014). Yu and Goh (2014) mentioned that higher investments in RFID are likely to lead to higher levels of SCV. Van Hoek (2019) stated that RFID can coexist with blockchain technology to attain increased levels of SCV. The application of blockchain can improve visibility in areas such as order management (Agrawal et al. 2022) and product life cycle (Liu et al. 2020). Higher levels of SCV can also be attained by combining blockchain with additive manufacturing (Kurpuweit et al. 2021). Based on their studies, Wang, Chen and Zghari-Sales (2021) and Wang et al. (2019) mentioned that blockchain contributes to higher levels of SCV for tracking and tracing.

2.3. The benefits of SCV

The benefits of SCV can be envisioned in two steps: a direct effect in terms of the analytics capability of the firm and an indirect effect on operational performance (Srinivasan and Swink 2018). The benefits reported in other studies fall into either of these two categories. For example, agility (Williams et al. 2013), risk management (Sarker et al. 2016), enhanced decision-making (Handfield and Linton 2017) and planning capabilities (Caridi et al. 2014; Ghasemy Yaghin and Goh 2021) are all examples of analytics capabilities.

The expected improvements in performance through increased SCV can improve cost management. For instance, SCV can aid in the identification and reduction of costs, leading to an overall improvement in supply chain performance (Lee, Kim and Kim 2014; Srinivasan and Swink 2018). In addition, SCV can enhance social (Brun, Karaosman and Barresi 2020) and environmental sustainability (Wang et al. 2019). Both Brun et al. (2020) and Wang et al. (2019) argued that SCV is essential for enhancing combined total sustainability. Furthermore, SCV has a positive effect on customer service (Williams et al. 2013; Caridi et al. 2014) and improves the ability to respond to customer requirements (Swift, Guide and Muthulingam 2019). Ultimately, a higher level of profitability can be gained through increased levels of SCV (Lee, Kim and Kim 2014; Swift, Guide and Muthulingam 2019).

2.4. Synthesis of the literature literature

There is a growing number of published papers on SCV, indicating its importance for extended supply chains. Table 1 summarises the data elements, factors and

Table 1. Summary of data elements, factors and benefits of SCV identified in the literature.

Data elements of SCV	Factors affecting SCV	Benefits of SCV
Internal visibility: - Inventories - Products - Processes	Managerial: - Culture - Information sharing - Inter-organisational collaboration - Trust	Analytics capability: - Agility - Decision-making - Planning capabilities - Risk management
External visibility: - Dynamic status - Prediction of status - Products in the upstream and downstream supply chain	Technological: - Additive manufacturing - Blockchain - Collaborative systems - Compatibility of IT infrastructures - Connectivity - Information quality - RFID	Operational performance: - Customer service - Profitability - Responsiveness - Sustainability (economic, social, environment)

benefits of SCV that are identified in the literature and discussed in sections 2.1–2.3. However, the extant literature for instance, Somapa, Cools and Dullaert (2018), Calatayud, Mangan and Christopher (2019) and Kalarasan et al. (2022), predominantly focused on the technological aspects of SCV and did not thoroughly explore managerial perspectives on how to deal with SCV, such as identifying or prioritising factors or understanding the benefits and requirements of implementation. Still, some studies have acknowledged that it is up to the managers to understand the merits of SCV and make decisions about its implementation. However, we still lack a thorough study on the managerial aspects of SCV, which this study addresses.

3. Delphi methodology

This study followed a Delphi method to address the research questions. Developed by Dalkey and Helmer (1963) at the Rand Corporation, Delphi is a well-established methodology used to collect expert-based empirical data to attain consensus on multifaceted and multidisciplinary questions. In this systematic approach, a group of experts—with extensive experience in the subject under study—interact anonymously in multiple rounds. The rounds continue until a saturation point or consensus is reached among the experts. Responses from each Delphi round are used as input to the next round in the form of the aggregate response. During each round, the experts can reflect on and change their responses. This helps in avoiding adverse effects related to interpersonal biases, dominating personalities, defensive attitudes and unproductive disagreements. Delphi research also creates opportunities to gain valuable insights from practising managers/industry experts and is suitable for exploratory theory building. In the

Table 2. The Delphi methodology followed in the study.

Step	Delphi methodology description	Purpose
1	Expert selection	Ensuring adequate representation of manufacturing firms and experts with extensive relevant knowledge
2	First round: exploring the issues related to SCV	Using open ended questions to eliminate possible bias and create a list of factors to consider
3	Second round: reaching an understanding	Validating the findings from first round and filtering out important factors for further study
4	Third round: quantifying the impact of different factors	Quantifying and ranking the factors on a numeric scale
5	Fourth round: focus group seminars	Collecting commentary inputs to gain better insights related to the results from the third round and to gain insights with 'why' and 'how' questions

first round, the experts traditionally answer open-ended questions that stimulate extensive, descriptive, independent and associative responses enabling the generation of new concepts. In consecutive rounds, either the open-ended approach can be repeated or (more often) the experts rank or rate previously derived constructs in several dimensions. As a consensus-based Delphi approach is deemed suitable for analysing the evolution and potential implications of new phenomena, this study follows the method of examining and understanding factors that influence SCV, especially after the pandemic. In the past, Delphi-based approaches have been adopted in various research studies for needs assessments, policy development and forecasting (Ogden et al. 2005; Melnyk et al. 2009). In supply chain management, applications of the Delphi approach are found in studies investigating factors that influence decision making (see, e.g. Agrawal and Pal 2019; Kembro, Näslund and Olhager 2017; Hassan et al. 2015). Therefore, the Delphi approach is appropriate for exploring the factors that influence SCV and crucial information sets made visible in a supply chain. Other methods—for instance, surveys—tend to use a very limited set of items to describe SCV factors. In addition, some literature discusses factors that affect SCV, while other works discuss the effects of having SCV in place. To the best of our knowledge, there are no studies that focus on the managerial perspective on SCV, which forms the motivation for this research and for using a Delphi study to capture the perceptions of industrial supply chain experts. This study follows a four-round process, as shown in Table 2 and discussed in the following section.

3.1. Expert selection

We followed the general guidelines for Delphi studies (Melnik et al. 2009; Kembro, Näslund and Olhager 2017)

to set up an appropriate panel to ensure the validity of the results. The experts should have extensive experience and knowledge related to the specific issue under study. We invited senior supply chain executives from large and medium-sized 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 at least 10 years of experience in global SCM. Overall, 34 SCM practitioners were invited, and 26 agreed to participate in the Delphi expert panel. They represented a variety of industries: aerospace, automotive, fast-moving consumer goods, food and beverage, forest and garden equipment, furniture, heat transfer, heavy industrial goods, optoelectronics, packaging, steel and telecommunication. An overview of our 26 panel experts is provided in Appendix A. This number is in the recommended range for Delphi studies, as less than 20 risks individual biases while more than 30 sometimes generates few additional insights and limits the exploration of insights that emerge (Ogden et al. 2005; Agrawal and Pal 2019).

3.2. First round: exploring the issues related to SCV

The first round consists of open-ended questions: (i) 'Please describe in your own words what supply chain visibility means to you, your company and your supply chains. Please provide examples', (ii) 'Why is supply chain visibility important to your company and your supply chains?', (iii) 'What factors affect the visibility of your supply chains and how?' and (iv) 'Is there anything else that you think is important in the context of supply chain visibility that you would like to add?' The first three questions refer to three fundamental perspectives on SCV and are linked to the three research questions addressed in this study. The questions were easy to comprehend, thus avoiding ambiguous responses. No supporting information or framework concerning SCV (e.g. from the available literature) were provided to the panelists in an attempt to avoid guiding the respondents in a particular direction.

For the first, second and third rounds, experts were given three weeks, in each round, to respond, directly by email or through the attached Microsoft Word documents. Reminders were sent every week, and the researchers' details were provided in case of any queries. The responses were analysed individually by the four researchers (one PhD student, one postdoctoral researcher and two professors) to identify potential themes and categories. Coding was compared, and in most cases, there was full agreement among the researchers. Differences in interpretations were thoroughly re-examined and resolved in consensus.

3.3. Second round: reaching an understanding

Based on the responses from the first round, an exhaustive list of factors and crucial SCV information were compiled in a Word document. Information was categorised under three headings: information concerning 'market and product', 'internal' operational data and 'supply' data. Factors were categorised into those affecting SCV, that is, 'enabler', 'drivers', 'barriers/challenges' and 'contingencies', and those concerning the implications of SCV, that is, 'capabilities' and 'performance'. Experts were asked to indicate the factors and pieces of information that they considered 'important' for SCV and those that they considered 'not important'. Provision for commentary input was provided with each factor and piece of information. The responses were analysed for each factor and piece of information by counting the number of experts that indicated 'important', 'not important' or 'no response'. Based on the results, an understanding was reached concerning the important factors and pieces of information (those with a high number of 'important' counts), while the factors and information with a high number of 'not important' counts were eliminated from further consideration (see Appendix B).

3.4. Third round: quantifying the impact of different factors

In the third round, experts were asked to rate the factors and information on a Likert scale of one to seven. For data/information, enablers and drivers, we asked the experts to rate how important each factor is for SCV (1 = not important and 7 = very important). For capabilities and performance effects, we asked the experts to rate how each factor is likely to be affected by an implementation or improvement of SCV (1 = not at all affected and 7 = extremely positively affected). Similarly, for barriers/challenges, we asked them to rate how difficult (or impossible) it is to overcome and solve a factor in implementing SCV (1 = not even a challenge and 7 = barrier). Finally, for contingencies, we asked how important SCV is in these situations (1 = not important and 7 = very important) and how feasible (1 = infeasible and 7 = very infeasible) it is to achieve a successful implementation of SCV in these situations. The responses were analysed for each factor and piece of information by calculating the mean and standard deviation. Based on the results, factors and information were ranked from highest to lowest. Again, factors with very low ratings were dropped (see Appendix B).

3.5. Fourth round: focus group seminars

As a fourth round, two focus group seminars were organised to facilitate maximum participation. During the

webinar, the results from the third round were presented. Special emphasis was given to factors with high standard deviation to understand the possible causes of dispersed responses. This was followed by a discussion on supply chain visibility to allow for knowledge- and experience-sharing among experts from various leading manufacturing companies. The input from the seminars was transcribed and used as supporting arguments while discussing the results.

4. Results

In this section, we present our findings from the Delphi study. The structure draws on the collective findings from the four rounds in the Delphi study and is broadly divided into managerial perspectives and experiences within three areas, as illustrated in Figure 1.

We first present the content of supply chain visibility, that is, the set of data for which visibility is important along the supply chain, as perceived by the Delphi experts. We then present the factors that affect SCV and, finally, review the implications of SCV. In each section, we discuss the factors that the expert group identified in this study (from stages 1 and 2) and the quantitative results that provide the relative impact of the various factors (from stage 3).

4.1. Data for which visibility is important

After examining the results of the first Delphi round, data elements that are crucial for SCV could be divided into three categories: customer-related, internal and supplier-related. To avoid complexities, we included only the most important elements. These elements were further filtered as per the results of the second round, and only the most important ones were carried forward to the third round. Table 3 summarises the crucial data elements in the three categories obtained in the third Delphi round. The elements appear in descending order of importance within the category, based on the mean rating obtained from the experts. The element with the highest mean is perceived as the most crucial data element for SCV.

These data elements are crucial, and actors should make efforts to capture them internally and share them externally among actors through a common database to attain the desired positive impacts of SCV. This was supported by experts, with one of the experts mentioning the following: 'Visibility is about having the same information as your partners in the SC at the same time. It is also about having good tools to visualise forecasts, plans and orders. A good BI [business intelligence] tool with the same information is key to analysing the current status and the future. Common SC master data is important.' It

Table 3. Data elements that are important for supply chain visibility.

Categories and factors	Description / Examples	Mean (Std. dev.) *
<i>Customer-related factors</i>		
Deliveries	Follow the status of the delivery process, to inform customers if needed	6.10 (0.83)
Deviations	Prompt information about deviations and their nature	6.05 (1.12)
Orders	Content and status of customer orders	6.00 (1.00)
Demand	Customer demand, incl. end customer demand	5.86 (0.73)
Forecasts	Sales forecasts	5.67 (1.11)
Country of origin	Establish material origin, to communicate to customers	5.14 (1.90)
<i>Internal factors</i>		
Inventory levels	Inventory levels at all locations	6.24 (1.22)
Capacity	Production capacity in all factories	6.10 (1.09)
Lead times	Production and transportation lead times	6.05 (1.07)
Production plans	Sharing internal production plans with suppliers and customers	5.62 (1.07)
Safety stocks	Security levels at stock points	5.29 (1.59)
<i>Supplier-related factors</i>		
Purchasing plans	Share planned purchase quantities with suppliers	5.76 (1.14)
Supplier capabilities	Supplier capacities, technical capabilities, and VMI experience	5.71 (1.38)
Supply	Follow the status of incoming material supply	5.57 (0.98)
Supplier location	Manufacturing and inventory locations for suppliers	5.24 (1.73)
Track and trace	Track and trace goods from the origin	5.24 (1.45)

* Scale: '1' = unimportant, and '7' = extremely important.

can be observed from Table 3 that information related to deliveries, deviations (customer-related), inventory levels, capacity, lead time (internal), purchasing plans and supplier capabilities (supplier-related) got high ratings and was considered very crucial for better SCV. As per an expert, 'Part of visibility in supply chains is about making information about capacity, lead time, order volume and inventory development visible by creating better processes for demand planning, capacity planning, phasing in and phasing out, etc. Another dimension of visibility in supply chains is about making information available and visible internally within the company and to other stakeholders in the supply chain, e.g. suppliers, carriers, etc.'

Regarding customer- and supplier-related data, one of the experts mentioned the following: '[For] visibility in supply chains, you should have access to data on customers' needs, suppliers' location, capacity and lead time, logistics suppliers' flows, capacity, lead time and all mapped risks available in real time visually so you can act, plan, customise and wing up in real time'. Another expert added: 'Visibility means that it is possible to see

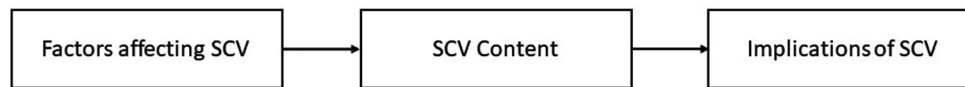


Figure 1. Input-output model of supply chain visibility (SCV).

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 areas to make an analysis and identify corrective actions. For example: [the] scheduled production start of a production order. This has consequences for the entire supply chain, including on purchased material which is to be postponed and also on the delivery of the order. This must be discovered so that information and corrective action can be taken.’

4.2. Factors affecting SCV

The Delphi panel identified a broad set of factors affecting SCV, which the research team categorised into four themes: drivers, enablers, challenges and contingency effects. The themes are presented in separate sections.

4.2.1. Drivers of SCV

Drivers are factors that cause a specific phenomenon to happen, grow or develop. Experts listed several drivers for SCV. The less important ones were eliminated in the second Delphi round. Table 4 lists all the important factors driving SCV in manufacturing SC. These are arranged in descending order of their importance based on the mean rating obtained from the experts.

Among these, managing deviations in SC and improving SC control emerged as the most crucial drivers of SCV. Some of the experts even had detailed thoughts and comments in relation to the same. They mentioned, ‘To know and understand the full value chain [through SCV] gives you the possibility to make proactive initiatives instead of reactive. Supply chain risk management has become increasingly important, given the recent years’ development with trade barriers, pandemic natural disasters etc.’, and ‘Through [SCV], as early as possible, [we] identify deviations and problems 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.’

One of the experts mentioned that better SC control is essential for the legal aspect that drives SCV: ‘Visibility is important for [our company], both downstream and

Table 4. Drivers for supply chain visibility.

Factors	Description / Examples	Mean (Std.dev.)*
Managing deviations	Detect deviations early and act accordingly	6.10 (1.09)
SC control	Control material, information, and payment flows from supplier to final customers	5.90 (1.00)
Customer service	Making information available and visible to stakeholders, including customers e.g. customers know where their goods are and when they will arrive	5.86 (1.06)
Decision-making support	Fact-based decision for operations and strategic activities	5.76 (1.09)
Sustainability: Economic	Profitability	5.48 (1.12)
Risk management	Know and understand full value chain to make proactive decisions, control from a risk perspective	5.38 (0.92)
Sustainability: Environmental	Circular economy	5.33 (1.11)
Sustainability: Social	Corporate Social Responsibility (CSR)	4.67 (1.39)

* Scale: ‘1’ = unimportant, and ‘7’ = extremely important.

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.’

It was interesting to observe that despite so many ongoing efforts and discussions around sustainability and overall sustainable industrial transformation, factors concerning sustainability still received relatively low ratings. The reasons, as perceived by the experts, were that (a) sustainability-related factors should be considered as performance effects rather than drivers, and (b) sustainability factors are related to processes rather than data-driven. As explained by one expert, ‘I believe that [sustainability-related factors] will be kind of covered anyway in the new processes [we implement], so they are kind of secondary [for us]. We will have them anyway because we are building things in this new circular process that will take care of the sustainability issues’.

4.2.2. Enablers for SCV

Enablers are factors that make it possible for a particular phenomenon to happen or be done. The experts

Table 5. Enablers for supply chain visibility.

Factors	Description / Examples	Mean (Std.dev.)*
Data quality	Data resolution, accuracy, consistency and timeliness	6.38 (0.74)
Information sharing	Willingness to share information, share real-time information	6.29 (0.72)
Top management support	Supply chain and senior management support to establish visibility system	6.19 (0.87)
Trust	High degree of trust	6.10 (1.04)
Inter-organisational collaboration	Collaboration with supply chain partners for long-term and reciprocal relationships	5.86 (0.85)
Common SC master data	Master data setup with strong information and data management capabilities, establish common language	5.62 (1.43)
Connected/integrated systems	System integration and support to create visibility	5.52 (1.25)
Standardisation	Develop system in a standardised way for usage e.g. have a harmonised definition of data fields	5.52 (1.03)

* Scale: '1' = unimportant, and '7' = extremely important.

listed several enablers that facilitate SCV implementation. Table 5 lists all the crucial enablers for SCV. They are also arranged in descending order of their importance based on ratings from the experts.

Data quality and information sharing are the top two enablers for SCV. As one of the experts highlighted, 'When you get information, the resolution of the information and how accurate it is [plays a crucial role]. There should be a balance between these information attributes and the inherent variance that exists in the various activities and processes. For example, detailed information needs to be accurate to be meaningful; the information should at the same time come within the reaction time to generate maximum value.'

Regarding information sharing, one of the experts stated, 'For us, it [SCV] mainly means to 'connect the islands' in our company. What I mean by that is that our different distribution centres 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.'

Trust is another important enabler identified by one expert: 'To be able to gain visibility in the supply chain, you need to gain trust from the suppliers, build a win-win relationship with your strategic partners. When you have trust, it's easier to share information between buyers and suppliers'.

4.2.3. Challenges to SCV

Factors considered to be challenges require great effort to be completed successfully, whereas barriers simply block

something (in this case, SCV) from happening. Table 6 summarises all the factors that are considered challenges for implementing SCV. As indicated in the table, a score of '1' signifies a factor that is not even considered a challenge, whereas a score of '7' is considered a barrier. The third column indicates the number of experts who marked the factor as a barrier. Although most experts do not think that these factors are barriers, at least one expert perceives a factor to be a hindrance to SCV.

Many of the experts stated that the main barriers to SCV are a lack of standardisation, SC complexity, a lack of IT infrastructure and an unwillingness to share data. Lack of standardisation is the top challenge for implementing SCV systems. As the product moves along the stages of the supply chain, standardisation becomes a vital element for effective data sharing and technology integration. As mentioned by one expert, 'If visibility means being able to "see" the supplier's supply chain, or my order's position against the plan in it, then that possibility is today greatly affected by existing IT systems that are rarely or never created for visualisation in this dimension'. Considering the many factors that act as challenges, creating successful SCV in practice seems like a most difficult task.

4.2.4. Contingency factors for SCV

Three contingencies were identified as important by the Delphi panel: customer order decoupling points (CODP)- Made-to-Stock (MTS) vs. Made-to-Order (MTO), supply chain complexity (low vs. high) and supply chain geographical dispersion (local vs. global). Supply chain complexity refers to the number of nodes, tiers, connections, etc., that need to be managed. The Delphi experts were asked to rate the *importance* (value) of having SCV in each situation as well as the *feasibility* of achieving SCV in each respective situation. Importance was rated along a seven-point scale, from '1' = unimportant (no value) to '7' = extremely important (extremely valuable), and feasibility was rated from '1' = infeasible to '7' = very feasible. The results, displayed in Table 7, show an interesting pattern. The two situations connected to a contingency factor (e.g. low versus high complexity) are rated inversely such that one is associated with a higher level of importance but a lower level of feasibility than the other. This holds true for all three contingency variables. This result is illustrated in Figure 2, where importance and feasibility are displayed as two dimensions.

4.3. Implications of SCV

Finally, we present the management perspectives on the implications of SCV. From the expert comments in the Delphi study, we concluded that the implications can be

Table 6. Factors acting as challenges to supply chain visibility.

Factors	Description / Examples	Mean (Std.dev.) *	# Indicated as barrier
Standardisation (lack of ...)	Lack of standardised tools, systems and technical standards	5.05 (1.18)	3
SC complexity	Global complex supply chains with long lead times, several warehouses, heavy and bulky products, large product portfolio	4.85 (1.23)	1
IT infrastructure (lack of ...)	IT systems that are rarely or never created for visualisation	4.75 (1.29)	3
Willingness to share data (lack of ...)	SC partners do not want to share information with others with respect to fear of losing information advantage	4.70 (1.84)	4
Data from multiple sources	Data coming from many different IT solutions and in different formats need to be mapped in the right way	4.60 (1.47)	1
SC competence (lack of ...)	E.g. Competence to develop methods and IT support to provide to businesses that will maintain and improve supply chains	4.47 (1.17)	1
Organisational culture	Silo thinking, Conflict of interest	4.35 (1.46)	2

* Scale: '1' signifies a factor that is not even considered a challenge, '2' represents a minor challenge, '4' a medium challenge, '6' a major challenge, and '7' is associated with a barrier.

Table 7. Contingency variables for supply chain visibility.

Context and factors	Importance Mean (Std.dev.)	Feasibility Mean (Std.dev.)
<i>Customer order decoupling point</i>		
Make-to-order	6.15 (0.88)	5.55 (1.28)
Make-to-stock	5.15 (1.46)	5.80 (1.15)
<i>SC complexity</i>		
Low	4.10 (1.29)	6.20 (0.89)
High	6.00 (0.97)	4.90 (1.41)
<i>SC geographical dispersion</i>		
Local	4.55 (1.19)	6.20 (0.89)
Global	6.20 (0.89)	5.00 (1.38)

categorised into two sub-groups: capabilities and performance effects. The relationship between capabilities and performance effects is such that capabilities refer to the

possibilities of utilising the data made visible through SCV effectively and efficiently, which in turn can lead to a better performance. Consequently, capabilities can be regarded as a direct effect, while performance as an indirect effect of SCV. Table 8 presents the effect factors divided into the two sub-categories of capabilities and performance effects.

The key capabilities identified by the panel experts are concerned with forward-looking planning and control: predictive capability, decision-making support, supply chain control and planning capability. These four factors score between 6.10 and 5.65 on the 7-point scale. One expert emphasises the forward-looking aspect: 'Supply chain visibility is an integral part of reaching a truly connected supply chain, which is one of our strategic

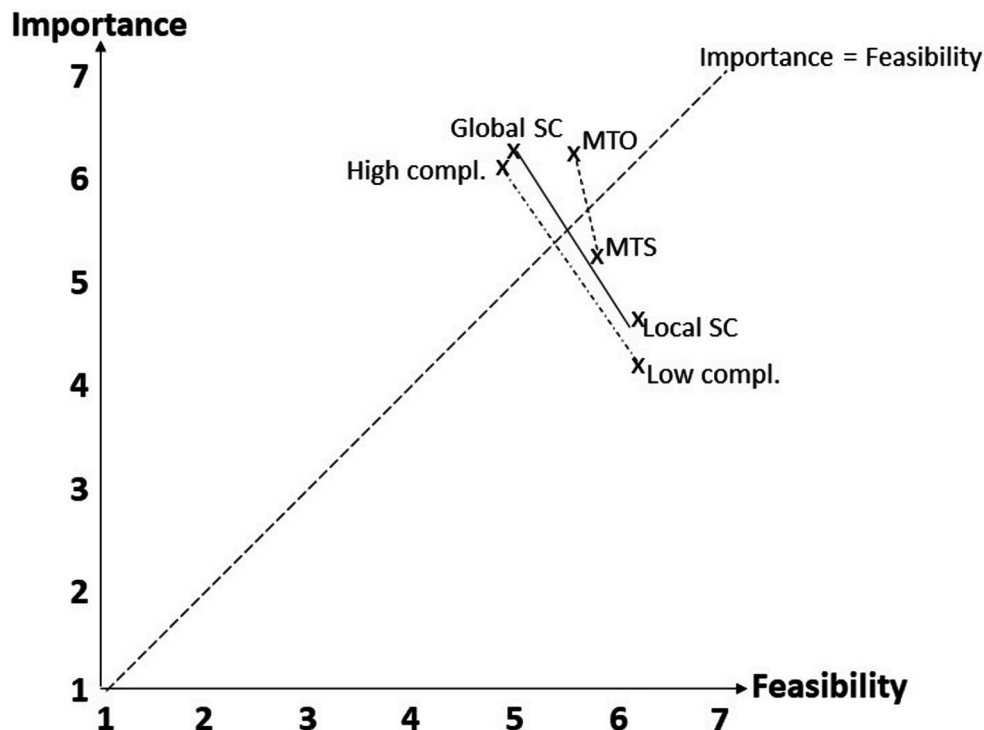
**Figure 2.** Importance versus feasibility for contingency variables.

Table 8. Effects of supply chain visibility.

Categories and factors	Description / Examples	Mean (std.dev.) *
<i>Capabilities</i>		
Predictive capability	Early prediction of deviations, disturbance and disruptions and capability to act accordingly	6.10 (1.02)
Decision-making support	Correct, fact-based decision e.g. being able to have a correct picture and able to understand the current situation in order to make the right decision about priorities and where changes need to be implemented.	5.95 (1.23)
SC Control	Control of supply chains i.e. controlling material, information and payment flows from supplier to final consumer	5.70 (1.17)
Planning capability	Planning strategically, tactically and dynamically for maximum resource utilisation	5.65 (0.99)
Risk management	Early and timely detection of changes in the supply chain for effective mitigation actions	5.60 (0.99)
Traceability	Track and trace ability e.g. for securing responsible sourcing and being transparent to customers.	5.60 (1.50)
Optimisation and simulation	Ability to build and simulate scenarios to thereby identify bottlenecks	5.55 (1.15)
Forecasting	Ability to effectively calculation or estimate of future sales	5.20 (1.01)
<i>Performance effects</i>		
Customer service	Making information available and visible to stakeholders, including customers e.g. customers know where their goods are and when they will arrive	6.10 (0.97)
Sustainability: Economic	Profitability	5.40 (1.05)
Flexibility	E.g. Possibility to reschedule and reorganise production to avoid disruptions due to missed / delayed deliveries.	5.25 (1.21)
Lead time reliability	More accurate production and transportation lead times	5.20 (1.01)
Sustainability: Environmental	Circular economy	5.20 (1.15)
Sustainability: Social	CSR	4.40 (1.27)

* How is each factor likely to be affected by an implementation or improvement of SCV? Scale: '1' = not at all affected, to '7' = extremely positively affected.

movements in the coming years, as it will make us better equipped for addressing future challenges, identifying new opportunities and delivering even more value to our customers'. Just below the general planning and control capabilities on the ranking in Table 8, we find two specific areas—risk management and traceability—which have received increasing attention during the pandemic and will most likely continue to be two key areas in

which SCV can be beneficial. This is emphasised by one expert: '[There is an] increasing importance of supply chain risk management, given the developments with trade barriers, the pandemic, natural disasters, etc. in recent years. It is important to know and understand the capacity availability in sub-tiers; one recent example is semi-conductors'.

The highest-ranking factor of the performance effects was customer service, which scored 6.10. Many experts rated it a 7, and one expert highlighted that customer service is the overarching goal: 'Everything collapses to customer service'. Of the three dimensions of sustainability, social sustainability (4.40) is ranked lower than economic sustainability (5.40) and environmental sustainability (5.20), which reflects the historical development of these sustainability goals. Nevertheless, one expert exemplifies the importance of the social aspect: 'For sustainability and CSR reasons, knowing how and where your ingoing components and raw materials are produced is important'.

5. Discussion

Our Delphi study systematically explored the perspectives that managers perceive to be relevant to SCV in one way or another. Figure 3 displays the outcome of our Delphi study in terms of a conceptual model. It includes the subcategories drivers, enablers, challenges, contingencies, content, capabilities and performance effects (from left to right in Figure 3).

The model informs that there is a multitude of factors that affect SCV, and thereby the content and expected outcome of SCV. By combining the individual contributions from 26 panel experts, the SCV model captured the extant managerial perspectives on and priorities in SCV.

5.1. Factors affecting the SCV

The study showed that many factors affect SCV. The key drivers for SCV are managing deviations (Ghasemy Yaghin and Goh 2021), executing supply chain control and providing better customer service (Caridi et al. 2014). Moreover, in terms of enablers for SCV, data quality (Barratt and Oke 2007), information sharing (Dubey et al. 2020), top management support, trust (Brun, Karaosman and Barresi 2020), and inter-organisational collaboration (Swift, Guide and Muthulingam 2019) are considered the most important. It is worth observing that most of the soft factors such as top management support, trust and collaboration are perceived as key enablers for SCV by the managers. This is contrary to the findings from the available research literature (Kalaierasan et al. 2022) that instead highlights hard factors such as

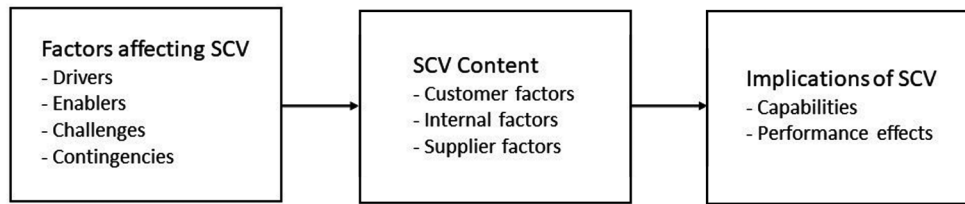


Figure 3. SCV model of factors to consider.

technology as the key enabler. Nonetheless, there are certain major challenges, such as a lack of standardisation (Klueber and O’Keefe 2013) and supply chain complexities (Brun, Karaosman and Barresi 2020), that are perceived as barriers to implementing SCV. Due to the involvement of multiple partners, most located in distinct geographical locations and using a variety of information management tools, it becomes challenging to share information. Many organisations (e.g. Odette for the automotive industry) are working towards standardising information-sharing tools and protocols.

5.2. SCV content

The study led to an argument that complete SCV entails data elements related to customer, internal and supplier being visible among the supply chain actors. Customer-related information concerning deliveries and deviations was among the most crucial for SCV. The experts gave it a high rating with a low standard deviation in the mean response, depicting a strong agreement among the respondents. The results are quite evident in the pandemic, as up-to-date deliveries and deviation information helps supply chain managers plan operational activities to ensure smooth production and material flow within the supply chain. This supports the findings of Swift et al. (2019). Concerning internal data elements, inventory level and capacity information are deemed crucial to ensure smooth production and on-time delivery. Finally, supplier-related information concerning purchasing plans and supplier capabilities is perceived as important, as it helps in strategic sourcing. An example of this is the recent semiconductor crisis, where insufficient visibility in supplier operations resulted in a major disruption in production at the buyers’ end. Nevertheless, information concerning ‘country of origin’ and ‘track and trace’ received comparatively low ratings and high standard deviations, which implies that this information was perceived as relatively less important by experts. On the other hand, due to high standard deviation, it is also notable that there is a high range of variation among the ratings. Upon further discussion with experts, we found that these data elements are crucial for some supply chains—for instance, textile (Agrawal and

Pal 2019), pharmaceutical (Chiacchio et al. 2020) and food (Doukidis, Pramataris and Kelepouris 2007)—where traceability and knowledge of product origins is a major concern; meanwhile, other products, such as, for example, automotive and steel products, have well-established supply chains with close buyer-supplier relationships, and traceability is crucial for product recall (Dai et al. 2021).

5.3. Implications: capabilities and performance effects

The experts highlighted several capabilities and performance effects as implications of SCV. Predictive and planning capabilities (Ghasemy Yaghin and Goh 2021), along with decision-making support (De Giovanni 2020), were among the highest-ranked capabilities that the experts perceived to be gained by organisations due to SCV. Recently, these capabilities have been among the most crucial ones following the pandemic, Suez Canal incident and semiconductor crises. Companies are suffering considerably, and SCV has emerged as an important solution that can help organisations develop resilience by having better predictive capacity and control over supply chains. It was also interesting to observe that forecasting, which has been among the key capabilities gained by SCV, as per the literature, is not currently as important due to the severe disruptions in the supply chains. The experts believe that, even after effective forecasting and inventory control, production has been disrupted due to bad predictive capabilities. Real-time visibility for better predictability and decision support is salient. In terms of performance, customer service (Swift, Guide and Muthulingam 2019) and economic sustainability (Dubey et al. 2020) are ably guaranteed by SCV. With SCV, organisations can better understand customer demand and provide better services. Similarly, SCV contributes to effective resource utilisation and better productivity, thus resulting in better profitability and cost savings.

5.4. Interrelationships and contexts

We observe a connection between enablers and challenges, as well as between drivers and effects. Factors

related to data appear both in enablers (data quality, common master data) and challenges (data from multiple sources). In fact, 'standardisation' was mentioned both as an enabler and challenge (the challenge was captured as 'lack of standardisation'). Experts mentioned that standardisation is one of the key elements to facilitate SCV. However, much needs to be done with existing data capturing and sharing systems to allow interoperability. Thus, if an enabler is not in place, it becomes a challenge.

There is a strong relationship between drivers and effects. All drivers are also cited as expected effects of SCV—either as a capability or performance outcome. The top driver 'managing deviations' is related to the top capability 'predictive capability', while the other driver-effect combinations are identical, such as 'supply chain control', 'decision making support' and 'risk management' as drivers and capabilities, and 'customer service' along with all aspects of sustainability as drivers and performance outcomes. This is natural, since any attempt to initiate or improve SCV should include the perception that one or more capabilities and/or one or more performance measures should improve.

The results on contingencies (displayed in Table 7 and Figure 2) shows two types of contexts: one where SCV is more important than feasible (MTO, high complexity and global supply chains) and one where SCV is more feasible than important (MTS, low complexity and local supply chains). The first context is characterised by a higher level of complexity and uncertainty, which makes SCV important—at the same time, however, it may be difficult to implement it. The second context is related to lower levels of complexity and uncertainty, which may not require SCV due to the simple nature of the situation—even though SCV could be implemented. This finding suggests that there may be a tension between importance and feasibility, such that SCV is difficult to implement in important contexts, and that the feasible contexts do not require SCV due to contextual simplicity. It will be important to report on these three contingency variables (at least) when the context of an SCV implementation's success is reported to improve our understanding of when and how SCV can contribute.

6. Conclusions

6.1. Answering the research questions

We addressed three research questions. RQ1 aimed to explore crucial information that should be made visible in a supply chain. We found multiple data elements and categorised them into three groups: customer-related, internal and supplier-related data, and listed them in their order of importance as perceived by the experts.

The top priorities were data on deliveries and deviations (customer-related), inventory levels, capacity, and lead time (internal) and purchasing plans and supplier capabilities (supplier-related).

RQ2 targeted the factors that affect the implementation of SCV. These were categorised as drivers, enablers, challenges and contingencies. These were further refined and prioritised to identify the most important ones and to examine potential relationships among them. Managing deviation (driver), data quality (enabler) and lack of standardisation (challenge) were the top priorities. The view on contingencies suggests that there is a tension between importance and feasibility; SCV is less feasible in important contexts, but more feasible in less important contexts.

Finally, RQ3 aimed to explore and examine the implications of SCV. We answered the question by exploring various effects of SCV. Predictive capability and customer service (performance) effects were among those with high rating and effects perceived as important by the experts.

6.2. Managerial implications

This study can function as a reference point for managers. In particular, the SCV model provides useful insights to supply chains and logistics managers by providing managerial perspectives on SCV gathered from various industries, such as automotive, aerospace and telecommunication. First, the factors categorised as enablers (eight factors), drivers (eight), challenges (seven) and contingencies (three) can be used by managers to aid the discussion, planning and implementation of SCV. These different categories help managers to gain a holistic view of the factors or intricacies relating to SCV. It is also important for managers to understand that all factors identified do not necessarily have to be relevant in a particular practical situation. Nevertheless, the rating of factors and commentary inputs from experts would facilitate developing a customised SCV implementation strategy for their company. Managers should also recognise and understand that tensions between importance and feasibility can affect the willingness to attain higher levels of SCV. Secondly, the SCV model captured 16 prioritised data elements that should be displayed in a potential SCV system. It further communicates to managers that to fully benefit from SCV, a multitude of factors that are customer-, internal- and supplier-related have to be made visible. This information supports managers in decision making and facilitates proactive actions by providing insights regarding SC deviation to visualise for manufacturing supply chains. Third, the SCV model presents the possible implications of SCV in terms of both capabilities and

performance effects that might not previously have been identified by the firm. This enables managers to determine how SCV can be used to improve both the operational and strategic performance of their supply chains and how vital SCV is for well-informed decision making to achieve the desired outcomes in terms of performance and capabilities.

6.3. Research implications

This research provides a state-of-the-art view of the practical issues of SCV. Most recent publications focus on technical and technological factors. Our study adds to the extant literature on SCV by providing empirical evidence on managerial perspectives. Furthermore, it identified new factors to consider for the planning, implementation and management of SCV. In particular, the factors can be used in survey research as a baseline for developing items and combining items into constructs. Together with previous studies, the results illuminate how SCV can support decision-making in practice. In the midst of the pandemic and digitalisation era, the identified implications of SCV also serve as guidance points for attaining both supply chain sustainability and resilience. Moreover, reflecting on a possible theoretical contribution, it was observed that SCV capabilities can deliver a competitive advantage especially in dynamic conditions. This Delphi study was conducted in the second and third quarters of 2021, that is, during the pandemic, which most likely has emphasised the dynamic nature of the surrounding environment in which the firms operate. Most of the managers prioritised SCV capabilities and performance effects like predictive capability, decision-making support, customer service and flexibility indicating SCV as key contributors to the dynamic capabilities for a gaining competitive advantage. Rich and real-time data from various sources along the supply chain can help organisations sense the deviations and reconfigure the resources to meet customer demands.

6.4. Limitations

A limitation of this research is that, although all experts have extensive experience with global supply chains, they are all based in Northern Europe. Since they represent many different industries with global presences, it is unlikely that another expert panel would arrive at a substantially different set of factors. However, as the area of SCV matures, other Delphi panels may identify additional factors that are important—for example, more contingency variables that affect SCV's perceived importance and feasibility.

6.5. Future research

The results call for future research on SCV. We propose four directions. First, survey research that can explore other geographical areas to understand the relative importance of the factors that we identified in our study is warranted. Cultural aspects, the level of innovation, digitalisation, industrial priorities, data sharing regulations and governmental policies may differ and can impact factors of SCV. Second, most previous studies have been limited to the first-tier supplier or customer perspective. However, our results support the view that the full potential of SCV is related to the end-to-end supply chain. Hence, there is a need to further explore and understand the factors influencing SCV beyond first-tier suppliers. We therefore encourage more research on extended supply chains involving multi-tier suppliers. Third, more empirical studies on SCV, such as case studies, action research and best practices are warranted. This will support a deeper understanding of the factors and their interrelationships, for example, identifying more contingency factors. Fourth, a better understanding of the development and implementation of SCV systems in practice is needed. A systems approach can be useful for gaining more knowledge regarding the practical aspects of SCV systems. Thus, many interesting research avenues can be pursued.

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Data availability statement

The data that support the findings of this study are available from the corresponding author, [TKA], upon reasonable request.

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APPENDIX

APPENDIX A. Overview of the panel experts in our Delphi study

Expert	Position	Industry	Years of 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	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 Mgr	Furniture	25
24	Global SC Manager	Packaging solutions	13
25	Business Development Manager	Furniture	25+
26	Senior Business Architect	Telecom	30+

APPENDIX B. Factors that were excluded in round 2 and 3.

These factors that were excluded, since they were mentioned by very few panel experts (less than 4 persons out of 26). Moreover, majority of the excluded factors were mentioned by only one expert.

B1. Factors dropped in round 2.

Category	Factor
Data (for which visibility is important)	Accuracy, Dependencies in supply chain, Details of raw materials, Flexibility, Government regulation and policy, Material plan, Mode of transport, Operational, Packaging material, Purchase plan, Sales, Strategic, Supplier abilities, Supplier capability, Supplier location, Supplier volume, Terms of deliveries
Drivers	Analysis and actionable visualisation, Automation, Building trust, Business intelligence, Capital efficiency, Common view on reality, Competitiveness, Compliance, Control on payment flow, Customer demand, Customer value, Enhance information sharing, Forecasting, Fulfil regulations, Inventory management, Overcoming silos, Resource efficiency, Responsible sourcing, Supply base management, Traceability, Transport efficiency, Trend analysis, Warehouse efficiency
Enablers	Business intelligence tool, Clear role and responsibility, Competence, Connectivity, Control tower, Customer attitude, Customer relationship, Dash board and report, Data accessibility, Data availability, Data format, Data integration, Data timeliness, Digitalisation, Forecast accuracy, Management support, Organizational culture, Planning process, Real time/Connectivity, SC competence, SC master data, Security, Transparency among partner
Challenges	Competence, Conflict of interest, Culture, Customer collaboration and relationship, Data accessibility, Data collection, Data quality, Data security, Delivery conditions, Different tools, Frequency of updates (real time vs. weekly), Identification of payback (cost vs. benefit), Internal conflicts, Legalisation, Management support, Patents (IPR), Receptivity to innovative ideas, Relationship with supplier, Reliability, Risk of sharing data, Silos, Supply chain integration, Technical limitation, Trust, Various time zones
Effects	Accountability, Analyze, Autonomous logistics, Avoid production disruption, Build trust, Collaboration, Control, Cost optimization, Customer safety, Customise, Decision making, Deliver to customer as soon as possible, Flexibility, Management, Network optimization, Optimization (including resource), Precision, Production location, Quality, Quick response, Resource utilisation (capacity utilisation), Right data at hand, Risk mitigation, Safety, SC development, SC status analysis, Scenario development, Simulate all options, Speed, Stock-out alert, Sustainability, Traceability, Trust

B2. Factors dropped in round 3.

These factors were excluded, since they received very low importance scores, i.e. majority of the experts mentioned these as ‘not important’ or very few (less than 4) mentioned it as ‘important’

Category	Factor
Drivers	Regulatory compliances, Transparency
Enablers	Technology maturity
Challenges	IT competence (lack of ...), IT maturity (lack of ...), Power asymmetry, Risks with sharing sensitive information (IPR, data leakage)
Capabilities	Accountability, Advanced analytics capability
Performance	Quality