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ORIGINAL RESEARCH

Towards supply chain resilience: A structured process approach

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Abstract
This paper aims to enhance the understanding of how small and medium-sized enterprises (SMEs) can bolster their resilience to supply chain disruptions by engaging and aligning cross-functional staff in the process of developing supply chain resilience (SCRES). Employing process theory, the study adopts a multiple case-study methodology involving 18 Danish production SMEs across two iterative phases: an *exploratory phase* encompassing eight case companies, and a subsequent *refinement phase* involving an additional ten case companies. Utilizing a mixed-method approach comprising semi-structured interviews, card sorting exercises, observational studies, and a questionnaire survey, the research proposes a four-stage process for enhancing SCRES. This process includes: 1) mapping the supply chain, 2) identifying vulnerabilities and capabilities within each function, 3) prioritizing and creating cross-organizational alignment, and 4) developing action plans. The refined approach, validated through the ten Danish SMEs in the *refinement phase*, offers a practical and relevant framework for companies seeking to mitigate vulnerabilities and enhance capabilities in their supply chains. By strengthening SMEs' resilience against supply chain disruptions, this approach serves as a potential model for other companies striving to achieve SCRES.

Keywords Process theory · Small and medium-sized enterprises · Mapping · Cross-functional integration

1 Introduction

The COVID-19 pandemic laid bare weaknesses in global supply chains, spotlighting vulnerabilities and prompting businesses to reevaluate their strategies and invest in more resilient, adaptable networks. Further strain was placed on supply chains when the Taiwanese container vessel "Ever Given" became grounded in the Suez Canal, and more recently, the Houthis in Yemen attempted to control ship traffic amid the conflict in Gaza. Additionally, the Russian invasion of Ukraine triggered boycotts of Russian raw materials and finished goods, heightening geopolitical tensions that impact global supply chains (Bednarski et al. 2024; Roscoe et al. 2022). Such events exemplify disruptions in supply chains, garnering increased attention (Faruquee et al. 2023; Herold and Marzantowicz 2023) and emphasizing the importance of supply chain resilience (SCRES). Consequently, there is not only a necessity for companies to recognize the significance of SCRES but also to understand how to achieve it. SCRES has become highly pertinent for business managers to prepare for, respond to, and recover from supply chain disruptions that could significantly impair performance (Faruquee et al. 2023; Nikookar and Yanadori 2022; Roscoe et al. 2022; van Hoek 2020).

SCRES is not only for large corporations but also for small and medium-sized enterprises (SMEs). SMEs face greater challenges in pursuing SCRES due to limited financial, human, and technological resources (Bak et al. 2023; Brustbauer 2016; Polyviou et al. 2020; Sullivan-Taylor and Branicki 2011). SMEs are intriguing subjects for study for several reasons. Firstly, SMEs comprise the majority of enterprises compared to larger counterparts (Gorgels et al. 2022, p. 14). Secondly, SMEs typically have fewer human and financial resources compared to larger enterprises (Kull et al. 2018; Pal et al. 2014; Sullivan-Taylor and Branicki 2011); they exhibit greater CEO involvement in daily operations and prioritize operational concerns over strategic and developmental activities (Halkos et al. 2018; Stentoft et al. 2021), and they tend to be less bureaucratic and more inclined towards success than larger companies (Nooteboom

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1994). Consequently, SMEs are more susceptible to vulnerabilities than larger firms (Chowdhury et al. 2019; de Sa et al. 2023; Halkos et al. 2018). The existing literature on SCRES calls for further research with a focus on SMEs (Ali and Gölgeci 2019; Bak et al. 2023; Drozdibob et al. 2023; Kamalahmadi and Parast 2016; Manuj et al. 2024; Scholten et al. 2017). According to Polyviou et al. (2020), there is a lack of research on resilience within SMEs, and little is known about what constitutes resilience in this context. A study by Bak et al. (2023) concludes that there is a necessity for research to enhance SMEs' SCRES capabilities, and Pettit et al. (2019) advocate for research that tailors SCRES frameworks to the context of SMEs.

A study by Ali et al. (2017) illustrates various definitions of SCRES that encompass firm, network, and system-wide perspectives. Recent literature reviews of SCRES have underscored an increasing emphasis on its importance and maturity in ensuring competitive advantages (Ali et al. 2017; Ali and Gölgeci 2019; Hohenstein et al. 2015; Kamalahmadi and Parast 2016; Kochan and Nowicki 2018; Pujawan and Bah 2022; Shekarian and Parast 2020). Moreover, existing literature highlights organizations' reliance on internal integration through cross-functional teams to bolster supply chain resilience (Poberschnigg et al. 2020; Sawyerr and Harrison 2020; Singh et al. 2023; van den Adel et al. 2023). Additionally, there is a growing need for research that delves into the "how" of SCRES development, complementing existing studies on the “what” and “why” (Eryarsoy et al. 2022; Li et al. 2020; Samson and Kalchschmidt 2019; Van Hoek 2020), signaling a demand for more normative research with practical, real-world insights (Narasimhan 2018; Samson 2020). Despite these advancements, there remain unanswered questions regarding the development of SCRES from an SME perspective. Furthermore, research based on empirical data is also demanded (Ali and Gölgeci 2019; Kochan and Nowicki 2018; Singh et al. 2019), with a welcoming stance towards mixed methods (Ali and Gölgeci 2019; Kamalahmadi and Parast 2016; Li et al. 2020).

This paper investigates SCRES using process theory, which entails inputs, actions, events, and consequents (Van de Ven and Huber 1990). Therefore, it adopts a process perspective (Drozdibob et al. 2023; Kamalahmadi and Parast 2016; Ponomarov and Holcomb 2009) and builds upon the SCRES framework of aligning supply chain vulnerabilities with capabilities (Pettit et al. 2010). Additionally, it incorporates resilience linkages that bridge supply chain vulnerabilities and capabilities (Pettit et al. 2013) from a firm-level perspective on SCRES. Despite existing frameworks for developing SCRES (Ali et al. 2017; Moktadir et al. 2023; Pettit et al. 2010; Singh et al. 2019), we contend that the current literature lacks comprehensive guidelines for SME practitioners on building SCRES (Iborra et al. 2022). Moreover, existing SCRES frameworks appear to overlook the financial and human resource constraints of SMEs. Against this backdrop, this paper aims to enhance the understanding of how SMEs can increase their SCRES by addressing the following research question:

> RQ: How can small and medium-sized manufacturers achieve supply chain resilience through a structured process?

To address this research question, the following objectives are pursued:

1. *Identify the phases, activities, events, and consequents pertinent in a process model for SCRES.*
2. *Compile a list of relevant vulnerabilities and capabilities for SMEs.*

The paper contributes novelty in several ways. Firstly, it offers fresh empirical insights into SCRES from an SME perspective through cross-functional data collection. Secondly, it proposes a process model for developing SCRES that emphasizes the “how” of improving SCRES. Thirdly, it suggests new and updated supply chain vulnerabilities and capabilities applicable to SMEs in a manufacturing context.

The paper is organized into five sections. The subsequent section presents a theoretical framework, followed by a description of the research design and data collection. Then, the findings of the analysis are presented and discussed which is followed up by a section discussing the results. Finally, conclusions, implications, limitations, and suggestions for future research are provided.

2 Theoretical underpinning

This section presents the theoretical frame of reference utilized to for data analysis and the development of the process model. The section is divided into three subsections. The first subsection delineates process theory and its adaptation to the current context. Following this, a subsection delves into the crucial elements of SCRES examined in this study. Lastly, the third subsection outlines the key characteristics of small and medium-sized enterprises (SMEs).

2.1 Process theory

This paper builds upon process theory, which explores how specific outcomes arise from a sequence of actions and events, taking into account specific inputs (Van de Ven and Huber 1990). Process data comprises narratives detailing what occurred, who was involved, and when, including events, activities, and decisions over time (Langley 1999). In a narrower sense, process theory is not a comprehensive

theory but rather a logical meta-model (Niederman et al. 2018). Process research is crucial for addressing questions related to "how" (Bizzi and Langley 2012). According to Van de Ven and Huber (1990), the fundamental components of process theory include inputs, actions and events, and consequents. Inputs are linked to antecedents that initiate the process. For SCRES, inputs could include supply chain disruptions like a significant environmental shock such as the COVID-19 pandemic (Stentoft et al. 2023), a cyberattack (Kumar and Mallipeddi 2022), or heightened geopolitical tensions (Roscoe et al. 2022) affecting supply chains. Such inputs may create awareness of the need to enhance SCRES to maintain competitiveness. Actions and events represent the concrete initiatives that participants in the process need to undertake. Who is involved, what tasks are being performed, when, and in what sequence? Examples of such activities include cross-functional meetings to map the supply chain, assessing supply chain vulnerabilities and capabilities, and developing action plans to enhance SCRES within the company. Consequents are the final outcomes of the theorized process. This could entail a prioritized action plan consisting of activities and projects necessary to improve SCRES, balanced with available financial and human resources. The perspective of process theory is applicable both in the development of SCRES and in the subsequent operation of the process, aligning with existing literature (Drozdibob et al. 2023; Kamalahmadi and Parast 2016; Ponomarov and Holcomb 2009).

2.2 Supply chain resilience (SCRES)

2.2.1 Engineering and ecological approaches

Supply Chain Resilience (SCRES) is a research area under immense growth, with numerous definitions proposed as evidenced by recent literature reviews (Hohenstein et al. 2015; Kochan and Nowicki 2018; Ali et al. 2017; Ali and Gölgeci 2019). A conventional understanding of SCRES, exemplified by Christopher and Peck (2004, p. 4), defines it as "the ability of a system to return to its original state or transition to a new, more desirable state after disruption." However, the traditional bounce-back approach to resilience (Sheffi and Rice 2005, p. 41) has recently been challenged by an ecological resilience perspective within Supply Chain Management (SCM) (Novak et al. 2021; Pettit et al. 2010). An ecological perspective is seen as better suited to capture supply chains as complex adaptive systems. Wieland and Durach (2021) introduce the concept of socio-ecological supply chain resilience, defining it as "the capacity of a supply chain to persist, adapt, or transform in the face of change," emphasizing the role of social actors. Their work draws from Holling (1996, p. 33), who distinguishes between engineering resilience, focused on efficiency, constancy, and predictability, and ecological resilience, focused on persistence, change, and unpredictability, with an emphasis on safe-fail designs. While engineering resilience seeks to stabilize the system near equilibrium, ecological resilience explores how systems shift and adapt to alternative steady states (Novak et al. 2021). Ecological resilience acknowledges that systems may have multiple equilibria and that returning to a pre-shock state may not be desirable, practical, or feasible. The process model developed in this paper can incorporate both engineering and ecological resilience approaches. We view them not as mutually exclusive options, but as complementary strategies. Some companies may require capabilities to rebound to equilibrium in existing supplier relationships (an engineering approach), while others may need to explore new suppliers and materials due to eroded relations and markets (an ecological approach with multiple equilibria).

We agree with Wieland and Durach (2021) that the engineering and social sciences roots of SCM must continue to advance together. Supply chain managers should draw lessons from both perspectives. The current understanding of SCRES encompasses both viewpoints. From a practical standpoint, some challenges are best addressed through an engineering lens, while others demand a social-ecological perspective.

2.2.2 Supply chain vulnerabilities and capabilities

Jüttner et al. (2003) define supply chain vulnerabilities as risks stemming from disruptions within the supply chain due to inadequate security measures, while Pettit et al. (2010, p. 6) describe them as "fundamental factors that render an enterprise susceptible to disruptions." Kochan and Nowicki (2018), utilizing the context-interventions-mechanisms-outcomes (CIMO) logic in their typological framework for SCRES, categorize supply chain vulnerabilities as interventions. They classify vulnerabilities into three groups: 1) external vulnerabilities, 2) internal vulnerabilities, and 3) structural vulnerabilities. Examples of supply chain disruptions include deliberate threats, external pressures, and resource limitations (Pettit et al. 2013). In contrast, supply chain capabilities can be understood as attributes that empower an enterprise to anticipate and overcome disruptions (Pettit et al. 2010, p. 6). Similar to vulnerabilities, capabilities are included as interventions in the framework by Kochan and Nowicki (2018). Supply chain capabilities may take various forms, such as prevention, impact mitigation, and enabling adaptation post-disruption. Pettit et al. (2010) propose a SCRES framework, Supply Chain Resilience Assessment and Management (SCRAM™), which emphasizes the importance of balancing supply chain vulnerabilities and capabilities to achieve resilience. A balanced resilience, achieved through resilience linkages between

vulnerability and capability, is considered desirable (Pettit et al. 2013).

Hohenstein et al. (2015) suggest grouping SCRES elements into proactive or reactive strategies for pre- and post-disruption scenarios. Ali et al. (2017), based on a literature review, expand this discussion by introducing concurrent SCRES strategies. Their framework outlines three strategies linked to different capabilities and practices across resilience journey phases: 1) pre-disruption strategies focus on anticipating disruptions, 2) concurrent strategies during disruptions emphasize adaptation and response, and 3) post-disruption strategies concentrate on recovery and learning from the disruption.

2.2.3 Supply chain mapping

Supply chain mapping plays a pivotal role in enhancing competitiveness through SCM (Burgess and Singh 2012; Lambert et al. 1998). According to Wood (1992, p. 4), a supply chain map offers a profound insight into reality, surpassing our natural vision and temporal limitations, providing an understanding otherwise unattainable. By visualizing the nodes (companies) and the extent of material flows both forward and backward, supply chain mapping facilitates comprehension of supply chain complexity (Craighead et al. 2007; Iftikhar et al. 2022). Mubarik et al. (2023) suggest three dimensions of supply chain mapping: upstream mapping, midstream mapping, and downstream mapping. Based on case study research, Fabbe-Costes et al. (2020) found that supply chain mapping offers visualizations that enhance comprehension of supply chain territories despite their structural and dynamic complexities (Iftikhar et al. 2022). It delineates supply chain activities, bridging the physical and intangible realms, fostering a preliminary understanding before action. This visualization process aids companies in becoming more resilient by elucidating the material flow dynamics in response to product development impacts (Reitsma et al. 2023).

Existing literature underscores the significance of supply chain mapping in identifying vulnerabilities (Choi et al. 2020; Colicchia et al. 2010). Christopher and Peck (2004, p. 7) assert that a fundamental requirement for enhancing supply chain resilience is a comprehensive understanding of the network linking the business to its suppliers and downstream customers. They advocate for the use of mapping tools to deepen this understanding. Mubarik et al. (2021) corroborate this, reporting a positive relationship between supply chain mapping and SCRES based on a questionnaire survey. Gunasekaran et al. (2011) suggest that SMEs can leverage process mapping of suppliers and customers to gain an integrated business process perspective, a critical factor determining their resilience and competitiveness.

2.2.4 Internal integration and cross-functional collaboration

In extant literature, several researchers underscore the significance of internal integration and cross-functional collaboration as precursors to SCRES (Christopher and Peck 2004; Molinaro et al. 2023). Pettit et al. (2010) advocate for the establishment of continuity teams to foster internal integration and cultivate a culture of risk management. They propose further research involving a diverse range of functional specialists and process integration experts to capture cross-functional interactions and capabilities. Thornton et al. (2016) report a negative correlation between perceptions of organizational politics and internal functional integration among employees in the retail sector. Conversely, they observe a positive correlation between supply chain orientation, defined as top management's ability to grasp the implications of managing upstream and downstream flows across suppliers and customers, and internal integration (Mentzer et al. 2001, p. 11).

In a simulation study, de Vries et al. (2022) uncover a negative relationship between internal integration issues within cross-functional teams and firms' robustness, suggesting the need for further research on how such teams can enhance early warning signal management. Another simulation study by van den Adel et al. (2023) demonstrates that internal integration reinforces the link between cross-functional team information scouting and organizational resilience. Razak et al. (2023) suggest that traceability systems can enhance intra- and inter-firm collaboration and interactions, thereby enabling SCRES. Drawing from a multiple case study, Poberschnigg et al. (2020) assert that cross-functional integration facilitates the development of supply chain capabilities and internal collaboration capabilities. They highlight integration factors such as effective communication, willingness to resolve conflicts, cross-functional meetings, information sharing, and acknowledgment of functional interdependence. Moreover, they propose conducting research on the relationship between cross-functional integration and supply chain resilience, based on multiple case studies involving multiple informants from each company.

2.3 Small and medium-sized enterprises

SMEs hold a crucial role in society and socio-economic development, constituting 99 percent of all enterprises by number (OECD 2023). Typically employing between 10 and 250 individuals, SMEs generate turnovers ranging from EUR 10 to 50 million and/or possess annual balance sheet totals not exceeding EUR 43 million (European Commission 2020). Globally, SMEs contribute significantly to the economy, accounting for at least 70% of worldwide production (Moore and Manring 2009). However, research on SCRES

from an SME perspective remains limited (Bak et al. 2023; Kamalahmadi and Parst 2016; Pal et al. 2014; Polyviou et al. 2020).

Several characteristics distinguish SMEs from large enterprises. Typically, SMEs have fewer human, financial, and technological resources (Brustbauer 2016; Pal et al. 2014; Polyviou et al. 2020) and operate amidst higher external uncertainty (Ali et al. 2017; Storey 1994, p. 74). They often face information shortages, management time constraints, and weaker cash flows (Pal et al. 2014). Additionally, their firefighting management style hampers their ability to pursue long-term strategic changes to enhance resilience (Ates and Bititci 2011; Kull et al. 2018). Moreover, SMEs encounter a challenging policy environment where they are frequently overlooked by policymakers (Polyviou et al. 2020). Ates and Bititci (2011) further note that SMEs are constrained in their resilience efforts due to a lack of focus on softer aspects of change, a reactive rather than proactive approach, insufficient emphasis on planning and preparation phases, and neglecting relationships with key partners and stakeholders. Despite these challenges, SMEs also possess advantages. They are typically less bureaucratic, operate with swift decision-making and higher risk tolerance, maintain rapid and effective internal communication, and boast shorter decision chains (Vossen 1998). Moreover, SMEs exhibit a capacity for learning and adapting to evolving market demands, rendering them more flexible and adap77 (Pal et al. 2014).

3 Method

The paper adopts a case study methodology to address its main research question. A case study is an empirical inquiry that explores a contemporary phenomenon within its real-life context, particularly when the boundaries between the phenomenon and context are unclear (Ellram 1996; Yin 2014, p. 16). Case studies serve various purposes such as exploration, description, explanation, and prediction (Ellram 1996; Yin 2014, p. 8), offering the flexibility to integrate diverse data sources and methods within the same study (Eisenhardt 1989; VanWynsberghe and Khan 2007; Dubois and Gibbert 2010). They are widely recognized in the field of operations management (Eisenhardt 1989; Narasimhan 2014; Voss et al. 2002). The case study method is deemed appropriate for this study because little is known about *how* manufacturing SMEs achieve SCRES. Following the three modes of case research Ketokivi and Choi (2014), this design focuses on theory elaboration. Theory elaboration involves applying a general theoretical logic in this case, the SCRES framework with vulnerabilities and capabilities proposed by Pettit et al. (2010) and Pettit et al. (2013, 2019), without testing a priori logic, but rather expanding upon it.

Within the case study framework, the study employs a mixed method in data collection. Mixed methods are well-established in operations research (Howick and Ackermann 2011) and advocated in operations management research to gain fresh insights and support meaningful research practices (Boyer and Swink 2008; Choi et al. 2016; Singhal et al. 2014). The study combines qualitative interviews in multiple case studies, card sorting processes, facilitated meetings, observation studies, and data from a questionnaire survey (Johnson et al. 2007; Tashakkori and Creswell 2008). These methods may be used concurrently or sequentially to obtain a comprehensive understanding of the phenomenon of interest (Venkatesh et al. 2013), with sequential employment chosen for this study. The overall design is a fixed mixed design, with data collection predetermined and planned at the outset of the research process (Creswell and Plano Clark 2018, p. 52).

3.1 Sampling

The aim of sampling is to select cases that are likely to replicate or extend emergent theory (Eisenhardt 1989). Qualitative research often employs purposeful sampling strategies (Miles et al. 2014, p. 31) designed to deepen understanding of the study object by selecting information-rich cases. The paper is based on 18 case studies, with 8 conducted in an *exploration* iteration to develop a SCRES process, and the remaining 10 conducted in a *refinement* iteration of the process model. Thus, the unit of analysis is the process of achieving SCRES at the firm level.

Companies were selected based on criterion sampling (Patton 1990, p. 176), which involves reviewing and studying all cases meeting predetermined criteria of importance. The criteria included: 1) SME status, 2) manufacturing sector, 3) impact of COVID-19 on supply chain performance, 4) willingness to participate in a project funded by the Danish Industry Foundation, and 5) geographic distribution across Denmark. The project was promoted through Danish supply chain magazines and a LinkedIn video to attract interested companies, resulting in over 30 applicants.

According to the funding application, ten case companies were chosen for the exploratory iteration, with two opting out early due to severe COVID-19-related supply chain challenges. In the refinement phase (round 2), another ten companies were selected. Literal replication logic guided case selection, predicting similar results (Miles et al. 2014, p. 32; Yin 2014, p. 57). The 18 selected cases are detailed in Table 1, with a majority being business-to-business companies. Although initial outreach targeted business-to-consumer firms, they were unable to commit time to the project. However, two such companies participated in the second iteration. Additionally,

Table 1 Overview of attending companies

Case companies in the exploration iteration			Case companies in the refinement iteration		
Case	Size	Industry	Case	Size	Industry
Case 1	125	Manufacture of lifting and handling equipment	Case 9	250	Manufacture of electricity distribution and control apparatus
Case 2	60	Manufacture of non-wovens and articles made from non-wovens, except apparel	Case 10	270	Manufacture of machinery for food, beverage and tobacco processing
Case 3	25	Other research and experimental development on natural sciences and engineering	Case 11	130	Manufacture of machinery for food, beverage and tobacco processing
Case 4	78	Manufacture of non-domestic cooling and ventilation equipment	Case 12	127	Manufacture of other furniture
Case 5	250	Manufacture of brooms and brushes	Case 13	300	Manufacture of builders' ware of plastic
Case 6	95	Manufacture of medical and dental instruments and supplies	Case 14	20	Manufacture of bicycles and invalid carriages
Case 7	105	Manufacture of motorcycles (brake pads)	Case 15	70	Manufacture of other special-purpose machinery n.e.c
Case 8	120	Manufacture of irradiation, electromedical and electrotherapeutic equipment	Case 16	55	Manufacture of other special-purpose machinery n.e.c
			Case 17	155	Manufacture of other special-purpose machinery n.e.c
			Case 18	187	Manufacture of non-domestic cooling and ventilation equipment

two companies slightly exceeded SME criteria with 250 employees but were included due to their Danish representation remaining under 250 employees.

3.2 Contact to key informants and the interview guides

As an initial step to secure access to pertinent empirical data, we contacted individuals responsible for supply chain management or operations management to obtain their agreement for participation in the project. Two representatives from each company attended a kick-off seminar where we outlined the project's objectives and explained the data collection process. Additionally, a letter of commitment was signed, delineating the company's resource commitment, granting access to data, and stipulating that any publications based on the data would require prior approval from the companies involved.

3.3 Data collection and processing

Data collection occurred across all companies using various methods. The initial iteration, involving eight companies in the exploratory phase, spanned from September 2021 to May 2022. The subsequent iteration, encompassing ten case studies, was conducted from August 2022 to January 2023. Throughout these phases, data was gathered through five distinct approaches, detailed below.

3.3.1 Interviews

During the first round involving eight case companies, interviews were conducted exclusively. Each company underwent interviews over two of the four designated days. Initially, interviews engaged representatives from various cross-functional departments such as sales, production, procurement, finance, product development, and IT (refer to Appendix 1 for the interview guide). Some companies had individuals managing multiple functions (e.g., finance and IT or logistics and planning), while others had multiple representatives for a single function. These interviews aimed to understand each function and gather insights into the supply chain challenges faced during COVID-19. The first set of interviews, totaling 38, lasted between 45 to 60 min each. On the subsequent day, additional interviews, lasting between 30 to 45 min, were conducted. These sessions delved into why informants selected specific vulnerabilities, including their prioritization, and the rationale behind their choice of capabilities. Overall, 32 interviews were conducted during this phase, with some functions grouped for reporting on the second day. Participants provided narratives detailing their perceptions of vulnerabilities and capabilities. All interviews were recorded and transcribed for coding purposes, following established methods (Cresswell and Plano Clark 2018 p. 184). Researchers employed probing techniques to extract rich, detailed data during the feedback interview (Robinson 2023), utilizing follow-up questions to clarify responses and gather additional information when needed.

3.3.2 Card sorting

Card sorting, originating from George Kelly's Personal Construct Theory (PCT) (Kelly 1955), is a straightforward method for researchers. Participants are presented with items from a stimulus set and are tasked with sorting them into groups (Fincher and Tenenberg 2005; Whaley and Longoria 2009). Staff members from various functions individually worked with vulnerabilities and capabilities outlined by Pettit et al. (2013). In the initial iteration involving eight case companies, a physical card sorting approach was employed. Participants received cardboard cards containing 41 vulnerabilities and 71 capabilities. Their task was to prioritize vulnerabilities perceived as most urgent for the company to address. In the second iteration, a digital solution incorporating the card sorting approach was utilized to prioritize vulnerabilities and align them with necessary capabilities from updated lists (refer to Appendices 2 and 3, Tables 8 and 9).

3.3.3 Facilitation and observation

Facilitation fundamentally involves making it easier for a group to learn something (Rogers 2010, p. 5). As a facilitator, you collaborate with a group to enhance their understanding of a problem area. Working with a facilitator during interdisciplinary meetings can help a group acknowledge differences and effectively navigate disagreements that may arise throughout the collaborative work process (Graef et al. 2021). Facilitation was utilized in both iterations with the case companies. In the first iteration, facilitation occurred on the third day of data collection, where the cross-functional team worked to develop a common prioritization of vulnerabilities and necessary capabilities. The researcher facilitating the process did not influence the outcome but guided them through the prioritization process. Observation, a research method involving systematic recording of observable phenomena or behavior in a natural setting (Gorman and Clayton 2005, p. 40), was conducted by another researcher at these group meetings. The focus was on how discussions unfolded and how everyone's input was ensured. Through observation, situations arose in some companies where consensus could not be reached, which was tacitly accepted. In the second iteration with the 10 case companies, facilitation and observation were employed on the first day of supply chain mapping, on the third day for collective analysis of vulnerabilities and capabilities, and on the fourth day for the development of action plans. Group discussions on both vulnerabilities and capabilities were recorded and transcribed.

3.3.4 Questionnaire-survey

All participants from the explorative iteration with the eight case companies received an electronic questionnaire asking them to assess the relevance of the listed vulnerabilities and capabilities based on Pettit et al. (2013) from an SME perspective, along with providing suggestions for new vulnerabilities and capabilities. A five-point Likert scale ranging from 1 = very low relevance to 5 = very high relevance was employed. In total, 44 individuals from the eight companies participated in the process, with 37 providing complete and usable responses, resulting in a response rate of 84.1%.

3.3.5 Advisory group

At the project's outset, an advisory group was established comprising an SME CEO, a trade council CEO, and a university professor. The objective was to ensure both a solid theoretical basis and practical business relevance. Throughout the project, the advisory group also played a role in evaluating and enhancing new vulnerabilities and capabilities within the process model.

3.4 Research design quality

Yin (2014, p. 45) outlines four criteria used to assess the quality of research design in case study research. These criteria include external validity, reliability, construct validity, and internal validity. External validity pertains to the generalizability of findings and is a consideration during the research design phase (Ellram 1996). In this paper, the focus is on analytical generalization rather than statistical generalization (Yin 2014, p. 41). Reliability concerns whether the study can yield consistent results upon repetition. The case study protocol is instrumental in ensuring reliability, with each case study having a structured protocol encompassing six key sections: 1) case sampling criteria, 2) initial project proposal used in engaging with case companies, 3) interview guides, 4) interview notes and transcriptions, 5) coding scheme for case descriptions, and 6) communication log with case companies and secondary materials/documents. Construct validity involves establishing appropriate measures for the concepts under study, which in this research, is grounded in the existing literature as presented in the theoretical framework section. Internal validity is primarily relevant for explanatory case studies aimed at demonstrating causation between variables (Ellram 1996). However, this research is exploratory, aiming to generate new insights into how manufacturing SMEs can develop SCRES. Therefore, data results are compared across cases and with existing literature on SCRES.

4 Data analysis

In this section, an analysis of the case studies from the two iterations will be conducted, following the structure outlined in Fig. 1. The first subsection will focus on the explorative case

studies, while the subsequent section will address the confirming case studies aimed at refining a process model to enhance SMEs' awareness of areas where they need to bolster capabilities to address supply chain vulnerabilities.

4.1 Explorative iteration

The first explorative iteration was structured in four phases as shown in Fig. 1: 1) AS-IS understanding of the supply chain, 2) functional assessment of vulnerabilities and capabilities, 3) cross-functional assessment of vulnerabilities and capabilities, and 4) action plans, learning, and implementation issues. These phases are further analyzed in the following.

4.1.1 AS-IS understanding of the supply chain

On the first day of engagement at the companies, representatives from various departments including sales, manufacturing, procurement, IT, finance, and product development gathered for an introductory meeting where the comprehensive research process was explained. Following this, individual interviews were conducted with personnel from each department, using a predefined interview guide distributed to participants beforehand. These interviews, lasting between 45 to 60 min each, were recorded and transcribed. The main objective was to gain deeper insights into the company's operations from various functional perspectives and to gather data to develop an overall picture of the supply chain for the entire team, providing a common starting point for the process. This presentation aimed to establish a shared foundational understanding for the subsequent phases. At the end of this initial phase in the exploratory iteration, a total of 38 interviews were completed across the eight companies. All interviews were transcribed, and the data processing was incorporated into a case study protocol for each company.

4.1.2 Functional assessment of vulnerabilities and capabilities

Phase two commenced with a presentation of the interview findings from the first day. For most case companies, this marked the first instance where individual team members convened for a collective meeting dedicated solely to discussing supply chain challenges. This transitioned the focus from bilateral to multilateral discussions on supply chain issues. Subsequently, a card-sorting approach was employed, with each participant receiving two sets of cards: one set printed on red cards representing supply chain vulnerabilities and another set printed on green cards representing supply chain capabilities outlined by Pettit et al. (2013). In this phase, a total of 32 interviews were conducted across the eight case companies. Each participant was tasked with reviewing all the cards and selecting the supply chain vulnerabilities they considered most

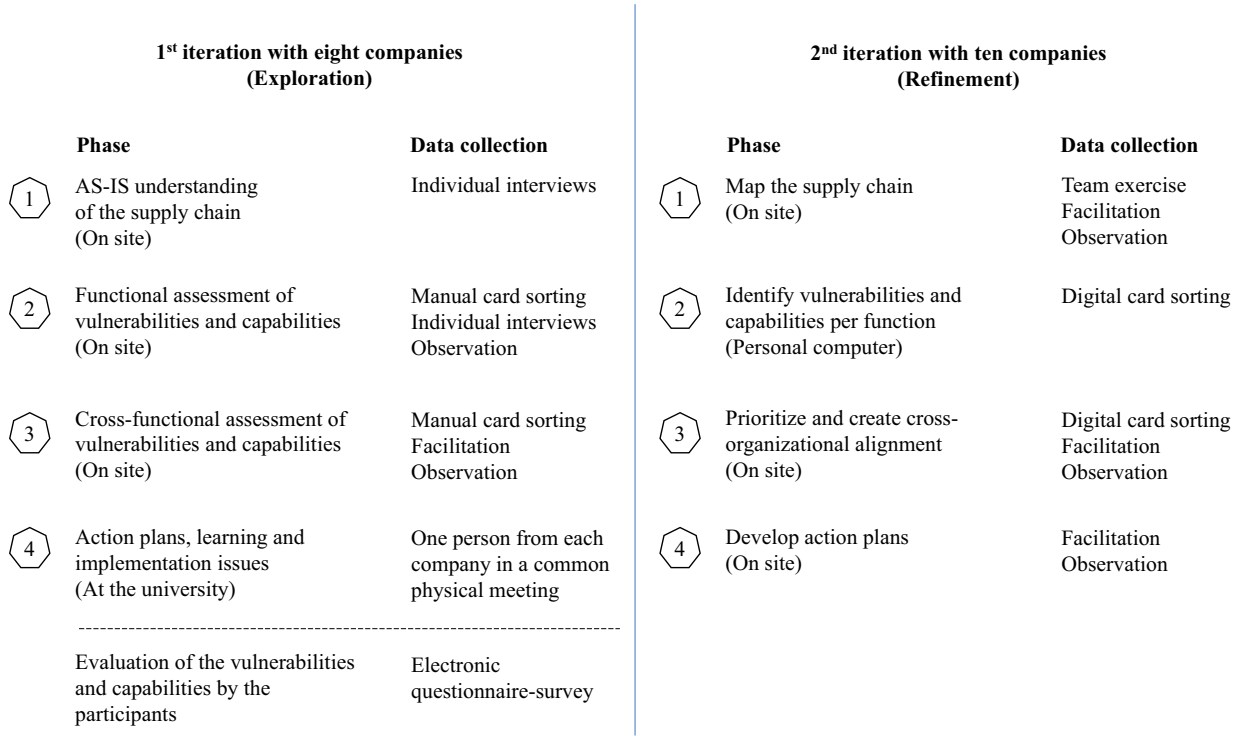

Fig. 1 Phases and data collection in the two iterations of case studies

critical for their company to address. Once identified, participants placed the cards on a table, arranging them in order of priority, with the highest-priority vulnerability positioned on top, followed by others in a prioritized sequence. This phase provided valuable insights for further deliberation, with select quotations included in Table 2.

Table 2 reveals that the quotes are categorized into five themes. Throughout the exercise, researchers probed participants about their perceptions of the process and reasons behind their prioritization of both vulnerabilities and capabilities.

Interviews indicate that participants found the prioritization process valuable, prompting reflection on past supply chain challenges and potential mitigation measures. However, quotes and researcher observations suggest that the exercise was time-consuming, with participants expressing a desire for more time. While participants appreciated the predefined cards for providing direction and structure, some found the process complex due to the volume of cards and difficulty in discerning their meanings, a sentiment echoed by researchers. Conducting the exercise function by function was deemed beneficial, allowing participants to form their own opinions without initial management influence and fostering curiosity about colleagues' prioritizations. Additionally, participants noted that the exercise stimulated reflection and facilitated the creation of a common language, prompting researchers to reconsider and refine the overall process, card content, and manual sorting procedure.

4.1.3 Cross-functional assessment of vulnerabilities and capabilities

In phase two, individual assessments of vulnerabilities and capabilities were synthesized to generate a comprehensive overview of responses across various functions within the companies. Initially, attention was directed towards vulnerabilities, with each participant's input presented individually. Subsequently, collective insights were discussed to distill a consolidated list, typically comprising 10–15 vulnerabilities. Following this, the entire group engaged in deliberations regarding the necessary capabilities for addressing these vulnerabilities, alongside an evaluation of the current level of development for each capability. This assessment was conducted through a collaborative dialogue utilizing a simple three-point scale: 1 = underdeveloped; 2 = somewhat developed, and 3 = well-developed.

As evident from Table 3, the collaborative dialogue in phase three led to a reduction in the number of vulnerabilities and capabilities identified in phase two, indicating a higher level of cross-functional alignment.

In addressing the capabilities identified as highly important, along with any existing gaps between current and desired levels, it is imperative to formulate concrete action plans aimed at bridging these disparities. Observing the collaboration of cross-functional teams yielded significant insights. Firstly, the individual preparation undertaken in phase two enabled quieter personalities to contribute

Table 2 Feedback on the individual/functional card sorting process in phase two

About the process

"Really exciting, and it gives something to think about." Purchasing Manager—case 6

"Very interesting exercise—but we definitely could have used some more time." Sales Manager—case 4

"The process shows what we are occupied with—and if the number of green cards reflects the willingness to find solutions, then we're on the right track. But there's rarely just one solution." Purchasing Manager—case 2

About the cards

"It was difficult to identify capabilities to address the vulnerabilities." Service Manager—case 6

"The themes on the cards are good although some are very close to each other." Purchasing Manager—case 8

"I like this approach as it forces us to think in specific directions—it's good to start from the predefined vulnerabilities and capabilities." COO—case 8

"There are many cards to deal with—I believe it's important to stick to one's initial intuition—otherwise, one could be here for a long time. It will be exciting to carry out this together with the others." Manufacturing Manager—case 7

"The cards with the printed vulnerabilities and capabilities were good—so we didn't have to start with a blank piece of paper." Supply Chain Manager—case 5

"There are many cards, and many of them are relevant to us." Sales Manager—case 7

"Some of the cards were difficult to understand the meaning of." Planning Manager—case 4

The functional approach

"It's good that we have to conduct the exercise per function first, so you have to make your own opinion." Sales Manager—case 2

"Very interesting exercise – I'm looking forward to see my colleagues' prioritizations." Finance Manager—case 8

Stimulated reflection

"It's a good exercise that makes us reflect on things—it helps create a common language." Planning Manager—case 1

"Even though there are many cards, the exercise is good in that sense it requires prioritizing among them – so what is really important for us now?" Finance Manager—case 5

"Super interesting—it raises many good questions." Finance Manager—case 3

Need for a digital tool

"I found it difficult with all these physical cards. I lost the overview. I started to think if we couldn't create a digital solution." COO—case 2

Table 3 Reduction of vulnerabilities and capabilities from an individual to a group perspective

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8
Vulnerabilities								
- Individual (phase 2)	25	15	17	23	15	20	22	21
- Group (phase 3)	11	9	5	14	17	10	17	16
Capabilities								
- Individual (phase 2)	64	31	56	72	62	54	55	47
- Group (phase 3)	12	24	24	45	40	32	27	27

meaningfully during phase three. Secondly, the sharing and discussion of facts and perspectives concerning the supply chain facilitated dialogues that were previously uncommon. Lastly, towards the conclusion of phase three, there was a consensus that internal communication among staff was insufficient, highlighting a lack of internal integration. Table 4 contains relevant quotations pertaining to phase three.

4.1.4 Action plans, learning, and implementation issues

On the fourth day of the explorative iteration, representatives from the eight companies convened at the university to delve into implementing initiatives aimed at enhancing supply chain capabilities. The conversation swiftly turned to the challenge of executing these initiatives amidst busy schedules filled with operational tasks (referred to as the issue of ambidexterity, as outlined by O'Reilly and Tushman in 2004). This challenge is especially pronounced among SMEs, given their relatively limited resources compared to larger enterprises. The following quotations underscore this point:

> "It is very important not to start too many things at the same time." Finance Manager – case 1
> "It's important to stay focused on the most essential issues, otherwise, we run the risk of it getting lost in the daily operations." Purchasing Manager – case 4

Participants in the discussion proposed several points to bolster the implementation efforts, as outlined in Table 5.

4.1.5 Summary of areas for improvement

Although the process of matching vulnerabilities and capabilities for SCRES proved valuable in helping companies identify and address areas for improvement, it became evident that the process needed optimization. Following the companies throughout the process and based on feedback, interviews, and observations, the authors identified several areas for improvement to streamline and simplify the process.

Firstly, it was crucial to simplify the manual process of matching vulnerabilities and capabilities and reduce the time involved, particularly during the alignment phase. In the initial iteration (exploratory phase), no limits were set

Table 4 Examples of feedback from the common car sorting process (1st iteration)

Number of cards

"There should be a maximum number of vulnerabilities one can choose i.e., a stronger prioritization" COO—case 8

"Some cards were also difficult to comprehend – we interpreted them differently." Purchasing Manager, case 2

"The positive aspect is that it's exciting to work with, but it became a bit overwhelming with all the cards I had chosen." Planning Manager—case 1

Cross-functional dialogue/understanding

"The positive aspect is that it becomes evident where we are most vulnerable and where we have the strongest capabilities" CEO—case 1

"Our involvement in the project has fostered a shared understanding of the vulnerabilities present in our supply chains and the necessary capabilities we either possess or need to develop in order to effectively manage these vulnerabilities." COO – case 7

"Phase was very important because the quieter types among the participants get a greater opportunity to speak in this third phase." Factory Manager—case 9

"The project has facilitated collaboration across our organization. We recognize that we face the same problems and challenges, but we approach them differently and handle them on a day-to-day basis in different ways. Production Manager—case 4

"Our company is a small growth company, and we highly value the importance of human resources and skills. The project has fostered a strong and aligned cross-functional focus within the company, making us aware of the significance of prioritizing scarce resources for tasks related to Supply Chain Resilience since our delivery capability serves as the foundation for future earnings." CEO – case 3

Challenging one's fundamental assumptions

"You get your assumptions challenged in the process of how practice is. For example, procurement might say that we evaluate our suppliers, while someone in another function might respond that they had no idea." Supply Chain Manager—case 5

"The silo mindset is challenged in the process. You find yourself aligning more with what's important and what's not. The issue you're dealing with right now can seem overwhelmingly significant, but in the bigger picture, it might not be that relevant." COO – case 6

Table 5 Participant feedback on getting better at implementing

Define a cross-functional group (e.g., a business continuity group) with a mandate to focus on SCRES
Plan meetings with regular intervals, e.g., once a month, and meeting cancellation is a sin
Ensure that specific meeting agendas are available and that minutes of the meetings are prepared
Agree on who is responsible for carrying out these identified activities and deadlines
Seek top management support (preferably report to them on the work and its progress)
Carry out project work held over half days so that there is also room to expedite operational tasks

on the number of vulnerabilities or capabilities to be used. Consequently, a significant number of vulnerabilities and capabilities were often chosen, leading to complexity. For instance, in case company 4, 45 capabilities were chosen. To manage this complexity, participants had to resort to writing post-it notes or side notes to link prioritized vulnerabilities and capabilities, making the process of compiling results time-consuming. As a result, one researcher spent six to eight hours compiling results for each matching day in each case company. To address this, an electronic version of the card sorting process was developed to optimize, structure, automate calculations, and streamline decision-making.

Secondly, the initial list of vulnerabilities and capabilities based on Pettit et al. (2013) did not fully reflect the context of SME manufacturing companies in 2023. Some vulnerabilities and capabilities were outdated, and others needed to be added. To address this, participants in the initial iteration evaluated the predefined vulnerabilities and capabilities through an electronic questionnaire survey. Those that scored above 3.5 on a five-point Likert scale were included in a new list for the digital solution. Input for new vulnerabilities and capabilities came from interviews, the survey, the project advisory group, and the authors' reflections and observations.

Thirdly, it was observed during the exploratory phase that participants often had different views on how their company's supply chain was designed and operated. To create a more aligned understanding and enable better decisions, a common mapping exercise was included as the first step in the final process.

Fourthly, participants in the exploratory phase requested an additional step focusing on action plans to be included in the process model. They also requested templates, tools, and guidelines to support implementation. Therefore, to assist SMEs in carrying out the process effectively, templates, tools, and guidelines were developed.

4.2 Refinement iteration

Based on the findings from the initial exploratory iteration, including interviews, manual card sorting exercises, observations, and participant feedback, a new process model comprising four phases was devised (refer to Fig. 1, the second iteration). These four phases include: 1) supply chain mapping, 2) functional assessment of vulnerabilities and capabilities, 3) cross-functional assessment of vulnerabilities, and 4) develop action plans. A significant enhancement from the exploratory phase to the refinement phase was the introduction of a digital solution to facilitate the handling of vulnerabilities and capabilities both individually and collectively, as well as streamlining the data processing.

4.2.1 Supply chain mapping

A cross-functional team was established in each of the case companies to develop SCRES. To guide each functional area, a set of questions was prepared, prompting participants to gather pertinent facts about their respective functions. Using a whiteboard, researchers facilitated discussions with participants regarding supply chain mapping. The process commenced by delineating customers, segments, products, and distribution channels. Subsequently, we traversed upstream, covering various aspects such as modes of transport, warehouse positioning, manufacturing sites, decoupling points, planning systems, supplier networks, and types of goods procured. The aim of the mapping exercise was to foster a collective understanding of the supply chain's structure and operations, as well as to identify challenges within the supply chains. It was important to avoid delving into excessive detail during this exercise, as the objective was to promote comprehension rather than instigate immediate change. Throughout the mapping exercises, we noted several instances where participants expressed surprise, as illustrated by the following quotations:

> "The mapping exercise provided many discussions that surprised me e.g., that our internal processes are weaker than I thought they are." CTO - case 15
> "The mapping has helped create a shared understanding of what the company's supply chain is. For instance, sales believed they weren't part of a supply chain, and the same applied to product development, which also makes decisions with significant implications for the supply chain. Therefore, having a common picture and language about it is important." Production Director - case 10

Table 6 Examples of feedback from the common card sorting process (2nd iteration)

"When you sit in a forum like this, it becomes clear that there are many more nuances in those challenges. You know that you should talk to each other to understand the nuances, but this process has just given a speed up in how quickly I understood some of the nuances, so it has been very fruitful." COO—case 15
"You can easily form a picture of the problems inside your head, but this is challenged when you get the perspectives of other functions; it becomes more nuanced." CEO—case 11
"It is important with a wide organizational representation. We have got a better insight into what challenges the other functions have in their daily work." Production Manager—case 10
"This common process has helped us to understand what is basic conditions and what we actually can do something about." Sales Manager—Case 14
"I think it was very interesting this common process where it became clear how different our world views are, but where we have an openness to move in the same direction." COO – case 12
"We come with different backgrounds and different experiences, so it is also very good that we get a calibrated world view" Distributor Channel Manager – case 17
"For our company, this project has revealed that we need more than just a quick fix in purchasing. It has highlighted the need for action across the entire delivery process. We have realized that our dependency on a few customers and suppliers is too significant, and we must enhance our resilience to navigate major global events such as pandemics, wars, and disruptions in volatile supply chains." CEO – case 16

4.2.2 Identify vulnerabilities and capabilities per function

In the second phase, the focus shifted to evaluating supply chain vulnerabilities and identifying necessary capabilities within each functional area represented by the company team. Revised lists comprising 68 vulnerabilities and 90 capabilities, derived from the insights of the first iteration of case studies, were emailed to each team member. These vulnerabilities and capabilities were categorized into seven distinct sections each (refer to Appendix 2 and 3). Participants were instructed to review the lists and select a maximum of ten vulnerabilities deemed most critical for the company to address in order to enhance its SCRES. Similarly, they were asked to identify up to five capabilities associated with each of the identified vulnerabilities. The predefined lists of vulnerabilities and capabilities were perceived as advantageous:

> "I am quite sure that if there had not been a list, we would still be sitting and discussing …" Supply Chain Manager – case 18

Additionally, they were provided with a link to a video introducing the functionality of the digital solution for assessing vulnerabilities and capabilities. Each participant was granted access to this digital tool, which was integrated into the specific company's IT infrastructure. After selecting and prioritizing vulnerabilities, participants were prompted to evaluate each vulnerability based on its impact on the supply chain and the likelihood of occurrence, utilizing a five-point scale ranging from 1 = very low impact/probability to 5 = very high impact/probability.

During the refinement iteration, participants were queried about the necessity of phase two or whether it could be omitted, opting instead for a unified process. All participants responded positively, emphasizing the importance of retaining phase two as it afforded them the requisite time for reflection on vulnerabilities and capabilities from their individual perspectives.

> "Phase two was crucial as it better equipped us for phase three." Planning Manager – case 10

The vulnerabilities and capabilities outlined in Appendices 2 and 3, Tables 8 and 9 stem from the explorative iteration, advisory group meetings, the questionnaire survey, the refinement iteration, and insights from Pettit et al. (2013). They have intentionally been defined broadly to facilitate their versatile application across various narratives among SMEs. Consequently, participants are not required to possess a uniform understanding of the vulnerabilities and capabilities during phase two; instead, they are encouraged to develop individual narratives.

4.2.3 Prioritize and create cross-organizational alignment

In the third phase, the unified team collaborated using the digital tool to formulate a shared, prioritized list of vulnerabilities and capabilities. The developed digital solution incorporates a feature that simplifies the creation of summaries, utilizing pivot tables to showcase each participant's selection of vulnerabilities and capabilities, as well as their assessments of their current levels and significance. Once more, we witnessed productive discussions among representatives from various functions, with much of their feedback centered on fostering a broader organizational comprehension. Table 6 comprises several quotations illustrating the results and significance of this phase.

During phase three with the companies, two vulnerabilities and four capabilities were suggested by the participants, along with the option to choose an "other" within each of the seven groups of vulnerabilities and capabilities. Consequently, the "other" option enables participants to define their vulnerabilities and capabilities

if they deem it necessary to express their meaning more precisely than the predefined options allow. As a result, the final process model comprises 75 vulnerabilities (including seven "others") and 97 capabilities (including seven "others").

4.2.4 Develop action plans

The final phase of the process model aimed at enhancing SCRES focuses on translating the results from phase three into action plans, reflecting on the learning process, and considering key aspects for implementing the selected initiatives. Discussions centered on the significance of avoiding overloading with initiatives given their limited resources and strong operational focus. Quotations illustrating the outcomes of this phase are provided in Table 7.

A distinguishing feature of SMEs, in contrast to large corporations, is their comparatively lower financial capacity. Throughout this study, participants suggested various capabilities that could potentially add to the financial strain on these companies. These included operating with excess capacity, expanding the supplier base, bolstering safety stocks, enhancing systematic maintenance, and refining relationship management. However, enhancing SCRES comes with associated costs. Consequently, while certain capabilities were initially considered for prioritization during the development of action plans, they were subsequently excluded, as illustrated in the following quotation:

> "We are in a situation where we need to demonstrate business professionalism towards our stakeholders, which means that the capital requirements for such resilience activities need to be self-financing." CEO – case 11

4.3 Supply chain resilience process model

The two aforementioned iterations lead to a process model for achieving SCRES, as depicted in Fig. 2. The figure incorporates elements from the applied process theory, such as inputs, actions, events, and consequences. Inputs for engaging with the process model, following the terminology of Ali et al. (2017), can be of proactive, concurrent, or reactive nature. The activities and events encompass supply chain mapping, functional assessment of vulnerabilities and capabilities, cross-functional assessment of vulnerabilities and capabilities, and the formulation of action plans. The consequences also include the development of action plans that must subsequently be monitored for implementation.

5 Discussion

This paper aims to investigate how SMEs can achieve SCRES through a structured process. In total, 18 case companies participated in two rounds of data collection: an exploratory phase and a refinement phase, respectively. The focus on SCRES from an SME perspective corresponds to the demand for such research in existing literature (Bak et al. 2023; Kamalahmadi and Parst 2016; Polyviou et al. 2020), which is empirically based (Kochan and Nowicki 2018). The research revealed that SMEs lack both financial and human resources to build SCRES, which aligns with existing research (Brustbauer 2016; Kull et al. 2018; Pal et al. 2014).

The process model for SCRES consists of four sequential phases and addresses how SMEs can enhance SCRES, an issue addressed by Iborra et al. (2022), reflecting a general demand for more real-life and practically relevant research (Narasimhan 2018; Samson 2020). These four phases include supply chain mapping, identifying vulnerabilities and capabilities per function, prioritizing and creating

Table 7 Examples of reflections after phase four

"We have a significant challenge with development alongside a busy daily routine." Sales Engineer – case 10
"I have had an eye-opening experience in this project. It has made me realize how much our management team has been focused on resolving daily issues without finding the time to think about long-term strategies. We have been part of practical relevant research that works. We were brought together and guided through risk management and crisis preparedness, which I am confident will bring benefits to our company." CEO – case 16
"It's important to select focus areas with an emphasis on delivery time, capital employment, and delivery capability so we ensure result-generating activities." CEO—case 11
"It is particularly impressive that such a complex subject is addressed practically, ensuring input and involvement throughout the company. Our participation in the project has propelled us years ahead in our thinking and actions to tackle the constant challenges we face in global supply chains." CEO – case 11
"The process model developed is quite structured, so it is not necessary to have an external facilitator in the process. However, an advantage with an external facilitator is that such a person can challenge the prioritization of tasks to reducer vulnerabilities and improve the capabilities" Finance Manager – case 13
"We do some things in the supply chain organization, but this process is even broader as now we have sales and product development included, including some of the things that are generated elsewhere that hits the supply chain." Supply Chain Manager – case 18
"We now meet monthly across functions to discuss issues in the supply chains. This fosters a common understanding and a shared language for the reality." COO – case 15

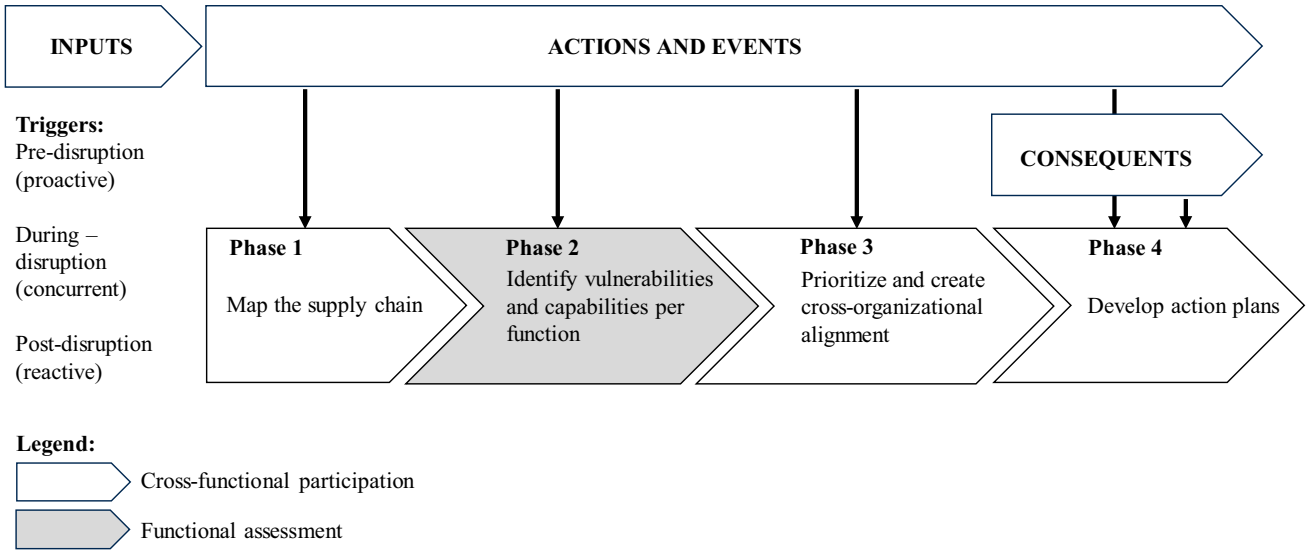

Fig. 2 A process model for supply chain resilience

cross-organizational alignment, and developing action plans. The developed process model is accompanied by 26 tools divided across the four phases. Both the process model and the tools are available in English at www.scr-smv.dk.

The first phase of the process model focuses on supply chain mapping with cross-functional representation, aligning with existing research that emphasizes the importance of mapping to enhance understanding of supply chains and their vulnerabilities (Choi et al. 2020; Christopher and Peck 2004; Colicchia et al. 2010). The case studies conducted during this process revealed several enlightening experiences where participants gained new insights into their respective companies, consistent with findings by Poberschnigg et al. (2020), underscoring the significance of cross-functional representation in achieving SCRES.

The second phase involve assessing vulnerabilities and capabilities necessary to address these vulnerabilities. The functions conduct this assessment individually using a predefined list of 75 vulnerabilities and 97 capabilities (refer to Appendences 2 and 3, Tables 8 and 9). Some of these vulnerabilities and capabilities are derived from the seminal work by Petit et al. (2013), with 24 of the 75 vulnerabilities and 42 of the 97 capabilities originating from this source, while the remaining ones are identified through the case study research. This SCRES process model, along with its accompanying software and tools, enriches the existing SCRES literature by balancing vulnerabilities and capabilities (Pettit et al. 2010; 2013; Polyviou et al. 2020). Moreover, it presents a novel SCRES framework tailored to the context of SMEs (Pettit et al. 2019). Accessible online, these tools and guidelines offer SMEs a practical approach to prioritize SCRES, particularly focusing on their SCRES capabilities (Bak et al. 2023).

In the third phase, the cross-functional team repeats the assessment of vulnerabilities and capabilities from phase two, emphasizing teamwork. This research underscores the importance of cross-functional collaboration in bolstering SCRES, echoing findings by Christopher and Peck (2004), Molinaro et al. (2023), Pettit et al. (2010), and Poberschnigg et al. (2020).

In the final phase, action plans are developed based on the teamwork in phase three, identifying a prioritized list of vulnerabilities along with several critical capabilities required to address them. Additionally, the team evaluates the current level of capabilities using a five-point scale ranging from 1 (very low level) to 5 (very high level), assessing their importance. This process helps identify gaps between the current and required capability levels, informing the development of action plans. It highlights the need for new supply chain competencies, such as improved forecasting techniques, the implementation of new digital tools, and enhanced collaboration skills. This aligns with findings by Nikookar and Yanadori (2022) and van Hoek et al. (2020), emphasizing the necessity of strengthening SCRES competencies in light of Covid-19. Indeed, the process can catalyze SCRES-driven organizational development (Anholon et al. 2021).

The SCRES process model developed in this paper embraces a process-oriented perspective, aligning it with existing theory (Drozdibob et al. 2023; Kamalahmadi and Parst 2016; Ponomarov and Holcomb 2009). The process model is grounded in process theory and utilizes a mixed-method approach, following recommendations by Ali and Gölgeci (2019) to broaden theoretical and methodological perspectives to offer fresh insights into SCRES (Kochan and Nowicki 2018). Notably, existing literature reviews on SCRES, which delve into the theoretical foundations of SCRES research, have not identified any that employ process theory as in this paper (Ali and Gölgeci 2019; Kochan and Nowicki 2018). This presents new

avenues for SCRES research utilizing process theory to distinguish between inputs, actions, events, and consequences. Moreover, the process model accommodates both an engineering and an ecological approach to SCRES. From an engineering standpoint, the emphasis lies on efficiency, consistency, and predictability, focusing on known risks. However, in the presence of unknown risks, an ecological resilience perspective may be more appropriate, allowing for multiple equilibria where the objective is not to return to the pre-disruption phase but to establish a new "normal". The process model demonstrates robustness in addressing both perspectives on SCRES, aligning with existing literature that advocates for the inclusion of both viewpoints in the discourse (Wieland and Durach 2021).

6 Conclusions

This paper addresses recent calls to prioritize SCRES among SMEs, aiming to investigate how SMEs can attain SCRES despite their limited resources. Employing a multiple case study design across two iterations—an explorative phase followed by a refining phase—the study develops and refines a process model based on process theory. The final process model comprises four phases: 1) supply chain mapping, 2) identify vulnerabilities and capabilities per functional area, 3) prioritize and create cross-organizational alignment, and 4) develop action plans. In the realm of process theory, the input refers to a distinct disruption, such as the impact of COVID-19, which prompts triggers both during the disruption itself (concurrent) and afterward (reactive), or it can signify a deliberate, proactive management approach to supply chain resilience (SCRES). The actions and events are depicted through the four phases of process models, while the consequents entail the development of specific action plans. In developing the process model, 75 vulnerabilities and 97 capabilities are delineated, drawing from existing theory and insights gleaned from the case studies. The findings highlight that personnel from non-supply chain functions possess limited understanding of supply chain dynamics and hold divergent views on vulnerabilities and required capabilities. Despite SMEs having potentially greater internal integration compared to larger companies, the study uncovers significant siloed behavior and lack of internal cohesion, even in smaller firms with 20 employees. Thus, the presented process model underscores the necessity of an integrated organizational approach towards SCRES. The study emphasizes the value of investing time in understanding supply chain vulnerabilities and capabilities, offering a common language for pursuing SCRES initiatives.

6.1 Implications for theory

This paper has several implications for theory and practice. For theory, the paper contributes new knowledge about how SMEs can organize work to create awareness of SCRES and obtain a cross-organizational understanding and alignment. Thus, the paper responds to calls in extant literature to focus on empirical research on how SMEs approach SCRES (Ali and Gölgeci 2019; Drozdibob et al. 2023; Polyviou et al. 2020) that also applies mixed methods (Kamalahmadi and Parast 2016). The presented process model, which is based on process theory, aims to help SMEs strengthen their SCRES capabilities (Bak et al. 2023) with a focus on the *how* question (Eryarsoy et al. 2022). The present study ends with the development of action plans to improve selected supply chain capabilities. Research is still needed that focuses on the change aspect in implementing a practice that improves a business continuity focus (Pettit et al. 2019) to achieve a genuine supply chain risk culture (Christopher and Peck 2004).

The presented process model enhances the framework established by Pettit et al. (2013), offering a more comprehensive perspective. Additionally, this study customizes the SCRAM™ framework for the manufacturing sector and SMEs, a refinement from previous research (Pettit et al. 2019). Unlike the original framework, which primarily focused on retail (Pettit et al. 2010), this adaptation integrates relevant vulnerabilities and capabilities tailored specifically for SME manufacturing in the current business landscape. While acknowledging the significance of the SCRAM™ framework, it is recognized as potentially too intricate for SME managers. This study underscores the necessity for customizing vulnerability and capability frameworks (Pettit et al. 2013) to suit the needs of manufacturing enterprises, particularly SMEs, aligning them with contemporary business realities and challenges.

The process model is adaptable for use in both engineering and ecological approaches to SCRES. The four phases of the model remain consistent regardless of whether one adopts an engineering or ecological perspective on SCRES. However, distinctions between these perspectives become evident in their views on vulnerabilities and necessary capabilities. For instance, engineering perspectives emphasize bounce-back capabilities (Sheffi and Rice 2005), whereas ecological perspectives focus on adaptive capabilities with multiple equilibria (Novak et al. 2021).

Finally, this paper adds to the literature examining the interplay between cross-functional integration and SCRES (Poberschnigg et al. 2020; van den Adel et al. 2023), highlighting a persistent challenge. Despite extensive research and efforts to emphasize the significance of internal integration, its implementation continues to be a widespread issue.

6.2 Practical implications

The study also holds implications for practice. Firstly, it underscores the significance of anchoring SCRES efforts within top management. Companies where the CEO actively participated

throughout the process demonstrated stronger decision-making authority, enabling them to allocate resources for specific improvement activities. Conversely, in companies lacking CxO representation, decision-making became ambiguous, requiring the outcomes to align with the company's strategic development. Secondly, the study emphasizes the importance of cross-functional involvement in enhancing SCRES, echoing findings from existing literature (Christopher and Peck 2004; Colicchia et al. 2010; Gunasekaran et al. 2011). Thirdly, the supply chain mapping element is important to obtain a common cross-functional understanding of the supply chain. Fourthly, it highlights the necessity of investing adequate time in the process. Meaningful discussions about supply chains and associated challenges revealed a lack of common understanding among staff, albeit time constraints were pervasive due to operational tasks. This underscores the importance of implementing SCRES-enhancing activities through sequential ambidexterity (O'Reilly and Tushman 2004). Fifthly, to sustain their efforts in SCRES, companies can establish cross-organizational business continuity teams. This practice has been adopted by several of the case companies, wherein the team convenes at regular intervals to oversee the advancement of ongoing tasks and to suggest fresh initiatives. Sixthly, when staff self-evaluate vulnerabilities and capabilities, they may be influenced by pre-existing perceptions, potentially leading to the oversight of certain vulnerabilities and capabilities. Therefore, we recommend the involvement of an external facilitator to assist in challenging these perceptions throughout the process. Seventhly, the findings underscore implications for policymakers, highlighting the necessity for government awareness programs on SCRES and publicly funded subsidy initiatives to support SMEs SCRES efforts. Lastly, recognizing the dynamic nature of the business environment, periodic revisiting of the presented process model is recommended to ensure its continued relevance and effectiveness.

6.3 Limitations and suggestions for future research

The paper has several limitations worth noting. Firstly, it draws from a sample of 18 cases within a Danish context, a culture characterized by low power distance (Hofstede 1980). Consequently, the developed process and proposed approach may require further exploration in diverse cultural settings through additional case studies. Different cultural contexts may perceive threats differently, necessitating distinct sets of capabilities (Manhart et al. 2020). Secondly, the study focuses specifically on manufacturing SMEs, overlooking other integral players in global supply chains such as retailers, wholesalers, and third-party logistics providers. Future research could delve into the vulnerabilities and capabilities specific to these types of companies. Thirdly, the vulnerabilities and required capabilities may vary depending on the geographic location of the company. Entities situated in regions prone to natural disasters like earthquakes, volcanic eruptions, and hurricanes may face unique challenges. Thus, future investigations could consider geopolitical differences when assessing vulnerabilities and capabilities. Fourthly, given the evolving geopolitical landscape, increased tensions may introduce novel vulnerabilities and required capabilities. Future research should address these emerging issues. Fifthly, the escalating level of cybercrime introduces new vulnerabilities and necessitates specific capabilities for SMEs. Consequently, future research can delve into methods for establishing SCRES, with a particular emphasis on cybersecurity. Sixthly, most case companies in the study operate within the business-to-business sector. Exploring potential disparities in supply chain vulnerabilities and capabilities between business-to-business and business-to-consumer companies could be a valuable avenue for further inquiry. Lastly, while the developed process model outlines improvement initiatives to bolster a company's SCRES, it does not guarantee their execution. Hence, future research should focus explicitly on the implementation aspect of SCRES initiatives, identifying success criteria and barriers.

Appendix 1. Questions to function on day 1 (first iteration)

Questions to sales, manufacturing, purchasing, finance, IT, and product development.

The purpose of the interviews is to gain insight into the AS-IS supply chain structure and processes of the company, as well as the disruptions that have been experienced and continue to be experienced, how they unfold, and how they are sought to be managed. Based on the data collection, the supply chain is mapped out, including the areas where the company is vulnerable.

1. What is your name, position, and area of work?
2. Please describe your function (activities and facts about it)
3. What is the strategy for the function?
4. How do you measure performance in your function?
5. What types of disruptions have you experienced/are you experiencing in the supply chains?
6. How has it affected/does it affect your function's performance?
7. Where is the supply chain, in your opinion, particularly vulnerable to disruptions?
8. Where do you believe your company is vulnerable and resilient?
9. What specific practices have you implemented to manage the disruptions and their consequences?
10. Which IT systems are currently used to support your function?

Appendix 2

Table 8 Development of a new set of vulnerabilities

	Authors reflection	Pettit et al. (2013)	Interviews in the explorative iteration	Survey among participants in the explorative iteration	The refinement iteration	Advisory Group
1. Finance						
V1.1 Asset turnover						x
V1.2 Access to liquidity			x			
V1.3 High level of net working capital						x
V1.4 Low cash flow	x					
V1.5 Other	x					
2. Customers/demand						
V2.1 Unpredictability of demand		x				
V2.2 Lack of sale					x	
V2.3 Product development pipeline						x
V2.4 Insufficient sales pipeline						x
V2.5 Customers frequently make changes in orders					x	
V2.6 Customer dependency						x
V2.7 Insufficient product assortment			x			
V2.8 Too large assortment				x		
V2.9 Product liability/compensation		x				
V2.10 Brand image		x				
V2.11 Time to market challenges	x					
V2.12 Time pressure	x					
V2.13 Unprofitable customers	x					
V2.14 Lack of market focus	x					
V2.15 Too low transport capacity		x				
V2.16 Other	x					
3. Processes/organization						
V3.1 Too low production capacity		x				
V3.2 Reliability of equipment's		x				
V3.3 Manufacturing does not take place at the right locations						x
V3.4 Undocumented processes				x		
V3.5 A too-high operational focus	x		x			
V3.6 Lack of cross-functional collaboration (silo-culture)			x			
V3.7 Lack of human resources		x				
V3.8 Lack of competencies		x				
V3.9 Too much tacit knowledge			x			
V3.10 Too high staff turnover			x			
V3.11 Too dependent on key persons				x		
V3.12 Lack of financial resources			x			
V3.13 Quality			x			
V3.14 Lack of maintenance			x			
V3.15 Insufficient foundation of production (master data)			x			
V3.16 Other	x					
4. Systems/data						
V4.1 Insufficient systems				x		

Table 8 (continued)

	Authors reflection	Pettit et al. (2013)	Interviews in the explorative iteration	Survey among participants in the explorative iteration	The refinement iteration	Advisory Group
V4.2 Lack of IT security			x			
V4.3 Lack of Quality Management			x			
V4.4 Too low data quality				x		
V4.5 Too low data accessibility	x					
V4.6 Too few/wrong KPI's						x
V4.7 Conflicting KPI's						x
V4.8 Insufficient use of systems				x		
V4.9 Other	x					
5. Purchasing/sourcing						
V5.1 Too low supplier capacity		x				
V5.2 Lack of accessibility of raw materials and supplies		x				
V5.3 Too low supplier reliability		x				
V5.4 Dependency on Supplier Relations			x			
V5.5 Lack of access to supplier competencies			x			
V5.6 Too little focus on new suppliers						x
V5.7 Supplier bankruptcy						x
V5.8 Requirements for product purity		x				
V5.9 Other	x					
6. Supply chain end-to-end						
V6.1 Lack of transparency	x					
V6.2 Price pressures from customers/suppliers		x				
V6.3 Too high/low growth			x			
V6.4 Import and export restrictions/channels		x				
V6.5 Too high complexity		x				
V6.6 Other	x					
7. Environment						
V7.1 Geopolitical disruptions		x				
V7.2 Fluctuations in prices and exchange rates		x				
V7.3 Terrorism/sabotage		x				
V7.4 Espionage/theft		x				
V7.5 Cyber-attack			x			
V7.6 Competitors innovation		x				
V7.7 Social/demographic/cultural changes	x					
V7.8 Requirements for CSR/sustainability/ESG/UN SDG's		x				
V7.9 Political regulatory changes		x				
V7.10 Stakeholders/NGO's		x				
V7.11 Disruptions	x					
V7.12 Unclear/lack of intellectual property rights			x			
V7.13 Strikes		x				
V7.14 Other	x					

Appendix 3

Table 9 Development of a new set of capabilities

	Authors reflection	Pettit et al. (2013)	Interviews in the explorative iteration	Survey among participants in the explorative iteration	The refinement iteration	Advisory Group
1. Finance						
C1.1 Degree of asset utilization		x				
C1.2 Access to capital		x				
C1.3 Insurances		x				
C1.4 Price margin		x				
C1.5 Cost estimates/costing						x
C1.6 Cash flow						x
C1.7 Terms of payment						x
C1.8 Focus on net working capital	x					
C1.9 Focus on customer/product profitability	x					
C1.10 Other	x					
2. Customers/demand						
C2.1 Customer loyalty/retention		x				
C2.2 Market share		x				
C2.3 Capability to create customer relations		x				
C2.4 Capability to market dispersion		x				
C2.5 Customer communication		x				
C2.6 Customer segmentation	x					
C2.7 Forecasting		x				
C2.8 Collaboration on forecasting		x				
C2.9 Product differentiation		x				
C2.10 Alternative distribution channels		x				
C2.11 Attractive product assortment			x			
C2.12 Sales Pipeline					x	
C2.13 Development projects (and pipeline)					x	
C2.14 Faster time to market	x					
C2.15 Capability of product pruning	x					
C2.16 Other	x					
3. Product/processes						
C3.1 Component commonality		x				
C3.2 Increased standard products/components		x				
C3.3 Modular product design		x				
C3.4 Capability to reduce product variability		x				
C3.5 Excess capacity		x				
C3.6 Manufacturing foundation	x					
C3.7 Phasing products in and out		x				
C3.8 Capability to prevent errors		x				
C3.9 Quality management					x	
C3.10 Productivity/elimination of waste		x				
C3.11 Optimize manufacturing lead-time		x				
C3.12 Fast changeovers		x				
C3.13 Flexible/scalable capacity		x				
C3.14 Postpone manufacturing		x				
C3.15 Systematic maintenance			x			
C3.16 Standardized workflows/processes				x		
C3.17 Documented workflows/processes				x		

Table 9 (continued)

	Authors reflection	Pettit et al. (2013)	Interviews in the explorative iteration	Survey among participants in the explorative iteration	The refinement iteration	Advisory Group
C3.18 Continuous improvement			x			
C3.19 Manufacturing at the right locations						x
C3.20 Outsourcing – make or buy analyses			x			
C3.21 Other	x					
4. Inventory management						
C4.1 IT-supported inventory management	x					
C4.2 Location management						x
C4.3 Safety stock						x
C4.4 Min/max inventory management						x
C4.5 ABC inventory management						x
C4.6 Focus on death goods/obsolescence						x
C4.7 Other	x					
5. Sourcing/purchasing						
C5.1 Being an attractive customer			x			
C5.2 Substitution of raw materials, semi-finished products, and components		x				
C5.3 Increased suppliers/sources of supply		x				
C5.4 Capability to create supplier relations						x
C5.5 Prioritization (segmentation) of suppliers						x
C5.6 Supplier assessment and auditing						x
C5.7 Supplier development	x					
C5.8 Knowledge about the supply market	x					
C5.9 Differentiated approach towards the suppliers	x					
C5.10 Preferred part list	x					
C5.11 Preferred supplier list	x					
C5.12 Other	x					
6. Systems/data						
C6.1 Exchange of information – internally		x				
C6.2 Exchange of information – externally		x				
C6.3 Use of contemporary information technology		x				
C6.4 Cyber security		x				
C6.5 Monitoring Early Warning Signals		x				
C6.6 Ownership of master data	x					
C6.7 Utilizing the potential of systems in use	x					
C6.8 Other	x					
7. Management/organization						
C7.1 Relationship management						x
C7.2 Delegated accountability		x				
C7.3 Execution skills	x					
C7.4 Employee involvement		x				
C7.5 Learning/benchmarking		x				
C7.6 Communication		x				
C7.7 Access to qualified labor						
C7.8 Capability to attract new employees					x	
C7.9 Crisis management					x	
C7.10 Risk management		x				
C7.11 Lobbyism		x				

Table 9 (continued)

	Authors reflection	Pettit et al. (2013)	Interviews in the explorative iteration	Survey among participants in the explorative iteration	The refinement iteration	Advisory Group
C7.12 Width in competency profiles			x			
C7.13 Creative problem-solving			x			
C7.14 Focus on core competencies		x				
C7.15 Design for manufacturing/supply chain			x			
C7.16 Sales and operations planning						x
C7.17 Digitalization	x					
C7.18 Right KPI's functional and corporate levels			x			
C7.19 Intellectual property rights						x
C7.20 Work based on documented supply chain strategy		x				
C7.21 Cultural understanding						x
C7.22 Cross training	x					
C7.23 Other		x				
		x				

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