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Bespoke Supply Chain Resilience

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*To my parents, my siblings, and Simone
for their love and support.*

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LIST OF ABBREVIATIONS

B2B	Business-to-business
CPG	Consumer packaged goods
CT	Contingency theory
EBITDA	Earnings before interest, tax, depreciation, and amortization
EDC	Expected disruption costs
ETO	Engineer-to-order
JDM	Joint design manufacturing
KPI	Key performance indicator
LCA	Lifecycle assessment
MTO	Make-to-order
MTS	Make-to-stock
OEM	Original equipment manufacturer
OTIF	On-time in-full
RBV	Resource-based view
RQ	Research question
SC	Supply chain
SCM	Supply chain management
SCRE	Supply chain resilience
SCRM	Supply chain risk management
SCS	Supply chain sustainability
SKU	Stock keeping unit
SVP	Senior vice president
TTR	Time-to-recover
TTS	Time-to-survive
US	United States
VaR	Value at risk
VP	Vice president

1. INTRODUCTION

1.1 Background and Motivation: The Importance of Supply Chain Management

“Although supply chain management (SCM) has only recently appeared as one of today’s most powerful strategic business concepts, its development can be traced back to the rise of modern logistics.” Finding such a statement in any recent article on SCM would not be surprising, as our daily life and the life of many professionals was heavily influenced by supply chain related topics during the last years. However, the statement is almost a quarter century old and the starting sentence of a book on the evolution of SCM (Ross, 1998). This shows that managing supply chains effectively and efficiently has been a important topic back then and continues to be so until now. Moreover, the overall aims of SCM also have not changed from generally reducing costs and increasing customer service and satisfaction to gain a competitive advantage (Cooper & Ellram, 1993). However, the underlying drivers of complexity that are responsible for SCM still being a major area for concern and therefore also for a competitive advantage have gradually changed over time (Peck, 2005). Globalization and increasing competition have led to geographically widespread supply chains, forecasting difficulties, and exchange rate uncertainties (Delfmann & Albers, 2000). In the last decade, other influencers such as rising geopolitical tensions, especially between China and the US (Dong & Kouvelis, 2020; Walmsley & Minor, 2020), and natural disasters such as the Thailand floods in 2011, Japan Earthquake and Tsunami in 2011, and Hurricane Maria in 2017 have shaped supply chains (Simangunsong et al., 2012; Giannakis & Papadopoulos, 2016). Finally, in 2020 the global COVID pandemic let many companies to rethink their supply chain and risk management, as they experienced a new level of supply and demand disruptions (Chen et al., 2021). This large-scale black swan event exposed the fragility of many supply chains and the various levels of resilience even among companies within the same industry. Moreover, expectations are that the supply chain market is expected to grow even further over the next years. A recent report found that the SCM market globally will almost double in size from 2020 until 2026 (Statista, 2021).

Due to the previously mentioned developments, supply chain resilience is currently a top priority for almost every company. However, the concept of supply chain resilience is multidimensional, complex and there is no collective understanding among scholars of how to delimit resilience from other concepts like *agility* and *robustness* (Tukamuhabwa et al., 2015). Moreover, supply chain resilience is a fairly new concept that has only received some research attention within the last 14 years (Ali et al., 2017). Thus, it can be concluded that supply chain resilience is an integral part of today's SCM but has so far received only limited attention from scholars. Therefore, this dissertation looks from different angles on the phenomenon of supply chain resilience and especially tries to bridge between the environment that supply chain executives are experiencing and the theoretical view on supply chain resilience.

1.2 Scope of the Dissertation

Understanding supply chain resilience is the central focus of this dissertation. The initial step involves providing a precise definition of the term and distinguishing it from related concepts. However, numerous literature reviews indicate that many scholars have already explored this area, yet a collective understanding has not yet been achieved (refer to Hohenstein et al., 2015; Tukamuhabwa et al., 2015; Kamalahmadi & Parast, 2016; Ali et al., 2017). Nevertheless, there is still a scarcity of empirical studies and papers that integrate existing theories with practical perspectives on supply chain resilience. Therefore, this dissertation aims to bridge this gap by examining intriguing aspects of supply chain resilience.

First, an investigation was conducted to determine why companies struggle to achieve resilience despite the well-known and not-so-secret strategies. The analysis revealed that the resilience strategies mentioned in operations management and supply chain management literature, as well as in consulting reports from 2020, were largely similar. Two recurring themes were evident across these reports: increasing redundancies or enhancing operational flexibility. The former involved strategies such as augmenting inventory or capacity, diversifying manufacturing footprint or supply base. The latter encompassed building a robust distribution network, standardizing products, and cultivating stronger relationships with supply chain partners. Consequently, it can be concluded that the strategies

for achieving resilience are well-established. However, many companies faced challenges in implementing these strategies in the wake of the pandemic. Thus, a team of scholars and I conducted interviews with top-level executives from large manufacturing companies to identify the barriers to supply chain resilience. Based on these interviews, six overarching barriers were identified, along with corresponding best practice strategies to mitigate and overcome them.

Second, the dissertation aimed to comprehend how companies can select the most suitable resilience strategies given their specific circumstances, considering that resources are limited and there is a multitude of strategies to choose from. In the second paper, we analyzed the underlying patterns between the operational characteristics of supply chains and the implemented resilience strategies. Employing an empirical research approach, we conducted multiple interviews with supply chain executives and identified key factors influencing the selection of supply chain resilience strategies. Through clustering analysis of the examined supply chains, three distinct archetypes were identified, sharing similar primary drivers of complexity and implementing comparable supply chain strategies. Consequently, we concluded that tailored supply chain resilience is essential for achieving true resilience, wherein each supply chain must customize a specific strategy based on its unique environment after identifying the appropriate archetype.

Third, we conducted a detailed examination of supply chain reports, often carried out by consulting firms, which serve as valuable resources for understanding the perspectives of practitioners on current issues. However, our interviews revealed that executives face challenges in translating the insights from such surveys into actionable resilience strategies. Fortunately, our research team had previously collaborated and gained access to the results of a comprehensive Gartner supply chain survey conducted in 2020, which we analyzed using various cross tables. In our paper, we investigate the extent to which using the company or industry as the unit of analysis, rather than the supply chain itself, hampers executives' ability to derive actionable insights. Furthermore, we present three case studies that demonstrate how this analytical gap can be bridged.

Fourth, we explore the relationship between supply chain resilience and sustainability, which are both significant strategic business objectives. In this chapter, we compare the existing literature on supply chain resilience and sustainability in terms of the strategies, barriers, and metrics employed. Additionally, we review the literature on the intersection of resilience and sustainability, and conduct a large-scale survey to gain further insights into the general relationship between these two concepts. Drawing upon the empirical findings, supported by statistical testing and the existing literature, we develop a framework that illustrates the distinctive characteristics of the identified relationship between resilience and sustainability.

1.3 Structure of the Dissertation

I organize my dissertation in four papers, i.e., in four different chapters. The first three papers focus exclusively on the phenomenon of supply chain resilience while the fourth chapter looks at the intersection of supply chain resilience and supply chain sustainability. Figure 1.1 gives an overview of the structure of my dissertation.

	Paper I	Paper II	Paper III	Paper IV
	Putting Supply Chain Resilience Theory into Practice	Bespoke Supply Chain Resilience	Why operational context matters: Realizing the full potential of supply chain resilience surveys	The Intersection of Supply Chain Resilience and Sustainability from a Practical Perspective – An Integrated Approach
Research question	What are the main implementation challenges for supply chain resilience strategies?	What are the main influencers of supply chain resilience strategies for supply chain executives?	Why are supply chain surveys on resilience not actionable for executives?	What is the relationship between SC resilience and SC sustainability in the context of supply chain management from a practitioner perspective?
Contribution	<ul style="list-style-type: none"> Empirical evidence on gap between well understood resilience strategies and implementation obstacles Identification of six cross-industry barriers to supply chain resilience implementation Four prescriptive recommendations with best-practice company examples 	<ul style="list-style-type: none"> First paper to analyze how operational supply chain factors influence the right resilience strategy Development of empirically grounded framework on bespoke supply chain resilience Identification of three supply chain archetypes distinguished by different complexity drivers 	<ul style="list-style-type: none"> Analyzed data from a large-scale survey of executives regarding supply chain resilience and agility Identified a unit of observation gap Recommendations for how to bridge the gap and conduct future surveys to increase its value to both practitioners and researchers 	<ul style="list-style-type: none"> First comparison of resilience and sustainability barriers First large-scale survey on the resilience-sustainability intersect Framework to clarify relationship between SC resilience and SC sustainability from a practitioner's view Three recommendations on how to align both objectives within the organization
Method	<ul style="list-style-type: none"> Semi-structured interviews with top level supply chain executives Case studies to illustrate best practices 	<ul style="list-style-type: none"> Empirically grounded research based on semi-structured interviews K-means clustering 	<ul style="list-style-type: none"> Cross tabulations of large (1300 people) supply chain survey data Three case studies with globally leading companies 	<ul style="list-style-type: none"> Online survey with 143 supply chain or general management executives Statistical hypothesis testing

FIGURE 1.1: OVERVIEW OF THE DISSERTATION

Chapter 2 presents the first paper which focuses on the implementation challenges of supply chain resilience strategies. It was found that the general roadmap for becoming resilient is well understood by executives as most reports and articles mention similar strategies. In this paper, a two-step process is

identified. First, the most appropriate resilience strategies need to be selected based on a weighted decision across the multiple elements of resilience, as no company has the resources to implement all strategies and choices should be responsive to tradeoffs and constraints. Second, the chosen strategy needs to be implemented while taking all limitations and boundary conditions into account. Thus, sometimes companies end up implementing the second or third best choice if their first choice turns out to be too costly or not feasible. Based on interviews with supply chain executives six overarching implementation challenges were identified across industries. Moreover, four prescriptive recommendations that mitigate these barriers to resilience implementation are provided together with a real-life best practice example.

Chapter 3 comprises the second paper which is summarizing the concept of bespoke supply chain resilience. After an introduction and a brief literature review on supply chain tailoring as a response to risk and uncertainties, an empirically grounded research approach is used to identify two primary influencers of supply chain resilience strategies. The two influencers are then used to cluster 26 different supply chains into three supply chain archetypes. The archetypes are analyzed in more detail based on eight operational attributes to better understand similarities within and differences between clusters. Finally, a bespoke supply chain resilience framework is introduced based on the three primary drivers of complexity that dictate the necessary resilience strategy. Each of the three archetypes is described in detail regarding common barriers and strategies.

Chapter 4 covers the third paper which has a closer look at supply chain resilience consulting reports. Due to the COVID pandemic and the subsequent other disruptions such as the semiconductor shortage or the bottleneck in logistical services, many consulting companies have picked up supply chain resilience in their reports. In this paper, twelve different consulting reports based on large-scale executive surveys are analyzed and compared to each other. It was found that there is a high degree of reoccurring messages in the survey reports, however, the recommendations are not actionable for companies. The identified underlying reason is the difference in the required unit of observation. Executives need detailed recommendations based on their specific operational supply chain context and environment. However, the consulting reports usually make recommendation

on a cross-industry and cross-country level. The paper introduces a two-step process to close this gap. The first can be done by doing further analysis of already collected data which is illustrated with a data set of 1300 executives from a Gartner survey in 2020. The second step requires altering the structure and the framing of the questions. Moreover, three real-life case study examples are given to illustrate the shortcomings of the traditional survey report approach and highlight the advantages of the newly proposed approach.

Chapter 5 presents the fourth paper that analyses the intersection of supply chain resilience and supply chain sustainability. First, a literature review is conducted to compare the two concepts with regards to the strategies, barriers, as well as metrics and to summarize current studies that look at the relationship between the two concepts. Second, the empirical findings from a larger scale survey of 143 supply chain executives are analyzed and compared to findings from other scholars. Statistical hypothesis testing is used to validate associations between different variables. Finally, a framework was developed to illustrate the identified multidimensional characteristics of the relationship between supply chain resilience and supply chain sustainability. Moreover, key learnings for executives are derived from the framework and the empirical findings.

Chapter 6 concludes this dissertation. The findings of this dissertation are briefly summarized and an overview of the contributions to research and practice is given. Finally, a critical reflection on all four research papers and potential avenues for future research are outlined.

2. PUTTING SUPPLY CHAIN RESILIENCE THEORY INTO PRACTICE¹



2.1 Introduction

While in a number of ways the COVID pandemic can correctly be regarded as once-in-a-lifetime, it is just the latest incident within recent times to cause a major supply or demand disruption. Other disruptors within just the last dozen years include the financial crisis in 2009, the Japan earthquake and nuclear disaster in 2011, the Thailand floods in 2011, and the US-China trade conflict that escalated in 2018. While supply chain resilience is often a source of competitive advantage, the scope and magnitude of the disruption at hand have made resilience into a matter of survival for many organizations.

The goal of this article is to understand why some firms have done well as they responded to the current crisis, i.e., they exhibited resilience, and some did not. How well a supply chain can react to the short-term changes is its “agility”, defined as the “ability to respond rapidly and cost-effectively to short-term changes in demand or supply disruptions.” In the long term, a disruption could result in a new “normal,” with lasting impacts. How well a supply chain can proactively adapt to this new normal, is its “resilience,” defined as the “ability to adapt to structural changes by modifying supply chain, products and technologies strategies.” Proactively creating a resilient supply chain can also enable the company to mitigate the risks of future disruptions. The focus of this article will be on resilience.

The potential impact of proactive resilience strategies can occur along multiple dimensions, including time to recovery (TTR), direct costs (e.g., added expenses, lost revenue), customer service level (availability, delay, product quality, responsiveness to customer demands), brand impact (based on market share, profit margin, customer loyalty), and the required managerial effort (time and energy of top-level management).

¹ The content presented in this chapter is based on an unpublished working paper by Cohen et al. (2021). The paper was accepted by *Management and Business Review (MBR)* and is waiting for publication. Within this chapter, “we” refers to the authors of Cohen et al. (2021).

Supply chain experts and authors have cited several proactive strategies that firms are employing or considering to enhance their resilience. As a reaction to the recent COVID pandemic, numerous articles on such supply chain resilience strategies have appeared (Barriball et al., 2020; Close et al., 2020; John & Raman, 2020). One example is Gartner's recent report "Weathering the storm: Supply Chain Resilience in an Age of Disruption" (May 2020), which is based on 260 responses from senior supply chain managers. It offers six strategies for achieving supply chain resilience. While the labels have evolved over time, the general topic is not new. The treatments in the literature (which we do not intend to review individually in this short piece) have converged to a common set of themes, suggesting that the basic roadmap to supply chain resilience is well established and generally understood by managers. But this does not mean that most companies have already built a resilient supply chain. In fact, the degrees of resilience of companies still vary considerably. The goal of our research is to understand what prevents companies from creating resilient supply chains, even if what constitutes a resilient supply chain is clear. This paper draws on our COVID-era interviews of senior supply chain executives to present experiences and perspectives that could help companies increase the resilience of their supply chains.

Our interviews revealed that short-term, reactive, and agile responses have been necessary to quickly "stop the bleeding" in the midst of a severe disruption. We also learned how companies have been developing proactive strategies to build resilience. The interviews showed that multiple supply chain resilience strategy elements have been adopted, which we organize into an integrative framework (Figure 2.1). We have divided the reported supply chain activities into two categories: enablers and resilience strategies.

The resilience strategies include policies that increase redundancy in a supply chain, such as investment in operational buffers, footprint diversification, and supply options; and decisions that enhance operational flexibility to mitigate risks, such as robust distribution, product standardization, and strengthening of partner networks.

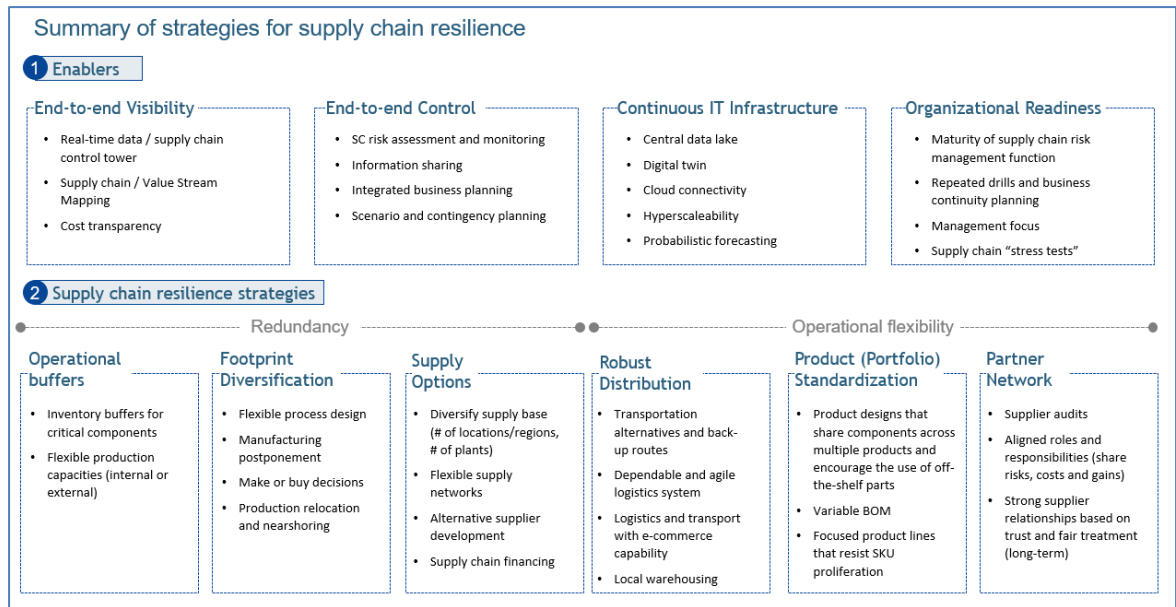


FIGURE 2.1: INTEGRATED SUPPLY CHAIN RESILIENCE MANAGEMENT FRAMEWORK

The first three clusters of enabler activities are generally understood to be best practices in supply chain management when the objectives and levels of uncertainty are those of "normal" times, while the fourth cluster directly prepares for environments that make resilience the focus. They are necessary to support making informed decisions on resilience and are prerequisites for implementing the strategy elements. For example, a manufacturing postponement strategy requires end-to-end control (information sharing, integrated business planning) and visibility (value stream mapping) to be effective.

We carried out a series of in-depth interviews with 14 supply chain executives from 12 companies in order to identify execution challenges for achieving supply chain resilience and to gather best practices to overcome these challenges. In choosing the companies we considered each one's global supply chain footprint and leading position in their respective industries. We aimed for an interesting mix of industries, HQ regions, and operating models. Four of the interviewed companies belong to this year's Gartner Supply Chain Top 25. See Figure 2.2 for more information regarding the companies included in the sample. Our interviews focused on the following themes: i) How has your company responded to the crisis? ii) What are the key elements of your company's resilience strategy? iii)

What tools and methods were used to develop the strategy? iv) What are the key learnings going forward?

No.	Industry	Revenue (bn€)	Employees	HQ Region
1	Chemistry/Agriculture	20,0	34.000	Europe
2	Food	2,5	2.000	Asia
3	High tech	2,0	8.000	America
4	High tech	46,0	76.000	America
5	Consumer products	14,0	34.000	America
6	Industrial goods	16,5	88.000	America
7	Chemistry/ Consumer products	20,0	53.000	Europe
8	High tech	26,0	60.000	America
9	High tech	8,0	41.000	Europe
10	Apparel	10,0	17.000	Asia
11	Apparel	9,0	77.000	America
12	Consumer products	52,0	150.000	Europe
∅		19,0	53.000	

FIGURE 2.2: OVERVIEW OF INTERVIEWED COMPANIES

2.2 Developing a Supply Chain Resilience Strategy

We found that designing a resilient supply chain is a two-stage process. The first step is to select the “right” set of strategies from the set of strategy elements noted in Figure 2.1. We note that no company can implement the entire range of resilience strategies due to cost and resource limitations as well as the potential for interactions among the elements. Choices should be responsive to tradeoffs and constraints. Defining the “right” strategy is therefore equivalent to defining weights for the different resilience strategy elements (defined in Figure 2.1) and whether or not these weights should be uniform across the company or whether they should be applied differentially to the various product groups/segments. Moreover, there also is a question of prioritization in the sequence and timing of the weights to define a timeline for implementation.

The second step, after making the weighting decision, is to define how to execute/implement the “right” strategy. This step should take all limitations and boundary conditions into account as well as available resources. Hence, companies eventually may need to accept a runner-up supply chain setup if their first choice turns out to be too costly or not feasible. The implementation of a resilience strategy can be improved by enhanced collaboration with supply chain partners such as core suppliers or logistics providers/distributors.

2.3 Execution and Implementation of a Resilient Supply Chain Strategy is the Key Challenge

This section focuses on the previously described second step of supply chain resilience, the implementation and execution of the strategy. Six common implementation challenges for resilience strategies are described that can complicate or hinder companies in their drive to achieve resiliency. These challenges are based on our observations drawn from our company interviews.

I. Heterogeneity of supply chains

Companies that achieve a certain size and scope in general cannot use a one-size-fits-all supply chain design. The supply chain of such a company is actually a portfolio of different supply chain structures. We observed supply chain diversity even at the level of a single business unit, with supply chains that are specific to individual products. We refer to this phenomenon as the “heterogeneity of supply chains”. Some of our interview managers also confirmed that current surveys on this topic often use the entire company as their unit of analysis. This relies on individual respondents to somehow aggregate the attributes of all the supply chains that co-exist within their companies and complicates the interpretation of survey results.

“Heterogeneity of supply chains” makes the implementation of resilience strategies more complex as all of a company’s supply chain strategies need to account for possible interdependences and interactions. Case-by-case decisions are needed, as many of the interviewed companies have adopted different designs for different elements of their supply chain strategy but converge with respect to others. This is especially true for logistics and distribution. Moreover, some companies recognized that a certain set of products need a different strategy, but the low volume of those products makes that hard to justify. The implication is that you may not be able to always have the “right” supply chain for a given product, even if you know what is right. We observed that even with a portfolio of supply chain strategies, firms also can use common approaches for some functions. Thus, coordination across the strategies within a firm can be a challenge. A specific resilience strategy might be beneficial for one product but not for the company as a whole. Moreover, some product types may not need a resilience strategy at all.

With diverse products, having heterogeneous supply chains has the advantage of tailoring the strengths and cost structures of a specific supply chain to the special needs of particular product segments. This, however, is achieved with potentially higher fixed investment and overhead costs. Of course, if the heterogeneous supply chains have been set up with some degree of flexibility, such as capacity or production capabilities for multiple product groups, then different supply chains could be leveraged to support the particular needs of different product segments. Thus, implementing heterogeneous supply chains, when designed right, could turn out to be a competitive advantage.

II. Fragmentation of the decision-making architecture

Due to decades of globalization and supply chain optimization most companies have outsourced segments of their manufacturing process, and some have even outsourced virtually all of it. The resulting fragmentation of the supply chain architecture leads to challenges such as reduced visibility, longer lead times, and the need for coordination among multiple decision-making parties in the presence of conflicts of interest and information asymmetries.

A key question to consider in the context of a multi-firm supply chain is how to allocate the costs and benefits of resilience. For example, manufacturers need to provide incentives to motivate their key suppliers to invest in new geographies or capabilities. One interviewee mentioned the delicate balancing act in creating a more flexible supply chain by expanding to dual or triple sourcing, while at the same time trying to coax incumbent suppliers to invest more to improve performance. A failure to integrate supply chain management across business units and company boundaries during a disruption can lead to an “everyone-for-himself” mentality resulting in a local rather than a globally optimal solution.

During the pandemic, we observed that some of the interviewed firms strongly relied on their cooperative relationships with suppliers and/or customers, which were based on sound visibility and risk sharing schemes that were in place. Fragmentation, in these cases, enabled empowered, decentralized execution, which is exactly what was needed for resilience. This allowed for quick responses to adjust orders and production plans. We note that, however, without such

extended visibility and cooperative relationships, fragmentation would be a bottleneck to resilience.

III. Accentuated efficiency and resilience trade-offs

According to the interviewed senior managers, cost-efficiency will remain the top priority when designing future supply chains. This is contrary to recent predictions that cost will no longer be the number one decision criterion for supply chain design. Globally competing companies may not be able to afford the inefficiencies that result from de-prioritizing cost, especially in an environment where their profit margins are shrinking. Therefore, even though calls for resilience are getting louder, firms must still consider the trade-offs among cost, speed, flexibility, and risk mitigation for both short-term dynamic resource allocation decisions and long-term resource investments. Each company ultimately will place different weights on each of these factors to account for product and market characteristic differences, which may also change over time.

We observed that companies can struggle with defining and identifying all necessary costs to make informed trade-off decisions. The total landed cost, which is based on allocating all fixed and variable costs for making a product available for a specific market, enables benchmarking of product profitability. However, it often does not include shortage costs and other intangibles such as reputation risks (which are hard to quantify). Ultimately, consideration of the total cost, which include the costs of acquisition, ownership, and post ownership support, can lead to making the right trade-off decisions.

After confronting a pandemic that has led to severe supply and demand disruptions, we also observed that many companies are allocating more importance to risk mitigation and robustness. A key question going forward, however, is whether some companies will switch back to the pre-pandemic weighting for cost and risk as soon as the pandemic is over by concluding that they have over-reacted to the disruption. Re-examination of cost vs. risk priorities will lead to efficient supply chain resilience management. In order to make informed decisions, all additional costs and benefits must be quantified and evaluated.

Achieving resilience, as any other cross-functional goal, will require that business functions and divisions consider the cost and benefit impact of their decisions throughout the firm. Thus, reward schemes and KPIs will need to incentivize the required collaboration across individual product managers and business units. Such cross-functional collaboration has been difficult to achieve before the COVID disruption, as both costs of failure and the benefits of success are hard to quantify. The current pandemic provides an opportunity to re-examine this issue.

IV. Limited resources for change (Resource trade-off)

“Robustness”, “resilience” and “supply chain risk management” are not new terms for most supply chain executives and often these concepts are included in supply chain strategy roadmaps. However, resources are limited, even more so due to the pandemic, which makes it difficult to focus on more than one major supply chain initiative. Many manufacturing companies, as indicated by our interviewees, are currently in the midst of a supply chain digitalization journey which will lay the foundation for end-to-end visibility which is a prerequisite for efficient supply chain resilience. COVID has accelerated ongoing digitalization processes. Other companies who have been occupied with post-merger or post-acquisition integration are more vulnerable to external disruptions.

All companies will need to balance their efforts between ongoing transformation activities, day-to-day business management, and the implementation of new forward-looking resilience strategies. Since companies have limited resources and multiple demands and priorities on how to use their (financial) resources, it may not be easy to get a common buy-in to invest in resilience, especially as implementing resilience strategies oftentimes requires upfront investments and has long-term payoff periods. According to our respondents, managers were more willing to invest in resilience strategies if they experienced difficulties in regaining their market position after previous disruptions. The additional expenses are easier to justify and are perceived as a cost-effective ‘insurance policy’. In general, achieving resilience requires executives to have a longer-term view without the myopic desire to get quick returns. Moreover, trade-offs need to be optimized subject to company-specific constraints, based on the

limited resources that include free cash flow, management capacity, and the company's ability to pivot.

V. Factor market limitations

Another aspect mentioned by the interviewees was that their ability to realize an "ideal" supply chain configuration can depend heavily on the limitations of factor markets. In contrast to internal resources, as discussed in the previous section, this limitation is based on external limitations. These require interaction and coordination outside the boundaries of the firm. The more complex and specialized the production process is, the smaller is the number of supply chain design options to choose from. Especially for high tech companies, this might result in the situation where a company must take whatever supply chain performance offered to them by qualified contract manufacturers or suppliers. Moreover, original equipment manufacturers (OEM) need to look at the entire, multi-tier, supply chain factor market. Having resilient final manufacturing processes might not help if upstream supply chains are less diversified and thus nullify the downstream resilience.

These limitations make it even harder for companies to implement resilience strategies, since long-term investments in supply alternatives are needed. Such "grooming" of the needed suppliers involves both technical and business capabilities as well as an appropriate geographical footprint. This long-term view can be derailed by ad-hoc supply chain issues, especially in the current turbulent times, which can leave companies without a viable second source or contingency plan.

VI. Supply chain financing and insufficient government incentives

Our interviews focused on large and financially strong companies, for whom financing is usually not a critical obstacle to supply chain resilience. However, these companies recognized that other parts of their supply chain may not be as fortunate. Hence, companies needed to provide financing or technical support to help the weaker links within their extended supply chains. Such cross-company collaboration can be an important element for implementing a resilience strategy, since the resilience of a supply chain is only as good as its weakest link. In the long-run, supply chains rather than companies compete against each other. Many

companies have gone beyond the basic elements of collaboration by appropriating the decision rights of their partners (customers or suppliers) to achieve a higher level of coordination. During a supply chain crisis such as the current one, the need to do so is even greater.

A lack of government incentives and subsidies can also be a barrier for companies to implement a resilient supply chain strategy. Our interviewees mentioned that the various governments they deal with reacted to the pandemic in ways that are all over the map. While this uncertainty is to be expected and can be accommodated, nevertheless, such differences heavily influenced their time to recovery. Unorganized and slow acting governments that fail to provide quick aid for struggling companies or for laid-off workers may turn this pandemic into a full-scale economic recession.

Governments have their own objectives and interests in setting up policies that either can become obstacles or can provide support to companies wanting to build resilience. The right level of support from governments, can make adjustments easier and thus can accelerate the development of a resilient supply chain. Without this support or, in some cases, having more frictions and disputes based on the inevitable differences between the goals of companies and governments, it is doubly hard for companies to make the necessary investments required to build a resilient supply chain.

Overall, interviewing supply chain executives revealed that there are multiple challenges a company must face to achieve supply chain resilience. These challenges intensify during disruptions such as the current pandemic. Heterogeneity of supply chains, factor market limitations and supply chain design differences are among the most important challenges. Figure 2.3 summarizes the key execution and implementation challenges we observed as well as options for dealing with these challenges.

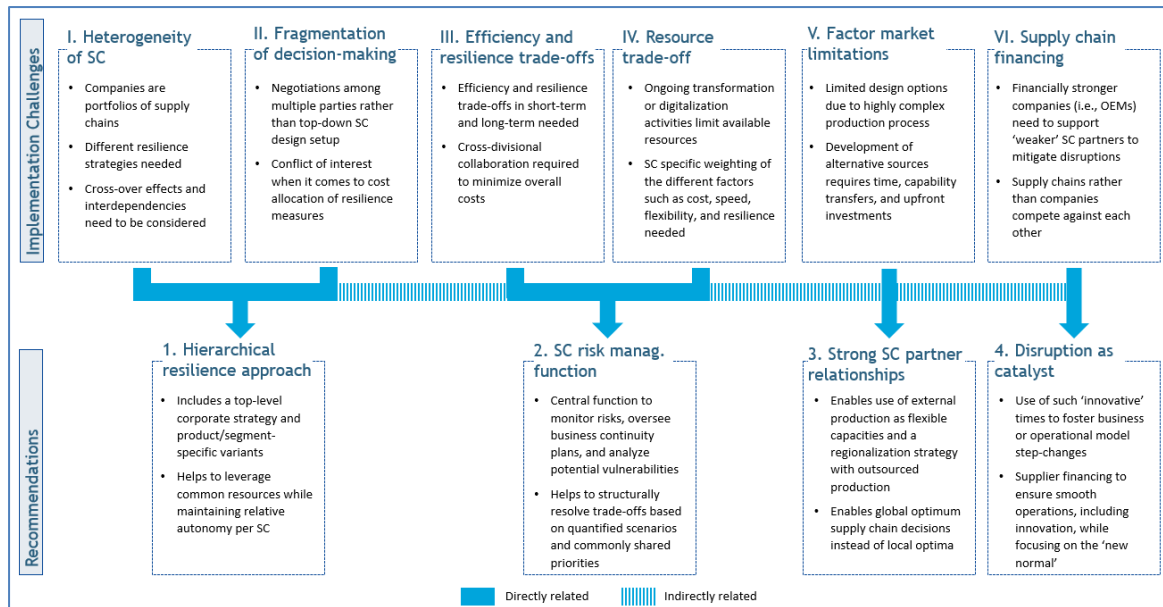


FIGURE 2.3: SUMMARY OF IMPLEMENTATION CHALLENGES AND CORRESPONDING RECOMMENDATIONS

2.4 Key Learnings and Recommendations

This section summarizes the key learnings from our interviews and offers prescriptive recommendations on how a firm can overcome the challenges noted in the previous section, to enhance their supply chain resiliency. The recommendations and best practices that we have come up with also can lessen friction and the resistances that have been the main challenges for implementing sound resilient strategies. Having the right corporate structure, developing the risk management function, strengthening supplier relationships, and finding values to serve the dynamic demands of all stakeholders, could overcome the barriers that we have noted, i.e., corporate silos and decision fragmentation, not having the right tradeoffs to match the right supply chains with the risk needs, the limitation of the factor market, and the lack of resources to invest in building the resilient supply chain. While it is probably too early to tell who will be a winner or loser in the ongoing pandemic, those companies in our sample that started thinking about resilience and crisis management a long time ago have an advantage. The following recommendations are motivated by observed best practice examples.

1. Companies with a wide product portfolio should implement a hierarchical approach to enabling resilience that includes a top-level corporate strategy and product/segment-specific variants.

All interviewees agreed that there is no single supply chain design that can efficiently serve different products in different countries with different customers (challenge I). Product, market, and customer characteristics determine the “right” setup. Therefore, supply chain differentiation is a key component for the design of an effective supply chain strategy. However, companies can still leverage their size by sourcing common resources and through effective management of logistics networks to be cost-effective, while achieving a higher level of customer service.

A hierarchical approach can help mitigate problems arising from the resulting heterogeneity of supply chains. Under this approach, two or three levels can be used to define a resilience strategy. The first level – the corporate level – ensures certain standards across the entire organization are met and enables collaboration and sharing of resources/inventory and learning across multiple business units in case of a disruption. The second level, which can be a region or a business unit, and which includes products/segments or region-specific entities, tends to be more autonomous. At this level, each entity is responsible for designing the “ideal” supply chain for their respective product group. The result will be a set of different supply chains that are governed by an overall corporate strategy. Moreover, fragmented decision making (challenge II) will be built-into the overall supply chain design, which makes it easier to include external manufacturing sites as well as independent internal business units within the firm’s supply chain decision making structure.

One example for successfully implementing this approach was observed in an interviewed company that manufactures products and provides engineering services for a wide range of industrial, commercial, and consumer markets. Despite having a wide range of offerings, multiple supply chains, and a complex sourcing network (sourcing about 1 million stock keeping units (SKUs) from over 20,000 suppliers) the company has managed to navigate the current pandemic with minimal impact to its level of customer service.

For this company, the key to successfully maintaining operations and supply chain performance was its hierarchical approach for enabling resilience. The first level of corporate strategy is designed to (1) set guidelines and standards across all business units, e.g., for contracts, dual sourcing or go-to-market strategies and

(2) leverage commodities where scale matters, e.g., steel, electronics, as well as the internally operated logistics network. Management of the business units is achieved by controlling the outcome in terms of performance metrics such as lead time and customer service level. The second level of business unit strategy includes relatively independent business units that are responsible for designing their own supply networks specific to their product and geography. 75-85 percent of products sold in a particular marketing region are both sourced and manufactured in the region.

The company operates regional supply chains through three hubs (Asia, Europe, and North America). This has reduced the company's exposure to recent "regional disruptions" such as tariffs, trade-wars, and the COVID pandemic. Mechanisms are in place to share or pool inventory across regions to safeguard against disruptions. However, the company has minimized the downside of a regional decentralized setup by leveraging raw materials and commodity components as much as possible, while preserving flexibility by virtue of its internal global logistics operations.

2. Establish an independent supply chain risk management (SCRM) function within the organization.

Instead of completely rethinking the current supply chain setup and strategy as some articles suggest, companies have accelerated certain aspects of their strategy which were planned to be implemented over the next couple of years. Moreover, the pandemic has helped to speed things up, e.g., due to increased levels of home office work. Two frequently named examples are digitalization of the supply chain and organizational processes, as well as integration of external partners, such as contract manufacturer, suppliers, or distributors. Our interviews showed that resilience is not a new topic for many supply chain executives, but the crisis has forced a re-evaluation of trade-offs they are making among cost, speed, and agility, giving more weight to agility and risk mitigation.

Moreover, many interviewed companies mentioned the need for a central function where all information flows for analysis are visible and where they can put their resilience plans into practice. In the long run, resilience depends upon constant monitoring of risks and having business continuity plans on stand-by. This

may call for the explicit formation of a Supply Chain Risk Management (SCRM) function to centrally manage efficiency and resiliency trade-offs (challenge III) and allocate resources effectively (challenge IV) within the supply chain organization. A particular challenge for effective business continuity is to maintain end-to-end visibility across multiple tiers of suppliers and distributors. Hence, a SCRM function directly benefits from “end-to-end visibility”, “end-to-end control”, and “organizational readiness”; which are three of the four enablers mentioned in our supply chain resilience framework (Figure 2.1).

Cisco, a high-tech telecommunications company, understood this over a decade ago and has acted accordingly. Outsourced production has enabled the company to be flexible in terms of designing an “optimal” supply chain. However, this could potentially hinder end-to-end visibility and direct control over the supply chain to pre-empt or contain disruptions. Nevertheless, Cisco has managed to become a role model with respect to SCRM.

Cisco’s resilience strategy was initiated in 2010, when they were one of the first globally operating companies to set up a SCRM function. The basic approach was to design a supply chain based on product and market considerations along with “boundary conditions” reflecting the economics of the company. From 2010 onwards Cisco applied a “risk lens” when designing or assessing its supply chains, which led to resilience measures such as proactively de-risking identified geographic risks by qualifying suppliers in other parts of the world to regionalize the sourcing of key components. These measures are costly and can increase network complexity but serve as an insurance policy. Every disruption felt by the industry since then, such as the major material shortage (2010), Japan earthquake (2011), and Thailand floods (2011), has validated the firm’s approach. Cisco repeatedly “practices” its crisis response and fine-tunes its supply chain designs. Consequently, the COVID pandemic resulted in minimal impact to customer service levels in spite of increased demand for key products.

3. Companies that (at least partly) manufacture at external production facilities should invest in strong relationships with their suppliers and contract manufacturers.

There is a rich literature that says when deep partnerships are appropriate, and when arms-length transactional relationships are sufficient. However, we observed more emphasis being given to partnerships and the reasons for doing them changed during the current crises.

When comparing advantages and disadvantages of different production locations, the unanimous view is that no country or region is dominant. The pandemic showed that even China, which has been the optimal location for many industries for some time, based on cost, scale and market, criteria, may no longer be preferred given current levels of risk. Hence, companies that have relied too much on a single country, have started to de-risk their supply chain by thinking about back-up locations and expect the same from their strategic suppliers. This also helps to explain why we do not see a lot of re-shoring activities as a reaction to the crisis. There is no guarantee that even with back-up locations, a complete shutdown of operations can be avoided when a disruption hits everywhere at the same time. However, when the disruption is localized, or when it hits different regions at different times, having back-up locations lets you operate for longer and re-start sooner, as the different regions recover over time.

Long-term collaborative partnerships are especially helpful for companies that are facing high factor market limitations (challenge V) and/or who rely solely on their manufacturing partners. A good supplier relationship enables an OEM to have partners who are willing to invest in upgrading their manufacturing capabilities and in diversifying their supply chain footprints. This also facilitates information exchange and therefore is key for developing an integrated production network.

One of the interviewed companies, that focuses on storage and network technology, depends on good partner relationships. Similar to many other information technology companies, it has outsourced most of its production, even though the manufacturing of its products is highly complex and requires specialized equipment. As a result, the company does not have access to the full range of supply chain strategy options noted earlier, but rather inherits the constraints of its contract manufacturers which strongly limit its footprint of choices. This creates susceptibility to disruptions and therefore the company has invested in one of the

previously mentioned resilience strategies from Figure 2.1, i.e., the “Partner Network” strategy.

However, its close collaboration with suppliers, such as in developing new products through a Joint Design and Manufacturing (JDM) approach, has enabled this company to build strong relationships and thus is viewed as a trusted partner. Risks and costs are shared through things like performance-based contracts. These relationships create resilience, as the suppliers are willing to invest in new capabilities and production facilities to support the company’s regionalization strategy. Naturally, during actual disruptions suppliers are more willing to give preferential treatment to their most trusted partners.

Another interviewed company, who is a major player in the apparel industry, also derives resiliency from its relationships with manufacturing partners. A fundamental part of this company’s supply chain strategy is to take key partners along when building new capabilities in less developed countries. Unlike many other apparel companies, during the pandemic this company continued paying its suppliers instead of canceling orders, thereby demonstrating a willingness to face the crisis together. These relationships will be critical as the firm explores ways to manufacture directly in its main consumer markets.

4. Use disruptions as a catalyst for business or operating model step changes especially when facing a demand-side disruption.

During disruptions, many mindsets and organizational barriers that can contribute to inertia can be easier to bypass. This creates an opportunity for pragmatic, solution-oriented thinking.

Most resilience measures that are currently being implemented to mitigate supply-side disruptions, such as multi-sourcing, inventory and capacity buffers, and ecosystem partnerships, can be expensive but are relatively easy to control. In contrast, sudden demand-side disruptions can introduce existential threats to some businesses. This is especially true if these disruptions are not short-lived and lead to a profound re-mix of demand. Successful companies use times of disruption to achieve step-changes in their business models.

Pivoting and diversification activities with respect to markets, product portfolio, and distribution channels can be such a step-change which mitigates those demand disruptions. For example, shifting volume from classical offline distribution to internet sales is one strategy that companies are deploying to cope with the shutdown of retail stores. Another example is streamlining the product portfolio down to the most valuable SKUs, which has helped some companies to master the crisis. In addition, re-purposing production facilities to manufacture products in need such as hygiene products or ventilators is another strategy. Hence, companies have options to mitigate demand disruptions up to a certain point, however, these options usually involve rather drastic operating or business model changes.

For a lot of companies, the primary focus so far during the pandemic has been to deal with the forced digitalization of internal processes and meetings, as employees needed to work from home. However, one consumer products company focusing on health care, personal care, and household products, realized before the pandemic that its current supply chain solution does not serve all its customers. During the crisis, the company turned out to be rather resilient and therefore had the time and resources to use the disruption as an opportunity to drive operating model changes. With the disruption providing the “activation energy”, the enterprise changed its product classification methodology from an elaborate version of the ABC classification into a new segmentation model that assesses products by both their potential risk for disruption to the supply chain and their potential growth in the market. The company has been very proactive in understanding risk through an enterprise risk management system that explicitly incorporates different forms of risk and their impact over both the medium and long term. This new segmentation is the basis for the company's “2025 Strategy” to develop built-in resilience by matching the supply chain design to product-specific supply and demand characteristics.

2.5 Conclusion

The basic roadmap to supply chain resilience is well established and is generally understood by managers, however, implementation and execution remains a challenge. Therefore, in this article we develop a framework to support

successful implementation, by identifying the principal challenges for achieving resilience and effective responses to these challenges. We introduced an integrative framework for supply chain resilience (Figure 2.1), which combines enablers such as end-to-end visibility with resiliency strategies.

For effective integrated supply chain management in normal times existing “enablers” and “supply chain resilience strategies” are sufficient for most companies. However, the pandemic requires consideration of intense interactions and multiple tradeoffs for the full range of resilience strategies. Reactive strategies can stop the bleeding, but they are not sufficient in the long run. Thus, proactive strategies need to be developed, analyzed, and implemented.

We observed six challenges to the implementation of resilient supply chain strategies and developed recommendations for how to overcome them. These findings are based on best practice examples as observed in the interviewed companies. These challenges show that the “right” supply chain setup depends on individual weighting of multiple factors as well as dealing with multiple trade-offs that can change over time. Therefore, it is difficult for a company to invest in resilience proactively and efficiently, and almost impossible for a company to do so if it has not installed a dynamic supply chain risk management process.

3. BESPOKE SUPPLY-CHAIN RESILIENCE: THE GAP BETWEEN THEORY AND PRACTICE¹

3

3.1 Introduction

For the general public, the global COVID pandemic that began in 2020 was a trigger to contemplate the concept of business resilience. However, for globally operating companies, this is just another instance, albeit with unprecedented severity, of an ongoing series of disruptions, leading many companies to prioritize resilience. A recent McKinsey & Company report (Alicke & Strigel, 2020) indicates that the frequency and magnitude of disruptions has increased over the past twenty years, suggesting that companies would be wise to already be planning for the next crisis.

Our discussion in this paper is not centered around the COVID pandemic, but rather around building supply-chain resilience in a broader sense. Our interviewed executives mentioned several earlier disruptions, such as the Japan earthquake and Thailand floods in 2011, as well as ongoing ones such as the US-China tariff escalation and the global climate crisis. These disruptions have led to changes in processes and structure for many globally operating companies.

Recent articles and research have focused on generic resilience strategies. Individual companies, however, operate within idiosyncratic environments and thus need more differentiated guidance. Company managers want to understand the specific obstacles that companies similar to theirs will most likely need to overcome. They will also benefit from an analysis that is granular enough to acknowledge the complex multi-dimensional issues that reside at the business unit or product group level, and that can lead to differentiated solutions. For example, a capital intensive, long product lifecycle, technology-intensive company may be better off achieving resilience by investing in an appropriate geographical footprint and technologies than by maintaining a large portfolio of suppliers.

¹ The content presented in this chapter is based on Cohen et al. (2022a). The paper was accepted and published by the *Journal of Operations Management (JOM)*. Within this chapter, "we" refers to the authors of Cohen et al. (2022a).

The literature, notably Fisher's (1997) advocacy of "the right supply chain for the right product", alongside the contributions of many others, has discouraged one-size-fits-all thinking, and encouraged a supply-chain design that reflects the characteristics and strategic intent of the business. In that sense, the concept of a "bespoke supply chain", meaning a supply chain that is custom tailored for the business setting, is not new. Our research confirms that practitioners operate supply chains that they have tailored to their business setting, and that on occasion might even be bespoke to an individual SKU. We also have observed that even for a given SKU the supply chain is not static, as practitioners may dynamically update supply-chain configurations to match changes in conditions.

Many companies have struggled to achieve resilience during the COVID pandemic, including ones that have historically managed to match the right supply chain to the right product using resilience strategies such as dual sourcing. We conducted surveys to discover what actions managers have taken to improve supply-chain resilience, then organized these findings into a "Triple P" framework (based on Product, Partnership, and Process complexity) that links operational attributes to resilience strategies.

This paper is organized as follows. The next section summarizes how previous operations management and supply-chain literature on responding to risk and uncertainty developed over time. That is followed by a section explaining our data collection and methodology. Our results are then presented in four parts, which explain the two primary influencers of resilience strategy, the obstacles, and the "Triple-P" framework of "bespoke supply-chain resilience." We conclude by discussing managerial implications, limitations of our study, and future research directions.

3.2 Supply-Chain Tailoring for Responding to Risk and Uncertainties

Before the term supply-chain resilience became popular, supply-chain research had examined how firms should respond to risk and uncertainty of various types, ranging from known unknowns to unknown unknowns. This section gives a short overview of the primarily deductive theorizing literature on how to mitigate supply-chain risks most effectively. We include only representative articles since a comprehensive survey is not our focus.

Fisher's (1997) approach of differentiating between "functional" and "innovative" products is a popular framework that matches a company's supply-chain design to the level of demand uncertainty. The Fisher framework defined the need for custom supply chains to achieve "agility" in a context in which supply is matched with demand day to day via short-term adjustments: Long-term risk management was not addressed in this framework. Lee (2002) expanded on Fisher's framework by including supply uncertainty, and the strategies were expanded to include some long-term practices such as vertical integration, strategic alliances, and dual sourcing. The resulting two-by-two matrix (supply-chain design vs. level of product innovation) distinguishes between efficient, responsive, risk hedging, and agile supply chains for functional and innovative products. All four combinations in the matrix can be observed in the approaches adopted by companies to achieve supply-chain resilience according to Kamalahmadi and Parast (2016). Moreover, other frameworks developed based on practice-oriented research reflect the premise that cost efficiency and velocity are not the only dimensions that make supply chains successful. The "Triple A" supply-chain framework adds that firms need to be agile, adapt, and align the interests of their company with other supply-chain actors (Lee, 2004). Recently, Cohen and Kouvelis (2021) have re-interpreted this framework on the basis of increasing uncertainties and disruption risks towards unknown unknowns, resulting in the notion of a "Triple A & R" supply chain in which robustness augments agility, adaptability becomes resilience through increased proactivity, and incentives are realigned to deal with the post-COVID "new normal". While these general frameworks can give companies a general direction for how to set up their supply chain, implementation will require more specific adjustments and flexibility to make the supply chain resilient.

As the previously mentioned papers state, one size does not fit all when it comes to finding the right supply chain for a product. Companies face different supply-chain characteristics/features which lead to a different balance of weights and tradeoffs, resulting in different supply-chain strategies to pursue in practice. The supply-chain literature of the last two decades mapped out what factors should be considered when tailoring supply-chains. For example, Milner and Kouvelis (2005) were the first to study how three different demand distributions, namely

standard distribution, Bayesian model, and Martingale model, affect the value of two types of flexibility: quantity flexibility in production or timing flexibility in scheduling. The example of Kanebo's cosmetic division is given, which tried to increase flexibility in order to cope with a large-scale expansion of its product portfolio. A point-of-sale information system for continuous sales updates and flexible filling lines that reduce production lead time by half gave Kanebo the needed flexibility. However, this type of flexibility might be too little or too much for other products or markets. For example, the cosmetics division of a consumer packaged-goods company studied by Saunders et al. (2021) also expected to require a large-scale flexibility initiative, but ultimately just making use of the data that was already available, i.e., a micro dose of flexibility, was sufficient. Thus, the findings show that a strict dichotomy between efficient and flexible supply chains can lead to suboptimal matches between products and the appropriate supply-chain type. The Ketokivi et al. (2017) study also draws upon transaction-cost economics to support the idea of supply-chain tailoring based on the product and market characteristics. These authors found that production location decisions can be better explained by analyzing the interdependence between production and suppliers, the market, and development activities, then can conventional economic measures such as industry, size, or degree of value added. High interdependence can come from high coupling, high specificity, or low formalization.

Besides looking at supply-chain tailoring for a single product, there has been some research on configuring the supply chain for a portfolio of products. Federgruen and Katalan (1999) showed that a portfolio approach needs to be implemented, since adding time-sensitive products to a plant which produces time-insensitive products can be extremely costly. Cattani et al. (2010) studied what they termed "spackling strategies" that combine the production of standard and mass-customized products in a flexible plant. The option value from postponing the decision about what exactly to produce can outweigh the cost benefit of producing in a low-cost country. That idea was further developed by de Treville et al. (2017) who considered the cost of a capacity buffer held to meet peak demand for a time-sensitive product as an option cost incurred by that product ("option-based costing"), even if the leftover capacity is then used for time-insensitive products. Thus, there is full flexibility for the profitable time-sensitive product and the leftover

capacity can be used for production of time-insensitive products in a high-cost region that is competitive with low-cost regions. Allon and van Mieghem (2010) introduced a similar idea of a tailored portfolio solution in the context of dual sourcing. Their concept of a base-surge sourcing allocation to align the ordering patterns with the core competencies of each supplier also requires supply-chain tailoring. In addition, the example of Fendt, an agricultural machinery manufacturer, shows that an assembly line with variable rather than fixed takt times can enable a company to handle a high degree of customization while reducing labor inefficiencies and assembly line balancing complexity (Mönch et al., 2021).

A stream of literature based on real-options theory adds to the discussion of supply-chain resilience, by enlisting flexibility and hedging options to mitigate market uncertainties such as in price or demand (Huchzermeier & Cohen, 1996). De Treville et al. (2014a) used real-options theory to quantify the exposure to evolutionary supply-chain risk and analyze how responsiveness through lead time reduction increases profits. The study shows that the value of a lead-time reductions depends on how the supply risk evolves and whether the lead-time reduction permits a make-to-order strategy. When quantifying the benefits of short lead times for three companies studied, de Treville et al. (2014b) found that the executives in all three cases struggled to choose the cost-optimal strategy as they underestimated the underlying costs of long lead times.

Another stream of deductive literature based on mathematical models provides normative recommendations concerning the design and management of supply chains to mitigate risks and achieve efficiency. Sodhi and Tang (2012), for example, give a comprehensive overview of quantitative models for managing supply-chain risks, defining three approaches to risk mitigation that lead to eleven robust supply-chain strategies. Other papers use simulation-based analysis and modelling to examine the connection between supply-chain structure and resiliency. Kim et al. (2015) modeled and compared the resilience of four different supply-chain network structures and found that conventional metrics such as network density, average walk length, or centralization do not reliably predict network resilience. The results implied that intuitive assumptions such as, redundancy increases network resilience, might not always be true. Tan et al. (2020) also included network structural properties in their simulation-based study

and found that cost-effective resilience improvements can come from either reducing accumulated backorders for which redundant structure or backup plant strategies work best, or from accelerating recovery through redundant capacity or backup supply-chain strategies.

Yin et al. (2017) described and analyzed how Sony and Canon moved away from their heavily automated processes as they realized that the efficiency gains provided were less than the cost of the resulting supply-chain inflexibility. Both companies introduced a cellular manufacturing concept called “seru” to increase responsiveness to cope with variable demand.

Another stream of literature—mainly driven by management consultants—identifies policies and strategies that can support resilience. Prominent examples for such reports are John et al. (2020) or Lund et al. (2020). These reports tend to describe companies deploying a specific strategy such as multi-sourcing as opposed to focusing more generally on strengthening partner relationships. Certain resilience strategies tend to recur among the prescriptions of the different reports, including (but not limited to) multi-sourcing, regionalization, increasing operational buffers in terms of inventory or capacity, and stronger partnering with other supply-chain actors. This led Cohen et al. (2021) to conclude that the basic toolkit for achieving supply-chain resilience is generally well understood by both academics and managers. The recommendations in these reports are often generic in nature, however, and do not consider the specific supply-chain characteristics of the company, thus leaving managers with an abstract idea of what an average company could do that lacks the precision that they need to address the resilience needs of their own supply chain. This practitioner-oriented literature invites an investigation of how situational factors should influence the choice of a resilience strategy.

The supply-chain literature describes the need for supply chains to be bespoke reflections of their market and product contexts. This theme has evolved over time and has now come into a new focus due to the rising levels of uncertainty. Our study aims at contributing to this theme by capturing a snapshot of what managers actually do to mitigate supply-chain risks and to increase resilience. Our paper focuses on what we can learn from observing what strategies companies have

adopted and initiates a dialogue concerning what how what is done compares to what would be recommended by the supply-chain literature.

3.3 Research Design

We conducted interviews of supply-chain executives and organized the responses into a framework that identifies patterns in resilience strategies across companies and industries based on supply-chain attributes and product and market characteristics. The framework is derived from the reported main influencers of resilience strategies, the supply-chain environment (e.g., product, production, and technology), and the overall business strategy. The information is gathered at a supply-chain level instead of at a company level, as this is the level at which companies implement decisions. Due to the granular unit of analysis used in this study, detailed company information is required. However, this information needs to be understood from the strategic perspective of the company, especially when there are other types of supply chains that operate within the company. This typically requires a senior supply-chain executive to be the survey respondent (see Table 3.1 for details of the positions of our interviewees). Figure 3.1 summarizes our research approach and illustrates its exploratory nature.

3.4 Data Collection

We used a mix of primary and secondary sources including interviews, focus groups, and consulting reports. Our emphasis was on semi-structured interviews with senior supply-chain executives. For the first round of interviews, we chose twelve companies in different industries that are regarded as leaders in the management of global supply chains. This included one of the first companies to structurally integrate a supply-chain risk management function into its organization. Each of the interviews in the first round was organized around three topics: (1) Organizational setup and supply-chain structure; (2) Business disruptions and major obstacles to becoming more resilient; and (3) Short-term counter measures and long-term resilience strategies employed by the organization in response to the current pandemic crisis. We also asked for any supply-chain resilience related information that the executives deemed relevant to these topics (see interview questionnaire in Appendix A.1).

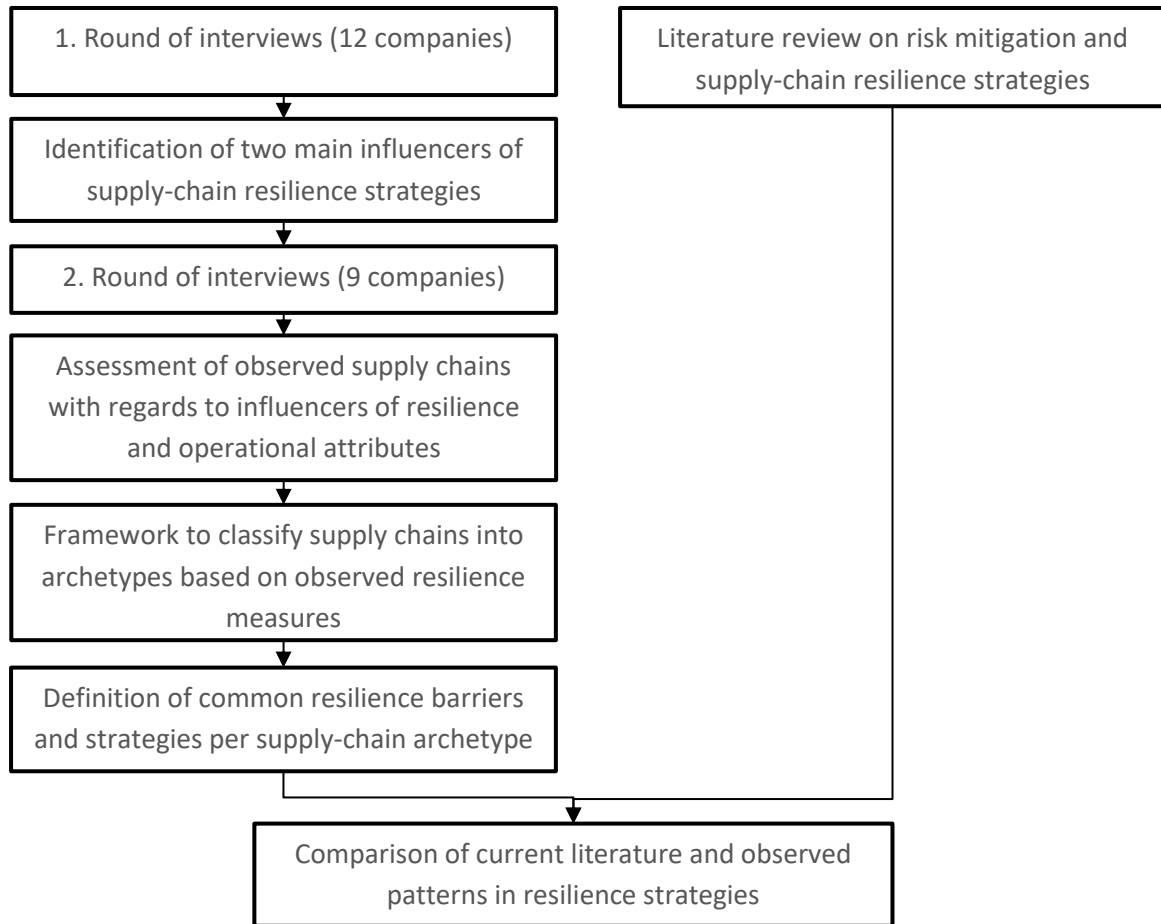


FIGURE 3.1: RESEARCH DESIGN

After the first round of interviews, we concluded that focusing on original equipment manufacturers (OEMs) was not sufficient to understand supply-chain resilience patterns. We also observed that companies within the semiconductor industry have remarkable built-in operations resilience due to the volatile nature of their demand, their short technology life cycles, and long lead times for receiving inputs from suppliers and fulfilling demand for customers. Therefore, our next set of interviewees included a contract manufacturer and other first tier suppliers as well as additional semiconductor companies. Moreover, for this second round we updated the interview guidelines to directly ask about the two influencers of resilience decisions that emerged in the first round (see Appendix A.1).

Table 3.1 details our data sources. We conducted 21 semi-structured interviews with 22 different top-level supply-chain executives from 16 global manufacturing companies well-regarded for business success in general, and their supply-chain practices in particular. Seven of the companies have made Gartner’s

Supply Chain Top 25 in the last four years and four of the companies have been designated as World Economic Forum Lighthouse factories. Two of these interviews were conducted in writing to mitigate the language barrier for non-native English speakers. All interviews were conducted by a committee of multiple members of our research team. Confidentiality concerns precluded recording the interviews. However, to maximize information capture, a dedicated note taker joined the researchers for each interview. The notes from each interview were immediately circulated among the interviewers for validation. The detailed notes generated in this way served as the basis for all further analysis.

TABLE 3.1: DESCRIPTION OF INTERVIEW SAMPLE

No.	Industry	Position of the interviewees	Revenue * (bn€)	Employees (k)	HQ Region	No. of SCs*	Divisions	Manufacturing sites	Countries
1	High tech / Semiconductor	Senior Director Global Logistic Services	15	28	Europe	1	1	8	16
2	Chemistry / Agriculture	Global Senior Director of EZE SC and Customer Experience Head of Global Planning Excellence	20	34	Europe	2	4	86	150
3	Food / Nutrition	Head of Operations	5	2	Asia	1	3	8	3
4	Automotive	VP for Material Control, Transport, Delivery Assurance	100	134	Europe	1	3	31	140
5	High tech	Head of Global Risk Management	45	76	America	2	4	0	95
6	Consumer goods	VP of Global Sustainability, Safety, and Global Supply Chain Strategy	15	34	America	2	2	16	80
7	Industrial goods	VP - Global Supply Chain Operations VP - Global Supply Chain Commercial & Residential Solutions	15	88	America	2	2	155	150
8	Electronics manufacturing services	Chief Procurement and Supply Chain Officer Head of SC solutions Head of Mechanical Commodity Procurement & Supplier Quality Head of Supply Chain for Health Solutions	20	160	America	2	2	100	30
9	Consumer goods	Chief Supply Chain Officer Laundry & Home Care	20	53	Europe	3	3	179	79
10	High tech	VP of Procurement and Global Sourcing	25	60	America	1	7	0	95
11	Semiconductor	VP Corporate Supply Chain	10	41	Europe	2	4	21	37
12	Apparel	Chief Operating Officer	10	17	Asia	1	3	0	50
13	Apparel	VP Global Sourcing and Manufacturing VP Global Sourcing	10	77	America	2	3	700	42
14	High tech	Assistant Chief of Strategic Planning	10	35	Asia	1	6	8	79
15	Semiconductor	Head of Manufacturing Division	10	6	Asia	1	3	8	75
16	Consumer goods	Executive VP of Supply Chain Europe	50	150	Europe	2	3	290	190

* rounded

* considered in
this research

3.5 Data Analysis

As indicated in Figure 3.1 the research design is centered around two rounds of in-depth interviews with company executives. These interviews were used to observe reactions to the pandemic, measures to increase resilience, and the underlying reasons for choosing a specific strategy directly from the decision makers. The analysis of the interview data used a three-step coding approach (Charmaz, 2006; Patvardhan et al., 2015). First, open coding was used to identify and label statements of the respondents (Charmaz & Belgrave, 2007; Patvardhan et al., 2015). Thereafter, the first order codes were grouped and combined into superordinate concepts (axial coding). The different second-order concepts were

integrated into two broader categories which form the basis for one cohesive framework (selective coding).

During the data collection and data analysis phase, we went back and forth between the categories and the resulting framework whenever new insights demanded it. For example, the first round of interviews identified two main drivers for complexity and influencers for supply-chain resilience strategies, which were then further analyzed regarding various characteristics after conducting the second round of interviews that were specifically tailored to these two influencing factors. This iterative process was stopped after 21 interviews, when little new information was being gained with regards to the two influencing factors by conducting additional interviews. The required sample size depends on the research question and the ability and experience of the researcher (Morse, 2000). Our 21 interviews fall in the range that Thomson (2010), based on a review of one hundred papers, found to be adequate, which suggests that it is a reasonable benchmark for empirically grounding a research question.

After analyzing the interview results, we conducted internal iterative group panel discussions to individually assess all supply chains in our sample regarding the two influencers and thereafter clarify uncertainties, understand issues, or resolve ambiguities in two rounds of discussions. These discussions continued until consensus was achieved. Usually, at least one researcher in our group had an ongoing relationship with a sample company through case writing, student tours, or professional activities with the executives. This enabled us to develop additional insights about the company. The same method was used to assess all the supply chains reviewed in our sample with regards to eight identified operational attributes on a five-point-Likert scale, which was used to describe the supply chains in more detail.

3.6 Finding Commonalities Across Resilience Strategies

After interviewing twelve supply-chain executives in the first round, it became clear that there are two primary sources of complexity considered by the decision makers that limit a company's options and therefore influence the focus of their resilience strategy. When asked how their supply chains are coping with the current

and past disruptions, the interviewees in our sample noted the following principal dimensions of the business that drive their approach to supply-chain resilience:

1. *Diversity of product portfolio*: defined by product variety with different product groups with various product characteristics and supply-chain requirements
2. *Complexity of supply-chain network*: defined by the complexity, and multi-layer structure of the network composed of many different supply-chain actors

Most explanations for why supply chains have suffered during the current pandemic or one of the many previous disruptions were associated with these two fundamental factors. Using a focus group setting, we then refined these two primary aspects of complexity into definitions of two perceived key influencers of a firm's approach to supply-chain resilience from a practitioner's perspective. We label these influencers as follows:

1. *Homogeneity of internal supply-chain processes (intra-company)*
2. *Integration with other supply-chain actors (inter-company)*

3.7 Analyzing the two Influencers of Resilience Strategies

For the second round of semi-structured interviews, we modified the questions to focus more on details of the two previously identified influencers of supply-chain resilience strategies. We conducted nine additional interviews with eleven supply-chain executives to learn more about the different forms of *homogeneity of internal supply-chain processes* and degrees of *supply-chain integration with other supply-chain actors*. The two influencers were subdivided, respectively, into 5 and 4 groups.

We define *Homogeneity of SC processes* as the degree to which different supply chains within one company are intertwined and share common resources (e.g., in terms of planning, inventory control, logistics, procurement, manufacturing equipment, etc.). We identify four stages of SC process homogeneity (sorted from low to high homogeneity):

1. "Multiple independent supply chains": Companies with several independently managed supply chains with only very limited sharing of resources across the

supply chains. Typically, companies/conglomerates with very broad and diverse product portfolios fall into this category.

2. “Shared services”: Companies whose multiple supply chains share some supply-chain processes or resources, typically functions such as procurement, logistics, or distribution.
3. “Central guidance”: Companies that manage all products centrally and in the same way, while having fundamentally different supply-chain structures for each. Usually, most internal resources such as personnel, plants, equipment, and IT systems are shared across the company.
4. “One-size-fits-all”: Companies that use one supply-chain setup to produce all its stock keeping units (SKUs). There might be slight differences in the way the SKUs are managed (e.g., priority rules, planning cycles) or handled (e.g., packaging). Such companies are usually seen as single-product-companies.

We define *Inter-company supply-chain integration* as the degree to which a supply chain is interlinked and aligned with the supply chains of partner companies, in terms of material flow, information flow and financial flow (Rai et al., 2006). We identify five degrees of supply-chain integration (sorted from low to high integration):

1. “Less dependency/engagement”: Companies that have arm’s length relationships with their suppliers/supply-chain partners. These are typically companies that do part of value adding inhouse, and externally sourced materials can be obtained in a transactional fashion. These companies do not have strategic suppliers and for most inputs they can easily switch sources.
2. “Coordination with key partners”: Companies that have only a limited number of strategic suppliers with which they coordinate efforts and share some information (e.g., market data). Most of the relationships are still transactional and less engaged.
3. “Integrated systems”: Companies that share some parts of the supply chain and have a system interface with their key partners (e.g., for customer or vendor-managed-inventory). These companies frequently share information with some strategic partners. Switching those partners would be very costly and disruptive.

4. “Collaboration”: Companies whose supply-chain processes are very interlinked with their partners. Goal alignment is typically strong between these companies and their partners. They may collaborate on the development of new products (e.g., Joint Design Manufacturing). Switching partners would be prohibitively costly in the short to medium term.
5. “Vertical integration”: Companies that control two or more, typically investment-intensive, stages of the production that in other contexts might be operated by separate firms. A company with this structure therefore does most of the value adding processes by itself.

An iterative group panel discussion was conducted to assess the supply chains in our data set with regards to the two influencers of resilience strategies. As supply chains are complex and multidimensional, there was not always a perfect match to one of the discrete labels we have used to segment each of the two factors. However, when focusing on the predominant characteristics of a supply chain, all of our expert panel members had no problems positioning the supply chains that emerged in our interviews. The result (average) of the individual assessments after two rounds of clarification and discussion, is shown in Figure 3.2.

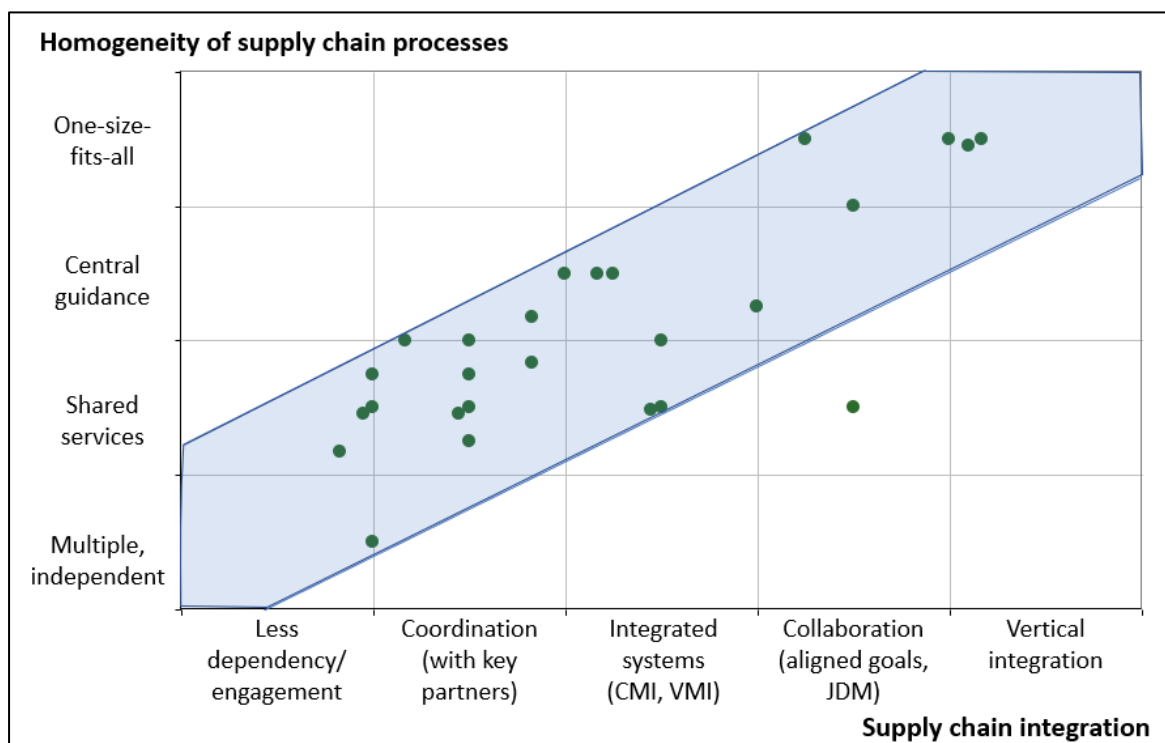


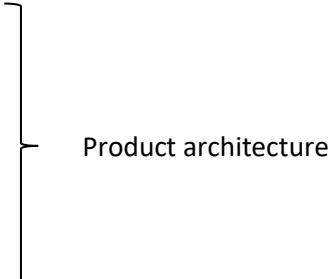
FIGURE 3.2: PLOT OF SUPPLY CHAINS WITH RESPECT TO TWO MAIN INFLUENCERS OF RESILIENCE STRATEGIES

The scatter plot shows a band going from the bottom left to the top right. This positive relationship between *homogeneity of supply-chain processes* and *inter-company supply-chain integration* suggests that the greater a company's interconnectedness with supply-chain partners, the lower is the diversity of its own supply chains (i.e., "You can either go broad or deep, but not both").

3.8 Clustering Supply Chains into Three Cross-Industry Groups

As shown in Figure 3.2, the 26 supply chains observed in our sample differ greatly in their degree of integration with other supply-chain actors and the overlap with other supply chains within the same company. Clustering is a commonly used method for pattern recognition within data sets. Hence, we conducted a simple k-means clustering to group observations into smaller groups of similar supply chains (Diday & Simon, 1976). To determine the optimal number of clusters we plotted the explained variation as a function of the number of clusters (elbow method) and concluded that three clusters are optimal. Details concerning the clustering can be found in the Appendix A.2. In our dataset the three clusters contained 5, 9, and 12 supply chains, respectively. Each cluster comprises supply chains that are similar despite being in different industries. From the attributes of these clusters we postulated that our responding companies belong to one of three supply-chain archetypes, which are defined by a set of common features and strategies.

To understand in more detail the similarities within each cluster and differences between the clusters, we identified eight operational attributes to use in discussing differences between supply chains in addition to the two variables used for the clustering. These attributes emerged from our interviews with the executives as central to their rationales for designing their supply-chain strategies (Figure 3.3). The first four are aspects of product architecture, the other four relate to supply-chain processes:

- Product complexity
 - Homogeneity of product portfolio
 - Degree of product modularity
 - Level of product customization
- 
- Product architecture

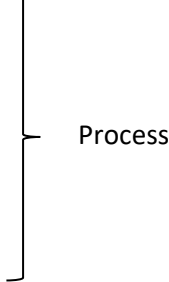
- Availability of potential suppliers
 - Level of Pull (vs. Push)
 - Length of lead time
 - Degree of (manufacturing) outsourcing
- 

FIGURE 3.3: OPERATIONAL ATTRIBUTES FOR DESIGNING SUPPLY-CHAIN STRATEGIES

3.9 Triple-P Supply-Chain Resilience Archetypes

We assessed all supply chains with regard to these eight attributes. Table A.1 in Appendix A.3 summarizes the results. “Availability of potential suppliers” and “Homogeneity of product portfolio” emerge as the two most distinguishing attributes, followed by “Product complexity,” “Lead time,” and “Level of pull”, suggesting that these five operational attributes join with inter-company supply-chain integration and homogeneity of intra-company supply-chain processes as good predictors for a company’s association with a supply-chain archetype. The other three factors varied less consistently among the three clusters. Following this analysis of attributes, we re-examined the coded interviews to identify patterns with regard to barriers for achieving resilience through supply-chain strategies. The results showed that supply chains belonging to the same archetype share common obstacles to resilience and utilize similar strategies to become more resilient.

A primary area of concern arose for each cluster (see Figure 3.4). The executives of the supply chains in the top right corner all mentioned their vulnerability to lack of design alternatives due to their technology and the capital-intensive nature of their products. Hence, their perceived main barrier to resilience is product complexity. Resilience in the cluster of supply chains in the middle of the diagram was primarily limited by dependence on resources outside of their own corporate boundary, requiring their executives to orchestrate the extended supply chain. Hence their main barrier to resilience is partnership complexity. Lastly, executives associated with the bottom left cluster described their primary barrier to resilience as arising from a need to manage a diverse product portfolio with supply chains that are partly independent and partly intertwined. Hence, their perceived main barrier to resilience is process complexity. Figure 3.4 illustrates the Triple-P

framework of challenges to resilience and articulates the three supply-chain archetypes in terms of each one's primary source of complexity.

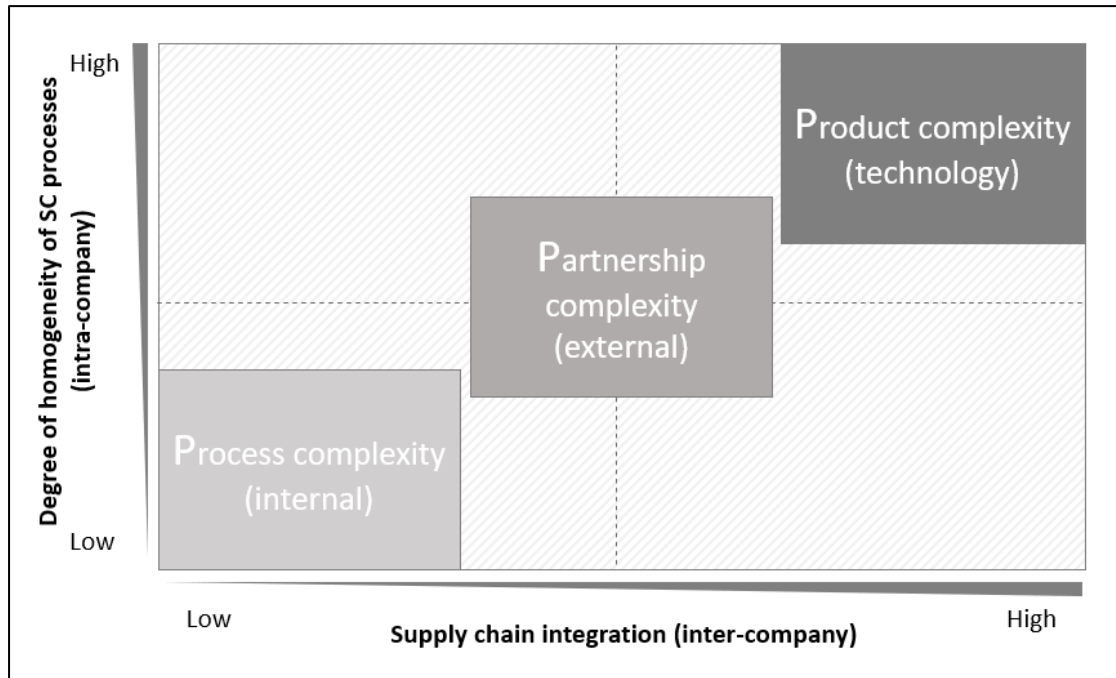


FIGURE 3.4: THE TRIPLE-P SUPPLY-CHAIN RESILIENCE ARCHETYPES

Figure 3.5 indicates the common resilience strategies used by each of the supply-chain archetypes in the Triple-P framework. The next section provides a more detailed description of each archetype and discusses common barriers for resilience and common strategies.

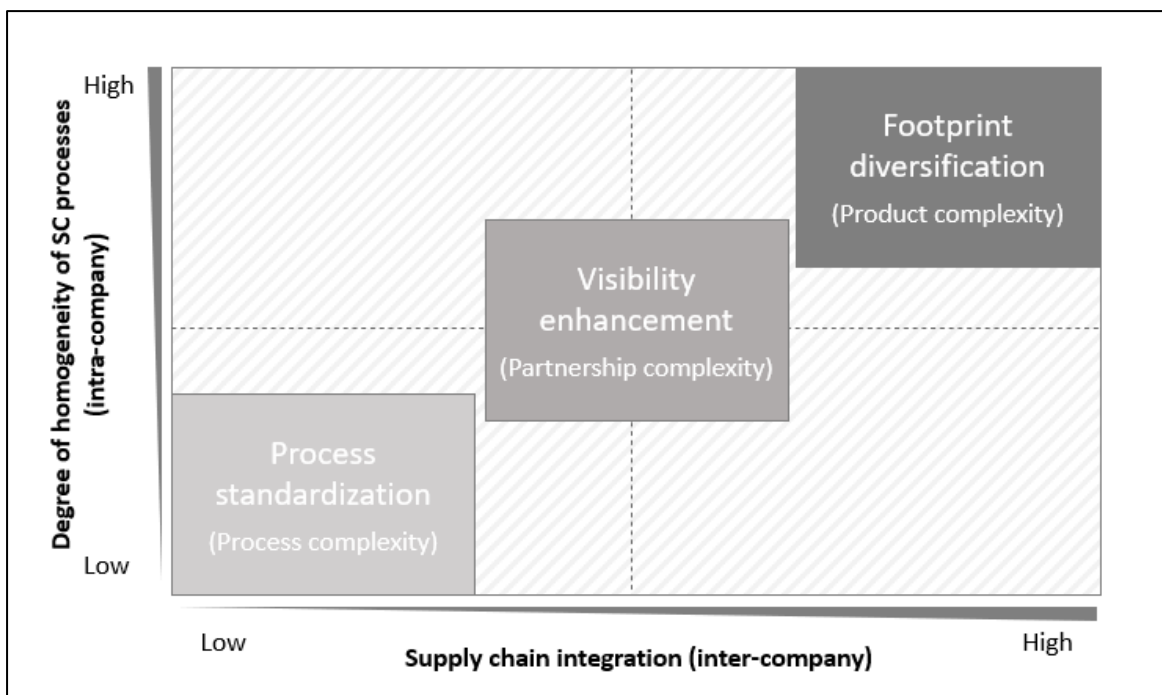


FIGURE 3.5: COMMON RESILIENCE STRATEGIES BASED ON TRIPLE-P ARCHETYPE CLASSIFICATION

3.9.1 Archetype 1: Product Complexity

The products in this archetype are produced by homogeneous supply-chain processes even though they serve at least two different markets: larger, long-term contractual relationships with important customers, and a more short-term market with transactional relationships with smaller players. Supply chains in this archetype tend to be vertically integrated to protect intellectual property, with limited outsourcing to a small pool of qualified suppliers. Upstream processes tend to be heavily automated to reduce labor cost, representing high capital investment. The capital investment requires that the upstream processes be run at a high utilization, which then limits flexibility throughout the supply chain.

Common barriers for the product complexity archetype

Product complexity and the resulting perceived need for heavy upstream automation are the dominant drivers of supply-chain design and resilience decisions for the supply chains in this cluster. First, these factors require the upstream operations to maintain a high-capacity utilization, which creates a push system that makes it difficult to match supply with a volatile demand. The bullwhip effect may also be triggered by such a supply-chain setup when demand exceeds supply (Lee et al., 1997). Second, the need for high utilization, specialized worker skills, and management of IP requires centralization of capacity, making regional production (whether outsourced or in house) difficult—perhaps even infeasible.

One high-tech company's executive gave as their biggest issue to becoming more resilient through geographical diversification (regionalization, which for many firms for now refers to a "China + 1" manufacturing strategy) the sparsity of production-location options offered by its supply base. Executives from the semiconductor industry similarly indicated that their fixed and highly specialized manufacturing infrastructure drastically limits their option space. Another interview partner explained that outsourcing options are limited by the specialized skills needed to make the product, while vertical integration is inhibited by the high capital requirements.

While the centralized planning structure of this archetype provides good visibility of the company's own assets and those of tier-1 strategic partners, visibility

beyond tier 1 tends to be limited. Two executives from the semiconductor industry mentioned the need to couple a six-month rolling demand forecast with daily revision of the order book and the production schedule. Also mentioned is that these supply chains usually depend on significant logistics/transportation operations due to the highly dispersed production process (“global center of excellence” structure). This can reduce resilience when logistics capacity becomes scarce, as occurred during the first months of the global pandemic in 2020 and in late 2021 because of a shortage of containers available to transport goods from China to the US. Lastly, changes in the mix of customers or market applications—such as producing a chip for the consumer electronics instead of the automotive market—puts stress on the “homogeneity” of the supply-chain processes and the efficiency of automation.

Common strategies for the product complexity archetype

To overcome the limitations arising from product complexity, all respondents in this cluster mentioned their need to maintain a long-term focus, and their investments to diversify the production footprint and build redundancies into their center of excellence structures. These strategies can be seen as “dialing back” the initial decision to automate upstream operations and run them at a high utilization. One semiconductor company invested in having two internal facilities for each technology with some redundant capacities, another company standardized its equipment and production methods to be able to move production seamlessly in case of emergencies, and one of the high-tech companies invested heavily in second sourcing by offering incentives to its strategic suppliers to diversify into new countries or to “groom” new partners in the target countries. Our observations suggest that supply chains within this cluster tend to buffer uncertainty using capacity (access capacity, multiple-site facilities) instead of inventory, as inventory is oftentimes customer specific and prone to obsolescence.

Several of the executives interviewed also mentioned their use of sophisticated supply-chain risk-management programs for owned assets and tier-1 partnerships. A large supplier of photolithography systems, for example, involves a small number of highly specialized technology-intensive tier-1 suppliers in joint product development, which spreads the risk and capital investment, and permits joint

monitoring of the critical path and optimization of production processes. The supply-chain structure that has emerged from this joint product development emphasizes single sourcing for tier-1 suppliers but allows multi sourcing for supplier's suppliers.

These risk-management programs—developed in response to prior disruptions such as the Japanese earthquake or the Thailand floods in 2011—may not address deeper tiers of the supply chains. Executives in these companies have thus sought to push digitalization up the chain to increase visibility and facilitate data analytics. While increased visibility has not increased resilience on its own, it has helped these decision makers to estimate the responsiveness required in a fully automated environment to control mismatch costs.

Thus, supply chains in this archetype all view product complexity as a major constraint and do not see an alternative to upstream automation. The limited flexibility resulting from this setup is then mitigated by either increasing responsibility through footprint diversification and capacity buffers or standardizing processes even further.

3.9.2 Archetype 2: Partnership Complexity

Supply chains in this cluster handle complex product portfolios of either standardized make-to-stock (MTS), make-to-order (MTO), or engineer-to-order (ETO) products for business-to-business (B2B) settings. Products are made complex primarily due to the large number of components, which results in supply chains with up to 5-10 tiers, and many suppliers at each tier. The company retains partial ownership of assembly and testing processes for quality purposes and lead-time control, and of a few key components to protect IP. The company uses strategic partnerships with key tier-1 suppliers and decentralized supplier management for others, management of which is partly delegated to the tier-1 firms. Here the product life cycles (5-7 years) are shorter than in the product-complexity archetype, with possible platform redesigns and minor upgrades of some systems within a cycle. Supply chains of this type sometimes sell both to tighter-margin markets in make-to-stock format and to higher-margin B2B markets with a MTO process. The supply chains reflect some process differentiation to handle this diversity on the demand side, while leveraging synergies for the

procurement of commodities, transportation, and some distribution activities. Firms of this type, for example an original equipment manufacturer from the automotive industry, typically pursue regionalized strategies, with only few facilities playing global roles. This makes the company-owned part of the supply chain shorter than for supply chains from the product-complexity archetype.

Common barriers for the partnership complexity archetype

The perceived need to select lowest cost-per-unit suppliers increases the total number of suppliers and the supply-chain length. The obstacles presented by this archetype are experienced by all these supply chains. As the OEM or full-service contract manufacturer, these firms are responsible for orchestrating the entire end-to-end supply chain—or at least big chunks of it. Although well-managed supply chains of this archetype usually have clear visibility, live data, and robust operations within their corporate boundaries, they are vulnerable to disruptions in the multilayered supply network. The number and geographic dispersion of deep-tier suppliers makes it difficult to establish comprehensive visibility or business continuity measures. Examples from our interviews suggest that the barriers to resilience originate outside of the corporate boundaries of the focal firm: (1) a high-tech respondent stated that he is also responsible for connecting different suppliers (tier 2 and 3) to find options in case of a disruption, (2) an automotive executive explained his company's need to oversee supply-chain design changes at strategic tier 1 or 2 suppliers as well as supporting lower-tier suppliers with employees or financial resources, (3) an industrial-goods manager explained that his company is not able to do business continuity planning for the entire supply base due to the "multi-thousand" of supplier chains, and (4) an executive from the agriculture industry described how the liquidity hardships of the firm's customer base (farmers) threaten demand.

Other issues that were mentioned multiple times were that dual-sourcing strategies often still rely heavily on Chinese supplier bases, and that the financial health of small suppliers is a major concern. Moreover, having more than one market segment with differential requirements requires having different supply-chain strategies with differences in some of the supply-chain processes. Thus, supply-chain differentiation increases the degree of difficulty of streamlining what

are traditionally more central and hierarchical corporate-planning activities. Another barrier to resilience mentioned was that transportation capacity constraints accentuate supply shocks. Lessons were learned in prior shocks, but still great pain was felt during the pandemic crisis. Lastly, customers expect and demand—but are not willing to pay for—"resilience insurance". The firms in this cluster struggle to establish mutual understanding of who will bear the cost of enhancing resilience. Although allocating costs is often more about power than system optimality, an upstream supplier that shuts down the total supply chain can cause substantial pain.

Common strategies for the partnership complexity archetype

As the common strategy to overcome partnership complexity, the respondents managing this archetype all named heavy investment in tools, people, and mechanisms to expand their "reach" into lower tiers and manage the end-to-end supply-chain design. One high-tech respondent mentioned a bi-directional communication system and central resilience team to support suppliers. Other respondents described creation of a "control tower" to guide supply-chain design and execution, and to support lower-tier suppliers (automotive respondent). Some of these control towers were coupled with investment in supply-chain analytics to make it possible to monitor the entire supply chain and proactively share information regarding potential disruptions or forecast errors with partners (electronics manufacturer). An industrial-goods manufacturer uses a central database to monitor and evaluate suppliers across business units. A high-tech company leverages its long-term investment in a supply-chain risk-management function to monitor multiple tiers of suppliers. An agricultural company together with its distributors created a customer financing program to ensure demand and make long-term profit more predictable. Supply chains in this cluster, contrary to "product complexity" supply chains, primarily buffer with inventories instead of capacity. Oftentimes, inventory "within the chain" (at suppliers) is used, as well as inventory across pooled different products or regions, often managed through centralized procurement functions.

Supply shocks of the last decade have shown that a diversified footprint combined with regionalization can effectively increase resilience. This strategy is

often implemented by supply chains in this cluster. When regionalization is constrained by supplier availability in the region and therefore depends on longer-lead-time global suppliers, vertical integration or industry coordinated (even implicitly with competitors) supplier development becomes easier to justify. Supplier development in a “China + 1” type strategy had been underway for at least a year for these supply chains due to intensification of bilateral US-China tariffs prior to the pandemic. For firms in this cluster, supplier development can be done typically within a year, which is significantly faster than in the “product complexity” supply chains. Regionalized suppliers can be constrained by material availability, making it worthwhile to invest in raw-material inventories even for lean and pull supply chains. Some executives also mentioned that they have found effective strategies to reduce product complexity such as postponement, and rationalization of supply chains such as having a list of preferred suppliers. One executive from the apparel industry told us that “data analytics is becoming more and more important, but you need a relationship as well” to decide which suppliers are worth investing in before and during a crisis. Lastly, these supply chains are making efforts in automation and digital transformation of their first two tiers, but cheap labor is still prioritized in the deeper tiers. OEMs thus must often rely on “certifications” rather than first-hand monitoring of those deeper tiers.

3.9.3 Archetype 3: Process Complexity

Supply chains in this cluster sell broad portfolios of consumer products. Their variants are used by industrial supply chains in support of service industries. Multiplicity of products and very different value propositions require a wide variety of supply-chain strategies, ranging from efficient but longer-lead-time flow chains to highly responsive short lead-time ones. Companies in this archetype heavily outsource to contract manufacturers and supply-chain orchestrators that have access to a global supplier network. The access to a diverse supplier portfolio allows for labor-wage arbitrage, currency exchange-rate hedging, and easy access to capacity for dealing with demand shocks.

Common barriers for the process complexity archetype

Respondents from this cluster are mainly concerned with internal obstacles and internal process complexity when it comes to increasing supply-chain

resilience. The diverse product portfolio with partly independent, partly intertwined supply chains increases complexity, confuses the execution of supply-chain strategies, and inhibits fast decision making and transparency of product profitability. Even when the locus of decision making is decentralized, complexity can remain high due to a constantly changing product mix and shared functions or assets to leverage economies of scale. For example, one interviewee named the proliferated product portfolio as a major issue for his consumer-products company. Other respondents from the apparel and chemistry industry reported that their resilience problems are a response to complexity driven by inorganic growth and lack of post-acquisition integration. A consumer-goods executive referred to the firm's large and inflexible production base that complicates flexibility. Other supply chains are experiencing opposing demand developments within one business unit and country due to their diverse product portfolio.

A key barrier to resilience named by multiple interviewees from this cluster was the lack of visibility into the supply chains of their strategic partners such as contract manufacturers, third-party logistics providers, or supply-chain orchestrators. Although supply-chain risk management is practiced to some extent with key suppliers, it was often not expanded deeper into the chain made up of small suppliers in emerging markets. In this archetype, supply-chain strategies tend to be segment specific, which makes it difficult to adjust to demand shifts or other shocks at the company level. Demand for consumer goods and industrial-service products can be price sensitive, encouraging decision makers to maximize capacity utilization and minimize costs. This makes it difficult to justify excess capacity in the chain, thus creating industry-wide bottlenecks not controlled by the firm.

Common strategies for the process complexity archetype

Interviews associated with the "process complexity" archetype identified two strategic directions that were followed by all these companies. First, all focused on complexity reduction through portfolio and supplier rationalization that required the focal company to take an active role in supply-chain management. Five interviewees from consumer goods, agriculture, and apparel companies described how portfolios were streamlined to focus only on the SKUs with greatest profit and

highest customer need. We did not observe capacity buffering for time-sensitive products. This is in line with de Treville et al. (2017) finding that managers have difficulty implementing a capacity buffer even when they can see the benefits from simulation models. Two interviewees streamlined their supply base to include only like-minded partners while ensuring that critical components are still multi-sourced. Second, all engaged in some sort of standardization of components, production methods, or assets to increase flexibility of the local/regional production network. For example, two companies increased standardization of mass-category products through late-stage customization (postponement). Another respondent described increasing resilience through increasing process and asset modularity. Another company works on increasing flexible production capacities through collaborative manufacturing partnerships with third party providers. Supply chains in this cluster need to optimize both inventory levels and capacity utilization due to the price pressure in their respective markets. In case of supply shocks these companies are experienced in finding “creative” solutions for handling shortages, such as the use of alternative materials or flexible bills of material.

Other strategies employed by supply chains from this cluster include efforts at regionalization for some products that are either costly to transport or have higher margins. Some automation investments can be made in key parts of the chain to bring the chain closer to the customer. Two executives mentioned that having material inventories closer to markets pays off for longer global chains. Moreover, operational flexibility in the product and channel portfolio, supplier network, and revenue management are part of the most effective path to resilience. These supply chains invest less in redundancy, and only with multiple smaller suppliers in emerging markets. They prefer to increase mix flexibility through flexible automation and process flexibility. Another interesting finding is that digital transformation happens mostly on the retail segment of the chain, where data analytics is heavily used for revenue management, while these practices are much less prevalent on the supply side.

3.10 Discussion

This study has provided a snapshot of what we have observed concerning how resilience efforts vary between three common supply-chain archetypes, illustrating

how supply-chain management has evolved from the dichotomy between efficient and flexible supply chains proposed by Fisher (1997). We observed that the primary complexity type faced in a given archetype aligns with the initial resilience strategy, as well as with the barriers and resilience challenges that the firm should expect to face. The resulting Triple-P framework that we propose can be compared to a made-to-measure suit with the three archetypes being the base pattern. Supply chains from the “product complexity” cluster are typically constrained by the perceived need to automate upstream operations which limits flexibility and therefore are most vulnerable to issues related to the nature of the product, such as the lack of responsiveness and design alternatives. A common strategy to overcome issues arising from product complexity is a long-term commitment to a production footprint that reflects investments in diversification as well as redundancy within a dedicated plant structure. Supply chains from the “partnership complexity” cluster are most vulnerable to issues related to other supply-chain actors outside their own corporate boundaries. Hence, companies of this archetype invest heavily in the means to expand their “reach” upstream and downstream to manage the entire end-to-end supply chain. Supply chains from the “process complexity” cluster are most vulnerable to internal complexity arising from a diverse product portfolio supported by multiple independent supply chains. These companies, on the one hand, use portfolio and supplier streamlining, and, on the other hand, adopt standardization of components, methods, and assets to increase flexibility of their production network.

However, as in tailoring a suit, bespoke adjustments based on the individual environment and operational characteristics of a supply chain improve its resilience capability. The literature cited in this paper suggests alternatives for improving supply-chain resilience that go far beyond what we observed in our study. While we observed considerable variation in supply-chain management and design between the three archetypes that emerged from our interviews, our review of the literature suggests that current practices fall short of what would be theoretically possible. The seru production approach (Yin et al., 2017) described earlier exemplifies what is possible for a firm that rethinks the constraints typically assumed for its archetype. Although many executives mentioned lessons learned from prior shocks, still great pain was felt during the pandemic crisis. Managers

learn from past shocks, but still have difficulty to prepare their supply chains for the next extreme disruption. Seru firms were observed to proactively design their supply chains to provide resilience to a wide variety of states of nature that they could possibly face, in sharp contrast to the strategies implemented by many of the firms that we observed that only begin to increase resilience once a shock has emerged. Based on our snapshot and our review of the literature, we recommend that decision makers not only invest in identifying the archetype that fits them, but also question the assumed constraints and consider opportunities to deploy the levers defined in the literature to tailor their supply chain resilience far beyond what we have observed during this study. The observed gap between what exemplar managers implement and what research findings recommend suggest that the supply chain research community should consider how to market their models and conclusions to be more implementable.

4. WHY OPERATIONAL CONTEXT MATTERS: REALIZING THE FULL POTENTIAL OF SUPPLY CHAIN RESILIENCE SURVEYS¹

4

4.1 Introduction

Business resilience in the context of supply chain management has become a top priority for most companies in response to the massive disruptions caused by the COVID pandemic and subsequent developments such as the chip shortage and bottlenecks in global logistics systems. Many supply chain executives are looking to develop a long-term strategy to increase their supply chain resilience since new uncertainties and major disruptions, such as the Russian invasion of the Ukraine, continue to arise.

This has led many market research and consulting companies to investigate the impact of such disruptions and to explore potential strategies to cope with them. Over the last two years multiple supply chain management surveys have been launched to discover supply chain resilience strategies. However, it has been difficult to develop actionable strategies based on insights from such surveys. This suggests that there is a need to deepen our understanding of how to interpret survey results as well as how to re-design them in order to explore supply chain resiliency.

Surveys on supply chain resilience typically use the totality of all companies in their sample as their unit of analysis, i.e., a typical result would be “x percent of all companies regionalize their supply chain”. In some survey reports industry specific differences are analyzed. This can lead to interesting insights for managers and scholars. However, companies operate within idiosyncratic environments and thus there is a need for more differentiated guidance. Executives need to define strategy decisions to achieve resilience at the individual supply chain level, taking the specific challenges and constraints of their company environments into account. Thus, there is a gap between the level of analysis that is needed for decision

¹The content presented in this chapter is based on an unpublished working paper by Cohen et al. (2022c). The paper was accepted by Supply Chain Management Review (SCRM) and is waiting for publication. Within this chapter, “we” refers to the authors of Cohen et al. (2022c).

making to support resiliency and the level of analysis that is typically provided. We call it the “unit of analysis gap”.

In this article, we want to show how this unit of analysis gap can be bridged with two steps, so that executives can benefit most effectively from survey-based insights. The first step does not require any change to the current format of the surveys since it is based on breaking down existing survey insights to the industry level. The second step requires asking additional questions in order to uncover insights at the supply chain level. Figure 4.1 illustrates the concept of the “unit of analysis gap”.

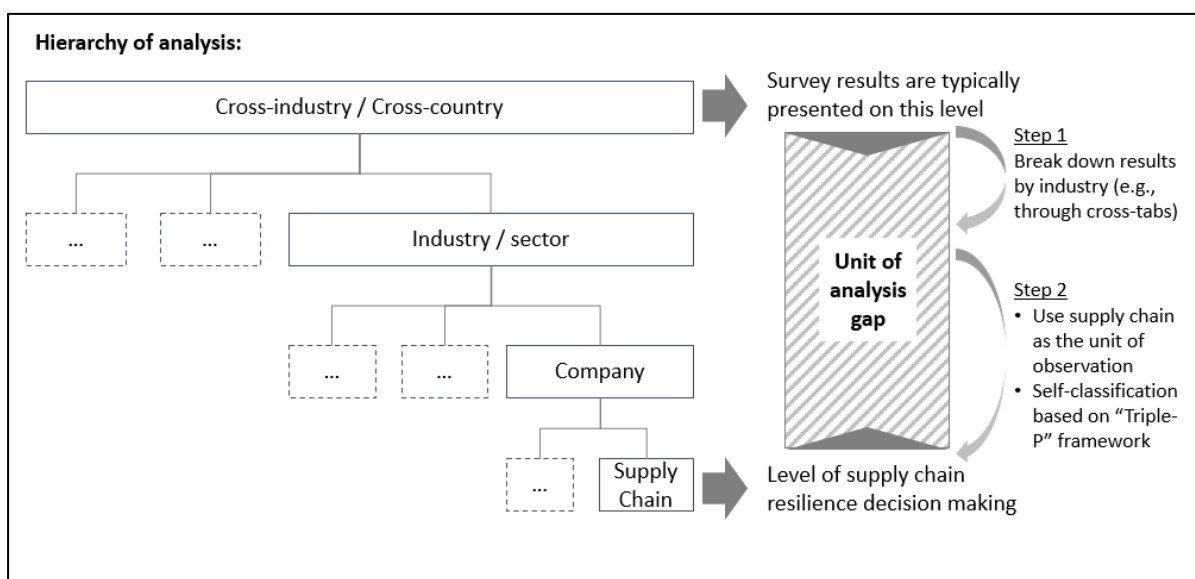


FIGURE 4.1: ILLUSTRATIVE CONCEPT OF “UNIT OF ANALYSIS GAP”

We were given the opportunity to collaborate with Gartner, one of the leading supply chain research and consulting companies, on the development of their 2020 global supply chain agility and resilience survey. Their report “Future of Supply Chain: Crisis Shapes the Profession” (John et al., 2020) is based on the results of that survey. We used the published report and additional access to some of the survey data such as the first five questions of the survey regarding supply chain resilience and agility (Figure 20-24 in Gartner report) to illustrate how survey results can be enhanced through the two steps noted above, leading to more differentiated and relevant insights. From the 1346 responses overall, only operations related job functions with a board level, VP/director, or manager/head role were included which resulted in 1,049 responses.

We have grouped our findings into three parts. The first part documents the advantages of this type of survey and why researchers and managers should see them as an important source of valuable information that is relevant to mitigating the risks present in the current supply chain environment. In this section, we outline the conclusions drawn from reviewing the survey data and comparing the results to other survey-based reports. The second part shows how survey data can be broken down and further analyzed at the industry level. We used additional data, based on the survey responses, that we received from Gartner, to show how further analysis can lead to additional industry-specific insights. In the third section, we explain our recommendations for how to conduct future supply chain resilience surveys in order to generate supply-chain specific insights. We provide three company examples, whom we interviewed, that illustrate our methodology and our conclusions. The Henkel supply chain example illustrates the value of having a supply chain as the unit of analysis. The two Nike supply chains show that two different supply chain archetypes can exist within one company. Finally, the Infineon supply chain example shows that the operational context of the supply chain in certain industries can limit the option space to such an extent that only one feasible supply chain configuration remains.

4.2 Advantages of Supply Chain Surveys

In this section, we discuss how surveys on resilience can support both supply chain practice and research. In particular, we discuss what can be learned from them with regards to resiliency. Consulting surveys and reports are a valuable means for discovering the perspective of practitioners concerning timely topics. Their value is based on the ability of consulting companies to reach a wide pool of respondents and their resources to conduct such surveys in a timely manner. This allows them to quickly generate large data sets that make drawing general conclusions derived from current practice feasible.

We have compared the results of 12 consulting surveys on supply chain resilience from May 2020 to July 2021 (see Appendix B.1 for a summary of survey details) and found that there are some recurring messages in the survey reports. In Table 4.1 we have summarized ten insights related to supply chain resilience that we found in multiple independent surveys. For example, all reports mention

that a digital transformation through investments in IT infrastructure is a key enabler for becoming resilient. A Deloitte survey (Arguilar, 2020) found that 78 percent of respondents view enhancing IT infrastructure to be a top operating model priority. In another survey from dimensional research, 91 percent of the 715 managers responding strongly agree or agreed to "Effective investments in digital technologies and analytics will help companies recover faster from the impacts of COVID" (Dimensional research, 2020). Moreover, a survey from Allianz Research (Dip, 2020) showed that highly digitized companies took significantly more actions to mitigate disruptions compared to less digitized ones.

TABLE 4.1: SUMMARY OF COMMON INSIGHTS FROM CONSULTING SURVEYS

Common insights across surveys	Gartner	Euler Hermes	BCI	Cap-gemini	Deloitte	Gartner 2	Hubs	Jabil	Kearney	McK	SCI	EIU	Sum
Most companies were disrupted due to the COVID pandemic	✓		✓	✓	✓	✓	✓	✓	✓	✓		✓	10
Covid-19 is only the most recent of increasingly frequent disruptions	✓		✓			✓	✓	✓	✓	✓	✓	✓	9
Different phases of resilience (short-term vs long-term)	✓		✓		✓			✓	✓	✓		✓	7
Digital transformation (e.g., ML, AI, robotics) is a key enabler to resilience	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	12
Companies can develop a sustainable advantage through SC resilience	✓			✓			✓			✓		✓	5
SC structure changes are needed to become more resilient	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	11
Government interventions play a role in SC resilience	✓	✓	✓			✓			✓	✓			6
The push for more SC resilience will not end globalization or offshoring		✓			✓	✓	✓	✓	✓	✓			7
Increasing ESG standards mitigates risk of potential future disruptions	✓	✓	✓	✓					✓	✓		✓	7
Collaboration with other SC partners is critical for SC resilience	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	11
Number of resilience strategies mentioned	10+	8	-	10+	8	6	5	10+	8	10+	8	10+	-

We note that 11 out of 12 survey reports conclude that changes to the current supply chain setup are needed for most companies. According to Gartner, 40 percent of executives believe that their current supply chain is not able to cope effectively with short- to medium term challenges (John et al., 2020). Another survey from our sample found that 65 percent of respondents said that they actively invest in regionalizing and localizing their manufacturing base or that 82 percent agree with the statement "Our supply chain footprint has shifted notably because of COVID" (Gya et al., 2020).

Thus, these consulting reports document similar developments when it comes to beliefs and actions of global supply chain managers. This is why Cohen et al. (2021) concluded that the basic roadmap to resilience is understood by managers.

The findings are interesting and relevant as they give an overview and cross-check of how managers think. Moreover, due to the large sample size, the survey results support making general statements about current management thinking. The insights also can be used as a starting point for scholars to examine resiliency in more detail and to develop analytical resilience models.

4.3 Generate Industry Insights through Further Analysis

In this section, we show how breaking down results to the industry level reveals interesting insights. Being resilient indeed does mean something different for each supply chain, as each company needs to balance different types of risks while minimizing overall costs. The “right” trade-off depends on individual circumstances such as regulatory requirements, geographic supply constraints, partner ecosystems, or risk appetite.

However, this is the first of two steps to bridge the gap between the general conclusions which are oftentimes found in consulting reports and supply chain-specific insights that managers require. Through this first step some questions can be answered. For example, are most companies in my industry implementing the same set of strategies? Do other executives in my industry share my beliefs regarding resilience? Why are some companies not investing in resilience?

Generating industry level insights can be done without any changes to the current format of most surveys, as usually the respondents are asked to specify the industry their company is competing in. We use the Gartner report as an example of how to conduct further analysis that can lead to additional industry-specific insights.

4.3.1 Example: Gartner Survey

The annual Gartner survey, which is the survey we analyzed in this paper, is one of the leading and most relevant supply chain surveys, because of its global reach, large sample size, and the quality of its respondents. We observed that 1049 from a total of 1,346 respondents work in operations and are a board member, director, vice president, or manager. Moreover, the respondents came from 18 different industries, which represents a good cross-section of all companies, while

excluding industries such as Services, Software, and Finance. Thus, the survey is well suited for examining supply chain related topics at a general level.

To identify additional insights, we conducted further analysis through three cross-tables of the reported survey questions responses that Gartner provided for us, and which were not included in the survey findings report. All three cross-tables can be found in Appendix B.2. It is worth noting that we were not given access to the raw data that generated them.

Resilience strategy deployment by industry

The first cross-table analyzes industry-specific differences in investment decisions that have already been implemented and are not just intended. The table (B.2) shows the total number of respondents per industry and how many of them indicated that they were currently investing in one of the sixteen agility and resilience strategies identified in the survey. Respondents that only intend to invest in the next two years were excluded, as intention does not necessarily translate into real action, which is what we want to focus on.

The results of this cross table show that there are significant differences in supply chain resilience strategies that were implemented across industries. For example, only 30 percent of managers from automotive companies reported that they shifted manufacturing from one region to another, while 61 percent of high-tech executives reported that they have done so. Moreover, the results show that chemical companies and automotive companies have implemented significantly less in resilience strategies than the other industries. Chemical companies reported that they have diversified their supply base (-20 percent compared to average), increased inventory (-22 percent), or outsourced (-17 percent) far less than all other industries to become more resilient. These results can be explained by the particular setup of many chemical supply chains being asset-intensive and continuously flowing. Automotive companies seem to shift manufacturing capacities (-18 percent), deepen collaborations with key suppliers (-16 percent), and use demand sensing technology (-18 percent) far less than other companies. Their asset intensive production explains the lacking flexibility of production capacities. Having more purely transactional relationships with suppliers might explain why it is especially challenging for the automotive industry to secure

enough of the supply-constrained semiconductor chips. We only mentioned some examples as this is not the focus of this article, however, more interesting insights can be found in the data.

Supply chain beliefs by industry

The second cross-table looks at how managers' beliefs or perspectives concerning factors or trends that can impact supply chain agility and resilience strategies vary by industry. The table (B.3) is based on fourteen different belief statements and asks managers to agree, disagree or be neutral with respect to each statement.

Over 90 percent of the High-tech, Logistics & Distribution, consumer packaged goods (CPG), Retail, and Industrial companies have indicated that they will invest in resilience and agility. These are industries where management generally understands and accepts the investments required to be more resilient and agile (see 2.5, Table B.3). For CPG companies, one reason for investing more might be that they lag behind other industries in terms of agility, as their supply chains have been designed primarily for cost efficiency rather than resiliency or agility in the past (see 2.3, Table B.3). The industries that are doing less to make their supply chains resilient include Aerospace & Defense because national interests and regulation hamper supply chain restructuring (see 2.8 and 2.7, Table B.3) or Food and Beverage because customers want local sourcing (see 2.9, Table B.3). However, further automation is needed to facilitate onshore manufacturing to make supply more agile and resilient (see 2.14, Table B.3). Moreover, investments in agility and resilience are simply too costly for Automotive companies and their leadership did not see the need for action at the time of the survey (see 2.4 and 2.5, Table B.3). For Medical Equipment & Devices companies the industry's current low-cost outsourcing strategy is still largely sustainable and does not require them to act quickly (see 2.9, 2.10, 2.11, and 2.13, Table B.3). Chemical companies already are very lean, based on continuous flow operations, and do not see the need to change their supply chain setup (see 2.6, Table B.3).

Overall, it can be observed that there are significant differences in answer patterns depending on the industry. For example, affirmative answers regarding a previous focus on cost efficiency (see 2.3, Table B.3) vary by up to 32 percent-

points, depending on the industry. The same is true for customer preferences for local sourcing (up to 43 percent difference; see 2.9, Table B.3) or whether the leadership accepts the need for investments in resilience (up to 36 percent; see 2.5, Table B.3). Thus, it can be concluded that even though basically every respondent (90 percent) indicated that they will invest in agility and resilience, the underlying motivations and reasons for doing so vary significantly.

Beliefs versus decisions

The third cross-table analyzes how the companies' supply chain investment decisions are linked to their beliefs or perspectives on supply chain factors and trends. The table (B.4) combines the answers from the investment decisions and the beliefs to show the split of agreeing and disagreeing to the fourteen statements by investment decision instead of by industry. Our hypothesis was that the actual decisions (i.e., the strategies implemented) tells us something about the underlying beliefs. For example, we expected companies that increased their safety stock levels or reduced their capacity utilization would agree to a greater extent that "our supply chains in the past have been designed primarily for cost efficiency rather than resiliency or agility". Surprisingly, the results (see cross-table 3 in Appendix B.2) do not show that the beliefs are linked to the ultimate investment decisions/actions. For all beliefs, the age of respondents agreeing and disagreeing is basically constant across all resilience strategies (standard deviation of 1.5 percent across all responses). Thus, companies implement different supply chain resilience strategies, but on average have similar beliefs regarding the resilience vs. cost-efficiency trade-off, regionalization, and customer preferences. This observation indicates that the implementation of a particular resilience investment can have multiple different reasons. For example, regionalization of the supply chain might implicate for a supply chain that previously operated a very lean global setup, the possibility to have more redundancies and diversified location risk. However, another company might want to regionalize its supply chain to reduce the time-to-market or relocate decision making to jurisdictions that are able to better serve the local customers. This suggests that further analysis is needed to understand how beliefs impact supply chain decision making.

The additional insights generated through the three cross-tables revealed that more can be learned, even without having full access to the raw data. However, it also showed that some patterns can only be explained through a more granular analysis. Staying at an industry level is not sufficient to understand how decision making for resilience is conducted in practice.

4.4 How Surveys can Provide Differentiated Answers to Managers

In this section, the second step for bridging the unit of analysis gap is described. Based on our collaboration with Gartner, our analysis of the survey data, and our review of current supply chain resilience research literature, we have developed two recommendations for future surveys that can lead to supply chain-specific results. To illustrate our reasoning, we give three real-life company examples based on in-depth interviews with senior supply chain executives.

4.4.1 Use Supply Chain as the Unit of Observation (Instead of Company)

We believe that future supply chain surveys will benefit most from using a more detailed unit of observation which allows for a more differentiated analysis of the results (i.e., the unit of analysis is the organization entity that you wish to say something about). However, consulting surveys usually ask respondents to answer the survey questions from the perspective of their company (see Appendix B.1). Thus, managers are forced to decide whether they are answering based on an average across all supply chains that are used by their company, which can be very misleading for conglomerates or companies with a wide product portfolio, or whether they are answering from the perspective of one specific supply chain without being able to document which one they are answering for. Both options can distort the results and complicate our understanding of the underlying drivers of resilience (see further details in Cohen et al., 2022b).

Changing the unit of observation to be the supply chain will require clarification at the beginning of the survey, so that respondents do not answer from the perspective of the entire company, but rather do so for a particular, specified supply chain. Ideally, the survey asks the respondents to name the product (group) they are referring to at the beginning of the survey. This will lead to a respondent's

commitment to only one supply chain, for that product (group), and enable more detailed understanding of the results.

Company example: Henkel

Henkel is a global manufacturer of consumer-packaged goods with 20 billion revenue and 179 production facilities in 79 countries. The company is divided into three different business units, each with its own supply chain setup. Due to different setups, each supply chain has its own “point of differentiation” along the value chain (see Figure 4.2).

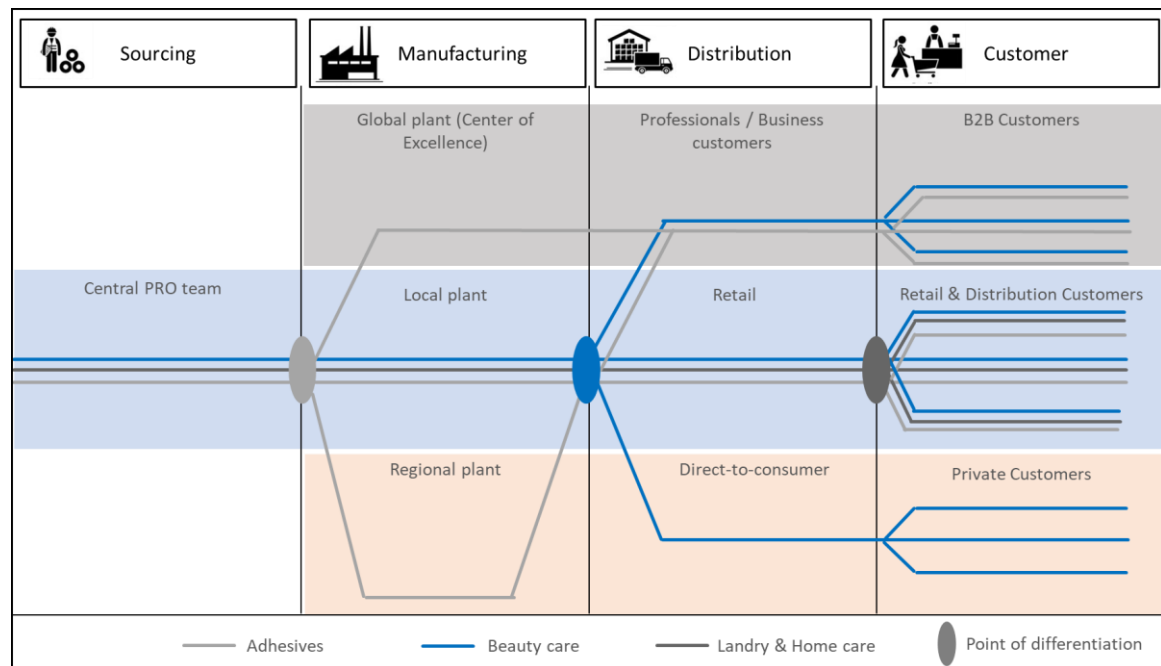


FIGURE 4.2: STRUCTURE OF HENKEL'S SUPPLY CHAIN PORTFOLIO

The laundry and home care products share the same footprint in terms of sourcing and production locations for scale efficiency reasons and use the same distribution network as all products are sold via retailers and distributors. However, the supply chains are differentiated based on a customer segmentation, resulting in different lead times and service levels. The beauty care products also share the same production footprint due to similar technology and the resulting economies of scale, but the supply chains are differentiated by distribution channel into retail and direct-to-consumer businesses, because personalized products which are directly shipped to the consumer require a different setup. And lastly, the adhesives business unit differentiates its supply chains based on production technology,

ranging from local production facilities for construction business customers to a global center of production excellence structure for electronics customers.

This company example shows that a company might have very different supply chain setups across and even within a business unit. As these different setups need different approaches to becoming more resilient it is crucial to use a specific supply chain as the unit of analysis. Otherwise, a manager from this company could have answered the survey in many ways. Only with a survey based on a supply chain, can it be ensured that these overlapping factors are not aggregated into one response.

4.4.2 Understand the Context

Choosing a more detailed unit of observation can remove some of the “noise” from the data since answers will be specific to one supply chain structure. Moreover, more can be gained by understanding the context associated with the responding managers answer.

There is a general belief that companies in the same industry tend to share the same supply chain resilience strategies. But that is not necessarily true. To understand why that is the case, it is important to realize that in general, industries are mainly defined by the primary product produced or sold. Other characteristics such as the production process or supply-side characteristics typically play a lesser role. Current research, however, suggests that grouping supply chains with regards to supply chain resilience requires similar operational product, process, and market characteristics (Christopher et al., 2006). Companies within the same industry can have different supply chain attributes due to factors such as company location, size, age, or number of product groups being offered.

One way to extract this information in a survey would be to ask detailed questions that reveal the operating characteristics of the product (group) with regards to the supply chain setup, market conditions, and product attributes. This approach will lead to more insights. However, this requires the addition of several "setup" questions, which already take up a significant portion of the total response time.

Instead of asking respondents to answer a lot of detailed questions about the operational attributes of their company, we recommend letting managers self-assess and classify their supply chain based on a resilience framework that associates a supply chain into a supply chain archetype which is defined by operational features of the company supply chain. Such self-classification captures the type of supply chain and the corresponding supply chain context for analyzing factors and attributes that influence current supply chain resiliency. This will put the managers' answers into perspective and enable derivation of more detailed insights, which help companies to understand how to actually achieve resilience. This way, only one or two questions need to be added at the beginning of a survey.

The framework should be simple and easy to understand, so that it allows all respondents to select an appropriate archetype. We suggest using the "Triple-P" supply chain resilience framework (Cohen et al., 2022a) which matches resilience strategies to supply chain archetypes. This framework requires responding to two questions:

- (1) about how the company's supply chain(s) are organized and coordinate decision making, (*homogeneity of internal supply-chain processes*) with answer options "multiple independent supply chains", "shared services", "central guidance"; and "one-size-fits-all" and
- (2) about how the company's supply chain(s) coordinate decision making and information exchange with external partners and stakeholders (*inter-company integration with other supply-chain actors*), with answer options "less dependency/ engagement", "coordination with key partners", "integrated systems", "collaboration", and "vertical integration".

Based on this classification into these two dimensions, three supply chain archetypes can be identified to group supply chains across industries based on their common barriers to achieving resilience and other operational features. Figure 4.3 summarizes the main results of the framework, adopted from Cohen et al. (2022a). We note that other possible frameworks could be used to classify a supply chain.

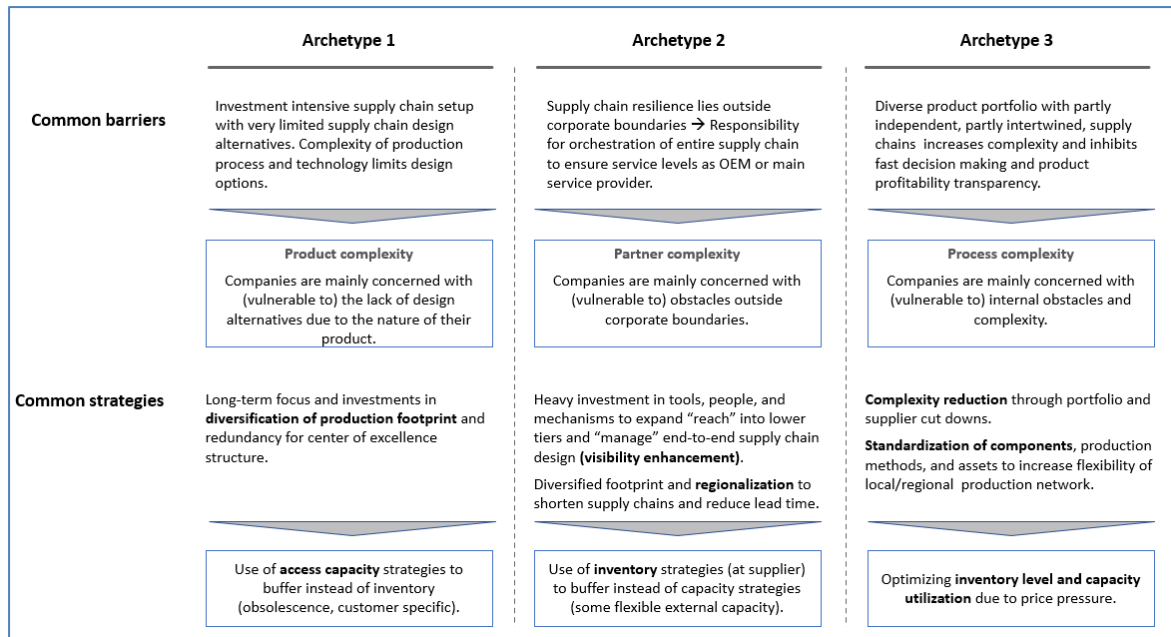


FIGURE 4.3: SUMMARY OF "TRIPLE-P" SC ARCHETYPES

Company example: Nike

Nike is a global apparel company focusing on sports and lifestyle clothes that sells Dollar 37 billion worth of products, which are produced in more than 600 factories in 54 different countries. The company is operating with essentially two different supply chain structures: a footwear and equipment supply chain and an apparel supply chain. Based on the “Triple-P” framework, the two supply chains belong to different archetypes (type 2 and 3) even though they are both within the same company. We illustrate the importance of understanding the supply chain context by considering how answers would be analyzed in typical consulting surveys versus how they can be interpreted when using the “Triple-P” framework instead.

(1) Consolidated footwear supply chain

The footwear supply chain belongs to archetype 2, partner complexity. It is structured around a consolidated supply base with only a few contract manufacturers that can produce almost the full product portfolio with a limited number of large-scale factories in low-wage countries. Moreover, demand is rather predictable, and the technology is simple. This makes it easy to move production around in case of local disruptions or tariffs. Thus, the focal company collaborates

with a dozen key partners after multiple decades of investing heavily in these key relationships to geographically diversify their manufacturing footprint.

Nike decided that further geographical diversification out of South-East Asia would make the footwear supply chain more resilient. Ultimately, the company wants to have production close to all demand hubs, in high-wage countries such as the US or central Europe.

(2) Diversified apparel supply chain

The apparel supply chain belongs to archetype 3, process complexity. It differs with regards to technology, process, supplier relations and market dynamics. Nike is faced with a fragmented supplier market consisting of many specialized plants due to the great variety of materials and the complexity of material processing. Moreover, quickly changing customer preferences (fashion trends, seasonality) hamper long-term partnerships with suppliers.

To make the apparel supply chain more resilient, the company decided to focus on a smaller number of strategic partners with which they try to establish long-term relationships by helping them in the short term with preferred orders and financial aid and in the long run to diversify their product offerings. Geographical diversification is less of a concern as the fragmented market allows the company to easily do business with new production partners in new countries.

Analysis with and without context

Even though the supply chains are set up in different ways, managers from both business units could have selected, for example, the response to invest in "Shifting manufacturing from one country/region to another (including reshoring or nearshoring)" in the Gartner survey, for different reasons.

With the context given above for the two supply chains, it is understandable that a footwear manager would choose this strategy as the business unit tried to geographically diversify their manufacturing base to be in close proximity to final demand. In contrast, a manager from the apparel business unit has the streamlining of supply base activities in mind when indicating, that he/she is investing in shifting manufacturing. Bundling manufacturing capacities at a smaller number of contract manufacturer sites also involves shifting manufacturing capacities across countries.

However, usually the context is missing and therefore the underlying reasons for selecting a strategy remain unknown, as shown in Table 4.2. If the respondents would have self-classified their supply chain beforehand, some of that context could have been understood (see Table 4.3). In contrast to Partnership complexity, supply chains belonging to the Process complexity archetype usually have regional or even local setups. Shifting manufacturing for them therefore does not involve re-shoring or diversification reasons. Thus, both business units could have chosen the same investment strategy for different reasons and this example shows that prior classification of the supply chain context could help to learn more about the reasoning behind the selected supply chain strategy.

TABLE 4.2: NIKE SUPPLY CHAIN INSIGHTS BASED ON TRADITIONAL APPROACH

Product (group)	Industry	Strategy implemented	Reasoning
Nike - unknown	Fashion / Apparel	Shifting manufacturing from one country/ region to another (including reshoring or nearshoring)	Motives remain unknown – hypothesis on industry level
Nike - unknown	Fashion / Apparel		Motives remain unknown – hypothesis on industry level

TABLE 4.3: NIKE SUPPLY CHAIN INSIGHTS WITH "TRIPLE-P" CLASSIFICATION

Product (group)	Supply chain Archetype	Strategy implemented	Resilience strategy focus based on archetype	Actual reasoning of executives
Nike - Footwear	Partnership complexity	Shifting manufacturing from one country/ region to another (including reshoring or nearshoring)	<ul style="list-style-type: none"> Diversified footprint and regionalization of supply chains Visibility enhancement to manage SC 	<ul style="list-style-type: none"> Geographically diversify manufacturing base to be close to final demand Prepare agile local-for-local supply chains
Nike - Apparel	Process complexity		<ul style="list-style-type: none"> Complexity reduction through portfolio and supplier cut downs Standardization of production methods, and assets to increase flexibility 	<ul style="list-style-type: none"> Bundling capacities at a smaller number of contract manufacturer sites Supplier streamlining to form strategic partnerships

Thus, using a framework, such as the suggested one, will enable surveys to mitigate the lack of crucial information to understand the underlying reasons for

resilience strategy decision making and to compare supply chain setups based on similar operational attributes instead of using industry classifications.

Company example: Infineon

Infineon's automotive supply chain is an example of the third archetype (type 1, product complexity). Infineon is a large player with Dollar 10 billion in revenues and 21 manufacturing sites distributed around the world. The company has basically one supply chain for its roughly 15,000 stock keeping units even though the product and demand characteristics differ. The existing structure of Infineon due to its high-tech environment, volatile demand, and capital-intensive production, has built-in mechanisms to mitigate risk and resolve supply and demand disruptions as unexpected events occur on a regular basis. One example would be the investments in creating inhouse redundancies for the center of excellence production structure. These limiting factors are faced by all companies in the semiconductor industry which results in having basically one supply chain setup for this industry.

In contrast to the Nike footwear supply chain, Infineon is not about partnering with your core suppliers and contract manufacturers to get closer to the main demand hubs. Instead, strategies for becoming more resilient focus on logistics and distribution rather than production location or capacity. Thus, the company expanded the reach of its regional distribution centers to be able to supply not only their respective region but also the entire world. Moreover, actions such as preparation of master data were taken to enable fast stock transfers between distribution centers.

The Infineon supply chain example shows that the operational context of the supply chain in certain industries can limit the option space to such an extent that only one feasible supply chain configuration remains. For these cases, an analysis on industry level would be sufficient.

4.5 Conclusion

We identified some clear messages regarding the treatment of supply chain resilience in consulting survey-based reports and explained why such supply chain

surveys are valuable for gaining an understanding about context and common approaches for new and upcoming topics such as the achievement of resiliency.

However, this article also showed that there is a mismatch between what can be inferred from these consulting surveys and what supply chain executives need to know to steer their supply chains effectively. We propose that this “unit of analysis gap” can be closed with two steps. The first step does not require any change to the current format of the surveys, as it breaks down the insights to the industry level based on further analysis of the raw data. An example is given in form of three cross tables drawn from a recent Gartner survey on supply chain resilience.

We noted that an industry level analysis alone, will not lead to supply chain-specific insights, which are required to develop a strategy such as resilience. We therefore introduce a second step that requires changing the unit of observation to the supply chain instead of the company. Asking additional questions to understand the context in which supply chain setup decisions are made supports overall understanding and enables differentiated statements to be made at the supply chain level. We propose letting respondents self-classify their supply chain according to the “Triple-P” framework. This classification provides the necessary context and allows for a more nuanced understanding of why companies have implemented their current supply chain structure and strategy and provides concrete guidance for how to adopt a strategy that promotes resilience.

Three company examples are given to illustrate the three different archetypes. The company examples show how contextual factors, i.e., operational characteristics, determine the supply chain archetype and impact the implemented supply chain resilience strategy. Based on what is known about the barriers for each archetype, this context gives guidance for managers on what to do (Cohen et al., 2022a). The Nike example illustrates the methodology by contrasting the information with and without using the Triple-P framework.

Thus, the results of this article suggest that the company-based format which is good for general management surveys is not a good fit for generating the insights necessary for a company to develop an effective resiliency strategy. Such surveys would benefit from more granular data. Questionnaire-based surveys that require

the respondent to speak for a monolithic company-wide supply chain cannot effectively link operational characteristics to a supply chain-specific strategy. When applying these strategies in practice, managers necessarily run into company or supply chain setup-specific challenges and therefore they need more customized insights in order to develop resiliency strategies that will be successful.

5. The Intersection of Supply Chain Resilience and Sustainability from a Practical Perspective – An Integrated Framework¹

5

5.1 Introduction

Companies can be stretched to the limit when competition and cost pressures intensify and when product life cycles become shorter while individualization increases. The overall business objective is to ensure long-term profitability by achieving and maintaining a competitive advantage. A competitive advantage arises when the company, in contrast to its competitors, can either offer a lower price (a cost advantage) or differentiate its product in terms of value (Porter, 1985). For many years, this dynamic has encouraged companies to concentrate on understanding customer needs and offering tailored products at competitive prices (Christensen, 2010). However, changing external factors – such as de-globalization, global warming, pandemics, geopolitical tensions, and depletion of natural resources – have increased the importance of supply chain activities. To mitigate the challenges posed by external factors and to ensure the company's long-term profitability, supply chains must become increasingly resilient and sustainable. Figure 5.1 illustrates this nexus of objectives along with the drivers of today's greater need for supply chain resilience (SCRE) and supply chain sustainability (SCS).

The resource-based view (RBV) is an approach to achieving sustained competitive advantage by exploiting a firm's internal strategic resources. According to the RBV, achieving long-term profitability requires the firm to capture value by harnessing resources that are valuable, rare, hard to imitate, and organized (VRIO; see Fredericks, 2005; Madhani, 2010; Rajesh, 2021). These resources can be product-related, process-related, and/or people-related. Our study focuses on the *process*, which in this case involves supply chain–related resources. Previous studies suggest that resilience and sustainability strategies meet the RBV requirements for intangible resources that can lead to competitive advantage, since

¹The content presented in this chapter is based on an unpublished working paper by Doetsch and Huchzermeier (2022).

these strategies are both heterogeneous and immobile and also have the VRIO attributes (Tukamuhabwa et al., 2015; Kähkönen et al., 2018; Arda et al., 2021). We shall use RBV to help explain the relationship between the two supply chain objectives (SCRE and SCS) with regard to the overall business objective of developing and maintaining a long-term competitive advantage.

The growing need for SCRE is driven by the rise in magnitude and frequency of disruptions. This trend is expected to continue because of increasing cost pressures and rising customer standards. A McKinsey & Company study from 2020 found that companies can anticipate to lose, every decade, 42 percent of one year’s earnings before interest, tax, depreciation, and amortization (EBITDA) owing to supply chain disruptions (Lund et al., 2020). Hence SCRE has become a top priority for managers and, at the same time, has received increasing interest from scholars (Han et al., 2020).

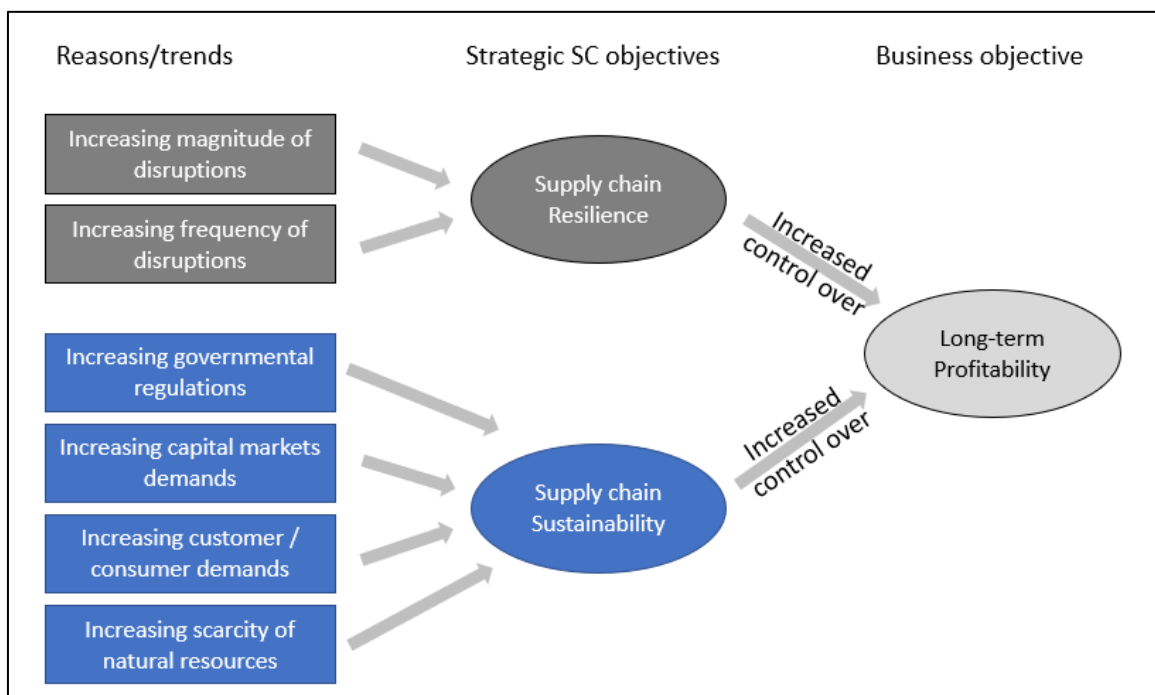


FIGURE 5.1: REASONS FOR INCREASED FOCUS ON SUPPLY CHAIN RESILIENCE AND SUSTAINABILITY

Over the past few decades, SCS has also gained more attention from top management. As Figure 5.1 shows, this trend reflects stricter governmental regulations, increased scarcity of natural resources, and growing pressure from consumers and financiers (Manupati et al., 2019). Incorporating SCS objectives entails managing the social, environmental, and economic impacts of supply

chains. Supply chain sustainability is not only a topic of great interest to practitioners; there is also a large body of literature in this field (Mujkic et al., 2018).

Both SCRE and SCS have received considerable media and research attention, and each is considered by a recent McKinsey & Company study to be among the top five priorities for chief executive officers (Hatami & Hilton Segel, 2021). Yet less is known about whether (and, if so, how) these two strategic supply chain objectives are connected (Negri et al., 2021). Papers on the relationship between SCRE and SCS can be grouped into three types. The first focuses on the conflicting elements of SCRE and SCS – for example, the need to maintain redundancy for resilience and the need to be resource efficient for sustainability (Zavala-Alcívar et al., 2020; Rajesh, 2021). The second type of studies comprises those that examine a particular mono-directional relationship between the two objectives. Thus Miller and Engemann (2019) argue that SCS must precede SCRE because the former can anticipate sustainability-related shocks, which might otherwise lead to business continuity plans that are too resource intensive. The third type of studies analyzes the overlapping themes between the two objectives. For instance, Fiksel et al. (2014) find that the concepts of SCRE and SCS are mutually reinforcing. So it is not surprising that Negri et al. describe the relationship between SCRE and SCS as “cryptic” and “inchoate”. A more comprehensive understanding is needed as regards their synergies and trade-offs.

Contingency theory (CT) is an organizational theory whereby optimal decision making and also the optimal organizational structure depend on both internal and external factors (Lawrence & Lorsch, 1967; Souder et al., 1998; Fredericks, 2005). According to CT scholars, there is no generic blueprint applicable to managing or organizing a company; rather, the optimal arrangements depend on the individual situation faced by the focal company. As a result, managers adopting this approach must be flexible and capable of quickly adapting to changing environments as well as to internal changes (Park, 2011). Contingency theory forms a natural theoretical basis for explaining proactive SCRE management and is widely viewed as a promising theory that complements the RBV (Grötsch et al., 2013; Brandon-Jones et al., 2014; Morais & Barbieri, 2022). Thus, CT highlights the necessity of understanding the context, which in this study is supply chain specific, so we use CT to emphasize that – when the goal is to

become resilient and sustainable – the optimal mix of resources must be regularly updated to reflect changing conditions.

In short, this study aims to clarify the relationship between SCRE and SCS by analyzing and comparing the two concepts with regard to implementation strategies, barriers, and metrics. We proceed by examining the connection between SCRE and SCS from the perspective of practitioners as determined by their responses to a large-scale qualitative survey. A particular focus is on barriers, since both SCRE and SCS are viewed as capital-intensive investments. This empirically oriented view will enrich the discussion, which to date has been mainly theoretical and based on just a few case studies. In this context, we address an overarching research question.

Research Question (RQ) *From a practical point of view, are SCRE and SCS complements or substitutes?*

This question can be divided into three “sub-research questions”, as follow.

Sub-RQ 1 *How do implemented supply chain **strategies** affect the overall level of SCRE and SCS in practice, and what do these effects reveal about the intersection of the two concepts?*

Sub-RQ 2 *What can practitioners' perceived supply chain **barriers** tell us about the intersection between resilience and sustainability?*

Sub-RQ 3 *What inferences can be drawn about the SCRE–SCS intersection from the **metrics** already used in practice?*

Our study is divided into seven sections. In Section 5.2, we review the theory and literature while discussing the intersection of SCRE and SCS and comparing them in terms of strategies, barriers, and metrics. We use the term “intersection” not only to capture the commonalities of supply chain resilience and sustainability but also to emphasize how each is affected by efforts to improve the other. Section 5.3 outlines the research design, and Section 5.4 presents and analyzes the findings from a qualitative large-scale survey in the context of our

three sub-research questions. We develop a conceptual framework for defining the SCRE–SCS relationship in Section 5.5, and Section 5.6 describes the key takeaways for practitioners. We conclude in Section 5.7 with a brief summary and outlook for future research directions.

5.2 Theoretical Background

In this section, we introduce the notions of SCRE and SCS and then investigate their connection. Toward that end, we summarize the literature streams that compare or at least touch on both concepts. We follow Negri et al. (2021) in analyzing the intersection of these two concepts along three dimensions: supply chain strategies, barriers to implementation, and metrics.

5.2.1 Supply Chain Resilience and Sustainability

Supply chain *resilience* became a huge priority for companies, governments, and the public following recent disruptive events: the Covid pandemic and the war in Ukraine. This multi-dimensional and multi-disciplinary phenomenon (Ponomarov & Holcomb, 2009; Ponis & Koronis, 2012) has garnered researchers' attention mostly in the last two decades. Despite being a relatively new literature stream, some aspects – such as basic definitions and the different stages of resilience – have been extensively researched and discussed (Ponis & Koronis, 2012; Kamalahmadi & Parast, 2016; Ali et al., 2017; Hosseini et al., 2019; Behzadi et al., 2020). Resilience is defined as the “ability to adapt to structural changes by modifying supply chain, products, and technologies strategies” (Cohen et al., 2021).

Most literature on SCRE considers three phases: pre-disruption preparation activities, responses during a disruption, and post-disruption recovery and growth (Hohenstein et al., 2015; Tukamuhabwa et al., 2015; Hosseini et al., 2019; Singh et al., 2019; Han et al., 2020; Shashi et al., 2020; Zavala-Alcívar et al., 2020). The notion of resilience encompasses preventive elements (to avoid a disruption's occurring), reactive elements (to contain and stabilize a disruption when it happens), and strategic elements (so that companies can reach, or exceed, their previous level of performance). Therefore, SCRE is not conceptualized as a single state or outcome; instead, resilience is viewed as a dynamic process. Resilience

requires being agile, adaptive, redundant, and flexible in order to cope with and recover from any type of disruption.

Supply chain *sustainability* is likewise a multi-faceted concept that has inspired a variety of interpretations (Zhang et al., 2021). Unlike the literature on SCRE, research into SCS is extensive and goes back nearly three decades. Martins and Pato (2019) identify 146 literature reviews on SCS published between 1995 and 2018. Two decades of research have concluded that sustainability rests on the so-called triple bottom line: the environmental, social, and economic “pillars” of sustainability; hence most definitions include these three pillars (Elkington, 1998). A commonly used definition is that of Seuring and Müller (2008), who define SCS as “the management of material, information and capital flows as well as cooperation among companies along the supply chain while taking goals from all three dimensions of sustainable development, i.e., economic, environmental and social, into account which are derived from customer and stakeholder requirements.” According to Eslami et al. (2019), more than half of all SCS-related studies address all three dimensions of sustainability while about another 20 percent of them are concerned only with the environmental aspect.

Our study focuses on the environmental aspect of supply chain sustainability. This paper does not offer a comprehensive review of the literature on each concept. Rather, we draw on selected studies to outline the current level of understanding within the largely unexplored intersection of resilience and sustainability. Ali et al. (2017) give more details on SCRE; for SCS, see the literature reviews by Seuring and Müller (2008) and Koberg and Longoni (2019).

5.2.2 Intersection of SCRE and SCS

Only a few studies have explored the intersection of supply chain resilience and sustainability. The extant literature exhibits a wide variety of approaches to defining the overall relationship between SCRE and SCS. This literature can be divided into three major streams: (1) literature focusing on the negative interactions and/or the missing connection between the two concepts; (2) research that adopts a sequential viewpoint and so analyzes the concepts while assuming one necessarily precedes the other; and (3) literature that analyzes the two concepts in terms of their positive interactions and overlapping themes.

The first (and smallest) group includes studies such as that of Rajesh (2021), who examines the resilience–sustainability relationship through various theoretical lenses: institutional, stakeholder, and complexity theory. The author reports that the principles of SCRE and SCS are at odds with each other, since SCRE focuses on flexibility while SCS focuses on efficiency. Yet this claim is contradicted by research showing that efficiency and flexibility are both elements of SCRE (Ponomarov & Holcomb, 2009). Other studies (e.g., Zavala-Alcívar et al., 2020) conclude that economic and environmental sustainability strategies reduce the resilience of a given supply chain. Even so, these principles are contrary in the short term only; in the long term, the goal under both paradigms is to satisfy customer needs while minimizing overall cost (Carvalho et al., 2011). Derissen et al. (2011) argue that resilience and sustainability are independent descriptions of different aspects of ecological and economic systems: resilience characterizes the system dynamics, whereas sustainability describes the normative intergenerational contract of preserving natural capital.

The second group of studies includes those that look for a specific mono-directional relationship between resilience and sustainability; they are not concerned about any interdependence between these two concepts. Thus resilience may be analyzed as an antecedent to sustainability, or vice versa. Some of these scholars posit that sustainability can be viewed as a kind of resilience strategy. For instance, Soni and Jain (2011) argue that complying with sustainably standards mitigates risks such as loss of reputation. Others claim that sustainability is largely about overcoming current challenges with given resources but *without* compromising the ability of future generations to overcome the challenges they will face (Jain et al., 2017; Singh et al., 2019). Miller and Engemann (2019) identify three ways in which sustainability contributes to resilience: (1) some sustainability-related shocks can be avoided that would otherwise lead to unnecessarily resource-depleting business plans; (2) sustainable practices help companies reduce the time to recover from disruptions by marshaling internal and external resources; and (3) adopting a sustainability-driven orientation can create goodwill with customers. Several studies focus on other causal connections – observing, for example, how sustainability is driven by resilience (Papadopoulos et al., 2017; Shin & Park, 2019).

In the third group of studies are those that address the multi-directional interdependence between supply chain resilience and sustainability. For the most part, this research concludes that these two factors are mutually reinforcing and have multiple common elements. Common elements include risk management, customer satisfaction, visibility, and information sharing. Risk management is vital not only for SCRE but also for SCS (Abdel-Basset & Mohamed, 2020). Giannakis and Papadopoulos (2016) underscore the crucial role of risk management in SCS by listing 30 sustainability-related supply chain risks. Rostamzadeh et al. (2018) propose a methodology for evaluating sustainability-related risks that would also enhance resilience. Yet the drivers for risk management are different: whereas SCRE is primarily driven by natural disasters and man-made disruptions (e.g., geopolitical tensions), SCS is typically driven by legislation or stakeholder pressure (Freise & Seuring, 2015).

Customer satisfaction is also seen as a critical aspect of both SCRE and SCS. Along with other factors – such as the ability to recover quickly after a disruption – customer satisfaction is an important element of SCS (Ahi & Searcy, 2015) and also of SCRE (Cardoso et al., 2015). Furthermore, information sharing and visibility are powerful strategies for overcoming SCS barriers and are key enablers of SCRE, since both concepts rely on cross-company alignment (Beske & Seuring, 2014; Jain et al., 2017; Zavala-Alcívar et al., 2020). According to Ivanov (2018), resilience and sustainability are interconnected through supply chain management (SCM); he cites the ripple effect as an example that demonstrates a tangible connection. The ripple effect occurs when a disruption cannot be localized and therefore cascades downstream. Some sustainability strategies have been shown to mitigate the ripple effect, yet others (such as sustainable single sourcing) enhance it. Fiksel et al. (2014) argue that, in general, the two concepts are mutually reinforcing: SCS reduces the risks associated with sustainability, and SCRE reduces future generations' risks of resource vulnerability.

Having summarized the relevant literature on both concepts, we are now ready to examine the three dimensions selected for the purpose of better understanding the SCRE–SCS connection. Thus, we compare their respective literatures and their relevance to the intersection of resilience and sustainability.

Supply chain strategies

Supply chain strategies play a decisive role in accomplishing the business objective of long-term profitability and also, of course, in achieving both the resilience and sustainability of a supply chain. Yet one must bear in mind that practitioners cannot be asked directly about the relationship between two multi-dimensional concepts – here, SCORE and SCS – because the question is too complex for a simple answer; also, it is fair to assume that few practitioners have previously dealt with the intersection of these two objectives. That said, the *strategy* dimension is suitable for asking about the extent to which strategies implemented in the service of one of these concepts affect outcomes related to the other concept. This is a question that is fairly easy for practitioners to answer reliably even if they are not yet aware of how these notions are connected. Practitioners know which strategies they have implemented as well as how these strategies have affected the overall supply chain.

The literature mentions a broad range of supply chain strategies that increase supply chain resilience. Researchers have described several ways of bundling resilience strategies, but most suggest structuring them along the drivers of resilience or along different “phases”. Thus Behzadi et al. (2020) group all identified strategies into two sequential phases: risk management strategies that increase robustness and are intended to sustain performance *before and during* a disruption; and resilience strategies that enhance the ability to recover *after* a disruption occurs. Hosseini et al. (2019) similarly use their notion of “resilience capacity” to cluster all resilience strategies into the three levels: resilience that reflects absorptive, adaptive, or restorative capacity. These three states correspond to the three temporal phases of before, during, and after a disruption. Another categorization proposed is one based on magnitude of the collaboration. Along these lines, Azadegan and Dooley (2021) differentiate between micro-, meso- and macro-level resilience. Micro-level strategies include two companies coordinating directly to minimize supply risk, meso-level resilience follows from multiple supply networks collaborating on supply risks, and macro-level resilience emerges when companies collaborate with their competition – or with institutions such as governments and trade associations – to manage or regulate supply risks. Prominent SCORE strategies in the literature are “multi-sourcing”, “end-to-end

visibility”, and “collaboration and strong relationship with network partners”. The leading SCRE strategies are tabulated in Appendix C.1.

Much has been written about supply chain sustainability strategies (see e.g., Laari et al., 2017; Malviya et al., 2018). According to Seuring and Müller (2008), SCS strategies can be divided into those that increase *product* sustainability (e.g., less packaging, less use of plastic, increased use of recycled materials) and those that increase *process* sustainability (e.g., less transport, reduced CO₂ footprint, use of renewable energy, less waste). However, product sustainability is most often discussed in research related to engineering – for example, by product development scholars. Strategies that increase process sustainability are diverse, but many focus on supplier management (Kumar et al., 2012; Govindan et al., 2014; Jayaram & Avittathur, 2015). Collaborating with suppliers and holding them accountable is critical for an end-to-end concept like SCS, but optimizing the supply chain also requires collaboration with competitors and other organizations; this topic has received short shrift in the literature. Chen et al. (2017) report that only four of 125 analyzed SCS papers addressed collaborating with the competition and other organizations. Prominent SCS strategies in the literature include “engage with suppliers in sustainability programs”, “reduction of CO₂ footprint across end-to-end supply chain”, and “adoption of reverse logistics and circular-economy models”. Appendix C.2 tabulates the most prominent SCS strategies.

Barriers

The second identified dimension is *barriers* (to implementation), which affords a useful way to compare resilience and sustainability. The large number of common barriers indicates the potential for supply chain strategies that increase SCRE and SCS both. Comparing barriers to implementation is also essential for understanding the intersection between resilience and sustainability. For example, Cohen et al. (2022a) find that the principal sources of complexity, which are closely related to SCRE barriers, determine the strategies that are most effective at increasing resilience. However, these complexity drivers are often neglected when analyzing SCRE and SCS (see Negri et al., 2021). We shall discuss barriers that are commonly found in both literature streams and that therefore provide a solid basis for investigating their intersection.

After interviewing top-level executives, Cohen et al. (2021) identify six major barriers to SCRE strategy implementation; these authors argue that implementation barriers are the primary cause of differences in the degree of resilience between (and even within) companies. Overall, however, the literature touches but lightly on the barriers themselves; these are sometimes defined with reference to enablers and include lack of visibility, lack of collaboration, and lack of integration (Roberta Pereira et al., 2014). Rajesh (2018) names and clusters 30 barriers to supply chain resilience, but the assessment of their relative importance is based solely on the opinions of three analysts. Shashi et al. (2020) identify 25 papers that mention at least one barrier to SCRE implementation. Altogether, 20 barriers are listed and include “poor implementations of plans” and “lack of control”; most of these are rather generic and require further analysis to be fully understood. The topic of barriers to SCRE has been discussed also by articles in the popular press (John et al., 2020; Gumaledar et al., 2021). Thus multiple SCRE barriers have been proposed by various scholars, and Shashi et al. (2020) show that some of them (e.g., “lack of information sharing” and “lack of risk assessment and contingency planning”) are ones that SCRE and SCS have in common. However, research on SCRE barriers (with the notable exception of Cohen et al., 2021) is mostly descriptive; the barriers are often merely listed, and studies fail to analyze how the barriers are linked to SCRE strategies, company attributes, and the supply chain context in which a company operates.

In contrast, barriers to increasing SCS have been researched to a much greater extent. A large number of papers summarize barriers to becoming more sustainable by dividing them into internal versus external types (e.g., Sajjad et al., 2015), viewing them as part of the triple bottom line (Soni et al., 2020), or examining the barriers in terms of much more granular categories (Rajesh, 2018; Gupta et al., 2020). After conducting four exploratory case studies with large corporations from New Zealand, Sajjad et al. report that internal barriers are behavioral and psychological in nature (e.g., people are resistant to change or have negative perceptions of sustainability) while external barriers include “lack of supplier’s capability” and “lack of customer interest”. Gupta et al. use a multi-case-study methodology and a multi-criteria decision analysis technique known as the best-worst method to rank the barriers and strategies for overcoming them. They found

that technological barriers – such as “lack of technical expertise and training” and “lack of research & development and innovation capabilities” – are the greatest barriers for the interviewed Indian manufacturers. It is interesting that also behavioral and psychological barriers (e.g., “popularity of traditional technologies”, “fear of extra workload and loss of flexibility”) were among the five barriers cited most often, which is in line with the findings of Sajjad et al.

When comparing our lists of barriers to implementing SCRE and SCS, we discovered a substantial overlap between them. Frequently mentioned common barriers are “lack of funding”, “lack of collaboration”, and “lack of knowledge and awareness”. Table 5.1 lists the barriers that have been mentioned with regard to both supply chain resilience and sustainability. There are, in addition, obstacles that are faced only by one of these goals. In particular, barriers that are unique to a sustainability objective include the lack of regulatory guidelines or legislative intervention as well as consumers’ unwillingness to pay a premium and insufficient market demand more generally. Implementation barriers that are exclusive to resilience include portfolio complexity, geographical dispersion of suppliers, and inadequate inventory control systems.

TABLE 5.1: OVERVIEW SHARED RESILIENCE AND SUSTAINABILITY BARRIERS

	Mentioned as barrier to supply chain resilience (SCRE)	Mentioned as barrier to supply chain sustainability (SCS)
<i>Internal barriers</i>		
Financial constraints / Lack of funding	Christopher and Peck (2004), Tang (2006), Pettit et al. (2010), Pal et al. (2014), Roberta Pereira et al. (2014), Scholten et al. (2014), Cohen et al. (2021)	Ageron et al. (2012), Giunipero et al. (2012), Al Zaabi et al. (2013), Ansari and Kant (2017), de Jesus and Mendonça (2018), Greenland et al. (2019)
Lack of knowledge and awareness	Christopher and Peck (2004), Sheffi and Rice (2005), Tang (2006), Ponomarov and Holcomb (2009), Carvalho et al. (2012), Ivanov et al. (2014), Pal et al. (2014), Scholten et al. (2014), Torabi et al. (2015), Kamalahmadi and Parast (2016), Rajesh (2018)	Ageron et al. (2011), Giunipero et al. (2012), Al Zaabi et al. (2013), Kiefer et al. (2019), Soni et al. (2020)
Lack of top management support	Skipper and Hanna (2009), Shashi et al. (2020), Mandal (2021), Mishra et al. (2022)	Ageron et al. (2011), Giunipero et al. (2012), Al Zaabi et al. (2013), Ansari and Kant (2017), Neri et al. (2018), Soni et al. (2020)

Negative perception / Resistance to change	Ehrenhuber et al. (2015), Rajesh (2018), Wieland and Durach (2021)	Correia et al. (2013), Bhanot et al. (2017), Delmonico et al. (2018)
Lack of skilled workers / technical expertise / training	Sheffi and Rice (2005), Pal et al. (2014), Scholten et al. (2014), Gupta et al. (2022)	Al Zaabi et al. (2013), Ansari and Kant (2017), de Jesus and Mendonça (2018), Soni et al. (2020)
Uncertainty of return / Seen as cost rather than investment	Christopher and Peck (2004), Cohen et al. (2021), Gupta et al. (2022)	Mathiyazhagan et al. (2013), Chan et al. (2018), de Jesus and Mendonça (2018), Arranz et al. (2019)
Lack of collaboration and willingness to share information	Tang (2006), Pettit et al. (2010), Roberta Pereira et al. (2014), Scholten et al. (2014), Soni et al. (2014), Kamalahmadi and Parast (2016), Rajesh (2018)	Mathiyazhagan et al. (2013), Beske and Seuring (2014), Neri et al. (2018)
Short-term profitability pressure	Diehl and Spinler (2013), Rajesh (2018)	Sajjad et al. (2015), Soni et al. (2020)
Complexity	Tang (2006), Pettit et al. (2010), Carvalho et al. (2012), Cohen et al. (2021), Cohen et al. (2022a)	Seuring and Müller (2008), Al Zaabi et al. (2013)
Lack of supply chain visibility	Christopher and Lee (2004), Christopher and Peck (2004), Ponomarov and Holcomb (2009), Pettit et al. (2010), Roberta Pereira et al. (2014), Brandon-Jones et al. (2014), Rajesh (2018), Cohen et al. (2022a)	Zailani et al. (2012), Rogerson and Parry (2020), Messina et al. (2022)
Lack of performance measures	Ivanov et al. (2014), Roberta Pereira et al. (2014), Chowdhury and Quaddus (2017)	Walker et al. (2008), Al Zaabi et al. (2013), Bressanelli et al. (2019)
External barriers		
Lack of supplier capability	Namdar et al. (2018), Rajesh (2018), Cohen et al. (2021)	Seuring and Müller (2008), Walker et al. (2008), Ansari and Kant (2017), Delmonico et al. (2018)
Lack of government support / incentives	Gupta et al. (2020), Cohen et al. (2021), Gupta et al. (2022)	Seuring and Müller (2008), Walker et al. (2008), Al Zaabi et al. (2013), Chan et al. (2018), Cecere et al. (2018), Greenland et al. (2019), Soni et al. (2020)

To the authors' knowledge, no published studies compare and analyze the implementation barriers that SCRE and SCS both face. So in addition to the work still needed on this front, more empirical research is needed if we are to develop a better understanding of how companies perceive these barriers – and of whether they approach them from a “combined SCRE and SCS” angle or separately.

Metrics

A third dimension along which to compare supply chain resilience and sustainability is in terms of metrics, or ways of measuring the two concepts. With regard to their intersection, quantifying its impact requires that we carefully examine any proposed metric. A *metric* is a measure of quantitative evaluation frequently used for assessing, comparing, and tracking performance. The literature on SCRE and SCS metrics is growing rapidly, but there are only few studies that compare the two. The current literature in these two fields has no common answer to the question of how best to measure resilience and sustainability. This state of affairs reflects that each concept, as discussed previously, has multiple dimensions.

Nonetheless, there have been attempts to devise a joint SCRE and SCS metric; examples include “ecosiliency”, a combined index for environmental sustainability and resilience (Azevedo et al., 2013), and the “gresilinece” index (Mohammed, 2020). Azevedo et al. (2013) propose an “ecosilient SC index” consisting of two indicators, SCRE and SC greenness, which in turn comprise several resilient and sustainable behaviors. The relative weights of each behavior and of the two indicators are estimated by a group of experts using the Delphi method. The resulting index’s applicability is then tested with four automotive company case studies that examined the supplier–manufacturer link.

Mohammed (2020) focuses on the supplier selection process and proposes a “gresilient” index consisting of: (1) traditional criteria such as costs, quality, and lead time; (2) resilience criteria such as agility, robustness, and flexibility; and (3) the sustainable criteria of waste management, environmental management systems, and environmental certificates. The relative weight of each criterion was assigned by the purchasing team members with the aid of a decision-making trial and evaluation laboratory (DEMATEL) algorithm. A case study of a UK-based chemical manufacturing company is used to evaluate suppliers’ gresilience performance in terms of this index. One finding that stands out is that none of the five vendors had an acceptable gresilience score.

Both the Azevedo et al. (2013) and Mohammed (2020) studies used expert opinion to weight the relative importance of each factor. Hence it will be difficult for

other companies, which may feature diverse supply chain structures and contexts, to adopt the same approach because factors that were *not* considered in the two specific examples may play a significant role for them. Additional research is needed to develop more generalizable models and to improve our understanding of how the individual factors should be weighted. We note that all published studies on SCRE and SCS metrics take the case-study approach to validating their proposed indices. It follows that empirical evidence on a larger scale is needed for the purposes of further validating the proposed metrics and better understanding what companies are actually measuring.

It is possible to quantify the relationship between resilience and sustainability. One example of a mathematical resilience–sustainability model is provided by Zahiri et al. (2017), who develop a model for designing a pharmaceutical supply chain network. The model is intended to minimize total cost and resilience measures and to maximize sustainability by optimizing environmental impact (low) and social impact (high). The authors used a multi-period planning horizon under uncertainty. Their model is one of the first that simultaneously considers SCRE and SCS and that aims, thereby, to quantify the trade-offs between them. Zahiri et al.’s model was validated using the French supply chain of Truvada, an anti-retroviral drug.

Another mathematical study is that of Pavlov et al. (2019a), who model a seaport logistics network. The goal of their model is to optimize contingency planning for a seaport operation while balancing sustainable resource utilization and supply chain resilience. The authors adopt a structural dynamics approach to consider interruption *scenarios* (i.e., rather than interruption probabilities of network nodes). So there are already some initial quantitative approaches to measuring the relationship between supply chain resilience and sustainability. However, metrics that attempt to combine SCRE and SCS (e.g., the ecosilient and gresilient indices) entail the manual and individual weighting of its underlying factors for each supply chain. A better understanding of the relationship between these two concepts would facilitate the development of more differentiated SCRE–SCS models.

5.2.3 Research Gap

Marchese et al. (2018) find that the intersection between resilience and sustainability is being questioned not only in the supply chain literature but also by scholars from other domains – such as civil infrastructure, urban planning, and public policy – who are debating how one concept affects the other or whether the two concepts are related at all. Although there is already some SCM literature on the intersection of SCRE and SCS, the exact relationship remains an open question. First of all, there is little agreement among scholars concerning the direction of any effects and whether a relationship even exists. This situation recalls Fahimnia et al.'s (2019) summary of the relationship between resilience and sustainability as being entirely unclear. Negri et al. (2021) similarly conclude that the relationship between SCRE and SCS is uncertain enough that further studies are needed to clarify it. Ruiz-Benitez et al. (2019) point out that previous studies have not addressed the possible synergetic effects of resilience and sustainability. Here again, additional research is needed to develop an integrated approach that clarifies the multiple intersections of the two objectives.

Second, the absence of large-scale empirical evidence has forced most research on the intersection of SCRE and SCS to remain on a theoretical basis. Miller and Engemann (2019), for example, call for more practitioner guidelines about the intersection. Shashi et al. (2020) identify empirical testing of the relationship between the two concepts as a possible future research direction. In sum, empirical research is needed to provide a practitioner's perspective on the intersection of the two concepts and to resolve differences between theory and practice.

Our paper's overarching research question emerged from these two research gaps: the unexplored intersection of SCRE and SCS, and the field's lack of an empirical foundation.

5.3 Research Approach

In this section, we describe the research design and our process for data collection and analysis. To ensure the transparency needed for any qualitative

research, we followed a five-stage structured approach. This qualitative mixed-methods approach is summarized in Table 5.2.

The mixed-methods approach and the variety of data sources together enabled methodological “triangulation”, which contributes to achieving high accuracy and valid results (Turner et al., 2017). This approach was beneficial also in the sense that our research questions sought to yield a better understanding of practitioners’ perceptions, thereby enriching scholarly discussion of the SCRE–SCS intersection.

TABLE 5.2: FIVE-STAGE RESEARCH DESIGN

Stage	<i>Stage I</i>	<i>Stage II</i>	<i>Stage III</i>	<i>Stage IV</i>	<i>Stage V</i>
Subject	Literature Review	Focus Groups	Survey	Results	Framework Development
Content	<ul style="list-style-type: none"> - Review of existing literature on SCRE & SCS & their intersection - Formulation of research questions 	<ul style="list-style-type: none"> - Sharpening of research questions - Development of a survey based on findings from the literature - Validation of survey with managers 	<ul style="list-style-type: none"> - Data collection via online survey with relevant target group 	<ul style="list-style-type: none"> - Analysis & synthesis of empirical data (including statistical hypothesis testing) - Discussion of results in light of the literature 	<ul style="list-style-type: none"> - Development of framework - Discussion of theoretical contribution - Derivation of managerial implications
Section	Section 2	Section 3.1	Section 3.2	Section 4	Section 5

5.3.1 Stage I & II – Literature Review & Focus Group

The literature review was selective rather than comprehensive and led to the formulation of the three sub-RQs, which are presented in the Introduction. After refining the RQ and the three sub-RQs a qualitative survey questionnaire was developed (Appendix C.3). The results from the literature review form the basis for the content of the survey. Thus, the same triad of strategies, barriers, and metrics was used in the questionnaire. Moreover, Appendix C.1 and C.2 include tables of the SCRE and SCS strategies identified as relevant from the literature. Using the tables as a starting point, the answer options for the SCRE and SCS strategies were refined in multiple rounds in a group of six supply chain scholars. Furthermore, the five most frequently mentioned common barriers from the literature (“Financial constraints / Lack of funding”, “Lack of visibility”, “Lack of collaboration and willingness to share information”, “Lack of supplier capability”,

“Lack of performance measures”) were included in the answer options for both concepts. Thereafter, the questionnaire was pre-tested with six scholars and two supply chain executives and further refined. The pre-testing was used to ensure that participants could complete the survey in a reasonable amount of time and that the questions were understandable and clearly worded.

5.3.2 Stage III – Online Survey

We followed the lead of other supply chain–related research (Fracarolli Nunes et al., 2020; Park et al., 2021; Queiroz et al., 2022) in using the researcher-oriented platform Prolific¹ for data collection; this platform is widely considered to be one of the most transparent for panels and surveys (Palan & Schitter, 2018). We use the online survey to test our research questions, whose main thrust is to uncover the relationship between resilience and sustainability from a practitioner’s point of view. The final questionnaire (reproduced as Appendix C.3) contains eight questions concerning SCRE and SCS; among these questions, there are four each of the open-ended and closed-ended type. The survey is divided into three parts. The first, introductory section asks six questions about the demographic characteristics of the participants and their employer (e.g., type of company, industry, sales size, number of employees). This part also includes a question about the unit of analysis: participants are asked to identify a product from a particular supply chain and then to respond to all survey questions from that perspective. (The definition of each concept was given prior to the questionnaire’s respective sections on SCRE and SCS.) The survey’s second and third parts are identically structured, with part 2 relating to resilience (Questions R1–R4) and part 3 to sustainability (Questions S1–S4). The four questions in part 2 and part 3 proceed as follows. Participants are first asked to name the three most effective implemented strategies. Second, they are asked to evaluate the impact of each of those strategies on the other objective. The third question concerns the barriers to SCRE and SCS implementation. In the fourth question, participants are requested to identify as many as three SCRE and SCS metrics and their associated targets.

In assembling the sample pool of respondents, we screened potential participants by way of the following restrictions. Participants were all executives

¹ <https://www.prolific.co/>

(C-level, President/SVP, VP/Managers) from the manufacturing sector or from business management and administration who worked for a large private or publicly listed enterprise and who had decision-making power for overall business strategy, operations or production, and/or supply chains. The target number of surveys was 140, which is enough (per Hill, 1998) for a qualitative survey.

5.3.3 Stage IV – Data Analysis

A total of 194 questionnaires were returned. After a first screening to eliminate those with incomplete responses, we were left with a sample of 149 valid surveys. In another, more detailed round of screening with regard to content, six questionnaires were removed because they concerned sectors not directly related to physical supply chains; hence the final sample contains 143 completed surveys. Among these, the average time taken to complete the survey was 10½ minutes. Of the final participants, 69 percent were male (31 percent female) and the average age was 38 years. Most respondents were from Europe (54 percent) or North America (25 percent). Practitioners from industrial, automotive, and consumer packaged goods companies account for 45 percent of all responses. Figure 2 illustrates that the sample includes a fairly diverse group of industries. More details regarding the data sample are presented in Appendix C.4.

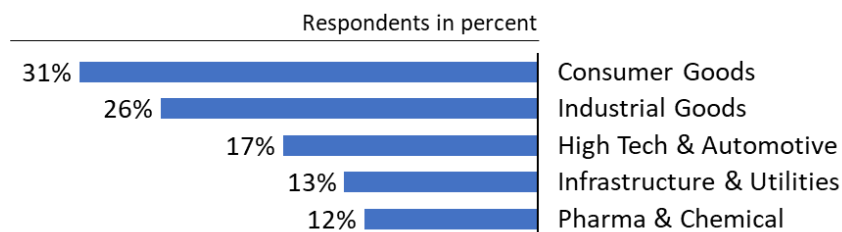


FIGURE 5.2: SURVEY RESPONDENTS BY INDUSTRY

The subject-specific questions from parts 2 and 3 of the questionnaire are analyzed in Section 5.4. Our analysis addresses the three sub-research questions spelled out in Section 5.1. The qualitative results from practice will be examined in the light of their possible contribution to both theoretical and applied research.

In the final aspect of our data analysis, statistical hypothesis testing is applied to validate the findings. Because all variables are categorical, we use the chi-square test of independence to determine whether two variables are independent or instead related (Franke et al., 2012). A statistically significant rejection of the null hypothesis indicates that the two variables are related, but it does not reveal the

strength of their relationship; hence Cramer's V is used to measure its effect size. Values for Cramer's V range from 0 to 1; $V=0$ means there is no connection whereas $V=1$ indicates that one variable can be entirely explained by the other. For interpreting Cramer's V values, a table (Table C.4) from Cohen (1988) is used. The interpretation is based on the degrees of freedom (df).

5.3.4 Stage V – Framework Development

In this last phase of our five-stage mixed-methods research design, the previously collected data were summarized and used to derive a framework for integrating supply chain resilience and sustainability. This SCORE–SCS framework is grounded in the results of our survey, which captured practitioners' perceptions and their realities. The framework was derived from our three sub-RQs and constitutes this study's main contribution. We designed the framework incrementally and developed it through multiple iterations, each time enriching it further with new insights from the data. Our inductive analysis led to a framework that revealed both differences and inter-relationships between supply chain resilience and sustainability. The integration of findings from the extant literature enhances the validity of our results.

5.4 Results

As mentioned in Section 5.2, the relationship between SCORE and SCS is a topic much debated in the literature; there is no consensus regarding whether SCORE and SCS are mutually reinforcing, must involve trade-offs, or are entirely unrelated (Negri et al., 2021). Our study, which is based on results from a large-scale qualitative survey of supply chain executives, is the first to examine the relationship from an empirical perspective and to analyze how practitioners perceive the SCORE–SCS connection. Our goal is to provide the basis for an improved understanding of the interplay between SCORE and SCS by developing a joint SCORE–SCS framework. In this section, the results are analyzed with reference to our three sub-research questions and are validated by statistical testing methods such as the chi-square test and Cramer's V .

5.4.1 Relationship in Terms of Implemented Strategies

Insights from implemented SCORE and SCS strategies

We start with a comparison of the most important resilience and sustainability strategies (see Figure 5.3). Among the reportedly most effective implemented resilience strategies, 52 percent of the practitioner respondents identified multi-sourcing as one of their top three SCRE strategies. Note also that, in the SCRE literature, multi-sourcing is a frequently named strategy and is often used for SCRE modeling (Han & Damrongwongsiri, 2005; Azevedo et al., 2016; Namdar et al., 2018). Moreover, “strong relationships with network partners” is (at 49 percent) the second most frequently mentioned SCRE strategy. Its popularity is not surprising if one considers that, when it comes to resilience, it’s the end-to-end supply chains themselves – more so than the companies – that are highly competitive (Cohen et al., 2021). This finding accords with a supply chain executive survey conducted by Gartner Inc., which reported that the most named SCRE strategy in which managers should invest is to “deepen collaborative relationships with key customers and suppliers” (John et al., 2020). A surprising result is that only 18 percent of the surveyed practitioners viewed supplier audits as an effective SCRE strategy. It therefore seems that collaboration, rather than surveillance or a strong focus on contract terms, is the more effective means for enhancing overall supply chain resilience.

In the Gartner survey of executives, 47 percent of the respondents indicated that they had already begun to invest in shifting their manufacturing sites across regions or countries. Yet when asked about successfully implemented supply chain strategies, only 15 percent of them mentioned product relocation or diversification (resp., “nearshoring” or regionalization) as one of their top three resilience strategies. There has been a lot of talk about nearshoring and production relocation, but to date only a few companies have actually implemented either one.

Much as for SCRE, collaboration is seen as being more effective than supervision for SCS: 38 percent of our respondents reported that engaging with suppliers to increase sustainability was effectively implemented, but only 28 percent had implemented supplier audits. Comparing the top strategies from both concepts, we can see clear evidence that SCRE and SCS can be achieved only through cross-company collaboration – a strategy that is ranked second and third, respectively (Beske & Seuring, 2014; Jain et al., 2017; Zavala-Alcívar et al., 2020). Strategies to enhance visibility are likewise viewed as less effective or not

worth implementing for either objective; “SC control tower” ranked seventh and “SCS indicator tracking” fifth. This result runs counter to the literature, which often names audits and visibility as fundamental elements (Beske & Seuring, 2014; Jain et al., 2017).

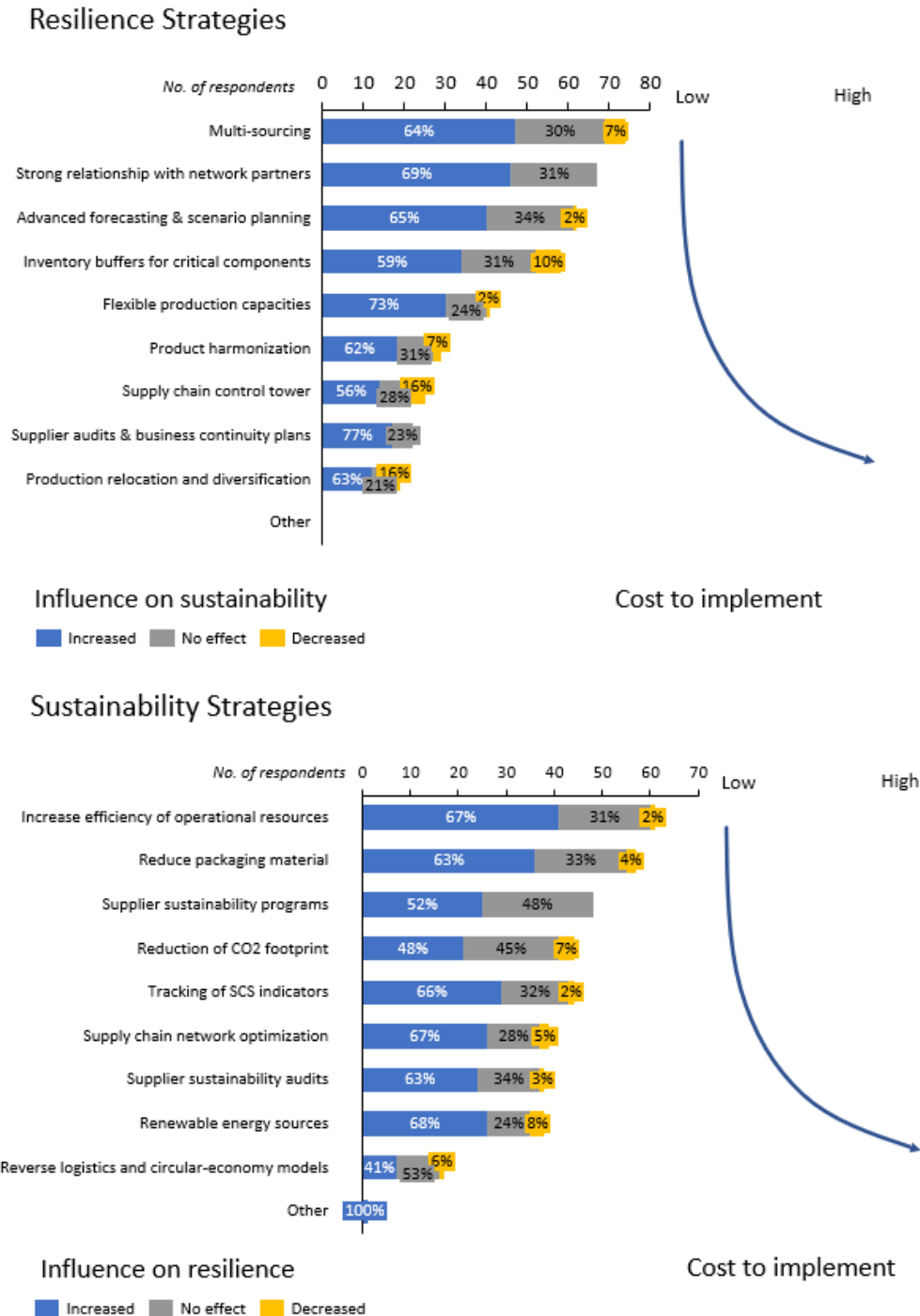


FIGURE 5.3: MOST FREQUENTLY MENTIONED STRATEGIES AND THEIR PERCEIVED IMPACT ON THE *OTHER* CONCEPT

The strategy of “reverse logistics / circular economy” is ranked last at only 11 percent. We conclude that companies either fail to see how this strategy would benefit them or still have a long way to go before they are capable of implementing such practices. When comparing the cost to implement supply chain strategies, the cases of SCRE and SCS are similar. Companies tend to tackle the basics first – such “low-hanging fruit” as using resources efficiently and reducing packaging materials. Even though there is an extensive body of literature on sustainable closed-loop supply chains, the number of real-world examples is quite small; in most instances, the firm merely undertakes some reverse logistics and recycling activities (Mehrerjedi & Shafiee, 2021; Jalali et al., 2022).

Overall intersection

We assumed that practitioners would be unable to describe how resilience and sustainability were related. Hence our next step was to infer what types of SCRE–SCS relationships might be possible. Toward that end, we asked practitioners first about their implemented SCM strategies and then about whether they perceived those strategies affecting the other objective (cf. sub-RQ 1). The results are displayed in Figure 5.4.

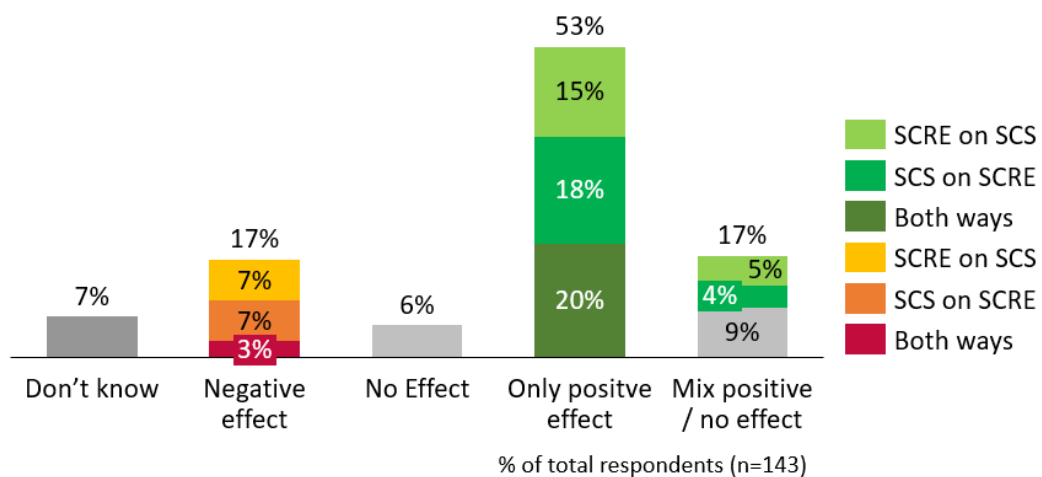


FIGURE 5.4: EXPERIENCED EFFECT OF SCRE STRATEGIES ON SCS, AND VICE VERSA

Figure 5.4 illustrates how practitioners assess the effect of SCRE strategies on SCS and vice versa. We find that 93 percent of the respondents were able to describe the relationship by stating that SCRE “increases SCS”, “decreases SCS”, or “has no effect on SCS”; a mere 7 percent said they were unable to describe the

relationship. This finding suggests that companies are already aware of the relationship or, perhaps more likely, that managers can readily assess the effects of their implemented supply chain management strategies without having previously considered the relation. This latter interpretation is reflected in one practitioner's survey feedback: "This is an interesting questionnaire because I have never looked at our [SCM] strategies from a combined resilience and sustainability perspective" (SC manager of a Food & Beverage company). Thus it appears that, in practice, little attention is given to managing SCRE and SCS jointly.

The group of respondents who claimed not to know whether implemented strategies affect the other objective contained mostly junior management respondents (70 percent), which means that their lack of knowledge might simply reflect their exclusion from the company's higher-level decision making. A chi-square (χ^2) test was used to determine whether two categorical variables, *Job level* and *Ability to describe relationship*, are independent or instead associated with each other (see Appendix E for the characteristics of these variables). So for two variables and $N = 143$, the test result values $\chi^2(2) = 10.721$ ($p = .0047$) imply that the null hypothesis can be rejected. It follows that the association between the two variables is statistically significant. We then calculated the effect size using Cramer's V, which revealed a small but significant effect. We found that *Ability to describe relationship* was associated also with type of industry: $\chi^2(8) = 17.427$ ($p = .026$), a moderately significant effect. For example, four of the ten respondents were from the Pharma & Chemicals industry, although this sector accounts for only 12 percent of the total sample. It may well be that Pharma companies have focused on SCRE owing to the medicinal nature of their products. Resilience is paramount in the pharmaceutical industry, since firms absolutely cannot afford any stock-outs. It seems that Pharma companies are so concerned with resilience that sustainability is largely neglected; hence we observe no SCRE–SCS effects in this industry. This result is in line with a recent survey of 434 respondents, which found that Pharma companies should focus more on environmental sustainability (Pharmaceutical Technology, 2021).

Among the 143 respondents to our survey, 24 perceive at least one negative influence between resilience and sustainability. In this group, only two respondents have a general management background. A chi-square test shows that *Job*

function and *Experience of negative effects* are associated, $\chi^2(1) = 6.9311$ ($p = .0085$), so the null hypothesis can be rejected (see Appendix C.5). The effect size is small but significant (Cramer's $V = 0.24$). The cross-tabs for these two variables (Cross Table 3 in Appendix C.5) show that respondents working in operations or supply chain departments experienced negative effects. A possible explanation is that employees in these positions experience the direct operational effects, which can be negative, of changes in supply chain management in their daily work. For instance, an executive from the packaging industry explained that, to increase flexibility in film lamination capacity, parts of the production were outsourced to a local provider (SC Executive, Expert Interview). However, doing so required bringing the pre-processed film from the plant to the third party and back again, which created extra CO₂ emissions and handling effort. So under this strategy, sustainability declined for the sake of an increase in resilience. In contrast, practitioners associated with general management functions have a broader view; hence they focus more on how SCRE and SCS strategies can each secure long-term profitability without compromising either objective.

About a third of all implemented SCRE and SCS strategies have, on average, no effect on the other concept (compare Figure 5.3). Since this outcome in itself tells us nothing about the underlying reasons, we analyzed the responses of all 17 participants who reported no effects on at least four implemented strategies. In this group, only 17 percent named a metric for SCRE or SCS even though more than half of all respondents could name at least one. A chi-square test of the variables *Experience of no effect* and *Use of SCRE/SCS metrics* yielded $\chi^2(1) = 7.8522$ ($p = .0051$); this indicates that the two are associated with a small significant effect (Cramer's $V = 0.256$). Cross Table 5 (Appendix E) reveals that, among respondents who reported no implemented SCRE or SCS strategy having an effect on the other objective, most did not name a single SCRE or SCS metric. One is led to surmise that the lack of reported effects could reflect, as much as anything, the absence of any metrics being used to assess changes in SCRE or SCS effectiveness. A few (6 percent) of the respondents saw no relationship between any of their implemented strategies and the other supply chain objective.

The responses given by another 17 percent of all survey participants are categorized as "mix positive / no effect" because they cannot be attributed to any

of the other categories shown in Figure 5.4. This group includes all respondents who reported either a mix of positive effects or no observed effects. It includes, for example, respondents who have experienced a positive effect of two SCRE strategies on SCS but no effect of a third SCRE strategy on SCS (and vice versa).

However, the vast majority (91 percent) of participants experienced at least one positive effect. In addition, 71 percent indicated that at least half of all implemented SCRE or SCS strategies had a positive effect on the other objective. Thus our survey results constitute empirical evidence that practitioners tend to perceive a causal relationship between SCRE (resp. SCS) strategies and the extent to which SCS (resp. SCRE) objectives are achieved. This relationship is often positive in both directions, which strengthens the findings of Fiksel et al. (2014).

The strategy specific differences

Most previous work addressing the resilience–sustainability connection does not identify the types of supply chain strategies that have a positive effect on both objectives. Therefore, analyzing each SC strategy and its impact on SCRE and SCS in terms of practitioners' perceptions yields new insights and increases our understanding. The results are summarized in Figure 5.3 (displayed at the beginning of this section).

We found that most respondents observe SCRE and SCS strategies affecting each other in a positive way; the level of agreement varied between 52 percent and 77 percent (see Figure 5.3). A good example is that of switching to a local supplier to reduce transportation emissions, which simultaneously improves SCRE (shorter lead times) and thus also increases flexibility. So on the one hand, empirical findings strengthen the position of those authors (e.g., Papadopoulos et al., 2017; Shin & Park, 2019) who claim that resilience drives sustainability. On the other hand, some scholars argue that sustainability drives resilience. According to Miller and Engemann (2019), for instance, sustainable supply chains can foster supply chain resilience. In light of these results, one should view the respective literature streams as being more complementary than contradictory. Two sustainability strategies (“reduction of CO₂ footprint” and “reverse logistics and circular-economy models”) are deviant in that most respondents experienced them

having no effect – either positive or negative – on resilience. However, any positive effect of these two strategies on SCRE would likely be difficult to discern, which naturally leads to a high proportion of “no effect” answers. Nonetheless, more than 40 percent of practitioners did report observing a positive effect.

The resilience strategies whose *negative* effects on sustainability are reported most frequently (roughly 15 percent each) are “supply chain control tower with end-to-end visibility” and “production relocation and diversification”. Setting up a supply chain control tower entails additional overhead costs, yet our finding contradicts those of Jain et al. (2017) and Zavala-Alcívar et al. (2020). Both of those studies argue that visibility enables resilience and sustainability both. The negative effect of relocation on sustainability could reflect that the practitioners experienced efficiency losses when diversifying the company’s production footprint – losses driven by accounting for the increased land use when multiple smaller factories replace a few large-scale production hubs. Further research is needed in order to explain these two outliers.

Three SCM strategies related to engaging with other supply chain partners (“strong relationship with network partners”, “supplier audits & business continuity plans”, and “engage with suppliers in sustainability programs”) are the only strategies for which no negative effects on the other objective were reported (Figure 3). Also, only one respondent observed a negative effect after implementing “supplier sustainability audits”. It follows that practitioners see no disadvantages for SCRE or SCS in any form of cross-company collaboration. These results strengthen the findings of Beske and Seuring (2014) and other studies (Jain et al., 2017; Zavala-Alcívar et al., 2020) that identify collaboration with supply chain partners as a common enabler. A packaging company executive commented: “We increased the communication with our suppliers and distributors, but there is still a long way to go before we can leverage the full potential of collaboration on sustainability” (SC Executive, Expert Interview). Thus, some companies are still lacking collaboration with others, and any improvements on that score are generally expected to have a positive effect on – or at the least to not harm – supply chain resilience or sustainability.

5.4.2 Relationship in Terms of Barriers

Recall from Section 5.2 that most research has considered separately the implementation barriers to resilience and sustainability. In this section we present an empirical comparison of barriers to these objectives (sub-RQ 2). Figure 5.5 summarizes results from the survey, which asks respondents about barriers to both SCRE and SCS implementations.

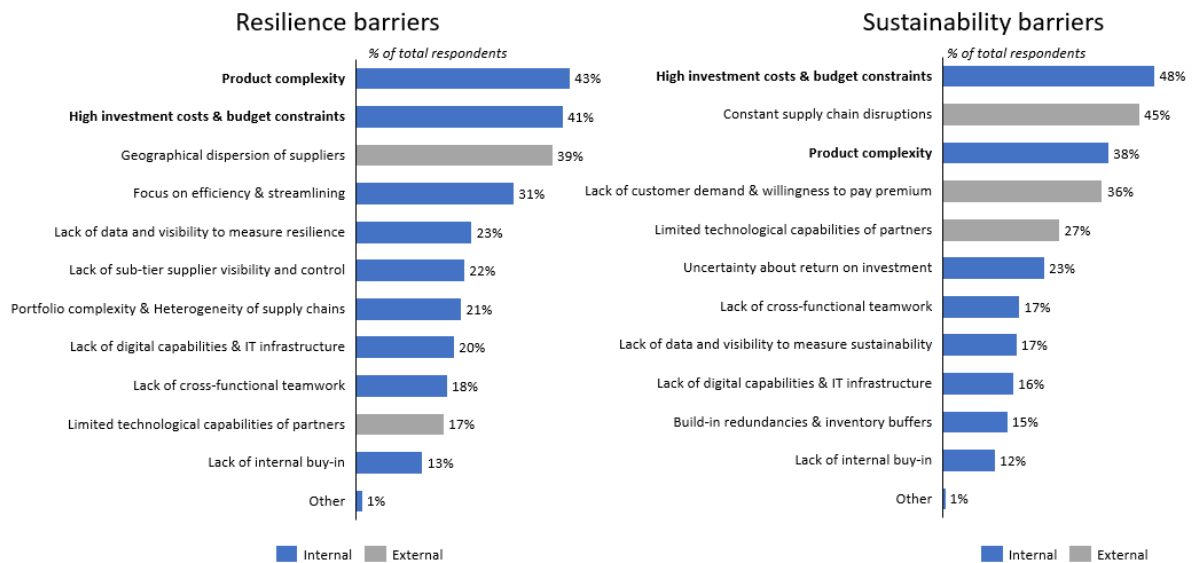


FIGURE 5.5: MOST FREQUENTLY MENTIONED SCRE AND SCS BARRIERS

The bar graphs show that, when asked to name the top three barriers for SCRE and for SCS, 80 percent of the participants named at least one of the top three barriers to both objectives; also, 18 percent listed two of their top three barriers for both concepts. These findings are evidence of considerable overlap between the perceived barriers to resilience and to sustainability. Observe that the barriers “product complexity” and “budget constraints” are each among the three most named barriers for both concepts. The implication is that SCRE and SCS are both costly and complex. The complexity of SCRE is driven by the products and the geographical dispersion of suppliers, and “product complexity” is the most frequently mentioned barrier. In the literature, though, only *supply chain* complexity figures prominently as a hindrance to SCRE implementation (Pettit et al., 2010; Carvalho et al., 2012; Spiegler et al., 2012). Yet for Cohen et al. (2022a), product complexity is one of three barriers incorporated into their definitions of supply chain archetypes.

In the context of supply chain sustainability, complexity arises from the products themselves and from frequent supply chain disruptions. As an SCS barrier, “product complexity” is ranked only third. This slightly lower importance is reflected in the literature, where complexity as a barrier to implementing SCS is mentioned only in terms of coordination complexity (Seuring & Müller 2008) or design complexity for sustainable solutions (Al Zaabi et al., 2013). So despite product complexity being viewed by practitioners as a major barrier to the implementation of either supply chain objective, it is under-represented in the SCM literature on both concepts.

We conclude that initiatives to reduce a product’s complexity would make it easier to implement resilience and sustainability strategies effectively. Our empirical results about budget constraints and lack of funding confirm theories advanced in both the SCRE literature (Roberta Pereira et al., 2014; Scholten & Schilder, 2015; Cohen et al., 2021) and the SCS literature (Cecere et al., 2018; de Jesus & Mendonça, 2018; Greenland et al., 2019).

Of some interest is that “lack of internal buy-in” is ranked last as a barrier to both supply chain objectives. This result is rather surprising because the SCM literature characterizes lack of management attention and lack of internal support as well-established barriers (Neri et al., 2018, Soni et al., 2020). It is possible that the ongoing Covid pandemic, along with the increasingly tangible effects of global warming, have shifted the mindsets of executives in large companies that operate globally.

Among other reported barriers to SCRE and SCS implementation are those related to insufficient investment and resources; examples include “lack of data and visibility”, “lack of digital capabilities & infrastructure”, and “limited technological capabilities of partners”. Technology and IT-related barriers are at the bottom of both rankings – despite being frequently identified as barriers in the SCRE and SCS literatures. Thus, de Jesus and Mendonça (2018) argue that inappropriate technologies are the chief barrier to a circular economy model. Other research on SCS (e.g., Al Zaabi et al., 2013) and SCRE (Gupta et al., 2022) report similar findings. In 2020, a large-scale supply chain survey by Gartner Inc. found that just 36 percent of executives see the lack of advanced digital technologies as

a barrier to resilience (John et al., 2020). This finding suggests that companies are making progress in the digital transformation of their supply chains and so technology is now less of a limiting factor. However, the perceived need for advanced technologies and digital infrastructures depends on the sophistication of the metrics being applied. Hence companies that have set unambitious targets using simple metrics are likely unaware of the capabilities needed to achieve a step change in resilience or sustainability.

Most of the barriers to SCRE concern *internal* issues (e.g., digitalization) and so are actionable for supply chain executives. However, “geographical dispersion of suppliers” is challenging in industries with highly specialized partners that are currently clustered in certain areas; this is an *external* barrier (one of the gray bars in Figure 5.5). A good example is the semiconductor industry, in which more than 70 percent of the world’s wafer capacity is located in China, Taiwan, Korea, and Japan. Two years ago, only 22 percent of interviewed supply chain executives believed that suppliers’ geographic dispersion posed a problem for supply chain resilience (John et al., 2020). This finding might reflect the greater attention paid by companies to uncertainties that stem from the ongoing Covid pandemic and from increased geopolitical tensions, factors that have led many supply chain leaders to adjust their thinking.

Among the barriers to sustainability, three of the top five are related to external factors and other stakeholders (e.g., customers and suppliers). These results imply that mitigating sustainability barriers requires increased collaboration with other supply chain partners and that customers have begun to place more emphasis on sustainability.

Another finding is that 45 percent of our respondents view “constant supply chain disruptions” as one of the greatest barriers to supply chain sustainability. This result is in line with Mari et al. (2014), who report that companies tend to abandon their sustainability objectives when coping with unexpected disruptions. Our finding also adds to the empirical evidence that increasing resilience has a positive impact on sustainability.

In summary, our empirical results indicate that there is substantial overlap between the most frequently cited barriers to improving supply chain resilience and

sustainability. It is clear that both SCRE and SCS are costly and difficult to implement when the company's products are complex. The geographical dispersion of suppliers is a SCRE-specific barrier, whereas frequent supply chain disruptions hinder the implementation of any SCS strategy. The remaining SCRE and SCS barriers, such as “lack of sub-tier supplier visibility” and “lack of digital capabilities & IT infrastructure”, are largely due to a lack of investment and resources. It follows that SCRE and SCS objectives are strongly interlinked and should be managed together.

5.4.3 Relationship in Terms of Metrics

Having analyzed the first two sub-RQs with respect to supply chain strategies and barriers, we use this section to describe the metrics that practitioners have adopted to measure SCRE and SCS (sub-RQ 3). We rely on our survey results when discussing and comparing these metrics. Figure 5.6 displays the SCRE metrics mentioned by practitioners (where KPI = key performance indicator); the groupings are based on the metrics' similarity.

As can be seen from the figure, most of the metrics that our respondents mentioned are fairly general supply chain performance measures related to service level (e.g., on-time deliveries, time to replenish), to lead times (order lead time, response time), or to inventory (target inventory, inventory turnover). Nearly a fourth of these practitioners reported a service-related metric, a greater share by far than for any of the other groups. The smallest group, customer-related metrics, was mentioned by only 3 percent of the respondents and includes just two metrics. In the literature, however, many studies use customer service as a metric for assessing SCRE (Hohenstein et al., 2015, Shashi et al., 2020). Other popular SCRE measures in the literature – including value at risk (Fahimnia & Jabbarzadeh, 2016), time to recover/survive (Simchi-Levi et al. 2018; Gao et al., 2019), expected disruption cost (Mari et al., 2014), and risk exposure indices (Gao et al., 2019) were mentioned only rarely by the survey respondents. In fact, only 13 of the 143 practitioners named even one metric (e.g., “time to recover” or “loss of sales”) from the recovery-related category, which is the second smallest group (response rate of 6 percent). These results suggest that few companies have

incorporated advanced metrics into their existing techniques for measuring supply chain resilience.

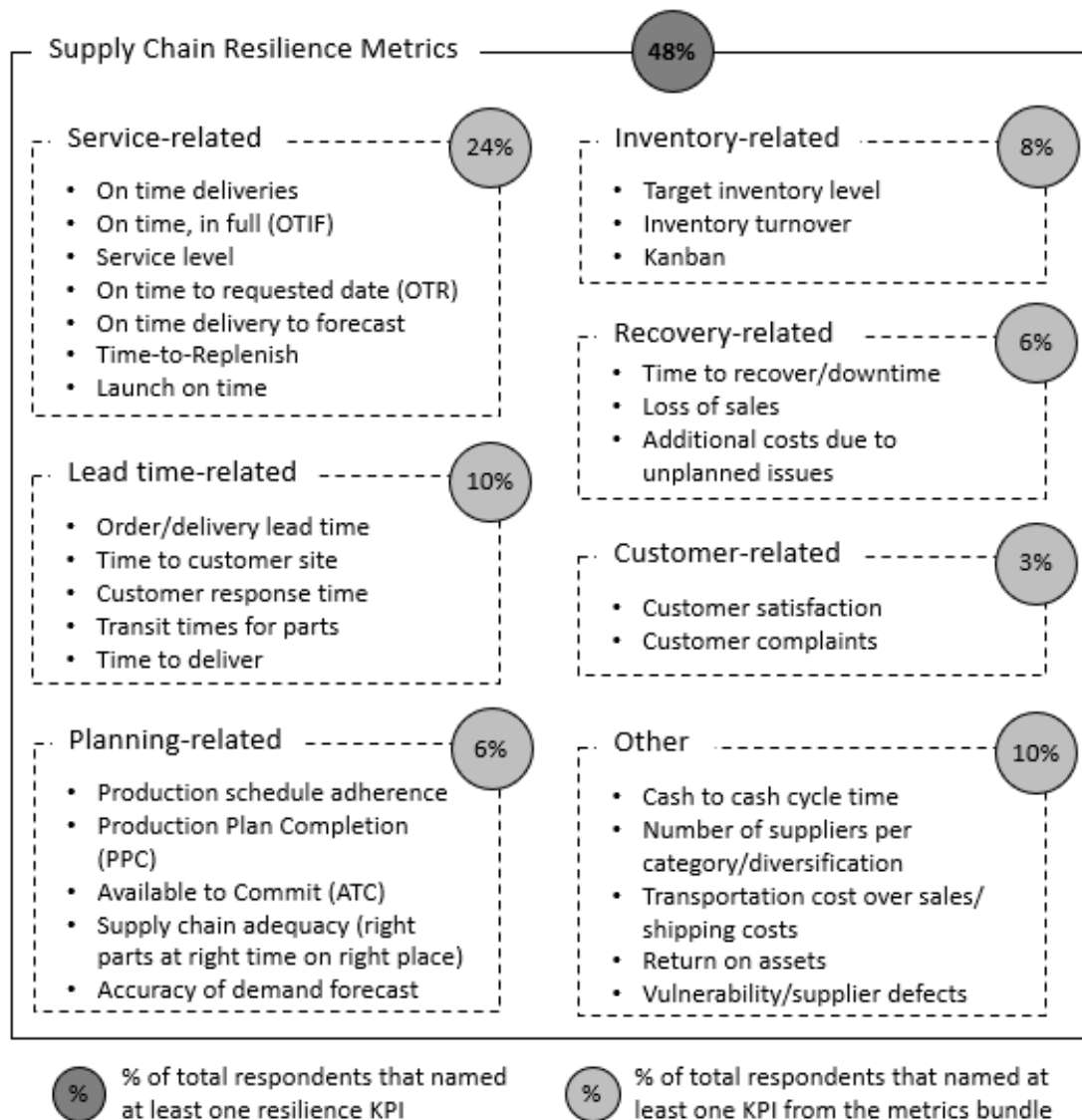


FIGURE 5.6: SUPPLY CHAIN METRICS FOR RESILIENCE BASED ON SURVEY

Traditional supply chain measures are used by the majority of companies. Yet these metrics do not capture all of resilience because they assess current plans only vis-à-vis the status quo; there is no measuring of how well a company is prepared to mitigate or recover rapidly from future disruptions. It has already been 15 years since Priya Datta et al. (2007) stated that customer service level, production change over time, average inventory, and total average network inventory are appropriate metrics for SCRE assessments. Three of these four metrics are evidently still valid, since they were frequently mentioned by our surveyed practitioners. Cohen et al. (2022b) explain why it is mostly these

“traditional” operational measures that are still used. They point out, however, that such metrics are meant for short-term evaluation whereas resilience requires a longer-term perspective.

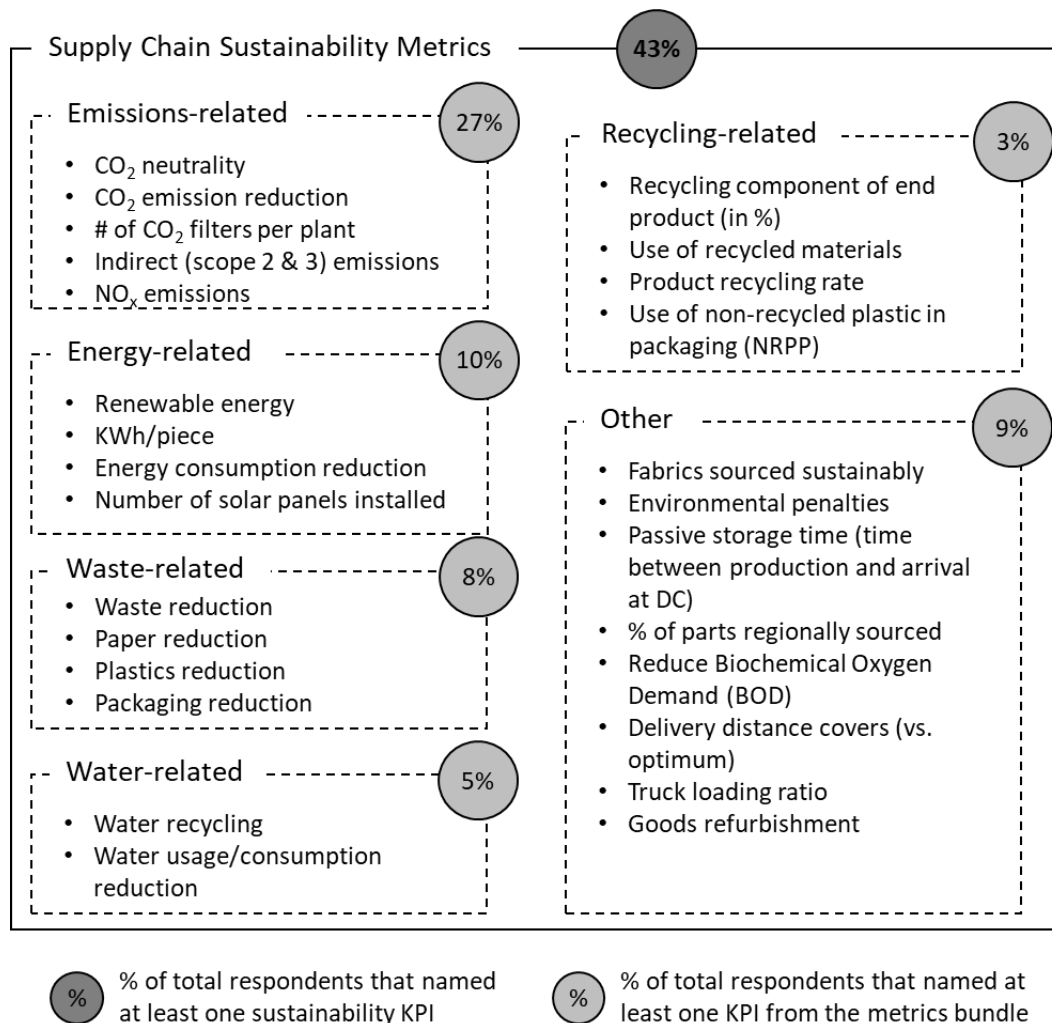


FIGURE 5.7: SUPPLY CHAIN METRICS FOR SUSTAINABILITY BASED ON SURVEY

Figure 5.7 presents results on the SCS metrics used by respondents. This figure reveals that the largest group is of metrics related to emissions; among the respondents, 27 percent named at least one emissions-related metric. The second largest group is that of energy-related metrics (named by 10 percent). These most frequently named groups of SCS metrics conform with previous research (Ruiz-Benitez et al., 2019). Our empirical results were hardly unexpected, since various requirements and regulations have placed CO₂ emissions at the top of many companies’ agendas. However, the surveyed practitioners did not mention more sophisticated measures. One example is life-cycle assessment (LCA), which many researchers believe is a promising means of comprehensively assessing the

environmental impact of all activities in a supply chain (Moreno-Camacho et al., 2019). Current examples of LCA-based environmental sustainability assessments in the literature show not only the complexity of such an approach but also the vast amount of information needed to implement it (Sultan et al., 2021; Vidergar et al., 2021). These factors probably explain why such sophisticated metrics are not used in practice (and so are not mentioned here). Moreno-Camacho find also that only 19 of 115 reviewed papers on supply chain sustainability have adopted the LCA approach to evaluating environmental factors. The results run parallel to those reported previously on supply chain resilience: sophisticated strategies (e.g., closed-loop models) and metrics (such as LCA) are currently being implemented by only a small fraction of leading companies.

Furthermore, we found that the variable *Use of SCORE/SCS metrics* is associated with the variable *Job function*. A chi-square test, $\chi^2(1) = 4.0493$ ($p = .0442$), establishes that the null hypothesis can be rejected, and the effect size is small (Cramer's $V = 0.1831$). Looking at the cross-tabs for these two variables (Cross Table 4 in Appendix E), we see that respondents who work in "general management" have comparatively more often indicated that they are *not* using either SCORE or SCS metrics. This finding may indicate that, despite being strategic objectives, SCORE and SCS have not gained company-wide attention.

When comparing the results on SCORE and SCS metrics, several findings emerge. Metrics related to SCS are naturally suitable only for measuring different aspects of sustainability, so it was necessary to incorporate them alongside the traditional supply chain metrics. In contrast, most SCORE metrics are traditional measures already in use for assessing various aspects of efficiency and plan compliance. This difference in type of metric could explain the difference in response rates. Among all respondents, 48 percent reported at least one SCORE metric while only 43 percent reported at least on SCS metric. This result is surprising because one would expect from the literature that, in practice, supply chain sustainability is more strongly pursued than supply chain resilience. Yet as explained earlier, proposed SCORE metrics are oftentimes simply broad supply chain management metrics that companies have been using for decades, irrespective of resilience. So if we compared the number of metrics that measure only SCORE to the number that measure only SCS, then we would obtain the expected result. Note also that SCS metrics are commonly understood and agreed

upon. Even though *defining* a metric is relatively straightforward, applying relevant metrics across an entire supply chain requires accurate measuring and a high degree of data visibility. The metrics proposed in the heterogeneous literature on SCRE, and the absence in practice of an appropriate resilience-specific metric, highlight the difficulty of determining what to measure

Comparing the most frequently mentioned metric for resilience (“on-time deliveries”) and for sustainability (“CO₂ emission”) illustrates how the two concepts differ. The sustainability-related metric, “CO₂ emission”, is not only more specific but also requires continuous effort and is oriented toward the long term (e.g., “CO₂ reduction of 50 percent by 2030”). In contrast, the most often named resilience metric of “on-time delivery” (e.g., a target of achieving an “On-time-in-full delivery level of 98 percent”) is short-term oriented; it measures delivery performance more so than resilience. We conclude that there is currently no metric that applies to SCRE and SCS objectives both. This conclusion is supported by empirical data from our survey. No metric (e.g., “CO₂ reduction”) was mentioned as being possibly applicable to assessments of supply chain resilience *and* sustainability.

5.5 Supply Chain Resilience-Sustainability Framework

In Section 5.4 we presented empirical evidence to answer the three sub-research questions regarding supply chain strategies, barriers, and metrics – evidence that helps us better understand how SCRE and SCS are inter-related. No large-scale empirical studies on this topic have been published, so we aim to sharpen our understanding of the connections between supply chain resilience and sustainability. Hence, we now use the Section 5.4 results to devise a conceptual framework for the SCRE–SCS relationship and thereby to account systematically for the notions’ connections and overlaps. The multi-dimensional nature of both SCRE and SCS calls for an integrated conceptual framework capable of providing a comprehensive view that reveals the inherent complexity of, and inter-relationships between, these supply chain objectives. Our proposed framework provides a foundation on which future research can develop appropriate models for resilience and sustainability. Thus, we will have answered the overarching research question if we can deliver insights into these factors’ intersection by

illustrating the relationship characteristics identified in Section 5.4. The framework for this undertaking is presented in Figure 5.8.

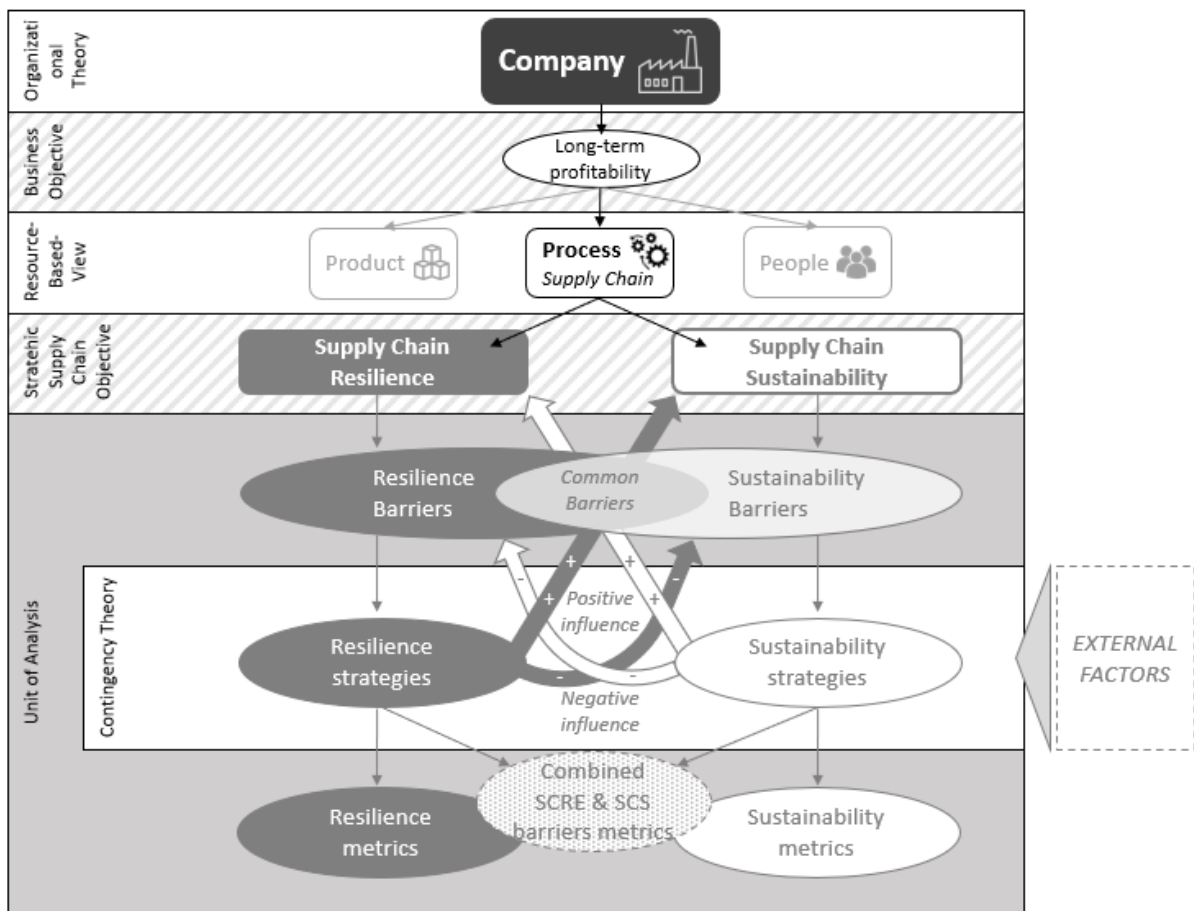


FIGURE 5.8: CONCEPTUAL FRAMEWORK FOR THE INTERSECTION OF SCRE AND SCS.

This framework incorporates three components. One is the *theory level*, shown in the figure's white areas. The hatched areas correspond to the *target category*, which consists of a firm's objectives, including overall objectives and supply chain specific objectives. The focal component of our conceptual framework is the *unit of analysis*, as shown in the figure's gray area.

Our proposed framework is adapted from that of Zavala-Alcívar et al. (2020), from whom we have borrowed elements such as the *strategies* dimension. The difference, however, is that Zavala-Alcívar et al. model the entire supply chain but not the relation between its resilience and sustainability – a relation that is covered in detail by our framework, as it outlines how companies address the two objectives in practice. Our focus is on the strategic level, where the available metrics and the barriers to implementation play a large role. The purpose of this framework is to

enrich theoretical discussions on the intersection by detailing the practitioner's perspective and what can be derived from it.

In Figure 5.8, the top four “bars” (“Organizational Theory” ... “Strategic Supply Chain Objective”) present SCRE and SCS from the corporate viewpoint; these components are based on findings from the literature. From a practical perspective, the company and its overall objective (i.e., achieving long-term profitability) are at the center of all considerations – a priority that research has confirmed (Shetty, 1979). According to the RBV, achieving long-term profitability requires harnessing resources that are valuable, rare, difficult-to-imitate, and organized (Fredericks, 2005). Our study focuses on process-related resources, or those related to the supply chain. The company's long-term profitability requires that supply chains be both resilient and sustainable (Azevedo et al., 2013; Sen et al., 2018). In the words of a supply chain executive from the packaging industry, “resilience and sustainability serve the same purpose, namely, to remain profitable and thus competitive” (SC Executive, Expert Interview). Thus one illustrative aspect of our framework is to show this first characteristic of that relation: how the two supply chain objectives are connected through the firm's overall business objective.

The upper segment of our framework's “unit of analysis” component consists of the barriers to implementation. The levels of resilience and sustainability that are ultimately achieved depend on the particular barriers and on how well they are surmounted. Our study's empirical results document a large overlap among the barriers to resilience and to sustainability. The barriers can be sorted into three groups: barriers to SCRE, barriers to SCS, and barriers that impede *both* resilience and sustainability. The large number of common barriers is a second major characteristic of the resilience–sustainability intersection, which is confirmed by survey results. In particular, “product complexity” and “budget constraints” are frequently named common barriers; others include “lack of data and visibility to measure resilience/sustainability”, “limited technology capability of partners”, and “lack of digital capabilities & IT infrastructure”. It should be clear from the framework that holistic approaches to SCRE and SCS are required if these common barriers are to be addressed in a collaborative fashion. Taking an integrated approach to implementation barriers has the virtue of making it possible

to “balance” contradictory remedies. For example, a resilience barrier is “Focus on efficiency & streamlining”, which is driven by strategies to increase the level of SCS. Moreover, it contradicts the sustainability barrier “Build-in redundancies & inventory buffers” which is driven by resilience strategies. Such negative effects are represented in Figure 8 by the two curved arrows containing minus signs.

The barriers also determine the “right” (i.e., most effective) strategies to achieving SCORE and SCS, which is the second level within the *unit of analysis*. Because there exist so many common barriers, one might expect the most prominent strategies for increasing resilience and sustainability to be similar if not the same. Yet our research shows that, from the perspective of most supply chain practitioners, there is hardly any overlap between the most favored strategies for increasing resilience and for improving sustainability. This situation is evident in the figure, which shows no intersection for the two strategies. Nonetheless, our empirical findings indicate that most of the top SCORE and SCS strategies were seen as having a positive effect on the counterpart objective. So even though the most frequently used SCORE and SCS strategies are different, they are capable of overcoming common barriers. This third relationship characteristic is represented in Figure 8 by the straight arrows that run from the strategies through the common barriers to the respective other concept. Thus we have identified yet another reason why supply chain resilience and sustainability should be considered from an integrated perspective.

Within the unit of analysis, our illustrated framework’s lower segment corresponds to appropriate metrics; these are needed for measuring how successfully the objectives were met and for setting targets. The survey results established that, in practice, there is no overlap between the two objectives’ respective metrics (as illustrated in the figure). Hence practitioners rely on concept-specific metrics. For sustainability, traditional SCM metrics are augmented by sustainability-related metrics that apply to long-term targets. For resilience, in contrast, most metrics are still based on such traditional SCM metrics as efficiency and service level – despite this leaving practitioners unable to assess the preventive and long-term aspects of resilience. Other metrics, such as value at risk (Duffie & Pan, 1997), have failed to bridge the notions of resilience and sustainability, despite risk management being a consideration in both strategies

(Seuring & Müller, 2008). In the absence of appropriate combined metrics for SCRE and SCS, the procedure we suggest is to measure the extent of overcoming identified common barriers (e.g., product and partner complexity) to SCRE and SCS implementation. These metrics yield reasonable approximations of overall supply chain resilience and sustainability.

In summary, the framework presented here showcases the practitioners' perspective on how SCRE and SCS are related. As illustrated in Figure 8, these two objectives both overlap and affect each other. Both the common barriers to implementation and the implemented strategies' reciprocal effects are central to characterizing their intersection. Recall that there was no overlap between the metrics named for SCR and the metrics named for SCS and that, especially with regard to SCRE, no entirely suitable metric exists. Because they share so many features, resilience and sustainability must be approached – from the standpoint of both theory and practice – in an integrated manner. However, there is no “one size fits all” solution that can achieve both objectives (Cohen et al. 2022a). As described by contingency theory, the individual context of internal and external factors ultimately affects how a supply chain is set up (Lawrence & Lorsch, 1967). Hence the “perfect” supply chain design does not exist; rather, each design is more (or less) appropriate for a given context.

5.6 Managerial Implications

Four managerial implications emerge from our empirical findings and the resulting integrative framework. We shall discuss each of these in turn.

1. Supply chain resilience and sustainability require an integrated approach and involve responsibilities that should be managed within the supply chain function.

Because of the extensive overlap between these two supply chain objectives, especially at the strategic level, it is crucial for organizations to approach SCRE and SCS in an integrated manner. Such an approach allows the prioritization of strategies that serve both objectives. If the SC function is responsible for both supply chain objectives then complexity and coordination efforts could each be reduced, given (i) the interdependencies among supply chain

strategies and (ii) the overlaps in barriers to implementation. An integrated approach also enables practitioners to leverage positive secondary effects when assessing various business cases. Properly quantifying the expected benefits of an SCRE or SCS strategy requires that the potential secondary effects on the other objective be considered in any cost–benefit calculation. So when evaluating investment costs – say, for transforming dedicated production capacities into flexible ones – in terms of the expected benefits, those benefits should include not only resilience but also the possibility of a positive sustainability effect. Leveraging such secondary effects can help mitigate high investment costs and budget constraints, which are the principal barriers to both objectives.

2. Practitioners should not be deterred if conflicts arise between methods of overcoming short-term barriers to SCRE and SCS implementation.

Dealing successfully with short-term SCRE barriers is often counterproductive to SCS objectives. For example: resilience depends on sufficient inventory buffers, yet these buffers are precisely what should be minimized for the sake of sustainability. Thus the redundancy needed for SCRE conflicts with the resource efficiency that SCS requires. Notwithstanding this contradiction, it is imperative that supply chains be both resilient and sustainable in the long term; both objectives must be met if the company is to achieve its overarching business objective of long-term profitability. It follows that supply chain practitioners should identify the greatest barriers to resilience and sustainability (e.g., product and partner complexity) in order to achieve a balance in strategies that will achieve those two objectives effectively.

3. The use of SCRE- and SCS-specific metrics should be complemented by a metric that assesses common barriers to implementation.

It is evident from both the literature and practice that the few available common metrics require considerable effort to apply. Hence practitioners should continue using metrics specific to the objective at hand. That said, assessing common strategies for overcoming the barriers to both objectives allows companies to track (though often indirectly) the success of SCRE and SCS initiatives. The resulting approximation of the “true” level of SCRE and SCS can facilitate decisions about which supply chain strategy to implement. However, more

resilience-specific metrics must be devised for SCRE tracking. As discussed in Section 4, most companies still measure resilience using general, backward-looking metrics based on static “snapshots” (e.g., on-time delivery, adherence to production schedules, the service level). Yet to parallel the sustainability metrics currently in use, we need metrics that can capture the longer-term and preventive aspects of resilience. Practitioners should therefore consider using some purely resilience-related metrics – for instance, those measure such factors as time to survive, time to recover, and value at risk (Simchi-Levi et al. 2015; Simchi-Levi et al. 2018).

4. Sustainability should be approached from two perspectives within each organization in order to be addressed holistically and efficiently.

This study reveals the strong intertwining between SCRE and SCS and thus urges that they be approached in a combined manner. However, the company must address two different types of sustainability. On the one hand, *internal* sustainability entails collecting all sustainability-related KPIs and measuring overall company performance in terms of such factors as CO₂ emissions, waste, and water consumption. These activities should be undertaken in close alignment with the centralized planning of a supply chain strategy, and our study offers empirical evidence for the advantages of assigning SCS and SCRE responsibilities to the same department. On the other hand, *external* sustainability involves inducing customers to purchase products that are more sustainable; this objective should be embedded in the firm’s marketing department and in other customer-facing functions such as application development. Such a hybrid set-up ensures that sustainability is centrally tracked and communicated – and also that it is part of developing new products and applications designed specifically for (and with input from) customers.

5.7 Conclusion

During the last decade, increasingly frequent disruptions and tighter regulations have pressured companies to invest more resources and effort into developing resilient and sustainable supply chains. Because long-term profits depend on achieving these objectives, it is not surprising that the concepts of supply chain resilience and sustainability are now receiving increased scrutiny in

academia and also in practice. Although numerous research papers have been devoted to each of these supply chain objectives, their intersection is relatively unexplored in the literature and surprisingly ignored by practitioners. We were motivated by this research gap to conduct a large-scale survey of supply chain practitioners, and the answers given by 143 respondents laid the groundwork for gaining new empirical insights into the SCORE–SCS relation.

Our empirical study confirms that SCORE and SCS have many similarities and also are affected by efforts to improve the *other* objective. Survey results allowed us to identify particular characteristics of the relationship between supply chain resilience and sustainability. First, these objectives are connected in the sense that both are subsumed by the firm’s overall (long-term profit) objective. Second, there is much overlap in SCORE and SCS implementation barriers, such as “high investment costs & budget constraints” and “product complexity”; thus both SCORE and SCS are costly as well as complex. Third, the most frequently implemented SCORE and SCS strategies are different but are nonetheless capable of overcoming common barriers; in other words, implemented resilience strategies affect sustainability and vice versa. The two objectives are so strongly related that it makes sense to address both via an integrated approach. However, SCORE and SCS currently share no common applied metrics. Those used for SCS metrics are, compared to SCORE metrics, better fitted to the purpose because they are specific, long-term oriented, and easily measurable. When assessing SCORE, most respondents still use traditional supply chain management metrics, such as service level and supply chain efficiency. A better approximation would result if practitioners would instead measure common SCORE and SCS barriers, such as product and partner complexity.

We employed statistical testing – in the form of chi-square tests and Cramer’s V – to identify associations between the different categorical variables. Several statistically significant associations were identified, including the one between *Job level* and *Ability to describe relationship* and that between *Job function* and *Experience of negative effects*. These findings increase our understanding of the overall relationship between SCORE and SCS and of how certain answers to the questionnaire might be affected by various factors: the

respondent's seniority as well as the industry and department in which the practitioner works.

Our study makes two contributions to the field of supply chain management. First, it augments extant theoretical discussions with evidence that is derived empirically. Second, this paper introduces a conceptual framework illustrating the relationship's identified characteristics and thereby explicates the multi-dimensional nature of the intersection between supply chain resilience and sustainability. We use inductive analysis in basing this framework on our empirical data, and its purpose is to show more clearly all the SCRE–SCS interconnections. To support practitioners implementing an integrated approach to these objectives, we derive (and discuss, in Section 5.6) four key managerial implications.

There are a few limitations to this study, especially as concerns its methodology and data. One limitation is that, within the survey sample, Asian and developing countries are under-represented (14 percent of all respondents) and so our results do not capture the global picture. With regard to SCRE and especially SCS, there are probably differences between developed and developing countries that merit qualitative and quantitative analysis in future research. Another limitation of our study is that its use of qualitative research methods limits the generalizability of our findings. Also, the goal of achieving a large sample size dictated that the questionnaire ask mostly closed-ended questions – so as to minimize the time burden on our practitioner respondents.

A new framework derived from empirical data naturally suggests avenues for future research. One requirement is for studies that focus on in-depth analysis to verify the framework we have devised. Validation could proceed by using an independent data set and also by using quantitative methods to analyze the relationships described here. Another direction worth exploring would be to assemble a larger sample, by industry, and then analyze typical pairings of SCRE and SCS strategies and how they are related to the underlying barriers. There is an urgent need also for research into how a firm's operational attributes and the supply chain context each affect SCRE and SCS objectives, with the aim of devising an appropriate metric that could be applied to both.

6. CONCLUSION

6.1 Contributions to Literature and Practice

In Chapter 2, we introduce an integrative framework for supply chain resilience that combines enablers such as end-to-end visibility with resilience strategies derived from the supply chain resilience literature and prominent consulting reports. This paper represents one of the initial attempts to understand the specific challenges faced by companies in establishing a resilient supply chain, despite executives having a good understanding of the basic roadmap to achieving resilience. To support the implementation of successful resilience strategies, we developed a framework that identifies the primary challenges for achieving resilience and offers effective responses to these challenges. Through interviews with top-level supply chain executives from leading companies, we gained insights into their experiences and how they have overcome these challenges. The prescriptive recommendations and the implementation challenges framework enable executives to better comprehend their individual barriers and find more effective solutions to overcome them.

In Chapter 3, we introduce the concept of "bespoke supply chain resilience," based on the belief that executives operate within unique environments and manage supply chains that are tailored to their specific business settings or even individual SKUs. This concept aids scholars in understanding the managerial perspective on supply chain resilience. Using empirical data from 26 diverse supply chains, we developed the empirically grounded Triple-P framework, which reveals that the primary complexity type encountered in a given archetype aligns with the initial resilience strategy, as well as with the barriers and resilience challenges that firms can expect to face. This study initiates a dialogue between supply chain scholars and practitioners to bridge the gap between knowledge and action regarding resilience strategies and to encourage further research in developing effective supply chain resilience strategies. The identified disparity between the practices of exemplary managers and the recommendations of research findings suggests that the supply chain research community should consider how to make their models and conclusions more implementable.

Chapter 4 focuses on consulting survey-based reports related to supply chain resilience. While these reports offer valuable insights into practitioners' perspectives on timely topics like supply chain resilience, this paper represents one of the first attempts to examine these reports specifically. We found a mismatch between the insights derived from these consulting surveys and the information supply chain executives require to effectively steer their supply chains. To bridge this "unit of analysis" gap, we propose a two-step approach that links survey insights to operational attributes, enabling customized or bespoke insights. Furthermore, this paper contributes to the literature by comparing different units of analysis for supply chain resilience strategies and highlighting the limitations of the commonly preferred company-level view through the analysis of three real-world company examples.

Chapter 5 makes a contribution to the literature on the intersection of supply chain resilience and sustainability. For the first time, this paper compares the barriers to implementing supply chain resilience and sustainability to draw conclusions about the overall relationship between the two concepts. The study adds an empirical supply perspective from 143 supply chain executives to an ongoing discussion on the sustainability-resilience relationship, which has primarily been theoretical or based on case studies thus far. Additionally, we introduce a conceptual framework that elucidates the multidimensional relationship between resilience and sustainability within the context of supply chain management. This framework serves as a foundation for future quantitative models aimed at testing various aspects of the resilience-sustainability intersection. Furthermore, we derive three key learnings for supply chain executives, which will assist managers in efficiently and effectively implementing sustainable-resilient supply chain management strategies.

6.2 Critical Reflection and Avenues for Future Research

The dissertation presents four research studies that examine supply chain resilience from different perspectives, offering valuable insights for both scholars and practitioners. However, it is important to consider the limitations of each study, as addressing these limitations can pave the way for impactful and promising future research.

In Chapter 2, six barriers for implementing supply chain resilience are proposed based on in-depth interviews with 14 supply chain executives from globally leading companies. The results have limited generalizability and serve as a starting point for a more comprehensive analysis of the relationship between implementation barriers and supply chain resilience strategies. Furthermore, the interviews were conducted in May 2020, shortly after the onset of the COVID-19 pandemic and global lockdown. Therefore, the proposed barriers are based on initial findings from each company, without the executives fully grasping the depth of the COVID-related implications. Given that we are now over 2.5 years into the pandemic, there is a need to better understand how implementation barriers influence the selection of resilience strategies. This could be achieved through conducting a larger-scale survey and taking into account company-specific environments and external/internal factors.

The bespoke supply chain framework introduced in Chapter 3 is limited by the size of the dataset, which is typical for empirical qualitative research. This limitation affects the generalizability of the findings. To further validate our Triple-P framework and the robustness of the three supply chain archetypes it defines, a larger dataset comprising a wider sample of executives and supply chains is needed. The study presents initial results that open up a new frontier for exploring supply chain resilience decision-making from a manager's perspective, but it cannot empirically prove all the points raised regarding the interplay between supply chain, market, and product characteristics in implementing a resilience strategy. Additionally, due to the long-term nature of supply chain resilience and the lack of objective metrics for assessing resilience, further research is needed to develop a method for evaluating the resilience of a supply chain.

Chapter 4 demonstrates how consulting reports can provide industry-specific insights, exemplified by three cross tables drawn from a Gartner survey on supply chain resilience. However, the raw data from the survey could not be obtained due to data privacy regulations. Therefore, validating the approach of transforming consulting survey results into actionable supply chain-specific insights requires access to the raw data and a shift in survey questions to focus on the supply chain as the unit of observation. Moreover, analyzing multiple surveys would enhance the validation of the results. Collaboration between consulting companies and scholars on large-scale surveys offers advantages for both parties. Consulting

companies can benefit from building their questionnaires based on existing literature, while scholars gain access to large datasets for making generalizable statements.

One limitation of the executive survey in Chapter 5 is that the majority of respondents come from Europe and North America, resulting in underrepresentation of Asia and other regions. As a result, regional differences between developed and developing countries cannot be explored, and future qualitative and quantitative supply chain research should focus on this aspect. Another limitation of the study is the use of qualitative research methods, which limits the generalizability of the findings. Thus, future research is needed to conduct an in-depth analysis of the identified characteristics of the resilience-sustainability intersection to verify and build upon the derived framework. Additionally, employing quantitative methods to analyze the presented relationships holds promise as a future research direction.

APPENDIX A SUPPLEMENTS TO CHAPTER 3



A.1 Interview Guide for First and Second Round Interviews

TABLE A.1: INTERVIEW GUIDE FOR FIRST ROUND INTERVIEWS

Topic	Interview questions
Organizational setup and supply chain structure	<ol style="list-style-type: none"> 1. Please tell us about the general supply-chain situation at your company. 2. How many different supply chains do you operate for how many "Product Groups" within the company? Please name two examples for different supply chains and how they are different. 3. What are the key variables or drivers your company uses for defining the number of different supply chains? 4. Do some "product groups" with different supply chains share resources in sourcing, manufacturing, or distribution?
COVID pandemic and other disruptions	<ol style="list-style-type: none"> 1. How and to what extent did the current pandemic disrupt your supply-chain operations? In what ways is the pandemic different from previous disruptions? 2. Were there any differences across product groups/business units with regards to the disruption? If so, please explain. 3. What are your major obstacles for becoming more resilient?
Measures to become more resilient, agile, or responsive	<ol style="list-style-type: none"> 1. Has your company already implemented any changes as a response to the pandemic? Please elaborate on the short-term measures that are already in place 2. What are the key learnings from handling the current pandemic? 3. Which other actions are you planning on implementing going forward?
IT infrastructure	<ol style="list-style-type: none"> 1. Which tools / technology do you use to steer your supply chain (i.e., for gaining end-to-end visibility to perform risk analysis and to conduct scenario planning)?

TABLE A.2: INTERVIEW GUIDE FOR SECOND ROUND INTERVIEWS

Topic	Core question (+ Sample interview questions)
Organizational setup and supply chain structure	<p>Please tell us about the general supply-chain situation at your company.</p> <ul style="list-style-type: none"> • How many different supply chains do you operate for how many "Product Groups" within the company? Are these product groups

	<p>standardized or vary depending on the "function" (e.g., production, distribution)?</p> <ul style="list-style-type: none"> • What are the key variables or drivers your company uses for defining these groups?
COVID pandemic and other disruptions	<p>Please tell us about your companies' situation with regards to the COVID pandemic.</p> <ul style="list-style-type: none"> • How and to what extent did the pandemic disrupt your supply-chain operations? In what ways is the pandemic different from previous disruptions? • Were there any differences between product groups/business units with regards to the disruption? If so, please explain.
Partnership	<p>How do partnerships (with suppliers, contract manufacturer, distributors, or customers) help to achieve more resilience?</p> <ul style="list-style-type: none"> • To increase geographical resilience, what are the ways in which you induce your current suppliers to diversify their factory locations, or do you try to groom new suppliers in new geographies? In doing so, can you ensure that social and environmental responsibility standards are upheld? • To increase technological resilience, what are the ways that you can help a supplier to invest for such upgrades? What new risks do you see by helping a supplier to have deeper sophistication and capabilities? • For companies that own their manufacturing, you may not have a network of diversified manufacturing sites due to the required heavy investments. How can you provide yourself some form of geographical resilience?
Supply-chain integration	<p>How does the structure of the supply chain portfolio help to become more resilient?</p> <ul style="list-style-type: none"> • Are your supply chains centrally controlled or managed independently (within regions or business units)? • To what degree are the supply chains within your company intertwined and share common resources (e.g., in terms of planning, inventory control, logistics, procurement, manufacturing equipment, etc.)? • How did the current supply-chain structure influence your level of resilience? Are you planning on changing the structure?
IT infrastructure	<ul style="list-style-type: none"> • Which tools / technology do you use to steer your supply chain (i.e., for gaining end-to-end

	visibility to perform risk analysis and to conduct scenario planning)?
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A.2 Clustering Results

All analysis was performed with R software. For analyzing the right number of clusters, the “*fviz_nbclust*” function from the *factoextra* package was used with k-means as clustering method and total within sum of square.

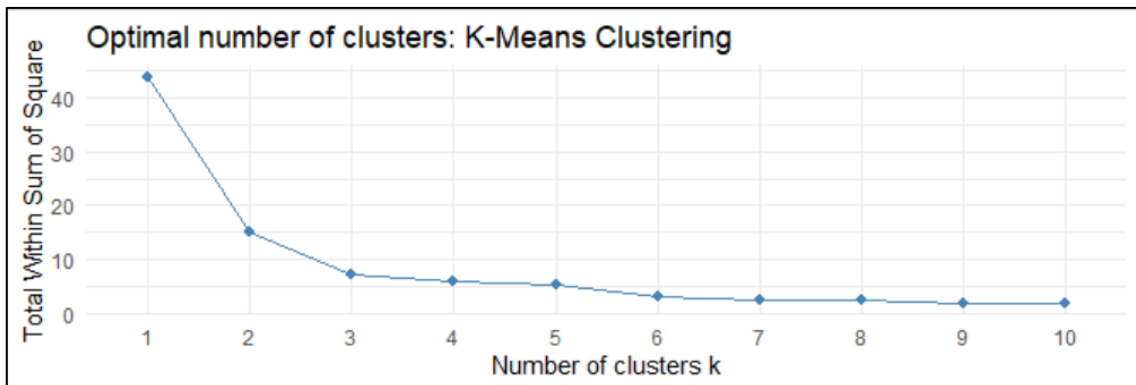


FIGURE A.1: OPTIMAL NUMBER OF CLUSTERS

For the clustering, the *kmeans* function from the *cluster* package with a clustering algorithm from Hartigan and Wong (1979) was used.

```
K-means clustering with 3 clusters of sizes 12, 9, 5

Cluster means:
  SCIntegration HomoSCP
1      1.741667 2.012500
2      2.966667 2.544074
3      4.283333 3.900000

Clustering vector:
[1] 3 1 2 1 2 2 1 1 1 2 2 2 2 1 1 1 3 3 3 1 2 1 2 3 1 1

within cluster sum of squares by cluster:
[1] 2.7225694 3.7037506 0.8055556
(between_SS / total_SS = 83.5 %)
```

FIGURE A.2: CLUSTER ALGORITHM (R SOFTWARE)

A.3 Operational Attributes per Cluster

The following table shows the results of the iterative group panel discussion to individually assess all supply chains with regards to the eight operational attributes on a scale from 1 (low) to 5 (high). For each cluster, the average score and standard deviation of the respective operational attribute is shown. The table reads

as follows: In terms of product complexity, supply chains from cluster 1 average 4.9 out of 5; in contrast, supply chains from cluster 3 average only 1.7.

TABLE A.3: OPERATIONAL ATTRIBUTES PER CLUSTER

	Cluster 1 (top right)		Cluster 2 (mid)		Cluster 3 (bottom left)		Delta Avg. 1 vs. 2	Delta Avg. 1 vs. 3	Sum of deltas
	Avg.	Std. dev.	Avg.	Std. dev.	Avg.	Std. dev.			
Product complexity	4,9	0,2	3,2	0,8	1,7	0,5	1,7	3,2	4,9
Homogeneity of product portfolio	4,9	0,2	2,8	0,8	1,8	0,8	2,1	3,1	5,2
Product modularization	1,8	1,5	3,4	1,1	1,9	1,3	1,7	0,2	1,8
Level of product customization	4,3	0,7	3,5	1,2	2,0	1,3	0,8	2,3	3,1
Availability of supplier	1,1	0,2	3,1	0,6	4,4	0,5	2,0	3,3	5,3
Level of pull	4,8	0,3	3,4	1,2	1,6	1,2	1,4	3,2	4,6
Lead time	4,8	0,4	2,9	0,8	1,8	0,9	1,9	3,0	4,8
Degree of outsourcing	2,4	1,9	3,1	1,2	2,5	1,5	0,7	0,1	0,8

Scale from 1(low) to 5(high)

APPENDIX B SUPPLEMENTS TO CHAPTER 4



B.1 Overview Consulting Reports

TABLE B.1: OVERVIEW CONSULTING REPORTS

ID	Title	Company	Date	Number of responses	Scope	Unit of observation	Unit of analysis
1	Global Supply Chain Survey - In Search Of Post-covid-19 Resilience	Allianz Research / Euler Hermes	December-2020	1181	US, UK, FR, GER, IT	Company	Country/area & Industry/sector level
2	Supply Chain Resilience Report 2021	Business Continuity Institute (BCI)	March-2021	173	Global	Company	Cross-industry level
3	Fast forward - Rethinking supply chain resilience for a post-COVID-19 world	Capgemini Research Institute	October-2020	1000	Global	Company	Country/area & Industry/sector level
4	Save-to-thrive	Deloitte	August-2020	1089	Global	Company	Country/area & Industry/sector level
5	Future of Supply Chain: Crisis Shapes the Profession	Gartner	December-2020	1346	Global	Company	Cross-industry level
6	Weathering the storm	Gartner	May-2020	236	Global	Company	Cross-industry level
7	Supply chain resilience report	Hubs	July-2020	1281	Global	Company	Cross-industry level
8	Supply Chain Resilience In A Post-pandemic World	Jabil	September-2020	715	Mainly US	Company	Industry level
9	The Resiliency Compass: Navigating Global Value Chain Disruption in an Age of Uncertainty	Kearney	July-2021	360	Global	Company	Cross-industry level
10	Risk, resilience, and rebalancing in global value chains	McKinsey & Company (MCK)	May-2020	605	Global	Company	Industry level, some company specific
11	Navigating the Supply Chain through the Pandemic	Supply Chain Insights (SCI)	February-2021	118	Global	Company	Cross-industry level
12	The Resilient Supply Chain Benchmark: Ready for anything?	Economist Intelligence Unit (EIU)	May-2021	308	US	Company	Industry / sector level

B.2 Cross Table from Gartner Survey Raw Data

TABLE B.2: CROSS TABLE 1

	Industry										
	Aerospace & Defense	Automotive	High Tech	Retail	CPG	Food & Beverage	Healthcare & Pharma	Logistics & Distribution	Chemicals	Medical Equipment & Devices	Industrial
N	27	23	201	101	112	109	149	65	65	28	106
Supply chain segmentation	14	12	118	58	67	49	93	37	32	17	61
Increase inventory (safety stock)	10	13	111	37	50	50	65	37	14	14	32
Reduce manufacturing and/or warehouse utilization (for redundant capacity)	9	7	65	33	44	38	54	31	25	11	32
Shift manufacturing from one country/region to another (including reshoring or nearshoring)	10	7	123	51	51	53	65	27	22	12	55
Diversify the supply base (move to multi-sourcing)	20	12	148	71	63	69	85	40	28	19	65
Increase outsourcing of key supply chain components (i.e., manufacturing, 3PL, etc.)	10	6	109	48	56	40	67	37	18	10	40
Additional vertical integration of core operations	14	9	82	50	35	35	52	20	23	13	26
Diversify markets (including geographies or product lines)	13	11	131	58	66	58	80	36	38	18	59
Redesign products (reduce variety, increase common components, etc.)	14	13	126	58	66	77	84	25	34	18	59
Demand sensing technology	11	8	123	65	62	51	78	30	33	11	47
Supply chain visibility and mapping (e.g., multi-tier suppliers)	19	13	157	78	73	62	90	39	43	19	66
Supply chain risk/disruption monitoring (e.g., control tower)	20	15	144	60	66	61	91	40	33	19	64
Enhanced planning (based on big data and machine learning)	18	12	142	61	61	58	80	47	34	10	54
Deepen collaborative relationships with key customers and suppliers (training, investments, incentives, etc.)	21	13	161	85	91	72	107	51	49	18	75
Stronger government lobbying	10	9	94	45	27	45	68	15	28	16	33
Form coalitions with peer companies to influence policies or joint development	13	9	89	51	30	42	76	18	26	9	28

Resilience strategy

TABLE B.3: CROSS TABLE 2

	All Industries	Aerospace & Defense	Automotive	Chemicals	CPG	Food & Beverage	Healthcare & Pharma	High Tech	Industrial	Logistics & Distribution	Medical Equipment & Devices	Retail
2.1 Within two years we will invest to make our supply chains more resilient	Total	1049	26	65	112	109	149	201	106	65	28	101
	Agree	88%	85%	83%	90%	83%	87%	93%	90%	91%	79%	90%
	Neutral	10%	12%	13%	8%	15%	10%	6%	9%	9%	11%	9%
	Disagree	2%	4%	4%	2%	2%	3%	1%	1%	0%	0%	11%
2.2 Within two years we will invest to make our supply chains more agile	Total	1050	27	65	112	109	149	201	106	65	28	101
	Agree	91%	81%	87%	95%	85%	91%	92%	90%	91%	89%	96%
	Neutral	8%	15%	13%	4%	13%	8%	7%	9%	8%	7%	3%
	Disagree	1%	4%	0%	3%	1%	2%	1%	1%	1%	2%	4%
2.3 Our supply chains in the past have been designed primarily for cost efficiency rather than resilience or agility	Total	1049	27	64	112	109	149	201	106	65	28	101
	Agree	60%	67%	61%	73%	67%	63%	52%	57%	42%	61%	57%
	Neutral	24%	26%	22%	17%	24%	19%	28%	27%	37%	29%	28%
	Disagree	15%	7%	17%	10%	9%	18%	20%	16%	22%	11%	15%
2.4 Resilient and agile supply chains are more costly to operate	Total	1048	27	65	112	109	149	201	106	65	27	100
	Agree	30%	22%	43%	33%	28%	32%	32%	28%	38%	30%	31%
	Neutral	37%	26%	43%	33%	39%	30%	35%	41%	43%	48%	39%
	Disagree	32%	52%	13%	34%	32%	39%	33%	31%	18%	22%	30%
2.5 Our executive leadership understands and accepts the investments required to be more resilient and agile	Total	1043	27	65	112	106	147	200	106	65	28	101
	Agree	57%	41%	30%	65%	55%	50%	65%	55%	66%	50%	61%
	Neutral	28%	37%	48%	21%	32%	35%	22%	28%	26%	32%	28%
	Disagree	15%	22%	22%	14%	13%	14%	14%	17%	8%	18%	11%
2.6 Lean and/or just-in-time supply chains will be less applicable in our future strategy	Total	1047	27	65	112	109	149	200	106	65	28	99
	Agree	19%	26%	26%	23%	19%	21%	18%	18%	28%	14%	11%
	Neutral	33%	37%	13%	34%	30%	19%	36%	24%	42%	43%	37%
	Disagree	49%	37%	61%	43%	50%	60%	47%	58%	31%	43%	52%
2.7 National interests and pressure to favor domestic operations will increase in influence on our future supply chain decisions	Total	1042	27	64	112	109	148	197	106	64	28	100
	Agree	52%	63%	39%	48%	49%	60%	60%	57%	45%	29%	41%
	Neutral	33%	22%	39%	37%	36%	26%	28%	27%	41%	39%	38%
	Disagree	16%	15%	22%	15%	16%	14%	12%	16%	14%	32%	21%

CROSS TABLE 2 (CONTINUED)

	All Industries	Aerospace & Defense	Automotive	Chemicals	CPG	Food & Beverage	Healthcare & Pharma	High Tech	Industrial	Logistics & Distribution	Medical Equipment & Devices	Retail
2.8	Total	1038	27	23	65	112	109	147	104	63	26	100
	Agree	34%	44%	39%	23%	29%	32%	40%	26%	40%	31%	33%
	Neutral	48%	44%	35%	62%	54%	53%	37%	53%	46%	46%	52%
	Disagree	18%	11%	26%	15%	17%	15%	22%	19%	21%	14%	15%
2.9	Total	1047	27	23	65	112	109	148	105	64	28	101
	Agree	27%	30%	13%	28%	27%	43%	27%	20%	25%	0%	28%
	Neutral	45%	48%	52%	38%	44%	39%	42%	48%	56%	57%	46%
	Disagree	28%	22%	35%	34%	29%	18%	31%	32%	32%	19%	43%
2.10	Total	1047	27	23	65	112	109	149	106	64	27	101
	Agree	45%	44%	43%	45%	42%	47%	42%	51%	52%	33%	49%
	Neutral	33%	19%	52%	32%	32%	34%	33%	29%	34%	33%	24%
	Disagree	22%	37%	4%	23%	26%	19%	26%	20%	14%	14%	33%
2.11	Total	1045	27	23	65	111	109	148	106	63	28	100
	Agree	30%	19%	35%	25%	43%	31%	29%	39%	24%	18%	28%
	Neutral	33%	41%	39%	34%	31%	34%	39%	25%	40%	36%	32%
	Disagree	37%	41%	26%	42%	26%	35%	32%	37%	37%	46%	40%
2.12	Total	1047	27	23	65	112	109	147	106	64	28	101
	Agree	30%	26%	35%	31%	43%	39%	31%	30%	23%	32%	27%
	Neutral	31%	22%	30%	31%	36%	25%	29%	33%	36%	39%	33%
	Disagree	39%	52%	35%	38%	21%	36%	40%	37%	41%	29%	41%
2.13	Total	1047	27	23	65	112	109	149	106	64	28	101
	Agree	18%	33%	13%	31%	19%	23%	21%	18%	9%	11%	15%
	Neutral	41%	26%	35%	35%	46%	51%	42%	34%	39%	64%	36%
	Disagree	41%	41%	52%	34%	35%	26%	36%	48%	52%	25%	50%
2.14	Total	1044	27	23	64	112	109	149	105	63	28	100
	Agree	54%	63%	48%	56%	67%	69%	54%	63%	44%	46%	47%
	Neutral	35%	26%	39%	30%	27%	27%	38%	30%	46%	50%	39%
	Disagree	11%	11%	13%	14%	6%	5%	8%	7%	10%	4%	14%

TABLE B.4: CROSS TABLE 3

		Resilience strategies								
		Supply chain segmentation	Increase inventory (safety stock)	Reduce manufacturing and/or warehouse utilization (for redundant capacity)	Shift manufacturing from one country/region to another (including reshoring or nearshoring)	Diversify the supply base (move to multi-sourcing)	Increase outsourcing of key supply chain components (i.e., manufacturing, 3PL, etc.)	Additional vertical integration of core operations	Diversify markets (including geographies or product lines)	Redesign products (reduce variety, increase common components, etc.)
Beliefs	Total	591	453	362	497	657	464	378	601	603
	Within two years we will invest to make our supply chains more resilient	Agree	92%	90%	93%	90%	91%	92%	90%	90%
		Neutral	7%	8%	6%	8%	8%	6%	8%	7%
		Disagree	1%	2%	1%	1%	2%	1%	2%	2%
	Total	591	453	363	498	657	464	379	601	604
	Within two years we will invest to make our supply chains more agile	Agree	96%	92%	93%	91%	92%	92%	93%	92%
		Neutral	4%	7%	6%	8%	7%	6%	6%	7%
		Disagree	1%	1%	1%	1%	1%	2%	1%	2%
	Total	591	453	363	498	657	464	379	601	604
	Our supply chains in the past have been designed primarily for cost efficiency rather than resilience or agility	Agree	60%	59%	61%	58%	58%	59%	57%	59%
		Neutral	25%	24%	24%	24%	25%	23%	25%	24%
		Disagree	15%	17%	15%	17%	18%	18%	19%	17%
	Total	589	453	363	498	656	464	378	600	604
	Resilient and agile supply chains are more costly to operate	Agree	31%	33%	32%	32%	31%	30%	29%	30%
		Neutral	35%	36%	35%	36%	36%	38%	36%	37%
		Disagree	34%	30%	34%	32%	33%	31%	35%	34%
	Total	587	449	361	496	653	461	378	598	600
	Our executive leadership understands and accepts the investments required to be more resilient and agile	Agree	63%	61%	64%	60%	62%	64%	67%	61%
		Neutral	25%	26%	24%	26%	25%	23%	22%	25%
		Disagree	12%	13%	12%	14%	13%	12%	11%	14%
Total	590	451	362	497	656	462	377	600	603	
Lean and/or just-in-time supply chains will be less applicable in our future strategy	Agree	19%	25%	19%	19%	19%	19%	18%	19%	
	Neutral	32%	32%	31%	31%	32%	30%	32%	33%	
	Disagree	49%	43%	50%	50%	49%	52%	50%	49%	
Total	588	449	362	494	652	459	377	597	600	
National interests and pressure to favor domestic operations will increase in influence on our future supply chain decisions	Agree	52%	57%	52%	56%	51%	52%	51%	54%	
	Neutral	32%	30%	32%	29%	33%	33%	31%	32%	
	Disagree	15%	13%	16%	15%	16%	15%	17%	15%	

CROSS TABLE 3 (CONTINUED)

		Resilience strategies							
		Demand sensing technology	Supply chain visibility and mapping (e.g., multi-tier suppliers)	Supply chain risk/disruption monitoring (e.g., control tower)	Enhanced planning (based on big data and machine learning)	Deepen collaborative relationships with key customers and suppliers (training, investments, incentives, etc.)	Stronger government lobbying	Form coalitions with peer companies to influence policies or joint development	
Beliefs	Within two years we will invest to make our supply chains more resilient	Total	545	691	643	604	796	422	421
		Agree	92%	91%	91%	92%	89%	88%	88%
		Neutral	7%	7%	8%	6%	9%	9%	10%
		Disagree	1%	1%	1%	1%	2%	2%	2%
	Within two years we will invest to make our supply chains more agile	Total	545	691	644	604	797	423	422
		Agree	94%	94%	92%	93%	92%	90%	93%
		Neutral	4%	5%	7%	6%	7%	8%	6%
		Disagree	1%	1%	1%	1%	1%	2%	1%
	Our supply chains in the past have been designed primarily for cost efficiency rather than resilience or agility	Total	545	691	644	604	797	423	422
		Agree	58%	58%	57%	56%	58%	61%	58%
		Neutral	26%	25%	27%	27%	25%	20%	23%
		Disagree	16%	16%	16%	17%	17%	18%	19%
	Resilient and agile supply chains are more costly to operate	Total	544	689	642	603	796	423	422
		Agree	31%	32%	30%	31%	31%	32%	28%
		Neutral	36%	37%	38%	36%	37%	37%	37%
		Disagree	33%	32%	32%	33%	32%	31%	34%
	Our executive leadership understands and accepts the investments required to be more resilient and agile	Total	543	687	641	601	792	417	418
		Agree	63%	61%	63%	65%	61%	56%	58%
		Neutral	26%	27%	25%	25%	27%	30%	29%
		Disagree	10%	11%	12%	10%	12%	14%	13%
Lean and/or just-in-time supply chains will be less applicable in our future strategy	Total	543	688	643	601	796	423	422	
	Agree	19%	20%	20%	21%	19%	19%	21%	
	Neutral	32%	32%	32%	34%	33%	34%	32%	
	Disagree	49%	47%	49%	45%	48%	47%	47%	
National interests and pressure to favor domestic operations will increase in influence on our future supply chain decisions	Total	541	686	640	598	791	422	419	
	Agree	53%	55%	54%	54%	52%	58%	56%	
	Neutral	33%	30%	31%	33%	32%	28%	29%	
	Disagree	13%	16%	15%	13%	15%	14%	16%	

CROSS TABLE 3 (CONTINUED)

		Resilience strategies									
		Supply chain segmentation	Increase inventory (safety stock)	Reduce manufacturing and/or warehouse utilization (for redundant capacity)	Shift manufacturing from one country/region to another (including reshoring or nearshoring)	Diversify the supply base (move to multi-sourcing)	Increase outsourcing of key supply chain components (i.e., manufacturing, 3PL, etc.)	Additional vertical integration of core operations	Diversify markets (including geographies or product lines)	Redesign products (reduce variety, increase common components, etc.)	
D Beliefs	Our executive leadership will support factoring national interests into business decisions regardless of government or regulatory influence	Total	585	448	360	493	648	459	376	594	598
		Agree	35%	40%	40%	38%	37%	39%	41%	35%	35%
		Neutral	47%	45%	42%	45%	46%	43%	41%	46%	47%
		Disagree	18%	15%	18%	18%	16%	18%	17%	19%	19%
	Our customers want locally sourced and made products	Total	588	452	361	496	656	464	379	600	603
		Agree	27%	32%	26%	29%	27%	28%	28%	27%	29%
		Neutral	45%	42%	45%	44%	46%	44%	45%	46%	46%
	Our customers care more about low prices than where our products are sourced and made	Disagree	28%	26%	29%	27%	27%	28%	27%	28%	26%
		Total	589	451	362	498	656	462	379	599	602
		Agree	42%	44%	46%	44%	45%	45%	43%	45%	44%
		Neutral	35%	33%	33%	34%	33%	33%	33%	33%	33%
	We are shifting from a global supply chain model to one that is more regionally based	Disagree	23%	23%	22%	22%	22%	22%	24%	21%	23%
		Total	589	450	362	496	655	462	379	601	603
		Agree	32%	31%	33%	37%	32%	31%	33%	31%	31%
		Neutral	33%	35%	34%	32%	32%	34%	28%	32%	31%
	Serving the world from distant global factories is unsustainable	Disagree	35%	34%	33%	31%	36%	35%	39%	37%	37%
		Total	588	452	361	497	655	463	378	600	603
		Agree	32%	28%	31%	31%	31%	28%	29%	31%	31%
		Neutral	30%	33%	30%	32%	31%	32%	29%	31%	30%
	Low-cost country sourcing has run its course	Disagree	38%	39%	39%	37%	39%	40%	42%	38%	39%
Total		589	451	362	498	657	463	379	600	603	
Agree		17%	18%	17%	18%	18%	17%	18%	18%	17%	
Neutral		40%	38%	42%	40%	39%	39%	40%	42%	42%	
Automation will enable us to make onshore manufacturing economically viable	Disagree	43%	44%	42%	42%	43%	43%	42%	40%	41%	
	Total	588	450	362	498	657	461	378	600	603	
	Agree	59%	57%	56%	58%	54%	53%	54%	55%	56%	
	Neutral	31%	32%	33%	28%	34%	35%	35%	33%	33%	
		Disagree	10%	11%	12%	13%	11%	12%	12%	11%	

CROSS TABLE 3 (CONTINUED)

		Resilience strategies							
		Demand sensing technology	Supply chain visibility and mapping (e.g., multi-tier suppliers)	Supply chain risk/disruption monitoring (e.g., control tower)	Enhanced planning (based on big data and machine learning)	Deepen collaborative relationships with key customers and suppliers (training, investments, incentives, etc.)	Stronger government lobbying	Form coalitions with peer companies to influence policies or joint development	
Beliefs	Our executive leadership will support factoring national interests into business decisions regardless of government or regulatory influence	Total	540	683	638	598	789	420	420
		Agree	36%	37%	36%	36%	36%	39%	38%
		Neutral	46%	46%	45%	47%	45%	41%	41%
		Disagree	18%	17%	19%	17%	19%	20%	20%
	Our customers want locally sourced and made products	Total	542	689	642	601	795	423	421
		Agree	25%	27%	27%	28%	27%	30%	29%
		Neutral	48%	45%	46%	46%	45%	43%	46%
		Disagree	27%	28%	28%	26%	28%	27%	25%
	Our customers care more about low prices than where our products are sourced and made	Total	543	690	642	602	797	422	421
		Agree	43%	44%	44%	42%	45%	44%	42%
		Neutral	36%	34%	33%	36%	32%	35%	32%
		Disagree	21%	22%	23%	22%	22%	21%	26%
	We are shifting from a global supply chain model to one that is more regionally based	Total	542	689	641	602	796	422	420
		Agree	29%	30%	30%	29%	30%	31%	32%
		Neutral	37%	34%	35%	36%	33%	32%	32%
		Disagree	34%	36%	35%	35%	37%	37%	36%
	Serving the world from distant global factories is unsustainable	Total	543	690	642	601	795	421	420
		Agree	29%	31%	29%	29%	29%	28%	30%
		Neutral	33%	31%	33%	33%	31%	29%	30%
		Disagree	39%	39%	38%	38%	39%	43%	41%
	Low-cost country sourcing has run its course	Total	544	691	644	602	795	422	422
Agree		18%	18%	17%	18%	16%	16%	18%	
Neutral		43%	41%	43%	42%	41%	41%	39%	
Disagree		39%	41%	40%	40%	42%	44%	42%	
Automation will enable us to make onshore manufacturing economically viable	Total	542	688	641	600	795	423	422	
	Agree	58%	57%	57%	57%	55%	57%	55%	
	Neutral	31%	32%	32%	33%	34%	32%	34%	
	Disagree	11%	11%	11%	11%	12%	11%	10%	

C.1 Overview of Supply Chain Resilience Strategies

TABLE C.1: STRATEGIES FOR SUPPLY CHAIN RESILIENCE

SC resilience strategy	References
Inventory buffers for critical components	Tang (2006), Dong and Tomlin (2012), Wieland and Wallenburg (2013), Chopra and Sodhi (2014), Hohenstein et al. (2015), Chowdhury and Quaddus (2017), Hosseini et al. (2019)
Redundancy / Development of flexible production capacities (internal or external)	Chopra and Sodhi (2004), Tang and Tomlin (2008), Pettit et al. (2010), Carvalho et al. (2012), Hohenstein et al. (2015), Adobor and McMullen (2018)
Multi-sourcing / diversification of supply base	Chopra and Sodhi (2004), Christopher and Peck (2004), Kleindorfer and Saad (2005), Tang (2006), Ponomarov and Holcomb (2009), Wieland and Wallenburg (2013), Hohenstein et al. (2015), Sadghiani et al. (2015), Torabi et al. (2015), Chowdhury and Quaddus (2017)
End-to-end visibility (e.g., supply chain control tower)	Christopher and Lee (2004), Christopher and Peck (2004), Sheffi and Rice (2005), Pettit et al. (2010), Blackhurst et al. (2011), Carvalho et al. (2012), Hohenstein et al. (2015), Chowdhury and Quaddus (2017)
Advanced forecasting methods / Scenario planning	Chowdhury et al. (2015), Das and Lashkari (2015), Sheffi (2015), Khalili et al. (2017), Pavlov et al. (2019b)
Product harmonization (shared components across multiple products)	Kleindorfer and Saad (2005), Kusiak (2019), Cohen et al. (2021), Cohen et al. (2022a)
Emergency planning / Business continuity planning (incl. Supplier audits)	Christopher and Peck (2004), Kleindorfer and Saad (2005), Blackhurst et al. (2011), Wieland and Wallenburg (2013), Hohenstein et al. (2015), Chowdhury and Quaddus (2017), Adobor and McMullen (2018)
Collaboration & strong relationship with network partners (share risks, costs, gains)	Christopher and Jüttner (2000), Christopher and Lee (2004), Sarathy (2006), Pettit et al. (2010), Blackhurst et al. (2011), Carvalho et al. (2012), Wieland and Wallenburg (2013), Hohenstein et al. (2015), Chowdhury et al. (2015), Chowdhury and Quaddus (2017), Adobor and McMullen (2018)
Production relocation and diversification (e.g., regionalization and nearshoring)	Kleindorfer and Saad (2005), Chopra and Sodhi (2014), Cohen and Lee (2020), Hosseini et al. (2019)
Information management	Christopher and Jüttner (2000), Tang (2006)
Quality management system	Kleindorfer and Saad (2005), Sarathy (2006)
Multiple transportation channels	Tang (2006), Kamalahmadi and Parast (2016), Khalili et al. (2017)
Postponement	Tang (2006), Manuj and Mentzer (2008)

C.2 Overview of Supply Chain Sustainability Strategies

TABLE C.2: STRATEGIES FOR SUPPLY CHAIN SUSTAINABILITY

SC sustainability strategy	References
Increase efficiency in the use of operational resources (e.g., recycling and reusing water consumed in operations)	Kumar et al. (2012), Govindan et al. (2014), Çankaya and Sezen (2019)
Reduce packaging material / re-design packaging	Kumar et al. (2012), Govindan et al. (2014), Jayaram and Avittathur (2015)
Engage with suppliers in sustainability programs	Kumar et al. (2012), Govindan et al. (2014), Jayaram and Avittathur (2015), Laari et al. (2017), Malviya et al. (2018)
Reduce CO ₂ footprint across end-to-end supply chain	Ameer and Othman (2012), Kumar et al. (2012), Jayaram and Avittathur (2015)
Track supply chain sustainability indicators (e.g., water usage, hazardous materials, pollution)	Kumar et al. (2012), Govindan et al. (2014), Jayaram and Avittathur (2015), Malviya et al. (2018)
Optimize the supply chain network to reduce movement of materials and finished goods (e.g., regionalization)	Crilly and Zhelev (2010), Kumar et al. (2012), Govindan et al. (2014)
Undertake supplier sustainability audits	Kumar et al. (2012), Govindan et al. (2014), Jayaram and Avittathur (2015), Laari et al. (2017), Malviya et al. (2018)
Invest in renewable energy sources and adopt energy-efficient technologies	Jayaram and Avittathur (2015), Çankaya and Sezen (2019)
Adopt reverse logistics models and circular economy models	Thun and Müller (2009), Kumar et al. (2012), Govindan et al. (2014), Jayaram and Avittathur (2015)

Note: Some strategies such as “reuse water consumed during production”, “recycling of scrap parts and rejects”, and “reuse of coolants and production energy” are grouped together into “increase efficiency in the use of operational resources”, due to the many slightly different strategies proposed.

C.3 Online Questionnaire

Part 1: Introduction questions

Please fill out the following information before answering the survey. Please note that these information will remain confidential and will NOT be published or shared.

Company name

Industry sector

Headquarter location

Company annual sales

Number of employees

Job function

Job level

Unit of analysis

Please answer the survey questions from the perspective of one particular supply chain instead of for the entire company. It should be a representative supply chain of a major business unit or product group. Please consider the chosen supply chain when answering all questions.

Please name the product of the chosen supply chain.

Part 2: Resilience questions

Question R1

Please choose the three most effective strategies to increase supply chain resilience that have been implemented at your supply chain?

If one of the strategies employed is not in the list, please specify in the last row.

Note: *Resilience* is defined as “the ability to adapt to structural changes and disruptions by modifying supply chain strategies, products, and technologies”.

- Inventory buffers for critical components
- Development of flexible production capacities (internal or external)
- Multi sourcing / diversification of supply base
- Supply chain control tower with end-to-end visibility
- Advanced forecasting methods / Scenario planning
- Product harmonization (shared components across multiple products)
- Supplier audits / stress-tests / business continuity plans
- Strong relationship with network partners (share risks, costs, gains)
- Production relocation and diversification (e.g., regionalization and nearshoring)
- Other, please specify

Question R2

Did the implemented resilience strategies have an impact on the level of sustainability in the supply chain?

	It increased sustainability	It had no effect on sustainability	It decreased sustainability	I don't know
Inventory buffers for critical components	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Development of flexible production capacities (internal or external)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Multi sourcing / diversification of supply base	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Question R3

From your perspective, what are the barriers for your supply chain to become more resilient? Please tick the Top 3 barriers to becoming more resilient.

- High investment costs/ Budget constraints
- Lack of cross-functional teamwork
- Lack of internal buy-in
- Lack of advanced digital capabilities and IT infrastructure
- Product complexity
- Portfolio complexity / Heterogeneity of supply chains
- Lack of data and visibility to measure resilience indicators
- Lack of sub-tier supplier visibility and control
- Geographical dispersion of suppliers
- Limited technological capabilities of supply chain partners
- Primary focus on efficiency and process streamlining
- Other, please specify...

Question R4

Which KPIs does your company use to measure supply chain resilience? Has your company identified targets for these measures? Please name up to three KPIs including the supply chain/corporate target.

Example KPI: *Time-to-Recover*

Example target: *Restore normal operations within 15 days after manufacturing node disruption*

Note: If you do not have any resilience KPIs or targets please write "not applicable"

	KPI / measure	Target
No. 1	<input style="width: 100%; height: 15px;" type="text"/>	<input style="width: 100%; height: 15px;" type="text"/>
No. 2	<input style="width: 100%; height: 15px;" type="text"/>	<input style="width: 100%; height: 15px;" type="text"/>
No. 3	<input style="width: 100%; height: 15px;" type="text"/>	<input style="width: 100%; height: 15px;" type="text"/>

Part 3: Sustainability questions

Question S1

From this list, please choose the three most effective strategies to increase supply chain sustainability that have been implemented at your supply chain.

Note: *Supply chain sustainability* is defined as "application of environmental management principles to the entire set of activities across the whole customer order cycle, including design, procurement, manufacturing and assembly, packaging, logistics, and distribution." (Social aspect of sustainability is excluded)

- Supplier sustainability audits
- Reduce packaging material / design packaging
- Increase efficiency in the use of operational resources. (e.g., recycling and reusing water consumed in operations)
- Tracking of supply chain sustainability indicators (e.g., water usage, hazardous materials, pollution)
- Reduction of CO2 footprint across end-to-end supply chain
- Optimization of the Supply Chain Network to reduce movement of materials and finished goods (e.g., regionalization)
- Engage with suppliers in sustainability programs
- Invest in renewable energy sources and utilize energy efficient technologies
- Adoption of reverse logistics and circular-economy models
- Other, please specify:

Question S2

Did one of the implemented sustainability strategies have an impact on the level of resilience in the supply chain? Please indicate

	It increased the level of resilience	It had no effect on the level of resilience	It decreased the level of resilience	I don't know
Supplier sustainability audits	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Reduce packaging material / design packaging	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Increase efficiency in the use of operational resources. (e.g., recycling and reusing water consumed in operations)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Question S3

From your perspective, what are the barriers for your supply chain to become more sustainable? Please tick the Top 3 barriers to becoming more sustainable.

- Constant supply chain disruptions
- Build-in redundancies and inventory buffers
- Lack of customer demand / lack of willingness to pay premium
- Uncertainty about return on investment
- High investment costs /Budget constraints
- Lack of cross-functional teamwork
- Lack of internal buy-in
- Lack of advanced digital capabilities and IT infrastructure
- Product complexity
- Lack of data and visibility to measure sustainability indicators (e.g., emissions, water usage, waste)
- Limited technological capabilities of supply chain partners
- Other, please specify:

Question S4

Which KPIs does your company use to measure supply chain sustainability? Has your company identified targets for these measures? Please name up to three KPIs including the supply chain/corporate target.

Example KPI: *CO2 emissions*

Example target: *Reduce scope 1-3 CO2 emissions by 50% until 2030*

Note: If you do not have any sustainability KPIs or targets please write "not applicable"

	KPI / measure	Target
No. 1	<input type="text"/>	<input type="text"/>
No. 2	<input type="text"/>	<input type="text"/>
No. 3	<input type="text"/>	<input type="text"/>

C.4 Overview of Data Sample

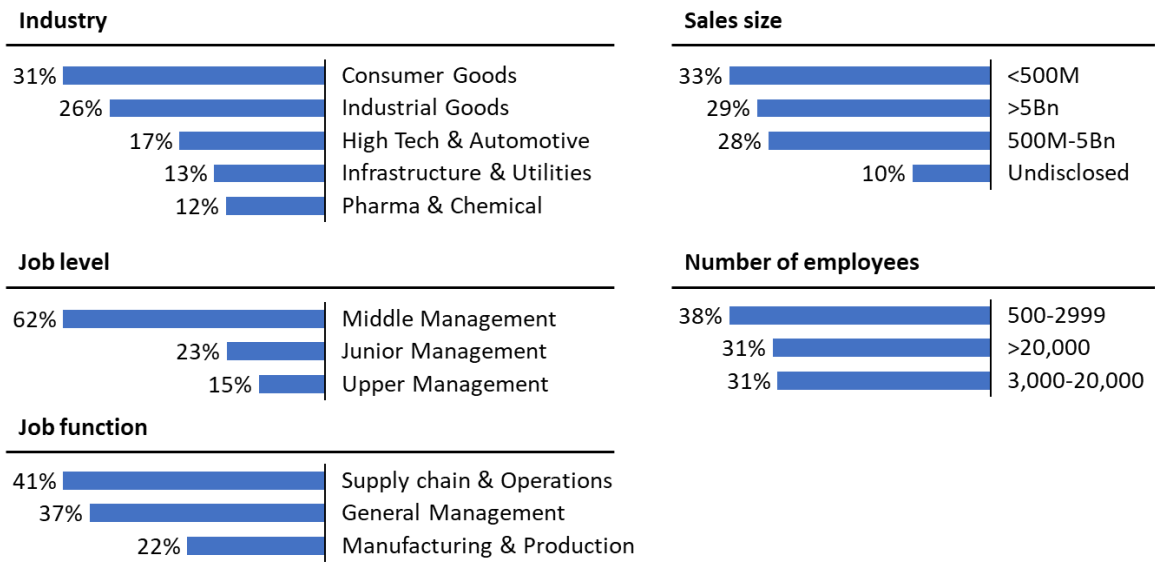


FIGURE C.1: DESCRIPTIVE STATISTICS FOR THE DATA SAMPLE (N=143)

C.5 Overview Results of Statistical Testing

TABLE C.3: STATISTICAL TESTING RESULTS

		Chi-squared test				Cramer's V						
Variable 1 name	Variable 1 characteristics	Variable 2 name	Variable 2 characteristics	χ^2	Df	p-value	Significance level	Df (Cramer's V)	Effect size (Cramer's V)	Lower boundary	Upper boundary	Interpretation of effect size (based on Cohen 1988)
Job level	Junior management, Middle management, Upper management	Ability to describe relationship	Respondents answered 'I Don't know' for question R2 or S2 (Appendix A) at least once vs. never	10.721	2	0.0047	***	1	0.2738	0.0875	0.4275	Small effect
Industry	Automotive & High tech, consumer goods, industrial goods, infrastructure & utilities, pharma & chemicals	Ability to describe relationship	Respondents answered 'I Don't know' for question R2 or S2 (Appendix A) never, 1-2 times, more than 2 times	17.427	8	0.026	**	2	0.2468	0.0000	0.3189	Medium effect
Job function	General Management, Supply chain & Operations	Experience of negative effects	Respondents answered 'It decreased Resilience/Sustainability' for question R2 or S2 (Appendix A) at least	6.9311	1	0.0085	***	1	0.2400	0.0760	0.4039	Small effect
Job function	General Management, Supply chain & Operations	Use of SCORE/SCS metrics	Respondents named at least one SCORE or SCS metric for R4 or S4 vs. no metric	4.0493	1	0.0442	**	1	0.1831	0.0000	0.3470	Small effect
Experience of no effect	Respondents answered 'it had no effect' for question R2 or S2 (Appendix A) at least 4 times vs. less than 4	Use of SCORE/SCS metrics	Respondents named at least one SCORE or SCS metric for R4 or S4 vs. no metric	7.8522	1	0.0051	***	1	0.2560	0.0920	0.4199	Small effect

* = 0.1, ** = 0.05, *** = 0.01

Cross table 1

	No "I don't know"	At least one "I don't know"	
Junior Management	31	7	38
Middle Management	81	3	84
Upper Management	21	0	21
	133	10	143

*Answers to Question R2 or S2

Cross table 2

	0 "I don't know"	1-2 times "I don't know"	3+ times "I don't know"	
Automotive & High tech	24	0	1	25
Consumer goods	38	4	3	45
Industrial goods	36	1	0	37
Infrastructure & Utilities	16	3	0	19
Pharma & Chemicals	11	3	3	17
	125	11	7	143

*Answers to Question R2 or S2

Cross table 3

	No "It decreased SCORE/SCS"*	At least one "It decreased SCORE/SCS"*	
General Management	46	2	48
Supply chain & Operations	73	22	95
	119	24	143

*Answers to Question R2 or S2

Cross table 4

	No Metrics	At least one metrics	
General Management	29	19	48
Supply chain & Operations	39	56	95
	68	75	143

Cross table 5

	0-3* times "It had no effect"	4-6* times "It had no effect"	
No metrics	54	14	68
At least one metrics	72	3	75
	126	17	143

*Answers to Question R2 or S2

TABLE C.4: INTERPRETATION TABLE FOR CRAMER'S V

df	negligible	small	medium	large
1	0 < .10	.10 < .30	.30 < .50	.50 or more
2	0 < .07	.07 < .21	.21 < .35	.35 or more
3	0 < .06	.06 < .17	.17 < .29	.29 or more
4	0 < .05	.05 < .15	.15 < .25	.25 or more
5	0 < .05	.05 < .13	.13 < .22	.22 or more

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