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What Options Do We Have? The Supply Chain Resilience Funnel

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ABSTRACT

Supply chain resilience (SCRes) enables an organization to deal with disruptive changes over time. Previous research has often examined SCRes as a standalone concept, overlooking its multidimensional and complex roots that enable organizations to deal with change. This research integrates SCRes with connectedness and potential. Together, these three dimensions determine the development of organizations in the adaptive cycle, conceptualized in panarchy theory. The research framework developed in this research combines well-known SCRes strategies with the idea of concurrent product, process, and supply chain (PPS) configuration. Analyzing in-depth, empirical data pertaining to 12 disruption processes experienced by seven organizations, this research develops the "supply chain resilience funnel." The funnel depicts how organizations prepare SCRes practices across PPS configurations limited by their specific contextual characteristics (laws and regulations, market developments, business models, and choices). During the response stage, disruption characteristics (scope and scale) further reduce the available options. The SCRes funnel clarifies how an organization's PPS configuration shapes resilience, connectedness, and potential, as well as how these dimensions interrelate to deal with disruptive change over time.

1 | Introduction

During the COVID-19 pandemic, a Danish juice manufacturer switched to the production of hand sanitizer, a German garment producer began producing face masks, and a US carmaker started to manufacture parts for medical ventilators (Wieland 2021; Wieland and Durach 2021). These organizations can be considered resilient as they were able to transform their operations when no other viable option to adapt or persist was available. However, transformation suggests *potential* (i.e., the capacity for change; Holling 2001; Mirzabeiki and Aitken 2023) rather than *resilience*, the opposite to vulnerability (i.e., invulnerability; Holling 2001). As such, focusing on resilience in isolation, as the supply chain management literature has done so far, provides an insufficient understanding of how an organization can deal with disruptive changes over time. At the same time, supply chain management research suggests that the adaptive cycle model is promising for gaining further insights into SCRes (Wieland 2021). The adaptive cycle outlines how a system develops over time determined by resilience, potential, and *connectedness* (i.e., the rigidity or inflexibility in making changes; Holling 2001; Mirzabeiki and Aitken 2023). To better understand the options available to organizations in the face of disruptions, this research investigates how SCRes is connected with the other two adaptive cycle dimensions.

To do so, this research proposes combining the adaptive cycle dimensions, as conceptualized in panarchy theory (Holling 2001), with the conceptual lens of product, process, and supply chain (PPS) configuration (Ellram et al. 2007). PPS configurations help to strategically position organizations and guide subsequent supply chain–related decisions

(Fisher 1997). As such, PPS configurations also shape how organizations prepare for and respond to supply chain disruptions (Cohen et al. 2022) to be resilient. A resilient supply chain achieves operational continuity in times of crises (Azadegan and Dooley 2021; Walker 2020), based on its flexibility, redundancy, visibility, velocity, and collaboration (Tukamuhabwa et al. 2015). Maintaining continuity may require organizations to adapt or even transform their resources and processes (Wieland and Durach 2021). Because different supply chain disruptions call for different PPS configurations (e.g., Dube et al. 2022), studying PPS configurations can offer fresh insights into SCRes.

While prior research has uncovered the link between PPS configurations and SCRes (Browning et al. 2023), connecting PPS with the other two adaptive cycle dimensions (connectedness and potential) also seems worthwhile. To date, research lacks a thorough exploration of all three dimensions within a supply chain management setting, either conceptually or empirically. This research shows how the three dimensions overlap or influence one another, through the PPS configuration. Thus far, relevant dependencies between potential, connectedness, and SCRes are poorly understood and have not been explored. For example, a globally diversified supply base can enhance resilience through redundancy and flexibility, allow for persistence and adaptation during response activities (increase potential), and reduce rigidity (lower connectedness) by creating more preparation and response options for an organization. Finally, this study also addresses recent calls for an extended, holistic view on SCRes that considers "the portfolio of products and services produced and the way in which the supply chain is configured" (Wieland et al. 2023, 2) and extends current thinking "from products to production process or even supply chains [...] with an eye for designing resilience" (Browning et al. 2023, 10). Specifically, the aim is to investigate *how an organization's PPS configuration enables resilience strategies, in preparation for and response to supply chain disruptions*. The answer to this empirical question also inherently elucidates how SCRes relates to connectedness and potential in the adaptive cycle.

Empirically, this research takes a process view (Cloutier and Langley 2020; Grimm et al. 2024) and investigates the general preparation for and specific response to 12 disruptions experienced by seven organizations. Twenty-six in-depth interviews with multiple representatives per organization were conducted. Theoretically, this study combine the idea of a PPS configuration with the adaptive cycle dimensions to examine SCRes and its linkages to connectedness and potential. As the first research to attempt to operationalize all three dimensions through PPS configuration, this study empirically shows how potential, connectedness, and SCRes overlap and influence one another in a supply chain management context. The effectiveness of resilience efforts is found to depend on the connectedness of an organization's supply chain, network, and environment. In turn, the potential for change is determined by the SCRes of an organization. These findings contribute to the understanding of co-dependencies in change over time predicted by the adaptive cycle.

Furthermore, this research introduces the "supply chain resilience funnel", which provides a unifying framework that links the disruption preparation and response stages with SCRes strategies and the socioeconomic environment through PPS. It depicts how during the preparation stage, characteristics of an organization's supply chain and socioeconomic environment (e.g., industry laws and regulations and business choices) reduce the number of available resilience practices enabled through PPS configurations. In the subsequent response stage, prepared practices are funneled further because of disruption characteristics (e.g., short-term vs. long-term). These findings answer calls to develop an in-depth, empirically based understanding of how SCRes can be shaped in different business environments and in response to different disruptions (Kochan and Nowicki 2018; Scholten et al. 2020).

2 | Theoretical Background

The first part of this section introduces the adaptive cycle, which traces change over time based on the three dimensions: resilience, connectedness, and potential. After elaborating SCRes and the PPS perspective in the two subsequent sections, the theoretical framework guiding the empirical exploration of this study is presented.

2.1 | Change Over Time: The Adaptive Cycle

Rooted in ecological and social sciences, the adaptive cycle model depicts change over time (Mirzabeiki and Aitken 2023). In an adaptive cycle, a system moves through four phases from exploitation over conservation and release to reorganization (Holling 2001). The progression of the adaptive cycle is determined by three dimensions: (1) the inherent *potential* of a system for future change; (2) the level of *connectedness* between actors in a system, which relates to the degree of rigidity (as opposed to flexibility); and (3) the invulnerability of the system to unexpected disruptions, as evident in its *resilience* (Holling 2001; Mirzabeiki and Aitken 2023). Systems move from exploitation to conservation, associated with increasing connectedness and lower resilience (Holling and Gunderson 2002), and then shift, through reorganization at low levels of connectedness that increase potential (Wieland 2021), to a release state, comparable to creative destruction (Schumpeter 1942). Thus, the four phases of the adaptive cycle represent change over time, as determined by the three dimensions of resilience, connectedness, and potential.

This adaptive cycle is conceptualized in panarchy theory (Holling 2001), which has recently been proposed as a new theoretical basis for resilience research in the supply chain management context (Wieland 2021). In a panarchy, adaptive cycles take place at nested levels that influence each other, such as the organization, the supply chain, and the socioeconomic environment. This study investigates resilience in combination with connectedness and potential from *an organizational perspective*. Consequently, the focus here is on how both the supply chain and the socioeconomic environment influence resilience at the organizational level, without explicitly investigating larger and smaller panarchy levels or cross-level linkages. In the remainder of this article, the three adaptive cycle dimensions—resilience, potential, and connectedness—are integrated in a research framework to inform findings and theoretical contributions.

2.2 | Supply Chain Resilience

Supply chain disruptions introduce change and require adaptation or transformation of routines (Scholten et al. 2019) due to problems in the flow of products or services to end consumers (Craighead et al. 2007). As outlined earlier, (supply chain) resilience aims to reduce vulnerability by building the adaptive capability to prepare for, respond to, and recover from supply chain disruptions in the most effective and efficient way (Ponomarov and Holcomb 2009; Tukamuhabwa et al. 2015). These efforts require continuous learning and growth (Scholten et al. 2019; Walker 2020). Inherently, SCRes requires a process view (Grimm et al. 2024) that can account for both preparation and response stages.

Being resilient implies being ready for any type of disruption by "persisting" with existing resources and processes, "adapting" resources and processes, or even "transforming" resources and processes into new business directions (Mirzabeiki and Aitken 2023; Wieland et al. 2023). Persistence, adaptation, and transformation indicate the *potential* of the system. Ultimately, resilience allows an organization to derive something positive from the negative impacts of a disruption (Ambulkar et al. 2015). The adaptive capability, which enables the resilience of an organization and its supply chain, in turn determine its survival and its ability to maintain a sustained competitive advantage (Brusset and Teller 2017; Pettit et al. 2010).

To be less vulnerable and more resilient organizations can employ a range of practices to increase their flexibility, velocity, redundancy, visibility, and collaboration (i.e., the most cited SCRes strategies; Sawyerr and Harrison 2019; Tukamuhabwa et al. 2015). Table 1 lists the definitions and some sample practices for each strategy. Rather than measuring resilience as a direct outcome (i.e., invulnerability), investigating the SCRes strategies enables us to explore different practices that contribute to resilience, in the process of preparing for and responding to supply chain disruptions. As noted previously, this article uses PPS configurations (Ellram et al. 2007) to connect SCRes with the other two adaptive cycle dimensions potential and connectedness. The following section outlines the idea of PPS configuration.

2.3 | Product, Process, and Supply Chain Configuration

PPS design elements are interrelated and mutually influential (i.e., three-dimensional concurrent engineering; Ellram et al. 2007; Browning et al. 2023), so they should be considered concurrently. Product design involves determining the technical specifications or functions a product must have to satisfy customer needs (Ellram et al. 2007). It might require modularity (Browning et al. 2023; Jiao et al. 2007) but also reflects product packaging, which can affect customers' perceptions of product value (Azzi et al. 2012). Product design in turn influences process design (Koufteros et al. 2002). For example, through shared modules, an organization can achieve standardization and increase the efficiency of setup, equipment, and routing (Jiao et al. 2007). Process design concerns the methods used to manufacture products. It requires

TABLE 1 | SCRes variables, definitions, and sample practices.

Resilience strategy	Definition	Sample practices (Ali et al. 2017)
Flexibility	"The ease with which a supply chain can change its range number (i.e., the number of possible 'options') and range heterogeneity (i.e., the degree of difference between the 'options') in order to cope with a range of market changes/events" (Jüttner and Maklan 2011, 251).	Flexible supply via multiple suppliers, flexible manufacturing processes or resources, flexible products via postponement, flexible pricing via responsive pricing, flexible transportation modes, flexible order fulfillment strategies
Velocity	"The speed with which a supply chain can react to market changes/events" (Jüttner and Maklan 2011, 251).	Acceleration and responsiveness
Redundancy	"The strategic and selective use of spare capacity and inventory that can be used to cope with disruptions, e.g., spare stocks, multiple suppliers and extra facilities" (Tukamuhabwa et al. 2015, 5602).	Excess capacity in production, transportation, or resources; multiple suppliers; safety stock; strategic inventory; emergency backup/storage facilities; and low-capacity utilization
Visibility	"The extent to which actors within the supply chain have access to or share timely information about supply chain operations, other actors and management which they consider as being key or useful to their operations" (Jüttner and Maklan 2011, 251).	Monitoring performance (key performance indicators metric and measurement), information technologies capabilities, information sharing, transparency through integrated systems, and connectivity
Collaboration	"The level of joint decision making and working together at a tactical, operational, or strategic level between two or more supply chain members. Scalable through the magnitude of relationship strength, quality and closeness" (Jüttner and Maklan 2011, 251).	Collaborative planning, supply chain intelligence, information sharing, coordination, and coopetition with competitors

decisions about manufacturing strategies (e.g., make-to-order and make-to-stock), production facilities (e.g., number, location), and equipment (e.g., general-purpose vs. specialized; Ellram et al. 2007). Product design also influences sourcing considerations and thus the supply chain design (Browning et al. 2023).

The design of the supply chain determines how internal functions interact with other supply chain members, according to choices related to outsourcing, logistical channel configuration (e.g., number and location of warehouses), customer and supplier involvement, and contractual relationships (Ellram et al. 2007). Accordingly, Fisher's (1997) seminal model suggests interrelatedness such that the type of supply chain design (efficient or responsive) needs to align with the organization's processes and capabilities to meet customer requirements, as well as the product type (e.g., functional or innovative).

2.4 | Research Framework

This section integrates the previously discussed literature into a research framework. Following previous arguments, it is likely that a PPS configuration can provide insights into the three adaptive cycle dimensions *resilience*, *connectedness*, and *potential*. Specifically, a PPS configuration can enable all SCRes strategies (flexibility, velocity, redundancy, visibility, and collaboration) that support an organization's ability to prepare for and respond to supply chain disruption to be *resilient*. Furthermore, a PPS configuration might provide insights into *connectedness*, in terms of how rigid a PPS configuration is when change is required (e.g., How easy is it to replace a specific component of a product? Are multiple suppliers available, without loss of quality or speed?). The *potential* might relate to the level of change that a PPS configuration can support (persistence, adaptation, or transformation) in reaction to disruptions. While this paper studies SCRes primarily from an organizational perspective, the PPS approach inherently considers influences of the supply chain. Accordingly, this research empirically investigates how organizations configure PPS to foster resilience practices in preparation for and response to supply chain disruptions, while considering how resilience relates to connectedness and potential.

3 | Methodology

With a multiple case study approach, this research investigates seven organizations and 12 supply chain disruptions (i.e., embedded unit of analysis) in the organizations' main product category. Using case study methods allows to provide causal explanations for how a PPS configuration links to SCRes practices within organizations and throughout their supply chains when disruptions occur. The authors' critical realist philosophical stance assumes ontological realism (i.e., the social world is an open system of events, structures, and mechanisms that can be experienced only in parts) (Bhaskar 1978; Wynn and Williams 2012). Furthermore, critical realism is associated with the unique epistemological assumption, that knowledge of reality is based on ontological realism influenced by socially produced personal experiences (Archer and Bhaskar 1998; Easton 2010; Eriksson and Engström 2021).

3.1 | Case Environment and Case Selection

The food and beverage, retail, automotive, electronics, and chemical industries were targeted as being prone to disruptions and featuring varying levels of product complexity (e.g., component variety and volume; Jacobs and Swink 2011). This element of product design also influences supply chain design (e.g., Novak and Eppinger 2000). In the retail industry, customers strongly influence product variety; the automotive and electronics industries feature substantial component variety; and the chemical and food industries include notable component volume. Within these industries, seven global organizations were chosen, each generating annual revenues of €500 million to €14.8 billion. The selection process sought literal and theoretical case replication (Yin 2009), relative to one another in terms of product complexity, as determined by component volume and variety (Table 2). That is, both different and similar insights are expected from these selected cases (Yin 2009). Table 2 provides detailed information about these cases (beyond the case selection criteria).

3.2 | Data Collection

Twenty-six semi-structured interviews were conducted across the seven organizations. All interviews started with general questions about the organization and its strategy, products, supply chain design, industry characteristics, and about the organization's preparedness for any supply chain disruptions. Then the core part of the interview focused on the management of one or two actual disruptions that affected the organizations main product category in the last year. Interviewees were prompted to describe the timeline of events, who participated, what actions were taken (and why), and how their preparedness influenced the response to the disruption. In addition, interviewees were asked for a detailed overview of the response practices adopted and a reflection about what worked and what did not, including specific aspects that helped or hindered recovery. Following each respondent's answers, individual- and situation-specific follow-up questions were posed, to ensure that the interviewers could grasp the situations in their entirety.

Within each organization, three to four interviews were conducted with knowledgeable employees in different departments and at different managerial levels, seeking triangulation and insights from various perspectives. As the list of interviewees and their positions in Table 2 reveals (Yin 2009), each respondent was involved in and able to reflect on the same disruption(s) from different perspectives. Thus, the risk that the gathered insights are idiosyncratic to individual sources was avoided, while also obtaining thick descriptions of how the situations unfolded (Cornelissen 2017; Lincoln and Guba 1985). All interviews were conducted by two researchers in November 2021; mostly online, due to restrictions surrounding the COVID-19 pandemic. They lasted on average 69 min.

TABLE 2 | Case and data collection overview.

Case	Primary industry	Product value	Pricing strategy	Process design	Supply chain length/position	Component variety	Component volume	Interviews		
								Interviewee	*Position*	*Length*
A	Food and beverage	€ .XX	Commodity	MTS	Short/middle	Low	High	A1	Global logistics director	80 min
								A2	Sales manager export	73 min
								A3	Product logistics manager	55 min
								A4	Customer service manager	83 min
B	Food or chemical	€ .0X	Commodity/ premium	MTS	Very short/ towards beginning	Low	High	B1	Supply chain manager	89 min
								B2	S&OP planner	65 min
								B3	Sales manager	75 min
								B4	Tactical buyer	68 min
C	Retail	€ XX	Commodity	PTO	Medium/end	Medium	Medium	C1	Supply director	59 min
								C2	Logistics manager	52 min
								C3	Head of procurement	55 min
								C4	Head supply and inventory planning	55 min
D	Vehicle	€ XXXXX	Premium	MTO	Long/end	Very High	Medium	D1	Head of operations	58 min
								D2	Purchasing manager	43 min
								D3	Head of logistics	59 min
E	Bio-chemical	€ .X	Commodity/ premium	MTS	Short/towards beginning	Low	High	E1	VP integrated business planning	83 min
								E2	Director S&OP	88 min
								E3	Senior VP operations	69 min

(Continues)

TABLE 2 | (Continued)

Case	Primary industry	Product value	Pricing strategy	Process design	Supply chain length/position	Component variety	Component volume	Interviews		
								Interviewee	*Position*	*Length*
F	Electronics	€ XXXX	Premium	ATO	Medium/ towards end	High	Medium	F1	Senior supply chain manager	71 min
								F2	Key account manager	81 min
								F3	Senior supplier quality manager	57 min
								F4	Supply chain optimization manager	70 min
G	Food and Beverage	€ X	Commodity/ premium	MTS	Short/middle	Low	Medium	G1	Business unit director	70 min
								G2	Head of procurement	82 min
								G3	Supply chain manager	74 min
								G4	Supply chain and planning manager	73 min

3.3 | Data Analysis

After reducing the interview data to relevant sentences and paragraphs (Miles and Huberman 1994), the data were deductively coded for resilience practices and five associated resilience strategies (flexibility, velocity, redundancy, visibility, and collaboration; Table 1) that the organizations applied in preparation for or response to the discussed disruptions. In addition, it was explicitly investigated whether the preparation and response strategies related to the product, process, or supply chain. Juxtaposing resilience practices and strategies with the PPS configurations provided an overview of what was done (i.e., resilience practices and strategies), when (i.e., in preparation or response to a disruption), and in relation to what (i.e., product, process, or supply chain) (see Table 3 in Findings). In line with Scholten and Schilder (2015), who found that collaboration is an antecedent of other resilience strategies, the quotes coded for collaboration in this research were consistently also coded for one of the other SCRes strategies. Accordingly, collaboration was treated as inherent to the other SCRes strategies rather than as a separate code in the rest of the analysis, which then focused on flexibility, velocity, redundancy, and visibility.

Next, the analysis focused on the identification of patterns that link SCRes practices to the PPS configuration across cases (see Tables 3 and 4 in Findings). However, regardless of how the data was sorted or displayed, it was not possible to identify clear patterns using deductive reasoning (e.g., considering product complexity) or inductive logics (e.g., different industries and environments). Therefore, the analysis shifted to an abductive approach, in order to understand what makes each case unique and why patterns could not be discovered. Using large tables, columns, rows, and content were continually rearranged, which allowed to dissect the data in new ways and uncover explanations. This process led to the realization that socioeconomic environment characteristics affect the availability of resilience practices across PPS configurations in preparation for and response to supply chain disruptions.

More specifically, the availability of resilience practices and strategies across PPS configuration in preparation are influenced by larger level laws and regulations, market developments and conditions, and business models and choices. They were labeled as *contextual characteristics* and stem from larger (panarchy) levels that create surrounding but nested circumstances for smaller levels. Furthermore, *disruption characteristics* further reduce the range of resilience practice options that an organization can employ in response to be resilient in response: scope (i.e., short vs. long-term) and scale (i.e., local vs. global) of a disruption. On the basis of these insights, the analysis evolved, and shifted to seeking explanations for each organization's PPS configuration, linked to the specific contextual and disruption characteristics. Thus, inherently the unit of analysis switched from an organizational-level perspective for the preparation stage of a disruption to the supply chain disruption level for the response stage. A major advantage of qualitative case study research is its ability to include multiple levels of analysis (Bansal and Corley 2011). Appendices A and B contain some coding excerpts for the preparation and response stages, respectively.

Following the idea of linear theorizing where contingencies affect processes (i.e., disruption processes), at each stage and across stages (Cloutier and Langley 2020), explanations from the adaptive cycle were pursued. This led to the realization that the organization's contextual characteristics, together with the characteristics of the disruption, create unique SCRes funnels for each organization and situation. That is, the total range of all possible SCRes practice options, in terms of a PPS configuration, is reduced by contextual characteristics, which become evident during preparation for a supply chain disruption. These options shrink further as the disruption, with its unique characteristics, takes place. The funnel analogy (see also Slack et al. 2010, 121) meets the relevance criterion for analogies (Gruner and Power 2023), in that it provides a simple, clear visualization of the findings.

All the data were analyzed by two researchers; the results were discussed with the whole research team. If any different interpretations arose, the team engaged in discussion until it reached consensus, which ensures consistency. More generally, the quality criteria for the design of the case studies, case selection, and data collection and analysis were followed, as is suitable for critical realists (Bille and Hendriksen 2023), with a primary focus on trustworthiness (Guba and Lincoln 2005). For a detailed overview of applied strategies that guarded the study's trustworthiness, in terms of credibility, transferability, dependability, and confirmability following the examples of Selviaridis and Spring (2022) and Russo et al. (2021), see Appendix C.

4 | Findings

This section begins with examining the influence of contextual characteristics on SCRes practices in the preparation stage. Following, the influence of disruptions characteristics on remaining SCRes practice option is presented. Corresponding overviews are provided in Tables 3 and 4. In the final part of this section, the findings of the preparation and response stages are integrated into the SCRes funnel, depicted in Figure 1.

4.1 | Preparation Stage

In preparation for disruptions, the data show that organizations use just a few options to build resilience practices through product and process design (also evident in Table 3). In particular, the products in Cases B, D, E, F, and G were designed to support modularity, substitutability, or commonality, so the organizations could apply postponement in their process design or reassign components to different products. The data show that some aspects of product design provided flexibility in preparation for disruptions; process design, by decoupling decisions, appeared more relevant for determining the amount of flexibility versus redundancy, as well as the pace of flexibility (i.e., velocity). The limited examples across product and process resilience practices contrast with many practices in supply chain design to prepare for disruptions. The emphasis on supply chain–focused preparedness practices, instead of process and product practices, likely stems from contextual characteristics such as laws and regulations, market

TABLE 3 | Findings: PPS configurations in the preparation stage.

	Resilience practices (resilience strategy)		
Case	***Product***	***Process***	***Supply chain***
A		• Make to order (flexibility) • Spare capacity (redundancy) • Long production lead time ➔ schedule can be adjusted (flexibility)	• Dual sourcing: 80–20 (redundancy and flexibility) • Distributors maintain safety stock (redundancy) • Forecast and scenario sharing with suppliers (visibility) • Sharing contracts across sides (flexibility) • Suppliers keep stock for main ingredients (flexibility, visibility, and redundancy) • Suppliers located close to factories if possible (flexibility and velocity) • Use of third-party sales data (visibility)
B	Commonality and substitutability in components (flexibility)	• Make to order/make to stock (markets with decentralized warehouses) (redundancy and flexibility) • Postponement (flexibility) • Renting warehouse space (flexibility)	• Decentralized stocks (redundancy, flexibility, and velocity) • Rented, decentralized warehouses (flexibility) • Multiple sourcing from different positions in the value chain (redundancy and flexibility) • Preferred customer status (velocity) • Forecast sharing with suppliers/from customers (visibility) • Early warning systems with suppliers (visibility and velocity) • Diversified customer base (redundancy and flexibility)
C		• Outsourced manufacturing (flexibility) • B2B centralized, e-com decentralized (flexibility and velocity) • Point of sale = mini-warehouse (redundancy and velocity)	• Dual or triple sourcing (redundancy) • Spare production capacity suppliers (redundancy) • Different product mixes for suppliers (flexibility) • Purchase volumes are set within a certain range of supplier turnover (flexibility and velocity) • Suppliers maintain safety stock (redundancy) • Monthly forecast sharing with suppliers for upcoming year (visibility) • (Indirect) involvement with all upstream suppliers (visibility, velocity, flexibility, and velocity) • 98% sourcing from Europe (velocity) • Spare capacity warehousing (redundancy)

(Continues)

TABLE 3 | (Continued)

Case	Resilience practices (resilience strategy)		
	Product	***Process***	***Supply chain***
D	Modularity and commonality in components (flexibility)	• Assemble-to-order (flexibility and redundancy) • Just-in-time production (flexibility) • Certain parts can be retrofitted (flexibility)	• Multiple sourcing (redundancy and flexibility) • Suppliers maintain safety stock (redundancy) • Forecast sharing with suppliers (visibility) • (Indirect) involvement with second tier suppliers (visibility and velocity) • Early warning systems with suppliers (visibility and velocity) • Quality checks (visibility)
E	Commonality in products (flexibility)	• Make to stock (redundancy) • Postponement (flexibility) • Geographical diversification of production locations (flexibility) • Spare capacity (redundancy)	• Multiple sourcing (redundancy) • Forecast sharing with suppliers and from customers (visibility) • Decentralized intermediate stocks (redundancy and flexibility)
F	Modularity/commonality in components (flexibility)	• Assemble to stock for local market, assemble-to-order for exports (flexibility) • Just-in-time production (flexibility) • Produce same product in several locations (flexibility and redundancy) • Production throughput low (redundancy and velocity) • Organized centrally across several plants (flexibility and visibility)	• Multiple sourcing for key components (redundancy and flexibility) • Preferred customer status (velocity) • Suppliers share inventory if needed (flexibility) • Long-term forecast sharing with suppliers (visibility) • (Indirect) involvement with second tier suppliers (visibility and velocity) • Early warning systems with suppliers (visibility and velocity) • Quality checks (visibility) • Sharing supplier contracts across manufacturing sites (flexibility) • Suppliers maintain safety stock (redundancy)
G	Modularity/commonality in products (flexibility)	• 50% make to order (flexibility), 50% make to stock (redundancy) • Just-in-time production due to lack of storage capacity for raw material and finished products (flexibility) • Track and trace technology (visibility)	• Multiple sourcing for key components (redundancy and flexibility) • Use of a shipping broker (flexibility) • Suppliers maintain safety stock (redundancy) • Distributors keep finished product stocks (redundancy) • Customer prioritization (visibility) • Forecast sharing with suppliers/from customers (visibility)

developments and conditions, and business models and choices. As Appendix A indicates, contextual characteristics reduce available resilience practices at the organization level, specifically in product and process design, but less on the supply chain level.

In particular, contextual characteristics determined by the socioeconomic environment (i.e., laws, regulations, market developments, and market conditions) reduce design options that enable flexibility, so organizations instead must look for redundancy. The data show that laws and regulations affect all organizations' ability to configure PPS to enable SCRes practices. For example, Cases A, B, E, and G, in the food industry, confront strict regulations regarding hygiene in their process and supply chain design (cf. shelf life, which is not a concern), such that

> From a regulation standpoint, [the product] is globally approved in all kind of food ingredients and applications in pharma. But it's regulated, so it means it needs to fulfill certain specifications.
>
> (E4)

Furthermore, it was noted that market developments and conditions relate to on-shelf availability in Cases A and G; the use of natural products in Cases B, E, and G; the component amount and value in Case D; market growth in Case E; and market maturity in Cases F and G. All these considerations reduce the available options to be flexible in terms of product and process design. As a specific example, Case D in the automotive industry, known for its complex PPS configurations, acknowledges that "normally in the automotive industry there are no large stocks because also chips are quite expensive ... and working capital is at stake when we buy a lot of parts" (D3). As dictated by these market conditions, Case D operates on a just-in-time basis and maintains little on-site stock (i.e., process design). In turn, this situation requires more flexibility in the design of the supply chain, because suppliers must react to Case D's needs promptly during high-volume periods.

Laws and regulations and market developments and conditions are socioeconomic characteristics; business models and choices instead are made by an organization but also position the organization within a certain socioeconomic environment. Such positioning again creates contextual characteristics that influence the availability of PPS configurations to prepare for disruptions. For example, Case B markets a premium product to a specific market segment of customers who are willing to pay a higher price, in return for confidence that their expectations will be met. Consequently, Case B keeps extra inventory as a premium service:

> If the customer requires a certain activity or a certain service, then we usually provide it, or at least we try to provide it.
>
> (B1)

> Sometimes we are the warehouse for them [customers]. ... Then we are storing it for them and they can pick it up and start producing so that their storage space is not necessary.
>
> (B3)

Overall, it appears that contextual characteristics particularly affect flexibility of product and process design, which the organizations counter by establishing redundancy. For example, the time of year and weather determine harvest quality (business conditions), so prices can fluctuate significantly, as in Case G: "If [raw material] is very cheap, it's €40, but when it's very expensive [due to seasonality], it's €600 per ton" (G2). The company thus needs redundancy to counter the effects of price fluctuations. Organizations also appear to have more supply chain options, because contextual characteristics have less influence beyond their own internal operations. Appendix A provides further evidence.

4.2 | Response Stage

Three outcomes are identified that show how PPS configurations enable organizations to respond to disruptions. First, organizations apply preparation practices to the greatest extent possible. Second, the contextual characteristics that initially influenced preparation resilience practices also limit response options. Third, response practices are influenced by the scope (short- vs. long-term) and scale (local vs. global) of the disruption. That is, shorter-term and/or localized disruptions that largely can be addressed by redundancy preparedness practices (Disruptions EII and FI) enable persistence. In contrast, longer-term and global disruptions require additional resilience practices, to address supply deficiencies (disruptions AI, AII, BI, BII, DI, FII, and GI) or increased demand (disruptions CI and EI) and thereby seize market share opportunities. Such practices often go beyond persistence and require adaptability, through flexibility. The response practices are listed in Table 4; Appendix B provides example practices, reflecting the interviewees' responses.

4.2.1 | Shorter-Term and/or Localized Disruptions

The data show that responses to shorter-term and/or localized disruptions often can be addressed by preparedness practices that enable redundancy across PPS configurations. Also, some limited additional, mainly supply chain practices, support visibility and velocity. Disruptions EII and FI belong to this category. When the *Evergreen* became stuck in the Suez Canal, it made global news headlines. However, for Case E, the disruption had only minor implications, "roughly in the end a three-week delay" (E1), without causing any stock outs. It thus was able to mitigate the impact and persist with its preparedness practices, especially its safety stock (i.e., redundancy). This response was possible because the event was relatively short in duration, as well as localized. Thus, Case E could draw on its relationship with freight forwarders to "get input and the overview of what ships were where and how much material was on there" (E2), such that the situation became transparent (i.e., visibility).

Although disruption FI lasted longer (approximately 4 weeks), it was specific to one product and thus localized to a particular supply chain. It involved quality issues for a main component produced by a second-tier supplier: "So, in France, UK, Turkey, Netherlands, Portugal, Germany, we closed down production lines because we had a quality issue with this [product]. One

TABLE 4 | Findings: PPS configurations in the response stage.

Disruption case	Disruption characteristics influencing the response stage		Reason for disruption	Resilience practices in response beyond preparation practices		
	Scope	Scale		*Product*	*Process*	*Supply chain*
EII	Short-term (<1 month)	Relatively localized	Suez Canal	—	—	• Segmenting customers (velocity) • Preparing scenarios (visibility, velocity)
FI	Short-term (<1 month)	Product specific	Quality issue in main component (second tier suppliers)	—	—	• Blocking all finished goods stock (visibility) • Reviewing stock allocation to customers (visibility)
BI	Medium-term (>1 month, <1 year,)	Global supply shortage	Shortage in support material (pallets)	Changing specifications (flexibility and velocity)	Recycling of pallets (10%) (velocity and flexibility)	—
AI	Long-term (>1 year)	Global supply shortage	Shortage in support material (packaging)	• Using blank carton (flexibility and velocity) • Simplifying packaging (flexibility and velocity)	Increasing safety stock (redundancy)	- Adding suppliers (redundancy) - Extending forecast sharing with suppliers (visibility)
GI	Long-term (>1 year)	Global supply shortage	Shortage in support material (packaging)	Discontinuing of tail products (flexibility)	• Planning production based on can availability (flexibility, redundancy) • Prioritizing A-brand production (flexibility)	Integrating capacity planning with suppliers (visibility)
DI	Long-term (>1 year)	Global supply shortage	Shortage in components (semiconductors)	• Simplifying features (saved 30%–40% on semiconductors) (flexibility) • Offering product options without certain features requiring semiconductors (flexibility)	• Reducing production tax (flexibility) • Planning production based on the availability of semiconductors (visibility) • Creating an "extra organization" to deal with this issue (visibility, redundancy)	• Changing transportation mode when needed (velocity, flexibility) • Making spot purchases on the market (velocity)
FII	Long-term (>1 year)	Global supply shortage	Shortage in components (semiconductors)	—	—	Making spot purchases on the market (*turned out to be fake)* (velocity)

(Continues)

TABLE 4 | (Continued)

Disruption case	Disruption characteristics influencing the response stage		Reason for disruption	Resilience practices in response beyond preparation practices		
	Scope	Scale		*Product*	*Process*	*Supply chain*
AII	Long-term (>1 year)	Global supply shortage	Limited freight capacity	—	Placing un-palletized goods in containers (flexibility)	• Paying higher freight costs (branding) (velocity) • Diversifying suppliers as much as possible (flexibility, velocity) • Sending orders earlier to suppliers (redundancy)
BII	Long-term (>1 year)	Global supply shortage	Limited freight capacity	—	• Including procurement in sales and operations planning (visibility and velocity) • Increasing safety stocks (redundancy) • Supplying only forecasted demand (visibility) • Re-allocating tasks (flexibility and visibility)	• Flexible pricing (velocity, flexibility) • Indirect deliveries for all customers with local warehouses (velocity) • Switching transportation mode (customer pays) (velocity) • Receiving orders earlier from customers (redundancy)
GII	Long-term (>1 year)	Global supply shortage	Limited freight capacity	—	Planning production based on available transportation capacities (flexibility)	• Increasing supplier and distributor safety stocks (redundancy) • Passing on higher pricing to customers (velocity) • Rerouting (flexibility)
CI	Long-term (>1 year)	Global increase in demand	Demand increase	—	• Maximizing warehouse capacity (redundancy) • Changing asset purposes (possible due to lock down) (flexibility, velocity) • Change duties of workforce (flexibility, velocity) • Investing to double warehouse capacity earlier than anticipated (flexibility, redundancy)	• Increasing safety stocks (redundancy) • Moving to a multi-carrier strategy (flexibility, redundancy) • Changing sales channels (flexibility) • Renting additional storage (flexibility, velocity)

(Continues)

TABLE 4 | (Continued)

Disruption case	Disruption characteristics influencing the response stage		Reason for disruption	Resilience practices in response beyond preparation practices		
	Scope	Scale		*Product*	*Process*	*Supply chain*
EI	Long-term (>1 year)	Global increase in demand	Demand increase	—	• Outsourcing some manufacturing (velocity) • Implementing a new planning system, structure, and horizons (visibility) • Increasing decentralized intermediate product safety stock (redundancy and flexibility)	Delaying customer orders (redundancy)

part stops a lot of production lines" (F3). The SCRes practices all linked to the supply chain and persistence; laws and regulations made it impossible for Case F to identify alternative product or process designs that would support adaptability on short notice. Case F used secondary supply sources to cover some of the shortcomings, but it also moved the component stock among plants.

> We had 30,000 parts in [another] plant. We immediately shipped a lot of these alternative parts to all the other plants so they could start up production very fast within a couple of days. ... We immediately asked the second source to speed up and to scale up the production.
>
> (F3)

Case F thus was able to resolve the backlog of customer orders within 3 months.

4.2.2 | Longer-Term and Global Disruptions

Responses to longer-term and global disruptions require resilience practices beyond persistence based on redundancy. They generally need adaptability achieved through flexibility. The diverse response resilience practices in this category range from multiple SCRes practices across PPS configurations (Disruptions AI, BI, DI, and GI) to no action because adaptability was not possible (Disruption FII). Many of these disruptions reflect the effects of COVID-19, such that they represent low-probability events. The differences in the responses appear to reflect the organizations' contextual characteristics. The also show clear differences between global supply shortages (Disruptions AI, AII, BII, DI, FII, GI, and GII), which create the threat of losing customers, and global increases in demand (Disruptions CI and EI), which represent opportunities to gain new customers. Shortages, in (1) support material, (2) components, and (3) freight capability, as well as (4) increased demand, are addressed hereafter.

First, when faced with Disruptions BI, AI, and GI, the affected organizations suffered from insufficient support material and responded by modifying their product design, in a sense. That is, they did not change the products directly but rather adjusted the packaging and transportation support material for them. Disruption BI involved a pallet shortage, due to the global scarcity of wood, with an estimated time horizon of up to a year. On the basis of forecasts shared by suppliers that provided visibility, Case B recognized the risk of a possible shortage of 5000 pallets in the upcoming 3 months. In response, it turned to its three main suppliers and adjusted volumes as much as possible, such that

> If one supplier could not manage pallets, then we would ask another supplier. So, we shifted some volumes between the three suppliers.
>
> (B1)

> ... it was hard to get enough wood [for the supplier] to make the pallet, the supplier asked to check whether

> it's possible to change the specifications [of the pallet] .... We changed the specification so we can buy other pallets, which we did not buy before.
>
> (B2)

Ultimately, the organization never experienced a pallet shortage, due to its design flexibility and extensive, thorough preparedness practices (close collaboration and preferred customer status), which supported for the necessary adaptability in the situation. Nevertheless, "the disruption was there and our suppliers did have to say no to other customers, but we had everything in place" (B4). In contrast, the price increase of wood over a longer-term, with no foreseeable end, represented an ongoing disruption that prompted Case B to look for additional adaptability in processes and thereby discover that "10% [of pallets] can be reused" (B2).

In disruption AI, the supplier of 80% of Case A's shelf-ready packaging material was struggling with a global increase in demand for cardboard, with an estimated duration of one and a half years, so "Although we have in the contract that there is a certain margin to increase [volumes], they [supplier] were still not able to deliver ... tomorrow" (A1). The second supplier, which accounted for 20% of A's supply, could not adapt to the increased needs, nor did scouting new suppliers seem to be an option, because "getting them up to speed will also take four to five weeks, at least" (A1). Without a ready supply chain solution, Case A adapted internally by redesigning its product packaging: Instead of four, it included three colors, which doubled production capacity for the current supplier, which could apply the three colors in a single production run. Fortunately for Case A, "if I show you the example of three-color combinations vs. four-color combination, you won't see the difference" (A1). This adjustment explicitly avoided altering the company's well-known image among consumers. Nevertheless, before it could achieve this solution, Case A had to use unprinted cardboard boxes for two, maybe 3 weeks, with the reasoning that "missing your branding in the shop" (A4) would be better than having no product on shelves at all. Case A further responded by increasing its safety stock; extending forecast/order horizons; and scouting for additional suppliers, beyond local sources.

Finally, in GI, the market ran short on capacity for can production. However, G had a strategic advantage over its competition as it had dual sourcing with a priority status at one of the suppliers due to a just-in-time partnership. Furthermore, Case G strategically adapted its product portfolio design and seized this moment to "skip some quite complex products with the primary and secondary packaging" (G1) and thus "stop production of some of our tail items in the portfolio" (G4). Furthermore, it applied brand prioritization and integrated can availability into its production plan, while also including the can suppliers in its capacity planning.

Second, Cases D and F did not receive promised amounts of critical components from their suppliers in disruptions DI and FII. To deal with the component shortages, they both engaged in spot buying on the open market to avoid (further) production stoppages, while acknowledging the risk of doing so. For D2,

> The big question, especially with broker parts, is that you do not know the quality. You could for example get 1000 pieces, but if 30% is not meeting our quality standards, we can only calculate with 700 parts.

That risk materialized for Case F when "a very expensive purchase from a broker turned out to be fakes" (F4). Unfortunately, spot buying was the only feasible response strategy for Case F, which lacked an alternative source, such that even if an "alternative could work, it's not available. There are simply not enough parts in the world for all industries at the moment" (F4). Consequently, production lines for certain products stopped for months, resulting in a revenue loss of €6–10 million.

Due to the effects of the global shortage, Case D instead reconceived of its production-process strategy, shifting from an assemble-to-order strategy to assembling whatever was available, in terms of supply. It also adapted and deployed some other response strategies that helped it mitigate the "10–15% output loss roughly" (D2). For example, Case D switched from ocean to air freight to receive supplies; though it represented a more expensive shipping option, it was still less expensive than halting production. When it could not draw any further on the supply chain, due to the global scale of the disruption, Case D also changed its product design and "save[d] around 30 to 40% of semiconductors used" (D2), by leveraging its knowledge of product design regulations. Specifically, certain features were not required by law, so by simplifying the design, it could gain additional redundancy.

Third, Disruptions AII, BII, and GII all involved global freight capacity, which was so severely limited that none of the organizations' preparedness SCRes practices could completely mitigate the impact. In precise terms, "In deep-sea shipment, the reliability of container availability is normally 80%, but at the moment the reliability is about 20–25%" (G3). These constraints also increased prices: "importing a container from Asia is now 10 times more expensive than three years ago" (B1). Nor was there much to be done through supply chain design, given the global, cross-industry scale of freight shortages.

Although Case G already had begun working with a broker to increase its flexibility, the global scale of the shortage left it exposed to sharp price increases. Yet,

> if there aren't any products with our brands in Australia, the consumers will stop consuming [Brand Name], or [Brand Name], or another brand, and they will forget the brands. So, it's cannibalizing your brand equity and that's a big problem, of course
>
> . (G1)

Similarly, Case A tolerated zero-margin sales to ensure the on-shelf availability of its products, but even with this adjustment, it still suffered out-of-stocks in some markets. Case B enjoyed a relatively comfortable position, due to its industry characteristics, such that "we have a lot of safety stocks; we are not an

automotive producer that is producing everything just-in-time" (B1). Still, Case B adapted its process, such as by adding purchasing to the sales and operations planning (S&OP) cycle, suppling only forecasted demand, and reallocating tasks locally to ensure better visibility.

In contrast, Case G had to reduce its production volumes because it lacked warehousing capacity for finished products, and "We were seeing our warehouse filling up to such an extent that it really impacted our production. We needed to scale down production." (G4). Finally, Case A changed its process design to deal with the freight capacity shortage, such as by putting

> un-palletized goods into the container manually. We could fill up the containers with twice as much. The disadvantage is that once you take the goods into the country, you have to palletize them again. We were paying €300 for that [un- and re-palletizing] vs. having twice as much in a container, so the trade-off has easily been made.
>
> (A1)

Although Cases A and G experimented with alternative transport routes (e.g., train from China), neither organization found such experiments viable. Rerouting shipments via Antwerp or Barcelona provided some additional flexibility for Case G. Further supply chain related response practices can be found in Table 4.

Fourth and finally, to deal with increased demand, Cases C and E avoided product design options and instead embraced different process and supply chain design responses. Case E adapted its process to increase visibility:

> We did not have a global supply chain setup. But I mean this whole end-to-end discussion from raw material to customer supply, that was actually vulnerability in our organization.
>
> (E2)

In such visibility efforts, Case E created a new global supply chain department and invested in its S&OP, particularly scenario planning. Before COVID-19, Case E had a capacity use rate of 80%, but the massive production increase it undertook required it to keep closer track of available capacities. With the new planning structure and tool, Case E could attain "visibility of unconstrained demand, and … have visibility of the constraint demand, which is allocated" (E2). Such increased visibility also helped Case E decide whether to outsource some manufacturing, "because we then knew we couldn't make it all ourselves" (E2).

Case C already had outsourced all its manufacturing; it leveraged the flexibility designed into its supply chain in preparation to "triple our output, our outbound" (C3). At the same time, Case C also examined its processes to create further flexibility, which it needed to seize the opportunities created by the demand increase. For example, it transformed shops and outlets temporarily into warehouses to store additional stock when COVID-19 forced store closures:

> We had the situation where stores, you know, did not have any customers' insight, but we did have stock. We did have personnel that we were paying, and we had the functionality ready for click and collect to ship from store.
>
> (C1)

Thus, Case C created additional flexibility and velocity through supply chain design by using alternative transport options and changing the roles of sales staff (i.e., process design). In a practical example, "We bought bikes. And the staff in the stores, instead of handing it over to customers, went on their bike and drove across Amsterdam to bring packages" (C4). In terms of transport, Case C created extra capacity (redundancy) to manage its increased product volume by switching to a multiple sourcing strategy.

4.3 | PPS Configurations Across the Disruption Process

From a disruption process perspective, the findings reveal that organizations plan different SCRes practices across PPS to prepare for possible disruptions, with a primary focus on the supply chain (evident in Table 3). Yet, organizations are not completely free in their PPS configuration, due to contextual characteristics that reduce the available SCRes practice options, particularly those related to flexibility (see Appendix A). As a result, available resilience practices are filtered and organizations can only implement a reduced set of SCRes practices across PPS during the preparation stage. Their resilience options get limited even further in the response stage, depending on the disruption's scope and scale (see Table 4 and Appendix B). Figure 1 provides a visual representation of how resilience practice options are reduced in each disruption stage. It depicts different emerging disruption processes as funnels that represent the availability of resilience practice options across the entire process, as limited by contextual and disruption characteristics.

Specifically, Figure 1 Panel α shows the SCRes funnel for *short-term localized* disruptions, as experienced by Cases E and F. In Disruptions EII and FI, resilience practices enabling flexibility were secondary to the availability of redundancy, which allowed both organizations to persist and survive the short-term disruptions. Thus, findings show that for short-term disruptions, the amount of available resilience practices and possible PPS configuration linked to environmental characteristics have less importance, because redundancy practices (illustrated by the bold font for the word redundancy in Figure 1 Panel α) are used as the main SCRes strategy.

Panels β and χ refer to *long-term and global* disruptions, which require additional measures, because these disruptions last beyond the level of available redundancies. Adaptation is observed through resilience practices, aimed at flexibility during the response stage, though the resilience practice options remain

subject to the environmental characteristics observed in the preparation stage. In cases marked by very influential contextual characteristics, such as for Case F in response to FII, resilience options, particularly those enabling flexibility, are substantially reduced already in the preparation stage, then even further limited by the long-term global disruption, leading to a very narrow resilience funnel (Panel χ). That does not mean there are no flexibility practices available to organizations at all, but that there are clearly less options (illustrated though a reduced font size of the word flexibility in Figure 1 Panel χ).

If contextual characteristics exert weaker influences as in Case C in response to CI, varied resilience practice options appear in the wider resilience funnel with an emphasize on flexibility (illustrated through bold font of the word flexibility in Figure 1 Panel β). Overall, it appears that short-term disruptions tend to

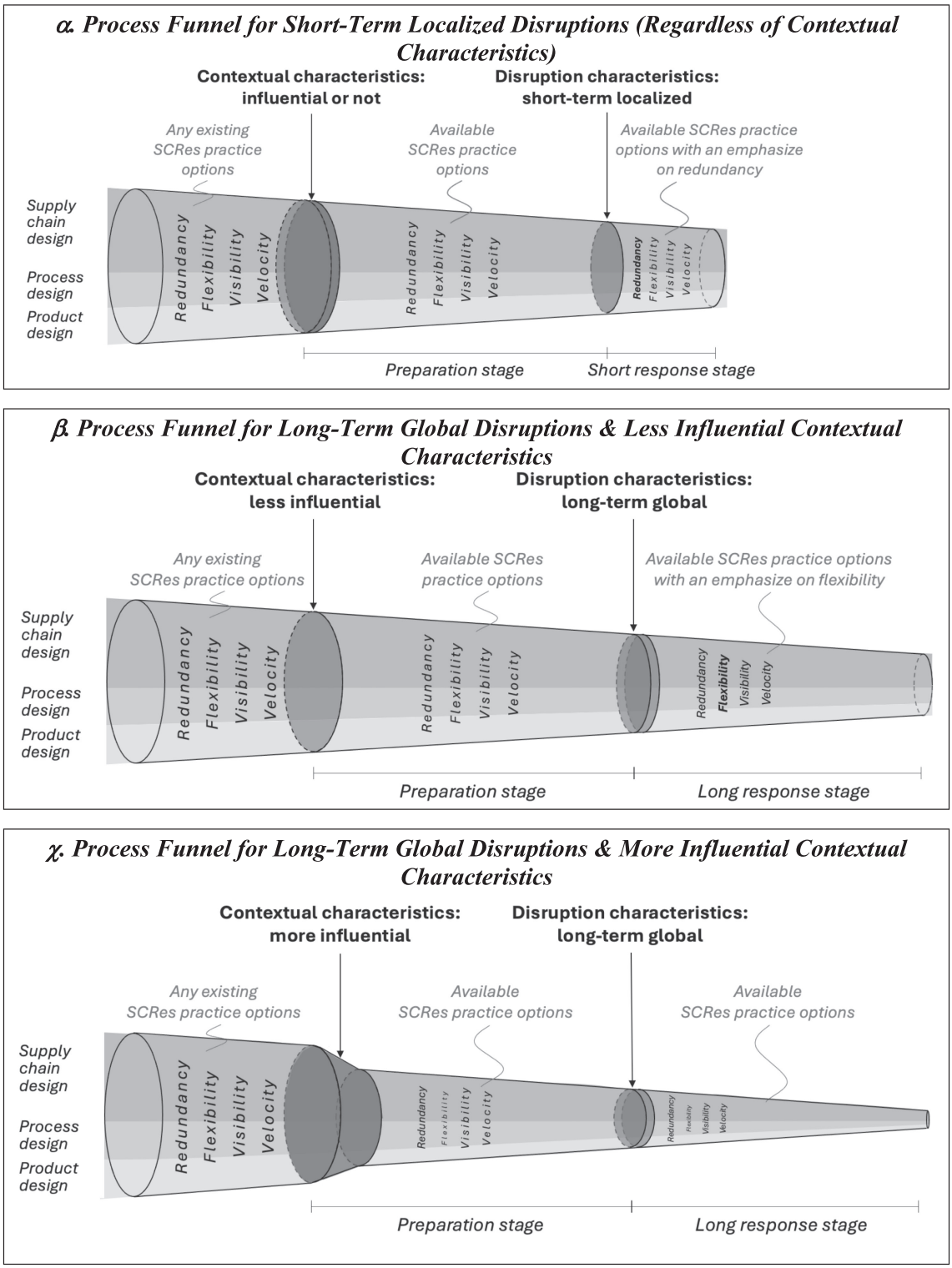

FIGURE 1 | Different SCRes funnels.

offer less potential than long-term disruptions (persistence vs. adaptation). The width of the funnel, indicative of the influence of environmental characteristics, represents the amount of SCRes practice options and, indirectly, the connectedness of an organization across the disruption process. These insights are further used in the following section to develop "the supply chain resilience funnel."

5 | Discussion

This study aims to understand how an organization's PPS configuration enables resilience strategies, in preparation for and response to supply chain disruptions, incorporating the three dimensions of the adaptive cycle, as conceptualized in panarchy theory. By combining insights on preparation with insights on disruption responses into a process perspective, this research determines that a PPS configuration also allows for a better understanding of the three dimensions: resilience, connectedness, and potential. This is depicted in Figure 2, which combines the empirically derived funnels from Figure 1 with the adaptive cycle dimensions into the proposed SCRes funnel. Specifically, it shows the supply chain *resilience* of an organization enabled through SCRes strategies employed by each organization in preparation for and response to a disruption across PPS (i.e., actual resilience practice options, highlighted in gray within the funnel in Figure 2). It also depicts the *connectedness* of an organization evident in the available SCRes practices and related strategies across PPS in the preparation and response stages (evident in the width of the funnel on the left side of Figure 2). Finally, *potential* is determined by the resilience practices employed and becomes evident in the response stage, in the form of persistence, adaptation, and/or transformation (right side of Figure 2). The funnel shows, in line with the findings, that the three dimensions are not independent; decisions on one dimension affect the other two dimensions through a PPS configuration.

Regarding *potential*, this study shows that, in the preparation stage, redundancy resilience practices lead to persistence and lower potential. In contrast, a PPS configuration that facilitates flexibility enables adaptation, and higher potential, in response to disruption (when possible). For example, redundancy allowed Cases E and F to persist in response to disruptions EII and FI. The flexibility achieved by Case B through postponement, or that attained by Case D by embracing just-in-time production, facilitated their adaptations in response to disruptions. Furthermore, visibility and velocity (primarily through supply chain design) can be used to spot threats and build redundancy quickly, before the full impact of the disruption unfolds, or else enable flexibility by establishing an overview of different options. Thus, visibility and velocity facilitate both persistence and adaptation.

Additional resilience practices in the response stage, beyond those implemented during preparation, typically facilitate more permanent adaptations (i.e., higher potential). Examples are the adapted products and pallets in Cases D and B, changed packaging in Case A, new S&OP structures in Case E, and adaptations to the delivery model in Case C. This study does not find any resilience practices across PPS that enable transformation, indicative of the highest level of potential.

Finally, this research identifies that *connectedness* relates to the number of resilience practices across PPS. Case F provides a good example of high connectedness resulting in few options for responding to either of the disruptions that were investigated, beyond redundancy. Companies with lower connectedness have more flexibility to identify and implement additional SCRes practices across PPS in the response stage. Even though Case F invested in flexibility in process design (assemble to order), it could not exploit this prepared potential and adapt to disruptions, due to its high connectedness. To mitigate the consequences of high connectedness, Case F might have used alternative product designs that it had proactively certified for each market, but such a response seems infeasible from a cost perspective. Thus, persistence enabled by redundancy, rather than adaptation enabled by flexibility, likely is the key for Case F.

Taken together, the SCRes funnel links the empirical findings to the three adaptive cycle dimensions, using the PPS configuration.

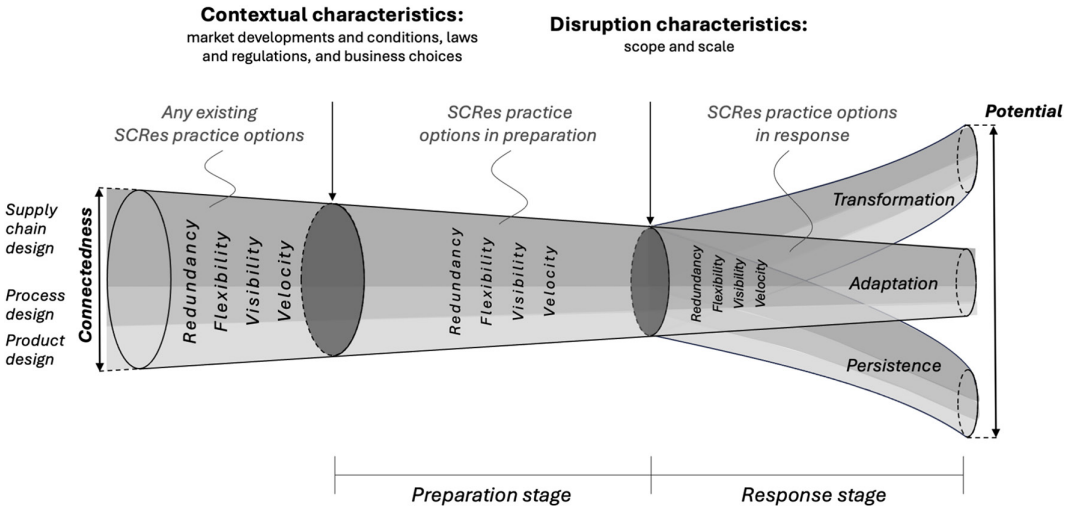

FIGURE 2 | The SCRes funnel: A process view enabled by PPS configurations. [Colour figure can be viewed at wileyonlinelibrary.com]

6 | Theoretical Contributions

Building on the discussion and the SCRes funnel introduced in Figure 2, this section links the findings of this study to the current state of knowledge in supply chain management. Two key insights for supply chain management literature are thereby formulated: (1) SCRes depends on connectedness and (2) potential depends on SCRes. These insights are then linked to the adaptive cycle to elaborate key theoretical contributions of this study in the supply chain management context.

6.1 | Contributions to SCRes

This article advances literature on SCRes as the developed the SCRes funnel in Figure 2 provides a more holistic, process view of resilience. It integrates previous work on the preparation and response stages of resilience, the SCRes strategies associated with each stage (e.g., Chowdhury and Quaddas 2016; Tukamuhabwa et al. 2015), and the organizational context for SCRes (e.g., Dittfeld et al. 2022; Vanpoucke and Ellis 2020). This article also shows the interrelatedness of the core adaptive cycle dimensions: resilience, connectedness, and potential. Together they explain how an organization evolves in response to disruptive change over time. These findings help to establish a clearer understanding of the content–process–context interrelatedness of SCRes, as outlined in the following two key insights.

6.1.1 | Insight 1: SCRes Depends on Connectedness

This article finds that some socioeconomic environments hinder or even preclude SCRes implementation. Specifically, organizations with *high connectedness* might struggle with SCRes; as an adaptive capability, it requires flexibility (Brandon-Jones et al. 2014). Extant research has linked high connectedness with reduced horizontal complexity and thus reduced frequencies of supply chain disruptions (Bode and Wagner 2015). However, redundancy—an expensive way to achieve SCRes (Christopher and Peck 2004)—is key in such situations, to be able to deal with supply chain disruptions. As the findings show, the socioeconomic environment consistently influences the width of the SCRes funnel, which represents its connectedness as the number of PPS options available in the preparation stage. In all cases except Case F, options still remained to adapt PPS choices at the organizational and supply chain levels though. Thus, these organizations were able to prepare for the unexpected. In Case F in contrast, the SCRes funnel was very narrow, due to strict industry regulations that limited PPS configurations. Consequently, the only way it could prepare for the unexpected was through redundancy, with few options to respond to a disruption, despite its use of an assemble-to-order strategy.

In turn, this research asserts that connectedness affects the usefulness of SCRes. This suggests that SCRes is not the right strategy for every organization if, due to connectedness, an organization cannot match vulnerabilities with capabilities in a so-called zone of resilience (Fiksel et al. 2015). Rather, traditional risk management might be more suitable in such cases, given its structured approach to risk identification, assessment, and implementation of concrete solutions for the previously identified, specific risks (Fan and Stevenson 2018). This is in contrast with resilience, which does not focus on such identification, assessment, and management of specific risks but instead takes a more holistic approach to be ready for any risk (Tukamuhabwa et al. 2015).

Focusing on risk management practices, an organization with high connectedness can create potential and persist despite a disruption (i.e., being robust, with no change in performance, Durach et al. 2015; Walker 2020), rather than trying the impossible, which is to adapt to the situation through its resilience practices. This finding also reflects how normal accident theory (e.g., Perrow 1984; Skilton and Robinson 2009) conceptualizes the role of tight coupling. Furthermore, any preparedness measure, whether designed for persistence or adaptation, also might be insufficient in the face of a large-scale global crisis, like COVID-19, which instead requires organizations to respond with "whatever it takes." Such a response is only possible if the state of connectedness is not too restrictive though. Therefore, the usefulness of SCRes depends on connectedness.

6.1.2 | Insight 2: Potential Depends on SCRes

Preparedness pays off (Kovács and Falagara Sigala 2021) as many preparation practices get used in the response stage, as the findings confirm. Yet, the specific characteristics of the disruption also determine which preparedness practices are available, appropriate, and useful. Notably, this research finds that organizations prepare for disruptions by using SCRes practices with a limited focus on product design, a slightly greater focus on process, and the most extensive focus on supply chain design, primarily to enable redundancy. The findings also show that many of these practices are adequate only for *shorter-term and localized events*, such as maintaining operations for 48 h to a few weeks (e.g., Case E and Disruption EII), in that they enable persistence rather than adaptation or transformation. Thus, it appears that organizations tend to strive for persistence first. In line with Bode et al.'s (2011) argument, their motivation to act in a certain way depends on the scale and scope of the disruption.

To respond adequately to disruptions of *large scope and scale,* also known as black or gray swans (Akkermans and Van Wassenhove 2018), such as the pandemic, organizations must be comprehensively and holistically prepared. Plans are required for possible production capacity changes, logistics redesigns, improved supply chain visibility, or expanded IT capabilities (Seuring et al. 2022). Our findings emphasize the need for more fundamental, strategic responses related to adaptations in process or product designs. Organizations in the preparation stage often overlook (intentionally or not) fundamental internal design options. Specifically, they miss opportunities to build potential, which also creates the need for more fundamental options in response to major disruptions. This finding resonates with the conceptual ideas offered by Thompson (1967), who proposes that organizations try to seal off their core technologies (i.e., product and process) from external uncertainties and disruptions. The uncertainties that Thompson describes mainly relate to supply and market uncertainties, rather than to disruptive events with substantial scale or scope. In SCRes studies of disruptions that can be labeled "uncertainties and variety"

(Browning et al. 2023), Thompson's conceptual ideas might hold. However, the findings of this study challenge whether sealing off core technologies is adequate for black or gray swan events.

These findings in turn suggest that the SCRes funnel might be conceived as a staged model, in which organizations change their approaches to resilience across the stages of the disruption process. Many of the observed preparation practices pursue low potential through redundancy, enabling persistence, whereas more fundamental, strategic practices in the response stage could transform resources and processes or other product functionalities or even change a business model completely (Mirzabeiki and Aitken 2023; Wieland et al. 2023). This research finds that organizations alter their approach to resilience with the disruption: they initially aim for persistence through supply chain level preparedness practices (low potential), then later shift toward higher potential through adaptation at the organizational level (process or product) if they can, given their connectedness.

A possible alternative, aligned with suggestions by Wieland and Durach (2021) and Wieland (2021), is that organizations search for even greater potential and transform, rather than persist or adapt. This study does not find any empirical evidence of transformation though. In the absence of any transforming case, it is hard to determine why companies transform, or not. The case organizations in this study all survived the studied disruptions, so seemingly, their responses were adequate, or at least not entirely wrong in the given situation. Alternatively, our observation period might have been too short to witness their transformation, possibly even due to other disruptive changes taking place over longer time periods. Overall, though, it can be concluded that SCRes practice options across the disruption process influence organizations' potential.

6.2 | Contributions to the Adaptive Cycle

The findings of this study, summarized in the SCRes funnel in Figure 2, explicate the contextual and disruption characteristics that relate to and affect connectedness, potential, and SCRes– the three dimensions of the adaptive cycle through a PPS configuration. The chosen empirical approach provides initial insights into how to operationalize the three dimensions that determine the position of an organization in the adaptive cycle. In the following, these observations are translated into two empirical contributions that elaborate on the conceptual ideas of the adaptive cycle, as conceptualized in panarchy theory (Holling 2001; Holling and Gunderson 2002), within the supply chain context.

6.2.1 | The SCRes Funnel Indicates the Phase in the Adaptive Cycle

This section elaborates how the SCRes funnel (Figure 2) links the three dimensions of resilience, connectedness, and potential, according to the empirical results. It explains how the SCRes funnel can be used as an empirically grounded indicator of the phase of the adaptive cycle that an organization has entered. Key for that is the PPS configuration perspective that allows to link the three dimensions to tangible choices, such as a modular design, visibility through S&OP in processes, or flexible capacity arrangements with suppliers.

During the *reorganization and exploitation phases*, an organization is more flexible, because its connectedness decreases, and it encounters many opportunities to build potential, both of which enhance resilience (Wieland 2021). Organizations with a wide SCRes funnel can choose among many SCRes practices to prepare for and respond to a supply chain disruption, enabled by their PPS configuration. In our study, Cases B and C, with their relatively wide funnels, can be considered organizations in the exploitation phase, as indicated by how they engaged with their environments to seize opportunities and adapt in whatever ways they could.

A narrower SCRes funnel instead seems to indicate further progression in the adaptive cycle (assuming that it moves from reorganization through exploitation and conservation to release). The most prominent example is Case F: the combination of its environment and choices for a specific product, process, and corresponding supply chain left fewer choices of resilience practices in the preparation and response stages. The *conservation phase* in particular features very specific PPS configuration choices, such that the system orients toward efficiency. Actors exhibit high levels of connectedness (e.g., dependencies between buyers and suppliers), with limited potential (few options to adapt or transform). In turn, the system is more vulnerable and less resilient (Holling and Gunderson 2002).

This reasoning can also be used to theorize how business choices on the organizational level might shape the socioeconomic level—so called cross-level effects in panarchy theory (e.g., Wieland 2021). PPS choices place the organization in a specific, regulated environment that evokes the previously described situation, in terms of the three adaptive cycle dimensions, and thus a conservation phase. In a sense, one could also say that a system in isolation might have unlimited options, but limitations are imposed on it through its interactions with the socioeconomic environment. Altering business choices might enable higher potential and options to *transform*, such as moving from using hazardous products that invoke strict safety regulations, toward a PPS configuration that uses novel, sustainable technologies without regulations. Such transformations can be shaped by external actors (e.g., the public, laws), the supply chain (e.g., by customers and suppliers), or the organization (e.g., sustainability policies, product designs). Again, this research does not find evidence of transformation in the studied cases. Further investigations might identify situations or boundary conditions that favor transformative behaviors. Such efforts would help elaborate on and empirically challenge the so-far mainly conceptual approaches to panarchy theory in the supply chain management context. For example, in the conservation stage, inertia and strategic persistence might have influential roles (e.g., Audia et al. 2000).

6.2.2 | Transformation as a Last Resort?

The findings complement assumptions that the strength of a disturbance is the dominant determinant of whether a system is likely to transform rather than persist (Mirzabeiki and

Aitken 2023; Novak et al. 2021). In a supply chain context though, transformation instead might represent a last resort. For example, a powerful, global, longer-term crisis, such as the COVID-19 pandemic, arguably should be linked to higher potential and thereby trigger the need for transformative approaches across PPS configurations. Wieland and Durach (2021) and Wieland (2021) even mention some COVID-19–related transformation examples, as outlined in the introduction. According to our in-depth observations though, such examples represent exceptions, rather than the rule. None of the studied cases featured transformative approaches in response to COVID-19 disruptions. Rather, persistence and adaptation (e.g., changes to packaging and offering components as product options) were observed. On the basis of these findings, this article postulate that organizations first try to persist through disruptions, by applying preparedness practices through supply chain design and searching for new supply chain practices in the response stage. Only if those supply chain options fail to work do organizations investigate process or product redesign(s) internally. Based on the findings of this study, changes that involve the core business and lead to transformation, such as entering a new market, appear to be considered only if no other options are available. This article encourages future research to further investigate whether this represents a more general pattern.

Transformation during a crisis (i.e., disruption of large scale and scope) also might require support from additional changes, such as regulatory shifts, as illustrated in the well-documented case of ventilators in the United Kingdom (e.g., Dube et al. 2022). These types of interactions between the socioeconomic environment and organizations might evoke changes to PPS configurations. Alternatively, transformation might stem from long-term, incremental, or radical changes taking place during business as usual, rather than during crises. Or perhaps organizations simply might be fortunate, such that a specific crisis or supply chain disruption change the socioeconomic environment enough to reveal previously nonexistent options and opportunities that allow for transformation. Even then though, the sustainability of such transformations is uncertain. Does the Danish juice manufacturer that transformed still produce hand sanitizer in the post–COVID-19 crisis period when demand for hand sanitizer has decreased substantially, for example?

7 | Conclusion

This study showed how an organization's PPS configuration in preparation for and response to disruptions provides insights into resilience, connectedness, and potential—three dimensions of the adaptive cycle that help explain how systems develop over time in response to disruptive changes. The SCRes funnel was introduced, as illustrated in Figure 2. The SCRes funnel is a process model that depicts how resilience practice options across PPS are funneled first in preparation of a disruption, by contextual characteristics (e.g., laws and regulations, market developments and business choices), and then further in the response stage, by the disruption's scope and scale. It was shown, that the range of available resilience practice options, across PPS, which is determined by contextual and disruption characteristics, influences the connectedness of an organization and its supply chains. Furthermore, this study illustrated that organizations can prepare for disruptions by tailoring their PPS configurations to their environments, such that their available SCRes practices can help them outlast a short-term disruption, mainly through redundancy, and then adapt, with the help of flexibility, in response to longer-term disruptions. Ultimately, a PPS configuration determines approaches toward SCRes and thus the light at the end of the funnel.

7.1 | Managerial and Societal Implications

The SCRes funnels in Figure 1 provide practical tools that managers can use to prepare for and respond to supply chain disruptions with SCRes practices across PPS. When the SCRes funnel was presented to participating interviewees, they found it to be an intuitive and useful tool for balancing practices against their own overall business situation and, in turn, against specific disruptions.

This research recommends that organizations implement as many preparedness options (i.e., resilience practices) as possible, within their investment limits and according to their usefulness. For short-term disruptions, many valuable practices stem from the supply chain design but can be less fundamental or strategic. These include multiple sourcing strategies, sharing forecasts, and other types of information in the supply chain (e.g., having suppliers keep safety stock and local sourcing) (see Table 3). To respond to major disruptions though, responses involving process or product designs also might be necessary. Organizations need to recognize that SCRes preparedness practices, which typically target the supply chain level, have limitations. More fundamental events require significant response initiatives that encourage adaptation. Therefore, depending on the disruption characteristics and the options available (as determined by contextual characteristics), process or product (re)designs could have substantial impacts on the long-term response. Such designs need to be prepared in advance and could entail, for example, alternative design options of a product, alternative ways of planning processes in the internal network, or flexibility in the workforce.

If an organization enters a scenario in which many contextual characteristics influence its preparation options, the SCRes funnel is likely to be very narrow. In such a case, this research suggests focusing on risk management, by identifying specific risks that might occur, assessing them, and building appropriate counter practices. Redundancy seems preferable, if flexibility is limited. At the same time, a narrow funnel might indicate the need for transformation, if the organization hopes to survive in the long-term. Managers should think about possibilities for transforming during periods marked by business as usual or consider building capabilities that support transformation if they confront a long-term disruption. Transformation is critical in many industries to achieve sustainability and tackle grand challenges (e.g., climate change); it also is important for society as a whole. Considering our finding that a change in the adaptive cycle might not require drastic changes on all the underlying dimensions, due to their interdependence, managers in a conservation phase might not have to reconsider their choices across all three dimensions of the adaptive cycle. Rather, incremental changes on one dimension can help alter the others,

moving the organization to a slightly different position on the adaptive cycle. For example, an organization might start to explore how to transform individual components rather than the overall product. These small changes can accrue, as small steps toward transformation, so that the many small changes add up to a big change over time.

Beyond the organizational level, the SCRes funnel might also apply for building resilience at the societal level, where short-term crises can be managed with persistence through redundancy, but larger crises require adaptation through flexibility and changes to the way things are done. Preparation is key to ensure sufficient response options, as well as to prepare transformative capabilities. The role of policy makers becomes salient here, because laws and regulations can limit or support organizations' SCRes practices. For example, developing regulations that allow for adaptive measures in times of crisis, such as temporary relaxations or modifications of certain rules, can help organizations maintain their operations, without compromising long-term regulatory goals. Providing specific incentives for research and development also can help organizations transform and innovate during business as usual.

7.2 | Limitations and Further Research

Some limitations of this study should be considered, alongside opportunities for further research. For example, most of the disruptions described by our study respondents were longer-term and global, reflecting the COVID-19 context in which this study was conducted. They provide a unique and timely perspective, complementary to extant literature that mainly focuses on short-term, localized disruptions (Browning et al. 2023). However, a more systematic comparison among disruptions that differ in scope and scale would be very valuable. Another direction for comparative research might explore whether it is preferable to (1) imagine potential product design–related SCRes practices in preparation or (2) wait to take action after a gray or black swan event. A comparison of disruptions of different sizes could yield additional insights.

This study provides some initial insights into the operationalization of the three adaptive cycle dimensions, though without providing a clear measurement. Studies that propose and test measures of the key dimensions, based on our findings, could help organizations identify their own positions within the adaptive cycle. Furthermore, a follow up step could be to use the operationalizations of the three dimensions via PPS configuration to trace the development of an organization in the adaptive cycle over time.

Finally, while the SCRes funnel represents a process, data collection took place at one point in time, and retrospectively. The respondents were able to discuss the process they underwent in preparation for general disruptions and in response to specific ones. A longitudinal perspective on SCRes would still be helpful. It could trace adaptive cycles over time and thereby specify how and when an organization moves from one phase to another. A longitudinal design can also help researchers predict when temporary versus permanent adaptation or transformation is more likely to take place in response to disruptions.

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References

Akkermans, H., and L. N. Van Wassenhove. 2018. "Supply Chain Tsunamis: Research on Low-Probability, High-Impact Disruptions." *Journal of Supply Chain Management* 54, no. 1: 64–76. https://doi.org/10.1111/jscm.12162.

Ali, A., A. Mahfouz, and A. Arisha. 2017. "Analysing Supply Chain Resilience: Integrating the Constructs in a Concept Mapping Framework via a Systematic Literature Review." *Supply Chain Management* 22, no. 1: 16–39. https://doi.org/10.1108/SCM-06-2016-0197.

Ambulkar, S., J. Blackhurst, and S. Grawe. 2015. "Firm's Resilience to Supply Chain Disruptions: Scale Development and Empirical Examination." *Journal of Operations Management* 33: 111–122. https://doi.org/10.1016/j.jom.2014.11.002.

Archer, M. S., and R. Bhaskar. 1998. *Critical Realism: Essential Readings*. Routledge.

Audia, P. G., E. A. Locke, and K. E. N. G. Smith. 2000. "The Paradox of Success: An Archival and a Laboratory Study of Strategic Persistence Following Radical Environmental Change." *Academy of Management Journal* 43, no. 5: 837–853.

Azadegan, A., and K. Dooley. 2021. "A Typology of Supply Network Resilience Strategies: Complex Collaborations in a Complex World." *Journal of Supply Chain Management* 57, no. 1: 17–26. https://doi.org/10.1111/jscm.12256.

Azzi, A., D. Battini, A. Persona, and F. Sgarbossa. 2012. "Packaging Design: General Framework and Research Agenda." *Packaging Technology and Science* 25, no. 8: 435–456.

Bansal, P., and K. Corley. 2011. "From the Editors the Coming of Age for Qualitative Research: Embracing the Diversity of Qualitative Methods." *Academy of Management Journal* 54, no. 2: 233–237. https://doi.org/10.5465/AMJ.2011.60262792.

Bhaskar, R. 1978. *A Realist Theory of Science*. Harvester Press.

Bille, A., and C. Hendriksen. 2023. "Let Us Get Contextual: Critical Realist Case Studies in Supply Chain Management." *Supply Chain Management: An International Journal* 28, no. 4: 724–737. https://doi.org/10.1108/SCM-03-2022-0119.

Bode, C., and S. M. Wagner. 2015. "Structural Drivers of Upstream Supply Chain Complexity and the Frequency of Supply Chain Disruptions." *Journal of Operations Management* 36: 215–228.

Bode, C., S. M. Wagner, K. J. Petersen, and L. M. Ellram. 2011. "Understanding Responses to Supply Chain Disruptions: Insights From Information Processing and Resource Dependence Perspectives." *Academy of Management Journal* 54, no. 4: 833–856.

Brandon-Jones, E., B. Squire, C. W. Autry, and K. J. Petersen. 2014. "A Contigent and Resource-Based Perspective of Supply Chain Resilience and Robustness." *Journal of Supply Chain Management* 50, no. 3: 55–73.

Browning, T., M. Kumar, N. Sanders, M. M. S. Sodhi, M. Thürer, and G. L. Tortorella. 2023. "From Supply Chain Risk to System-Wide Disruptions: Research Opportunities in Forecasting, Risk Management and Product Design." *International Journal of Operations & Production Management* 43, no. 12: 1841–1858. https://doi.org/10.1108/IJOPM-09-2022-0573.

Brusset, X., and C. Teller. 2017. "Supply Chain Capabilities, Risks and Resilience." *International Journal of Production Economics* 184: 59–68.

Chowdhury, M. M. H., and M. Quaddas. 2016. "Supply Chain Readiness, Response and Recovery for Resilience." *Supply Chain Management: An International Journal* 21, no. 6: 709–731.

Christopher, M., and H. Peck. 2004. "Building the Resilient Supply Chain." *International Journal of Logistics Management* 15, no. 2: 1–13.

Cloutier, C., and A. Langley. 2020. "What Makes a Process Theoretical Contribution?" *Organization Theory* 1, no. 1: 1–32. https://doi.org/10.1177/2631787720902473.

Cohen, M., S. Cui, S. Doetsch, et al. 2022. "Bespoke Supply-Chain Resilience: The gap Between Theory and Practice." *Journal of Operations Management* 68, no. 5: 515–531.

Cornelissen, J. P. 2017. "Preserving Theoretical Divergence in Management Research: Why the Explanatory Potential of Qualitative Research Should Be Harnessed Rather Than Suppressed." *Journal of Management Studies* 54, no. 3: 368–383. https://doi.org/10.1111/joms.12210.

Craighead, C. W., J. Blackhurst, M. J. Rungtusanatham, and R. B. Handfield. 2007. "The Severity of Supply Chain Disruptions: Design Characteristics and Mitigation Capabilities." *Decision Sciences* 38, no. 1: 131–156. https://doi.org/10.1111/j.1540–5915.2007.00151.x.

Dittfeld, H., D. P. van Donk, and S. van Huet. 2022. "The Effect of Production System Characteristics on Resilience Capabilities: A Multiple Case Study." *International Journal of Operations & Production Management* 42, no. 13: 103–127. https://doi.org/10.1108/ijopm-12-2021-0789.

Dube, N., Q. Li, K. Selviaridis, and M. Jahre. 2022. "One Crisis, Different Paths to Supply Resilience: The Case of Ventilator Procurement for the COVID-19 Pandemic." *Journal of Purchasing and Supply Management* 28, no. 5: 100773. https://doi.org/10.1016/j.pursup.2022.100773.

Durach, C. F., A. Wieland, and J. A. D. Machuca. 2015. "Antecedents and Dimensions of Supply Chain Robustness: A Systematic Literature Review." *International Journal of Physical Distribution and Logistics Management* 45, no. 1/2: 118–137. https://doi.org/10.1108/SCM-08-2014-0267.

Easton, G. 2010. "Critical realism in Case Study Research." *Industrial Marketing Management* 39, no. 1: 118–128 Critical Realism in Case Study Research; ID: 619.

Ellram, L. M., W. L. Tate, and C. R. Carter. 2007. "Product-Process-Supply Chain: An Integrative Approach to Three-Dimensional Concurrent Engineering." *International Journal of Physical Distribution and Logistics Management* 37, no. 4: 305–330. https://doi.org/10.1108/09600030710752523.

Eriksson, D., and A. Engström. 2021. "Using Critical Realism and Abduction to Navigate Theory and Data in Operations and Supply Chain Management Research." *Supply Chain Management: An International Journal* 26, no. 2: 224–239. https://doi.org/10.1108/SCM-03-2020-0091.

Fan, Y., and M. Stevenson. 2018. "A Review of Supply Chain Risk Management: Definition, Theory, and Research Agenda." *International Journal of Physical Distribution and Logistics Management* 48, no. 3: 205–230. https://doi.org/10.1108/IJPDLM-01-2017-0043.

Fiksel, J., M. Polyviou, K. L. Croxton, and T. J. Pettit. 2015. "From Risk to Resilience: Learning to Deal With Disruption." *Sloan Management Review* 56, no. 2: 79–86.

Fisher, M. L. 1997. "What Is the Right Supply Chain for Your Product?" *Harvard Business Review* 75, no. 2: 105–116.

Grimm, J., A. Langley, and J. Reinecke. 2024. "Process Research Methods for Studying Supply Chains and Their Management." *Journal of Supply Chain Management* 60, no. 4: 3–26. https://doi.org/10.1111/jscm.12331.

Gruner, R. L., and D. Power. 2023. "Conceptual Wanderlust: How to Develop Creative Supply Chain Theory With Analogies." *Journal of Supply Chain Management* 59, no. 4: 3–21. https://doi.org/10.1111/jscm.12305.

Guba, E. G., and Y. S. Lincoln. 2005. "Paradigmatic Controversies, Contradictions, and Emerging Influences." In *Handbook of Qualitative Research*, edited by N. K. Denzin and Y. S. Lincoln, 191–215. Sage Publications.

Holling, C. S. 2001. "the Understanding Complexity of Economic, Ecological, and Social." *Complexity* 4, no. 5: 390–405. https://doi.org/10.1007/s10021-00.

Holling, C. S., and L. Gunderson. 2002. "Panarchy: Understanding Transformations in Human and Natural and Sytems." In *Panarchy: Understanding Transformations in Human and Natural Systems*. Island Press.

Jacobs, M. A., and M. Swink. 2011. "Product Portfolio Architectural Complexity and Operational Performance: Incorporating the Roles of Learning and Fixed Assets." *Journal of Operations Management* 29, no. 7–8: 677–691. https://doi.org/10.1016/j.jom.2011.03.002.

Jiao, J., T. W. Simpson, and Z. Siddique. 2007. "Product Family Design and Platform-Based Product Development: A State-of-The-Art Review." *Journal of Intelligent Manufacturing* 18, no. 1: 5–29. https://doi.org/10.1007/s10845-007-0003-2.

Jüttner, U., and S. Maklan. 2011. "Supply Chain Resilience in the Global Financial Crisis: An Empirical Study." *Supply Chain Management: An International Journal* 16, no. 4: 246–259. https://doi.org/10.1108/13598541111139062.

Kochan, C. G., and D. R. Nowicki. 2018. "Supply Chain Resilience: A Systematic Literature Review and Typological Framework." *International Journal of Physical Distribution and Logistics Management* 48, no. 8: 842–865. https://doi.org/10.1108/IJPDLM-02-2017-0099.

Koufteros, X. A., M. A. Vonderembse, and W. J. Doll. 2002. "Integrated Product Development Practices and Competitive Capabilities: The Effects of Uncertainty, Equivocality, and Platform Strategy." *Journal of Operations Management* 20, no. 4: 331–355. https://doi.org/10.1016/S0272-6963(02)00018–9.

Kovács, G., and I. Falagara Sigala. 2021. "Lessons Learned From Humanitarian Logistics to Manage Supply Chain Disruptions." *Journal of Supply Chain Management* 57, no. 1: 41–49. https://doi.org/10.1111/jscm.12253.

Lincoln, Y. S., and E. G. Guba. 1985. *Naturalistic Inquiry*. Sage Publications.

Miles, M. B., and M. A. Huberman. 1994. *Qualitative Data Analysis*. Saga Publications.

Mirzabeiki, V., and J. Aitken. 2023. "Panarchy-Based Transformative Supply Chain Resilience: The Role of Supply Chain Capital." *International Journal of Operations & Production Management* 43, no. 1: 99–139. https://doi.org/10.1108/IJOPM-03-2022-0191.

Novak, S., and S. D. Eppinger. 2000. "Sourcing by Design: Product Complexity and the Supply Chain." *Management Science* 47, no. 1: 189–204.

Novak, D. C., Z. Wu, and K. J. Dooley. 2021. "Whose Resilience Matters? Addressing Issues of Scale in Supply Chain Resilience." *Journal of Business Logistics* 42, no. 3: 323–335. https://doi.org/10.1111/jbl.12270.

Perrow, C. 1984. *Normal Accidents: Living With High Risk Technologies*. Princeton University Press.

Pettit, T. J., J. Fiksel, and K. L. Croxton. 2010. "Ensuring Supply Chain Resilience: Development of a Conceptual Framework." *Journal of Business Logistics* 31, no. 1: 1–21.

Ponomarov, S. Y., and M. C. Holcomb. 2009. "Understanding the Concept of Supply Chain Resilience." *International Journal of Logistics Management* 20, no. 1: 124–143.

Russo, I., D. Pellathy, and A. Omar. 2021. "Managing Outsourced Reverse Supply Chain Operations: Middle-Range Theory Development." *Journal of Supply Chain Management* 57, no. 4: 63–85. https://doi.org/10.1111/jscm.12244.

Sawyerr, E., and C. Harrison. 2019. "Developing Resilient Supply Chains: Lessons From High-Reliability Organisations." *Supply Chain Management: An International Journal* 25, no. 1: 77–100. https://doi.org/10.1108/SCM-09-2018-0329.

Scholten, K., and S. Schilder. 2015. "The Role of Collaboration in Supply Chain Resilience." *Supply Chain Management: An International Journal* 20, no. 4: 471–484.

Scholten, K., P. Sharkey Scott, and B. Fynes. 2019. "Building Routines for non-routine Events: Supply Chain Resilience Learning Mechanisms and Their Antecedents." *Supply Chain Management: An International Journal* 24, no. 3: 430–442. https://doi.org/10.1108/SCM-05-2018-0186.

Scholten, K., M. Stevenson, and D. P. van Donk. 2020. "Dealing With the Unpredictable: Supply Chain Resilience." *International Journal of Operations & Production Management* 40, no. 1: 1–10.

Schumpeter, J. A. 1942. *Capitalism, Socialism and Democracy.* Harper & Brothers.

Selviaridis, K., and M. Spring. 2022. "Fostering SME Supplier-Enabled Innovation in the Supply Chain: The Role of Innovation Policy." *Journal of Supply Chain Management* 58, no. 1: 92–123. https://doi.org/10.1111/jscm.12274.

Seuring, S., M. Brandenburg, and K. Petljak. 2022. "Comparing Regions Globally : Impacts of COVID-19 on Supply Chains – A Delphi Study." *International Journal of Operations & Production Management* 42, no. 8: 1077–1108. https://doi.org/10.1108/IJOPM-10-2021-0675.

Skilton, P. F., and J. L. Robinson. 2009. "Traceability and Normal Accident Theory: How Does Supply Network Complexity Influence the Traceability of Adverse Events." *Journal of Supply Chain Management* 45, no. 3: 40–53.

Slack, N., S. Chambers, and R. Johnston. 2010. "Operations Management." In *Harvard Business Review*. Pearson Education.

Thompson, J. D. 1967. *Organizations in Action*. McGraw-Hill.

Tukamuhabwa, B., M. Stevenson, J. Busby, and M. Zorzini. 2015. "Supply Chain Resilience: Definition, Review and Theoretical Foundations for Further Study." *International Journal of Production Research* 53, no. 18: 5592–5623.

Vanpoucke, E., and S. Ellis. 2020. "Building Supply-Side Resilience – A Behavioural View." *International Journal of Operations & Production Management* 40, no. 1: 11–33.

Walker, B. H. 2020. "Resilience: What It Is and Is Not." *Ecology and Society* 25, no. 2: 1–3. https://doi.org/10.5751/ES-11647–250211.

Welch, C., R. Piekkari, E. Plakoyiannaki, and E. Paavilainen-Mäntymäki. 2011. "Theorising From Case Studies: Towards a Pluralist Future for International Business Research." *Journal of International Business Studies* 42, no. 5: 740–762. https://doi.org/10.1057/jibs.2010.55.

Wieland, A. 2021. "Dancing the Supply Chain: Toward Transformative Supply Chain Management." *Journal of Supply Chain Management* 57, no. 1: 58–73. https://doi.org/10.1111/jscm.12248.

Wieland, A., and C. F. Durach. 2021. "Two Perspectives on Supply Chain Resilience." *Journal of Business Logistics* 42, no. 3: 315–322. https://doi.org/10.1111/jbl.12271.

Wieland, A., M. Stevenson, S. A. Melnyk, S. Davoudi, and L. Schultz. 2023. "Thinking Differently About Supply Chain Resilience: What We can Learn From Social-Ecological Systems Thinking." *International Journal of Operations & Production Management* 43, no. 1: 1–21. https://doi.org/10.1108/IJOPM-10-2022-0645.

Wynn, D., and C. K. Williams. 2012. "Principles for Conducting Critical Realist Case Study Research in Information Systems." *MIS Quarterly* 36, no. 3: 787–810.

Yin, R. K. 2009. *Case Study Research: Design and Methods*. Sage Publications.

Appendix A

Contextual characteristics that influence available PPS configurations in the preparation stage.

Case	Exemplary quotes	Contextual characteristics		Resilience strategies	PPS
A	"If you do not take the promotion, then the competitor will and then the market share will change. And your market share can really be influenced by the promotional level. So, you really want to be on the shelf. Otherwise, your competitor is." (A1)	On-shelf availability key	Market developments and conditions	Redundancy Flexibility	Supply chain
	"It is not easy because our products are not interchangeable. So, this is made in Italy, this is made in Turkey, this is made in [specific city] and this in [specific city]. We cannot transfer a product from one factory to another factory. That is because of scarcity of raw or packaging materials." (A4)	Availability of raw material		Flexibility	Process
	"There are a lot of rules and regulations regarding ingredients, regarding languages on the label. It's something everybody [in the industry] has to take into account." (A2) "The regulations have a negative impact on us because it would be much easier to shift goods from one market to the others [if the regulations were less restrictive]." (A2)	Regulations for the food industry regarding hygiene	Laws and regulations	Flexibility	Product
B	"We harvest [raw material of B] and that happens between August and the end of April. So, within that period, we have to build a huge amount of stock." (B1)	Natural product dependent on harvest, campaign-based (raw material is harvested 6 months of the year)	Market developments and conditions	Flexibility	Product Process
	"In general, we are a very customer-focused company. If the customer requires a certain activity or a certain service, we usually provide it, or at least we try to provide it." (B1) "Sometimes, we are the warehouse for them [customers]. Because if you only need one metric ton and one pallet full of 1000 kg of a product a month, you can store it. But sometimes customers need 20,000 k per month or 40, 60, or 80. Then we store it for them, ... so that their storage space is not necessary." (B3)	Higher market segment ➔ customer focused, offer additional services to customers, for example, to maintain inventory	Business model and choices	Redundancy Flexibility	Process
	"It's a food product, and, [product of B] we could not sell in the U.S. before. We have legislation there, so it was not possible to sell it even if the customers wanted it. So, you have to think of that as well, and it varies by product. In Latin America, there are several products for which we first have to get an agreement with the government to make sure that the product can be imported into the country, or it's not allowed, or we have to wait until all the testing is done. We cannot import another [product of B] yet in specific regions in Asia or Australia. So, those are the things that are limiting us globally." (B3)	Serving different markets ➔ regulations from different industries and countries		Flexibility	Product
	"As compared to other products, it's difficult, for example, to combine [product of B] in one trip with other materials [because of possible contamination]. So, therefore, we tried to do as much as possible with full truck- and full container loads. We have very strict restrictions on using the type of transport. For example, all our containers and trucks have to be smell-free, odor-free, and we have strict rules on the previous loads." (B1)	Regulations for the food industry with regards hygiene	Laws and regulations	Flexibility	Product

Case	Exemplary quotes	Contextual characteristics		Resilience strategies	PPS
C	"We do not buy from our second tiers, but we have a commercial agreement with our second tiers, so we tell the first tier where to buy their components from." (C2)	Outsourced production ➔ collaboration important	Business model and choices	Visibility	Supply Chain
	"We have the EU, there's one set of regulations, and although it is bureaucratic, it's familiar and clear. We're now trying to get into Asia, and each country in Asia has different regulations. You need to register your products, you need to be compliant with the local law. I think, from a global perspective, it's very difficult." (C1)	EU regulations, outside of the EU per country	Laws and regulations	Flexibility Visibility	Product
	"We are obliged to keep those products in an area that is compliant to local legislation with regards to fire. [...] So, we have to make sure that we have some kind of guarantee that we have enough storage capacity for the next few years. A pallet cannot just be put away in a regular warehouse." (C2)	Partly hazardous product ➔ influences storage and transportation options		Flexibility Redundancy	Process Supply chain
D	"Normally in the automotive industry there are no large stocks because chips are quite expensive [...] and working capital is at stake when we buy a lot of parts." (D3)	High value components	Market developments and conditions	Redundancy	Process
	"Every [product] has 1000,000 parts if you break it down to pieces. There are a lot of suppliers. We have factories worldwide where they assemble parts to a full [product]. It's a very complex supply chain with a lot of distribution points for collecting the parts from suppliers. Thousands of suppliers, mainly within Europe, but also around the globe." (D3)	Very high number of components		Visibility	Supply chain
	"We can build more or less 40.000 different products. We have modular products, which is great for our customers of course." (D4)	Premium market segment	Business model and choices	Flexibility	Product
	"We can deliver a [product] without a certain option, which may be nice to have, but is not something that should be there." (D2)	Customized products		Flexibility	Product
	"It's illegal not to have it [feature] on the driver's side. But on the passenger side, it's not illegal to not have it." (D2)	Regulated market	Laws and regulations	Flexibility	Product

Case	Exemplary quotes	Contextual characteristics		Resilience strategies	PPS
E	"We used to grow by 3% to 5% or 6% per year, and all of a sudden, we grew 50% and sometimes more per year. You must accept that you have a forecasting accuracy of no more than 60 or 70%. [...] A customer may say, 'I want to buy 100 in a given period of that product', but you should not be surprised if that same customer comes back a few weeks later and says, 'Hey, could it also be 120, please?'" (E1)	Fast-growing market	Market developments and conditions	Flexibility	Process
	"Competitive pressure is not very big yet. This is a market which is very tensed because there is more demand than supply." (E4)	Market with more demand than supply		Redundancy	Process
	"Both in Brazil and in Thailand you can have two harvests per year. [...] In Western Europe, the source of [raw material] is seasonal [...]." (E1) "And the effect it [weather] can have on the crops like [raw material]. And there were the last two years, some droughts in Thailand, which resulted in lower [raw material] production, which increases price of [raw material]." (E4)	Natural product dependent on harvest		Flexibility	Process
	"From a regulation standpoint, [the product] is globally approved in all kind of food ingredients and applications in pharma. But it's regulated, so it means it needs to fulfill certain specifications." (E4) "The US cannot supply Europe because in Europe it's GMO status." (E2)	Serving different markets with different regulations	Laws and regulations	Flexibility	Product
	"We have both powder products and we have liquids. We have dangerous goods that are basically dangerous to ship and can be explosive or they burn really easily. We also have acids that are irritating. [...] Container transport can become really hot, and if you are unlucky, your container is on top of the ship if you are going to Asia or to the US in the summer, the West Coast, for instance. So, we have to use cooled containers." (E2)	Partly hazardous products ➔ influences storage and transportation possibilities		Flexibility	Process
F	"In our business, it's the climate change and the shift to [alternative product]. The market [for product of F] is now in decline, a price competition market. You really need to innovate to get the market, and you need to have more [alternative products]." (F3) "It's currently a very mature market and a lot of replacement products." (F4)	Mature market with many replacements, sustainability pressure	Market developments and conditions	Flexibility	Product
	"We are not actually producing anything and we just assemble. We procure components and we plug them together, stick them together, mount them in the frame, and in the end, it is [product F]. We are more and more working towards modularity." (F1)	Not producing but assembling only	Business model and choices	Flexibility	Process
	"The market is highly regulated. The products could be very dangerous. There are a lot of regulations which need to be fulfilled. You need to certify all products that you will bring on the market by a lot of certifying parties." (F3) "Regulations are what is striking; within Europe, there's a lot of difference. So, you see that for every country, you have a different, let us say, different set up." (F1)	Strict and diverse regulations per market and product	Laws and regulations	Flexibility	Product

Case	Exemplary quotes	Contextual characteristics		Resilience strategies	PPS
G	"Competitive pressure [in the industry] is high, there's overcapacity in the market." (G4) "It's really a buyer's market; all the power is with the buyer. If they could get ½ cent discount somewhere, they would drop the whole volume to another supplier." (G4)	Mature market with overcapacity	Market developments and conditions	Redundancy	Supply chain
	"The biggest risk at the moment is our export market because the price gap is getting bigger and bigger. I think customers will decide more for a cheaper [product]." (G3)	Changes in consumer choices		Flexibility	Process
	"The power is really at the retailer as they determine what to puts on shelf. And because we are relatively small compared to [our] big competitors, we have less power in that relationship. Where we differentiate ourselves is with the portfolio play." (G4)	On-shelf availability key		Flexibility	Product
	"If [raw material] is very cheap, it's €40, but when it's very expensive [due to seasonality], it's €600 per ton." (G2)	Natural product dependent on harvest		Flexibility	Process
	"We have less power in that relationship [with retailers] based on volume. Where we differentiate ourselves is with portfolio play. Our wide portfolio gives us, some more leverage in the relationship with the retailers." (G1)	Differentiate based on portfolio and high service levels	Business model and choices	Flexibility	Supply chain
	"We have asked the Dutch consumers what they are going to do if there would be a deposit on cans, and 30% of the current consumers said 'I'm going to buy another packaging, like one-way, or, returnable bottles'." (G1)	Global, national, and regional regulations for the food industry	Laws and regulations	Flexibility	Supply chain

Appendix B

Findings: PPS configurations in the response stage.

Disruption case	Disruption characteristics		Reason for disruption	Quotes about disruption impact	Example quotes about response practices in addition to preparation practices	Resilience strategies	PPS
	Scope	*Scale*					
EII	Short-term (3 weeks)	Relatively localized	Suez Canal blockage	"We had roughly a three-week delay." (E1)	"The freight forwarders had to give us the input and the overview of what ships were where, and how much material was on there." (E2)	Visibility	Supply chain
					"We were able to manage and we were not short on product. We anticipated a potentially very big dip in our safety levels, but our safety stock settings were OK." (E2)	Redundancy	Process
FI	Short-term (4 weeks)	Product specific	Quality issue in main component (second tier suppliers)	"So, in France, UK, Turkey, Netherlands, Portugal, and Germany, we closed down production lines because we had a quality issue with this [product]. One part stops a lot of production lines." (F3)	"We had 30,000 parts in [another] plant. We immediately shipped a lot of these alternative parts to all the other plants so they could start production very fast, within a couple of days. [...] We immediately asked the second source to speed up and to scale up the production." (F3)	Redundancy	Process
					"We could immediately shift to that supplier as being the second source." (F3)	Redundancy	Supply chain
BI	Medium-term (<1 year, >1 month)	Global supply shortage	Shortage in support material (pallets)	"The disruption was there and our suppliers did have to say no to other customers, but we had everything in place." (B4)	"If one supplier could not manage, then we would ask another supplier. So, we shifted some volumes between the three suppliers." (B1)	Flexibility	Supply chain
					"It was hard to get enough wood [for the supplier] to make the pallet, so the supplier asked to check whether it's possible to change the specifications [of the pallet] [...] We changed the specification so we could buy other pallets" (B2).	Flexibility	Product
AI	Long-term (>1 year)	Global supply shortage	Shortage in support material (packaging)	"All of a sudden that supplier said: 'I'm not able to support your volumes anymore'. Although we have it [agreed quantity] in the contract, we have a certain margin to increase. They were still not able to deliver the volumes." (A1)	"What we found out is that we used four colors in the design and the machine the supplier had was only able to print three colors at the same time. In order to print the carton, they had to run the carton twice through the machine, taking double the capacity. Then they said 'if you go to a three color combination, then we can use it only once.'" (A1)	Flexibility	Product
				"I do not think the UK sold less due to the fact that they got blank carton. The whole commercial team was not okay with this, but I said: 'having products or not having products', that's at least the trade-off you need to make." (A1)	"We asked the UK: 'can we ship blank cartons?' It was not what they wanted because then you miss your branding on the shelf in the shop [...] But, that's what we did for 2 to 3 weeks." (A1)	Flexibility	Process

Disruption case	Disruption characteristics		Reason for disruption	Quotes about disruption impact	Example quotes about response practices in addition to preparation practices	Resilience strategies	PPS
	Scope	*Scale*					
GI	Long-term (>1 year)	Global supply shortage	Shortage in support material (packaging)	"If volumes double, ideally you have a dual sourcing, or backup capacities. But manufacturers just do not accept that you reserve capacity and then you do not use it." (G4) "I think we have a competitive advantage there because we buy a lot of cans, we have priority at our can suppliers. Smaller producers or local producers are having much more issues with procuring cans, which gives us a competitive advantage. Just having the cans available is really a competitive advantage at this point in time." (G4)	"We decide week on week which products we are going to produce and which not, also based on a minimum run at the site of the can supplier … normally you can choose whether you want to have 100,000 cans or 1000,000 cans in one run, but because of the lack of production capacity on the site of the can producer, they asked us to make a run as big as possible." (G1)	Flexibility	Process
					"The most important thing, I think, is to give priority to [production of] our A Brands. So, that was the main driver for our decision-taking process." (G1)	Flexibility	Process
DI	Long-term (>1 year)	Global supply shortage	Shortage in components (semiconductors)	"But still with all the alternative solutions, we prevented roughly 10 to 15% output loss. The total loss is, I think, a little bit bigger." (D2)	"We ask customers if they can live with a [product] that has temporarily no central locking system and we can retrofit it later." (D2)	Flexibility	Product
					"We found alternative sources for semiconductors on the market. We call it 'the broker market'. It is not coming from the original supplier, but we are buying it in another way." (D2)	Redundancy	Supply chain
FII	Long-term (>1 year)	Global supply shortage	Shortage in components (semiconductors)	"There are simply not enough parts in the world for all industries at the moment." (F4) "The salesforce has no products now to sell in the Netherlands." (F1)	"We also tried to buy parts from a broker. In fact, we made a very expensive purchase from a broker and they [purchased semiconductors] turned out to be fake." (F4)	Redundancy	Supply chain
AII	Long-term (>1 year)	Global supply shortage	Limited freight capacity	"If you say no to the container, then you do not get it. So, we have negotiated a certain price for a container, but now the supplier says: 'I'm not giving you the container for that price'". (A1) "We could not speed up the transport. We just had to sit and wait. Yes, you can decide to fly stock but that is very expensive and not sustainable. There are no alternatives." (A4)	"By un-palletizing goods into the container manually, we could fill up the containers with twice as much. The disadvantage is that, once you take the goods into the country, you have to palletize them again. We were paying €300 for that [un- and re-palletizing] vs. having twice as much in a container; so, the trade-off was easily made." (A1).	Flexibility	Process
					"We tried to ship goods from China with the train, instead of the boat." (A4)	Flexibility	Process
					"We send orders one month earlier to China. It is quite effective. If you increase the lead time, you cannot act on changes in demand. You lose flexibility. You can order everything one year in advance but you cannot steer anymore." (A4)	Redundancy Flexibility	Process

Disruption case	Disruption characteristics		Reason for disruption	Quotes about disruption impact	Example quotes about response practices in addition to preparation practices	Resilience strategies	PPS
	Scope	*Scale*					
BII	Long-term (>1 year)	Global supply shortage	Limited freight capacity	"It is really hard to push shipping companies, because they will see who pays the most, so it's really hard to get enough containers. You can ask the shipping company: 'where are my containers?', but you have to pay the full price." (B2) "The prices went up. I think that's also a lot in the media that importing a container from Asia is now ten times more expensive than three years ago." (B1) "If I'm looking to all the orders that we have for the US market, I think 95% could be delivered without any issues. And the other 5% is very difficult. But if you can explain to the customer 'it's on the water, it's on its way', they understand the situation. They're not blind for what's happening in the world." (B3)	"You have to deal with the situation of the shipping company. And if we decide to increase safety stocks, it takes at least four months to have the stock available in the USA. So, we need to look further than we did in the past." (B2)	Redundancy	Process
					"In the past, it was all from the Netherlands, but now we do have a local person to get rid of this situation. I think that really improved the situation. And that also changed the organizational structure." (B2)	Visibility Velocity	Process
					"We also switched customers from direct legs to indirect legs; normally, we deliver the customer from the warehouse in Europe, but now we changed them to an indirect delivery. So first bring the product to the warehouse in the USA and then deliver to the customer." (B2)	Redundancy	Process
GII	Long-term (>1 year)	Global supply shortage	Limited freight capacity	"In deep-sea shipping, the reliability of container availability is normally 80%, but at the moment the reliability is about 20–25%." (G3)	"We re-routed some business to Antwerp also to Barcelona. We also investigated, but I do not think we have actually done, to use the railroad from China to the Netherlands." (G4)	Flexibility	Process
					"We build up some extra stock, tried to have good forecasts and make sure that the variability of shipping companies used is at the max. Those are the only things that you can do. But to be honest, it's not a reliable supply chain because one of the chains is linked to a deep-sea carrier. At the moment, the carrier is not reliable." (G3)	Redundancy Flexibility Visibility	Process Supply chain
CI	Long-term (>1 year)	Global increase in demand	Demand increase	"People were in lockdown and the stores were closed. So, within days we saw, let us say, tripling or quadrupling of the demand. And today, it's still, you know, at a much higher level than before COVID." (C1)	"We were able to deliver consumers who ordered via e-com from our stores and made usage of the stock that was locked inside those stores." (C2)	Flexibility Redundancy	Process
					"And we needed to have a discussion with our forwarders because normally we delivered once a week to [forwarder]. And all of a sudden, we were doing six trucks a day. So, I think the deliveries went mad." (C4).	Flexibility	Supply chain

Disruption case	Disruption characteristics		Reason for disruption	Quotes about disruption impact	Example quotes about response practices in addition to preparation practices	Resilience strategies	PPS
	Scope	*Scale*					
EI	Long-term (>1 year)	Global increase in demand	Demand Increase	"We used to grow by 3% to 5% or 6% per year, and all of a sudden, we grew by 50%. And we needed to start looking at building the capacity, we needed to look at our planning tools." (E1)	"We did not have a global supply chain setup. We basically had operations and, within operations, we had supply and planning, we had logistics and warehousing, and we had procurement. And several departments might talk to each other, but there was not really a person organizing the supply chain .... This whole end-to-end discussion from raw material to customer supply, that was actually a vulnerability in our organization. So, we created a new position overseeing everything." (E2)	Visibility	Process
					"We organized third party manufacturing. So, we were looking to get material from the market, because we knew we could not make it all ourselves." (E2)	Flexibility Redundancy	Process Supply chain

Appendix C

Measures to ensure research trustworthiness (based on Guba and Lincoln 2005; adapted from Russo et al. 2021; Selviaridis and Spring 2022).

Criterion	Implementation in this research
Credibility, that is, *findings are congruent from the perspective of participants*	• Case companies are part of a research project for at least 4 years with regular workshops and engagements. • Collected data from at least three different viewpoints and strategic levels in each organization. • Presented analysis and tentative conclusions to peer scholars; related feedback helped to keep the validity of findings in check. • Research participants and broader project members checked validity of findings and provided feedback on the funnel. Further engagement in how to operationalize the funnel together with the case companies and additional companies.
Transferability, that is, *transfer of findings to different projects or research settings*	• Wrote detailed case narratives containing information about the organizations, their supply chains and environments as well as about the disruptions experienced. These detailed insights helped us to understand the cause-and-effect mechanisms derived. Information guarding anonymity of involved organizations is provided in Table 2. • Theorizing (i.e., SCRes) focused on providing a detailed understanding of the causal linkages and conditions under which mechanisms are expected to generate outcomes i.e., Insights 1 and 2. • Reflected on the boundary conditions of the findings in the conclusions section.
Dependability, that is, *consistency and traceability of data collection and analysis procedures. Dependability relates to the transparency of the research process*	• Detailed explanation of the evolution of the aim of the research moving from deductive to inductive and ultimately abductive. • Outlined case selection criteria in the case selection section. • Interview database (see Excerpt in Table 2). • Interview guide ensured focused reflection on specific topics, questions asked outlined in the data collection section. At the same time, interviews were discovery-oriented seeking detailed overviews about the disruptions and how the enfolded in each case. • Detailed explanation of the data analysis process from raw data to findings in the data analysis section.
Confirmability, that is, *match between data and findings*	• Followed established case study methods based on the literature (e.g., Yin 2009; Welch et al. 2011). • Developed and maintained a case study database including all interview transcripts, publicly available organizational data, analysis steps and version, progression of findings, and manuscript versions.