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Sensing for Transformation: A Typology of Strategic Resilience Responses in Supply Chains

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Abstract

Recent disruptions have highlighted the limitations of traditional, engineering-based approaches to supply chain resilience. In response, scholars have called for a shift toward resilience as transformation – the capacity to fundamentally reconfigure supply chains and business models considering systemic change. This study integrates resilience thinking with the dynamic capabilities framework, focusing on the sensing phase as the critical moment in which firms identify environmental signals that may trigger transformational responses. Drawing on qualitative interviews with firms undergoing strategic supply chain shifts, the study explores how organizations interpret signals from complex and uncertain environments. The findings contribute to a more nuanced understanding of sensing under conditions of volatility and offer insights into how firms distinguish between adaptation and transformation. The research advances theory on supply chain resilience and dynamic capabilities, while providing practical implications for managers navigating long-term structural change.

Keywords: Supply chain management, dynamic capabilities, disruption, supply chain resilience, transformational resilience.

1. Introduction

In recent years, the frequency and magnitude of disruptions such as pandemics, geopolitical conflicts, and environmental crises have significantly challenged firms' ability to maintain continuity and competitiveness across global supply chains (SCs) and value networks (Flynn et al., 2021; Wieland et al., 2023). These events have underscored the importance of supply chain resilience (SCRes) as a core concern in supply chain management (SCM), highlighting the need for firms to build not only robust but also adaptive and forward-looking capabilities (Brandon-Jones et al., 2014; Tukamuhabwa et al., 2015). Traditionally, resilience in SCM has been defined as the ability to return to a prior equilibrium following a disruption – a view often rooted in engineering logic and focused on persistence and recovery (Wieland and Durach, 2021). While this perspective has offered valuable insights, it proves insufficient in the face of systemic and long-term disruptions that question the very viability of existing supply chain (SC) architectures (Adobor and McMullen, 2018; Scholten et al., 2019). In response, scholars have called for a broader and more dynamic understanding of resilience that includes adaptation and, critically, transformation – the capacity to fundamentally reconfigure SCs in light of environmental change (Wieland et al., 2023; Adobor and McMullen, 2018). This transformation-oriented view aligns with the growing recognition that resilience is a multidimensional construct, involving both the structural design of supply networks and the behavioral responses of firms to uncertainty and complexity (Azadegan and Dooley, 2021; De Vries et al., 2022). Resilience is thus no longer regarded as an optional attribute but as a strategic imperative in SCM, one that underpins firms' ability to sustain value creation under volatile conditions.

Parallel to this shift, the dynamic capabilities (DCs) framework (Teece et al., 1997; Teece, 2007) offers a powerful lens to examine how firms navigate change. At its core, the framework emphasizes three organizational capacities: sensing, seizing, and transforming (Teece et al., 1997). The sensing capability, in particular, refers to the ability to identify, interpret, and prioritize environmental signals – making it a critical antecedent to strategic reorientation (Teece et al., 1997). However, while the DCs literature has largely focused on technological and market sensing, it remains less clear how firms sense disruptions and under what conditions these lead to transformational responses rather than incremental adaptations.

To address this gap, this study integrates insights from resilience thinking (Wieland et al., 2023) with the sensing phase of DCs theory (Teece et al., 1997). Specifically, it investigates the following research question: *How should organizations structure their sensing capabilities to recognize early signals of the need for transformation in supply chains?*

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Drawing on qualitative interviews with firms undergoing substantial transformation, this study examines how organizations interpret signals from uncertain environments and how sensing capabilities support resilience in SCM. The German manufacturing sector provides a salient context, as firms are highly embedded in global SCs and exposed to disruptions such as COVID-19, the Suez Canal blockage, and trade volatility (Ivanov and Dolgui, 2020). Combined with a strong engineering tradition and efficiency-driven resilience, this exposure makes the current shift toward socio-ecological resilience particularly noteworthy, offering a critical setting to investigate how sensing enables strategic reconfiguration.

2. Theoretical background

2.1 Dynamic capabilities

The concept of DCs has emerged as a central theoretical lens in strategic management and organizational theory, explaining how firms sustain competitive advantage in rapidly changing environments (Teece et al., 1997). The DCs framework shifts attention from operational efficiency to the strategic processes that enable firms to adapt, renew, and transform their resource bases (Teece, 2007). At the core of this framework lies a tripartite structure comprising sensing, seizing, and transforming (Teece et al., 1997). These dimensions reflect the sequential and interdependent activities required for organizational adaptation and renewal in volatile and uncertain environments (Teece, 2007; Eisenhardt and Martin, 2000; Helfat and Winter, 2011).

Sensing refers to a firm's ability to identify and interpret emerging opportunities and threats in both the external and internal environment (Teece et al., 1997). It includes processes such as environmental scanning, market analysis, exploratory learning, and the monitoring of technological, regulatory, and socio-economic trends (Teece, 2012; Adobor and McMullen, 2018). Sensing is particularly crucial because it provides the informational foundation upon which all subsequent strategic actions are based. Without effective sensing, firms are unlikely to recognize the need for change or anticipate critical disruptions (Teece, 2020; Bokrantz and Dul, 2023). Sensing capabilities are not purely technical or mechanistic, instead they are embedded in organizational routines, shaped by managerial cognition, and dependent on absorptive capacity and attention mechanisms (Zahra and George, 2002).

The seizing capability, which follows sensing, involves mobilizing and configuring internal and external resources to respond to perceived opportunities or threats (Teece et al., 1997). Transforming, in turn, refers to the continuous renewal and reconfiguration of the firm's asset base and capabilities to align with an evolving environment (Teece et al., 1997). All three capabilities are of equal importance, but sensing is of particular significance as it establishes the foundation for the subsequent effectiveness of strategic responses. The quality and scope of what is sensed by a firm directly determines the success of its strategic responses (Teece, 2007; Helfat and Peteraf, 2015).

Although the DCs literature has traditionally emphasized sensing in the context of technological change, market turbulence (Kauppi et al., 2018), and innovation (Ambulkar et al., 2022), this view may be too narrow in the context of contemporary disruptions. However, less attention has been paid to how firms sense and interpret systemic, slow-moving, or cross-scale disruptions (e.g., ecological degradation, shifting societal values, or institutional instability) which are becoming increasingly relevant for long-term strategic viability (Wieland et al., 2023; Henisz et al., 2010; Sharma et al., 2022). Moreover, the literature has only recently begun to address the interpretive dimension of sensing. While some studies have acknowledged the role of cognitive frameworks and decision-making biases (Scholten et al., 2019; Bokrantz and Dul, 2023), most empirical work still treats sensing as a largely objective process of information acquisition. This perspective neglects the fact that what is sensed, and how it is interpreted, is shaped by a firm's existing mental models, institutional path dependencies, and social context (Gruner and Power, 2023; Ketchen et al., 2022). In the face of complex disruptions, such interpretive work becomes critical. It determines whether a signal is understood as requiring minor adjustment, operational reconfiguration, or a full strategic transformation.

Calls for an expanded understanding of sensing have been echoed in recent contributions that advocate for systems thinking and anticipatory sensemaking in SCs (Harland, 2021; Adobor and McMullen, 2018). Sensing should not be limited to market-oriented triggers but must also encompass environmental, social, and regulatory signals that may initially appear weak or ambiguous but hold significant transformative potential (Harland, 2021; Adobor and McMullen, 2018). This broader perspective aligns closely with current research on resilience, which emphasizes the ability to detect and respond to fundamental shifts in complex systems.

By reframing sensing as a strategic and cognitive process that extends beyond immediate threats or opportunities, this study positions sensing not merely as a precursor to action, but as a central locus for sence-making and strategic foresight. In doing so, it provides a conceptual bridge to resilience thinking, which further deepens the understanding of what types of disruptions firms are attuned to, and how these inform transformational decisions within SCs and beyond.

Within the sensing phase, prior research has identified a set of sub-capabilities that help firms identify, interpret, and prioritize external and internal signals. Cognitive capabilities refer to the individual and collective ability to make sense of ambiguous developments by drawing on prior knowledge, intuition, and experience (Teece, 2007). These are particularly critical in uncertain environments, where foresight and judgment complement analytical reasoning. Processual capabilities describe the structured routines and methods used to observe and evaluate environmental change, including forecasting tools, risk dashboards, benchmarking activities, and scenario analyses (Teece et al., 1997). These processes make the sensing function traceable and repeatable across the organization. Organizational capabilities describe the configuration of structures and relational patterns that enable or constrain sensing, such as cross-functional collaboration, boundary-spanning roles, and openness to external inputs (Felin and Powell, 2016; Kump et al., 2018). Finally, technological capabilities refer to the use of digital infrastructures that support the continuous monitoring, visualization, and interpretation of SC conditions (Teece, 2007). The degree to which these capabilities are developed influences not only how accurately firms can perceive emerging risks and opportunities, but also how quickly and decisively they can respond.

2.2 Resilience thinking and transformation

In recent years, the concept of resilience has gained substantial traction within SCM and organizational research, particularly in response to increasingly frequent and severe disruptions. Traditionally, resilience was understood as a system's ability to absorb shocks and return to its prior state (Wieland and Durach, 2021). This engineering-based view of resilience emphasizes stability, control, and recovery, and is closely aligned with what Wieland et al. (2023) term persistence. Within this logic, resilience is achieved when the system's core structure and performance parameters are preserved despite external disturbances (Wieland et al., 2023). While such a view provides valuable tools for short-term continuity, it proves insufficient when dealing with systemic, long-duration, and cross-scale disruptions, such as those brought about by pandemics, geopolitical conflicts, or climate crises (Flynn et al., 2021; Gereffi et al., 2022).

In contrast, an alternative view has emerged from the field of social-ecological systems research, which reconceptualizes resilience not as resistance to change, but as the capacity to learn, adapt, and transform in response to dynamic environmental conditions (Davoudi, 2012; Walker et al., 2004). This perspective has increasingly informed SCM research and serves as the theoretical foundation for the three resilience responses introduced by Wieland et al. (2023): persistence, adaptation, and transformation. As noted, persistence reflects the ability to maintain core functions and structures in the face of disruption, consistent with the engineering paradigm (Wieland et al., 2023). Adaptation involves incremental adjustments that allow the system to operate under new conditions without fundamentally altering its architecture (Brandon-Jones et al., 2014; Scholten et al., 2019). Transformation, the most far-reaching response, entails systemic reconfiguration of SC structures, interdependencies, and value logics, often driven by proactive learning and long-term strategic repositioning (Adobor and McMullen, 2018; Azadegan and Dooley, 2021).

In our view, engineering resilience aligns closely with persistence, where the objective is to resist change and maintain functional stability (Wieland et al., 2023). In contrast, social-ecological resilience encompasses both adaptation and transformation, emphasizing the capacity to adjust or evolve in response to ongoing and uncertain change (Wieland et al., 2023; Tukamuhabwa et al., 2015). This shift from reactive recovery to anticipatory and transformative change is increasingly seen as critical, especially as firms operate in globally networked, complex, and interdependent systems (Harland, 2021; Henisz et al., 2010). Transformational resilience, in particular, entails a fundamental rethinking of organizational purpose and systemic design (Wieland et al., 2023). It may manifest in shifts toward circular economy models, relocalization of production, diversification of supplier bases, or the use of digital technologies to build more adaptive and distributed forms of coordination (Nikookar et al., 2024; Adobor and McMullen, 2018; Papert et al., 2024).

This broader and more integrative view of resilience complements the DCs framework discussed in the previous section. While the DCs perspective provides a structured account of how organizations enact change through sensing, seizing, and transforming (Teece, 2007), the resilience lens highlights what kinds of change are strategically relevant and how disruptions are interpreted within broader system contexts (Wieland et al., 2023; De Vries et al., 2022). Specifically, the notion of transformational resilience enriches the understanding of the sensing phase as a strategic and cognitive process that shapes which signals are noticed, how they are framed, and whether they are perceived as requiring adjustment or fundamental change.

3. Methodology

3.1 Research design and theoretical foundation

While this study does not follow a traditional case study approach in the strictest sense, it draws on the logic and structure of case study methodology as outlined by Yin (2014). Specifically, the research design is inspired by Yin's (2014) processual guidance and quality criteria to ensure methodological rigor in the execution of a qualitative, interview-based study. This approach is particularly well-suited to the research objective, which aims to explore the conditions under which companies opt for radical rather than incremental SC transformations, and to understand the sensing capabilities required to identify such conditions.

Interview studies are recognized as particularly valuable when the aim is to investigate subjective experiences, interpretive processes, and complex decision-making in organizational contexts (Myers and Newman, 2007). In SC research, qualitative interviews allow for deep exploration of strategic phenomena, especially when empirical knowledge is scarce or emerging (Tukamuhabwa et al., 2015; Azadegan and Dooley, 2021). The study's research question is exploratory in nature and best addressed through qualitative inquiry rather than quantitative generalization (Eisenhardt, 1989).

The design of this study is guided by theoretical and methodological considerations rooted in qualitative research (see Yin, 2014; Patton, 2002). This allowed for strategic case selection across a range of firm sizes and contexts in the German manufacturing sector. The unit of analysis is the organization, represented through expert insights from individuals in senior SC and logistics roles. The study integrates prior theoretical work on DCs (Teece et al., 1997; Teece, 2007), engineering and socio-ecological resilience (Wieland and Durach, 2021), to both inform data collection and guide analytical interpretation.

3.2 Data collection, analysis and quality assurance

The primary method of data collection was semi-structured expert interviews, which provided a balance between comparability and flexibility (Yin, 2014). The interview guide was designed deductively, drawing from the theoretical frameworks in chapter 2, while leaving room for inductive insights. Interviews were conducted in person, or via video conferencing. To enhance trustworthiness, the same core structure was used in all interviews, while allowing the interviewer to follow emergent themes when necessary (Bryman and Bell, 2011). Transcripts were anonymized following academic standards (Yin, 2014), and data were organized using a database in MAXQDA software.

The interviewees were selected through theoretical sampling (Eisenhardt, 1989; Yin, 2014) to maximize insight into transformational resilience rather than statistical representativeness. Selection criteria included: (1) firms with globally operating SCs recently exposed to major disruptions; (2) senior managers in SC or logistics with strategic decision-making responsibilities; and (3) variation in firm size and subsectors to reflect different resilience challenges. This resulted in nine interviews across five firms, providing rich strategic expertise and reflective knowledge.

As part of the data triangulation process, corporate documents and corporate communications were analyzed for all case companies. Statements from the interviews were also compared with information in the documents and cross-checked for validation. For instance, the statement of one expert regarding the use of digital twins for risk simulations (1.A) was triangulated and corroborated by corresponding corporate press releases. The selection criteria focused on ensuring that interviewees held strategic decision-making responsibility in SC or logistics roles and were familiar with resilience-related issues. This approach provided access to deep, reflective data on transformation processes and the sensing phase of organizational decision-making. Table 1 gives an overview of the cases and experts. To ensure transparency, we applied a consistent notation: experts are labeled alphabetically within each case (Table 1), while combined identifiers (e.g., 3.F) in the findings link statements to both case (number) and expert (letter).

Table 1. Overview of cases and experts

Case	Expert	Position	Professional experience in total/in position (in years)	No. of employees	Revenue 2024 (in Mrd. EUR)
1	A	Global Vice President Logistics	27/5	100.000 – 500.000	50 – 100
	B	Head of Logistics	20/10		
	C	Group Lead Logistics	26/7		
2	D	Head of Supply Chain and Logistics	22/1	10.000 – 100.000	1 – 50
	E	Head of Supply Chain Management Strategy	18/8		
3	F	Senior Vice President Logistics	21/6	100.000 – 500.000	50 – 100
	G	Change Manager Supply Chain Management	8/2		
4	H	Senior Vice President Production Technology	29/10	10.000 – 100.000	1 – 50
5	I	Senior Director Supply Chain Management and Logistics	18/2	10.000 – 100.000	< 1

Data were analyzed using the Gioia methodology (Gioia et al., 2013), a three-stage process consisting of open coding (first-order concepts), axial coding (second-order themes), and theoretical aggregation (aggregate dimensions). An illustration of the analysis process and the supporting second-order quotes can be found in the online appendix. This structure allowed for inductive theorizing while maintaining closeness to the empirical material (Gioia et al., 2013). Cross-case analysis enabled the identification of recurring patterns and divergences across the five firms, enhancing analytical generalizability (Yin, 2014).

To ensure methodological quality, the study adhered to Yin's (2014) quality criteria. Construct validity was strengthened through triangulation and multi-source evidence, internal validity was enhanced through theory-driven design and iteration, external validity was supported by theoretical sampling and cross-case logic, and reliability was ensured through procedural transparency and systematic documentation (Yin, 2014).

4. Findings

4.1 Conditions and triggers for transformative vs. incremental adaptation

The interviews revealed a clear distinction between the triggers for radical transformations and incremental adjustments. Radical transformations were typically associated with sustained, systemic disruptions. External triggers included global pandemics, geopolitical conflict, regulatory shifts, and technological breakthroughs. These events created prolonged uncertainty, challenging existing SC configurations and prompting strategic overhauls. One expert described the COVID-19 pandemic as a wake-up call: "That was the 'aha moment' – we realized that old systems would no longer suffice" (3.F). For instance, multiple firms restructured global networks in response to geopolitical tensions and war-related production disruptions (1.A; 2.E; 3.F). Others relocated production to low-cost or geopolitically stable regions, citing shifts in labor costs, tariffs, and customer demands (2.D; 2.E; 4.H). In line with socio-ecological resilience, such transformations aimed not only to restore operations but to reconfigure the firm for increased adaptability. In contrast, incremental adaptations were triggered by more contained or temporary disruptions, such as supplier delays, minor regulatory changes, or seasonal fluctuations. These situations often led to short-term adjustments in inventory, logistics, or procurement. Here, engineering resilience was dominant, aiming to restore the previous operational state efficiently (1.B; 2.D; 3.G).

Decision-making between transformation and adaptation depended on the perceived duration and magnitude of the disruption, resource availability, and risk tolerance. Firms considered potential return on investment, speed of implementation, and internal capabilities before opting for transformation. The ability to interpret signals effectively, enabled by robust sensing capabilities, was found to be the key differentiator in choosing between resilience pathways (1.A; 3.F; 3.G). As one executive summarized, "we try to assess whether the disruption is short-term or systemic – and only then decide whether to adapt or transform" (3.F).

Firms that embraced socio-ecological resilience employed strategies such as SC regionalization, automation, and technological renewal (1.A; 1.B; 2.E; 3.G; 4.H). These approaches reflected a readiness to abandon outdated practices and foster long-term resilience. In contrast, companies guided by engineering resilience focused on conservative process optimization, maintaining supplier relationships, and re-establishing the pre-disruption status quo (1.C; 3.F; 5.I).

The coexistence of both resilience logics suggests a contingent approach. Companies weigh the type of disruption, their strategic orientation, and resource base before committing to a specific response. Table 2 summarizes the conditions and strategic responses in SCRes according to different trigger types, while Appendix 3 visualizes these results.

4.2 Sensing capabilities: identifying the need for transformation

The interview data revealed that firms deploy a range of distinct but interdependent capabilities during the sensing phase. Across the five case organizations, empirical evidence pointed to cognitive, processual, organizational, and technological capabilities as key enablers of early recognition and interpretation of disruptive signals. In what follows, these capabilities are not redefined but illustrated based on how they manifest in the studied firms.

Cognitive capabilities include environmental scanning and the interpretation of signals. Interviewees emphasized the need to detect shifting customer demands, geopolitical risks, and market volatility early (5.I; 2.E). Managers rely heavily on experience-based intuition as well as analytical skills to interpret ambiguous data (5.I; 2.E). For example, one participant noted the need to "know when the market is about to shift and how severely" (5.I). Another stated that "it's not just data" but "experience and instincts count equally" (2.E).

Processual sensing capabilities were reflected in firms' use of risk monitoring tools, KPI systems, forecasting routines, and scenario planning. These routines allow companies to track regulatory changes, supplier risks, and natural disaster threats. Annual PESTEL and SWOT analyses, as well as benchmarking activities, were highlighted as key practices for structured foresight. One participant noted: "We regularly conduct benchmarks with our competitors to detect if any major shifts are on the horizon" (1.C).

Organizational capabilities centered around cross-functional collaboration, participation in industry forums, and structured dialogue with external stakeholders. Companies emphasized the role of openness, trust, and transparency, particularly in their relationships with suppliers and customers. This exchange allows for the early identification of systemic pressures. "We need transparency and mutual trust – especially with our suppliers. Only then can we identify risks early" (3.G).

Technological sensing capabilities were reflected in the use of predictive analytics, AI-driven forecasting tools, and digital twins. Several firms implemented continuous monitoring systems to assess risks in real time. One expert underscored the potential of end-to-end visibility and AI-based simulations to proactively address disruptions: "The digital twin helps us simulate and stress-test supply scenarios before they unfold in reality" (1.A).

Table 2. Conditions, relevant capabilities and strategic responses in supply chain resilience

Trigger Type	Relevant Capabilities Identified	Example Quotes from Experts	Strategic Response	Resilience Logic
Global crisis (e.g. pandemic, global lockdowns, shortages, border closures)	- Cognitive capabilities - Processual sensing capabilities - Organizational capabilities - Technological sensing capabilities	- "That was the 'aha moment' - we realized that old systems would no longer suffice" (3.F) - "We learned we had to act faster and more flexibly" (3.F) - "The pandemic showed us the limits of our existing supplier structure" (2.D)	**Structural transformation** (e.g., building regional supplier networks (2.E), redesigning planning processes (1.B))	Socio-ecological resilience
Geopolitical instability (e.g. Ukraine war, Brexit, US-China trade war, Taiwan tensions)	- Cognitive capabilities - Processual sensing capabilities - Organizational capabilities	- "We shifted our footprint to more stable regions and rethought our procurement entirely" (2.E) - "Geopolitical tensions forced us to reorganize our supply chain" (2.D) - "The war in Europe made us close sites and redistribute production" (4.H)	**Reconfiguration of global network** (e.g., relocating production from high-risk areas to Eastern Europe (4.H), supplier diversification (2.E))	Socio-ecological resilience
Temporary disruption (e.g. Suez Canal blockage, factory fire, port strike)	- Cognitive capabilities - Processual sensing capabilities - Organizational capabilities - Technological sensing capabilities	- "We optimized our logistics step by step—but without changing the core" (2.D) - "After the Suez Canal blockage, we didn't change much—we knew the disruption would pass" (1.C) - "Such events require stabilization, not transformation" (1.A)	**Incremental process improvement** (e.g., rerouting deliveries (3.G), increasing short-term buffer stock (1.B))	Engineering resilience
Technological disruption (e.g. AI, digital twin)	- Cognitive capabilities - Organizational capabilities	- "The digital twin helps us simulate and stress-test supply scenarios" (1.A) - "We continuously run AI-based market analyses" (5.I) - "We must understand how technologies impact our supply chain decisions" (1.C)	**Investment in predictive technologies** (e.g., implementing AI-driven forecasting tools (5.I), real-time dashboards and digital twins (1.A))	Socio-ecological resilience
Infrastructure failure (e.g. IT outage, cyberattack, logistics hub collapse)	- Processual sensing capabilities - Technological sensing capabilities	- "We didn't react to the Suez Canal issue with big changes—it was temporary" (3.G) - "In such cases, it's about stabilizing quickly and returning to standard" (1.A) - "Engineering resilience is what matters in such moments" (3.F)	**Short-term stabilization** (e.g., activating emergency logistics providers (3.F), switching to backup IT systems (4.H))	Engineering resilience
Cost pressure (e.g. raw material price spikes, energy shock, margin erosion)	- Cognitive capabilities - Processual sensing capabilities - Organizational capabilities	- "We tried new tech, but reverted to the old system when it proved inefficient" (2.E) - "Our KPIs are cost-focused, so we aim to stabilize before investing heavily" (4.H) - "Sometimes it's more efficient to go back to what worked" (5.I)	**Return to standard systems** (e.g., reducing SKU complexity (4.H), consolidating supplier base (5.I))	Engineering resilience
Sustainability goals (e.g. CO_2 neutrality, EU supply chain law)	- Cognitive capabilities - Processual sensing capabilities - Organizational capabilities - Technological sensing capabilities	- "We want to eliminate child labor from our entire supply chain" (3.G) - "We aim to be CO_2-neutral by 20XX, and that drives change" (2.D) - "The board set ambitious ESG targets that affect supply design" (1.B)	**Strategic redesign** (e.g., replacing Tier-2 suppliers (3.G), certifying sourcing regions (2.D), redesigning compliance audits (1.B))	Socio-ecological resilience

5. Discussion of findings

This study provides important contributions to the understanding of SCRes by addressing conditions under which firms choose radical transformation over incremental adaptation, and what capabilities are required to identify and act on these conditions. Drawing on the DCs framework (Teece et al., 1997) and resilience theory (Wieland, 2021; Wieland and Durach, 2021), the findings offer a detailed and empirically grounded answer to this question.

First, the results highlight the critical role of the sensing phase in enabling organizations to differentiate between temporary disruptions and more fundamental structural shifts. As summarized in Table 2, organizations rely on a bundle of cognitive (e.g., individual foresight, analytical ability), processual (e.g., monitoring tools, KPIs), organizational (e.g., interdepartmental exchange), and technological capabilities (e.g., digital twins, predictive analytics) to detect and interpret early signals (Teece, 2007; Felin and Powell, 2016). For instance, one expert described how geopolitical tensions were tracked using digital dashboards and then discussed in cross-functional teams to assess their strategic relevance (2.E). Another example is the early recognition of tightening sustainability legislation, which led one company to begin reconfiguring supplier relationships to meet due diligence requirements (3.G). These capabilities are not evenly distributed across organizations and require long-term investment, organizational culture, and strategic foresight.

Second, the study emphasizes that the type and perceived duration of disruption significantly influence the strategic response. Engineering resilience, typically characterized by short-term stabilization and the return to a previous equilibrium (Wieland and Durach, 2021), is frequently applied when firms expect disruptions to be temporary, such as in the case of port blockages or IT failures. Experts described how alternative transport routes were activated within days during the Suez Canal crisis, or how backup IT systems were used after cyber incidents (1.C; 4.H). These responses reflect a logic of efficiency preservation, aligned with established routines and lean practices (Eroglu and Hofer, 2011). In contrast, socio-ecological resilience is applied when firms perceive systemic threats or long-term shifts in their business environment. Interview data showed that firms interpreted the COVID-19 pandemic and geopolitical realignments not just as interruptions, but as catalysts for the rethinking of global sourcing, regional footprints, and supplier relations (2.D; 3.F). For example, several companies actively pursued regionalization strategies and redesigned contracts to increase transparency and flexibility in the network. These strategic responses align with the literature on resilience as transformation (Adobor and McMullen, 2018; Azadegan and Dooley, 2021).

Third, the findings suggest that internal organizational conditions, including leadership, communication culture, and willingness to experiment, are just as decisive as external shocks when it comes to enabling transformation. Firms that successfully implemented strategic changes often had dedicated transformation teams, strong senior management commitment, and cultures that valued openness and learning (1.A; 2.E).

Moreover, Table 2 illustrates how combinations of external triggers and internal resources lead to distinct response patterns. For instance, firms that experienced both regulatory pressure and cost volatility pursued transformations that balanced efficiency and compliance, such as nearshoring of critical components while implementing ESG-aligned audits (1.B; 3.G). This shows how SCRes strategies emerge from the interaction of external stimuli and internal dynamics, echoing findings from the contingency perspective (Brandon-Jones et al., 2014).

While this study distinguishes four types of sensing capabilities, the findings suggest that these capabilities are not isolated, but interdependent. For example, technological infrastructures such as digital twins and AI-based forecasting tools provided inputs that allowed firms to simulate supply scenarios and anticipate market shifts (1.A; 5.I). These technological insights were subsequently structured through processual routines, including benchmarking, KPI systems, and scenario planning (1.C). However, such outputs required cognitive interpretation by managers, who combined data with experience-based intuition to assess their strategic relevance (2.E; 5.I). Finally, organizational capabilities, such as cross-functional collaboration and trustful relationships with suppliers, enabled these signals to be shared and validated across the firm (3.G). Rather than forming a strict hierarchy, the capabilities interacted dynamically: technological and processual mechanisms generate signals, cognitive capabilities interpret them, and organizational structures ensure collective sensemaking. Together, these interactions constituted a holistic sensing function that supported timely and effective resilience decisions.

Beyond aligning with the perspective of resilience as transformation, our findings also highlight areas that challenge and expand upon prior research. While much of the resilience literature assumes that disruptions are temporary shocks that can be addressed through stabilization and recovery (Christopher and Peck, 2004; Wieland and Durach, 2021), several of the firms studied interpreted events such as the COVID-19 pandemic or geopolitical realignments as systemic, long-term shifts. This interpretation led them to pursue transformative strategies such as regionalization and structural redesign, thereby contradicting the logic of short-term recovery. Our study expands the dynamic capabilities literature by showing that sensing is not merely a technical activity of data gathering and scanning, as often suggested (Teece, 2007), but a socially and cognitively embedded process. Managerial judgment, organizational culture, and leadership orientation played decisive roles in how signals were framed and acted upon. These insights emphasize that firms' interpretations may diverge significantly from existing frameworks and provide a more nuanced understanding of how transformational resilience emerges in practice.

Finally, the integration of DCs and resilience theory provides a robust conceptual lens. The sensing – seizing – transforming sequence (Teece et al., 1997) describes not only how firms identify opportunities and threats, but how they translate this awareness into strategic action. The findings confirm that DCs enable firms to select appropriate resilience pathways depending on contextual fit and organizational readiness. This dynamic interplay deserves further attention in future research, particularly with regard to how firms develop sensing routines in volatile and uncertain contexts (Bokrantz and Dul, 2023; Nikookar et al., 2024). While the primary focus of this study is on the sensing phase, the findings also offer initial insights into the transition from sensing to seizing. Several interviewees stressed that sensing alone does not lead to transformation unless supported by enabling mechanisms. Three factors emerged as particularly relevant: senior leadership commitment to prioritize sensed signals and allocate resources; cross-functional collaboration that ensures shared interpretation and reduces the risk of fragmented responses; and organizational readiness in the form of slack resources, experimentation capacity, and openness to change. These factors illustrate how the sensing of triggers can evolve into seizing activities, thereby initiating concrete strategic responses.

In sum, this study contributes to theory and practice by offering a differentiated view of resilience decisions in global SCs. It moves beyond binary notions of reactive versus proactive and shows how firms tailor their responses based on disruption types, capability endowments, and strategic intent. The typology developed in Table 2 offers a structured, empirically grounded framework for assessing such decisions. Further research could test this typology across industries, examine its applicability in small and medium-sized enterprises, or explore how digitalization reshapes the sensing logic of SCs.

6. Conclusions

6.1 Theoretical contributions

First, the study contributes to the literature on SCRes by integrating DCs with resilience thinking. In doing so, it moves beyond static notions of resilience as robustness or recovery and instead emphasizes the dynamic nature of sensing and responding to disruptions. This combination enriches our understanding of SCRes as a capability-driven, context-sensitive phenomenon (Teece, 2007; Wieland, 2021).

Second, the typology developed in Table 2 represents a novel contribution by systematically linking disruption types, organizational responses, and underlying resilience logics. Unlike previous frameworks, this typology captures both exogenous and endogenous triggers and differentiates between engineering resilience (persistence) and socio-ecological resilience (adaptation and transformation). It offers a foundation for future theory development and empirical testing in SC research (Adobor and McMullen, 2018; Azadegan and Dooley, 2021).

Third, the findings advance the understanding of the sensing phase within dynamic capabilities theory by offering detailed insights into how firms recognize and interpret change, thereby responding to recent calls for more nuanced theorizing in SCM (Goertler et al., 2025). By identifying cognitive, processual, organizational, and technological sensing capabilities, the study highlights the distributed and embedded nature of sensing processes within complex organizational systems (Felin and Powell, 2016; Kump et al., 2018).

6.2 Managerial implications

From a managerial perspective, the study provides several actionable insights. First, leaders must strengthen the organization's ability to sense change by investing in real-time monitoring tools, fostering interdepartmental collaboration, and cultivating open communication cultures. Building dedicated sensing routines helps firms proactively identify when SCRes requires not just stabilization but transformation.

Second, managers should carefully assess the nature and expected duration of disruptions before selecting a resilience pathway. While engineering resilience may suffice for short-term disturbances, systemic changes require a readiness to reconfigure SCs, rethink partnerships, and redesign governance models. The typology provided here can serve as a strategic diagnostic tool to support this assessment.

Third, transformation requires more than technical solutions, it requires leadership, trust, and the capacity to engage employees in change. Empowering decentralized teams, supporting change agents, and promoting cross-functional dialogue are essential steps in enabling adaptive and transformative capabilities.

Finally, firms are advised to move beyond reactive crisis management and to build forward-looking SCRes strategies aligned with long-term goals such as digital transformation, sustainability, and regional robustness. These strategies not only mitigate risk but also unlock innovation and competitive advantage.

In conclusion, this study underscores that resilience is not a fixed trait but a strategic process that unfolds over time and depends on the interaction between environmental triggers and DCs. As global disruptions become more frequent and complex, organizations that learn to sense and transform early will be better positioned to thrive in the next normal.

6.3 Limitations and future research

As with all qualitative research, this study is subject to several limitations. First, the data were drawn from a relatively small sample of large manufacturing firms based primarily in Germany. Although the multiple-case design enhances the robustness of the findings, caution must be exercised when generalizing results to other industries, firm sizes, or geographic regions (Yin, 2014; Flyvbjerg, 2006). Future studies could apply the proposed typology in different empirical contexts, including small and medium-sized enterprises, service SCs, or emerging markets.

Second, while the study focused on the sensing phase and its role in enabling transformative decisions, the subsequent seizing and transforming phases were not examined in depth. Longitudinal studies could provide deeper insights into how sensing evolves into concrete actions over time and under varying organizational conditions.

Third, the reliance on retrospective interview data may be subject to recall bias or post-rationalization (Howard, 2011). Future research could adopt real-time case tracking, or simulation-based approaches to better capture how decisions unfold under uncertainty.

Fourth, future research could further explore the connection between the resilience strategies (that is, persistence, adaptation, and transformation) and types of digital platforms. The consideration of the conditions and responses identified in this study and distinct platform archetypes (e.g., Goertler, 2025) would support further analysis of how digital platforms support resilience strategies. This may reveal how platform-based capabilities facilitate or constrain persistence, adaptational, or transformational responses in SCs.

Finally, this research highlights the need for further theoretical integration between DCs and resilience theory. Future work might explore how firms sequence and coordinate different resilience logics over time, or how digital technologies reshape the cognitive and structural foundations of sensing capabilities.

7. Online appendix

The online appendix is available via the following link: https://figshare.com/s/16b09f1159d67f54c6ba

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