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MULTIDISCIPLINARY APPROACH TO SUPPLY CHAIN RESILIENCE: CONCEPTUALIZATION AND SCALE DEVELOPMENT

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Abstract

This research aims, through a multi-perspective and multi-disciplinary approach, to identify the key dimensions as well as the scale of measurement of enterprise supply chain resilience for an in-depth understanding of the concept. This is among the first empirical studies examining the key dimensions and appropriate measurement scale of enterprise supply chain resilience to address disruptions induced by unavoidable risk events. A detailed literature review is conducted to identify the dimensions of the construct under study. Then, a measurement instrument is developed from a set of items. The questionnaire is purified through a pretest, a pilot test, and reliability and validity tests. Data are collected from a final sample of 150 senior and middle managers, whose responses are considered for confirmatory factor analysis using SPSS Amos 22. The research results show that the enterprise supply chain resilience construct is composed of seven distinct dimensions, including collaboration, alertness, preparedness, visibility, robustness, flexibility and velocity. Then, a measurement instrument containing measurement items for each of said dimensions is empirically validated. This research develops and validates a structured and comprehensive measurement scale for the concept under study while identifying measurement items that can guide further theoretical testing of this concept and thereby dilute the dimensional and measurement confusions surrounding this theoretical concept.

Implications for Central European audience: This research develops and validates a structured and comprehensive measurement scale for the concept of firm supply chain resilience while identifying measurement items that can guide subsequent theoretical testing and thus dilute the dimensional and measurement confusions surrounding this theoretical concept.

Keywords: Firm; supply chain; resilience; dimensions; scale measurement

JEL Classification: M10, M11, M16

Introduction

Firm supply chain resilience (FSCR) has attracted significant interest from researchers and practitioners due to the multiplicity of disruptive events and their potential impacts on business competitiveness and continuity (Christopher & Peck, 2004; Sheffi & Rice, 2005; Jüttner & Maklan, 2011; Han et al., 2020). Supply chain managers are forced to adopt more resilient approaches to immunize their supply chains from disruptions (Han et al., 2020). Currently, there is some consensus that the concept of resilience is multidimensional and about its relationship to a system's capability to eventually return to stability (Day, 2014; Hohenstein et al., 2015; Kamalahmadi & Parast, 2016).

Similarly, academics and supply chain managers have paid particular attention to capabilities dedicated to disruption management in global supply chains (Tang, 2006; Dolgui & Ivanov, 2022; Xu et al., 2022). These disruptions occur at different times and for different reasons. Some are man-made, such as wars and terrorism, while others are due to natural events, such as hurricanes, earthquakes and pandemics (Chopra & Sodhi, 2014). The effects of these disruptions can be short or long-term and can affect organizational performance (Craighead et al., 2007).

To address these supply chain disruptions, firms must invest in capability building, particularly supply chain resilience, to reduce the negative effects of unavoidable risk events (Ambulkar et al., 2015; Ivanov et al., 2017, 2021; Ivanov & Keskin, 2023). The implementation of FSCR requires the continuous generation and reconfiguration of prior capabilities, including collaboration, alertness, preparedness, visibility, robustness, flexibility and velocity (Ponomarov & Holcomb, 2009; Pettit et al., 2013). Further development of the FSCR requires knowledge about its dimensions and measurement indicators (Sillanpää, 2015; Han et al., 2020).

The COVID-19 outbreak caused disruptions in global supply chains. These disruptions highlighted the importance of supply chain resilience as a key capability for sustainability (Ivanov et al., 2021). A close examination of the existing literature on supply chain resilience shows some disparity in the dimensions of this dynamic capability (Pettit et al., 2010; Jüttner & Maklan, 2011). This research aims, using a multi-perspective and multi-disciplinary approach, to identify the key dimensions as well as the measurement scale of FSCR for a thorough understanding of the concept.

This research aims to fill the gap related to the ambiguity surrounding, among other things, the dimensions and measurement items of the FSCR construct by using a multidisciplinary literature review to better understand the concept. In addition, a comprehensive measurement instrument will be developed and empirically validated.

In light of the above, the main objective of this study is to identify the flagship dimensions that reflect the FSCR construct and, subsequently, to develop and validate a measurement scale. To this end, this research has the following sub-objectives:

- Obtain, using a multidisciplinary literature review, a deep understanding of the FSCR construct.
- Address gaps related to the ambiguity surrounding the dimensions and measurement items for deploying FSCR as a dynamic higher-order capability.

- Develop and empirically validate a comprehensive measurement instrument for the FSCR construct.

The remainder of this paper is organized as follows. The following sections present the literature review in Section 1 and the research methodology in Section 2, followed by the data analysis and results in Section 3. Finally, Section 4 presents the theoretical implications, managerial implications, limitations of the research and future directions.

1 Literature Review

1.1 Theoretical foundations

Supply chain management (SCM) research now pays particular attention to supply chains in times of disruptions and risk events, which can occur in almost any region of the world and in different forms (Glenn Richey, 2009). The present study incorporates multiple theoretical perspectives in hopes of grounding, uniting, and in some ways structuring the complexity involved in supply chain resilience research.

- **Relational perspective**

Dyer and Singh (1998) proposed a theory explaining competitive advantage by focusing on dyads and business networks as units of analysis. The theory proposes that partners' investment in inter-firm knowledge-sharing routines and relationship-specific assets, particularly collaboration, fosters the potential for relationship rents (Wieland & Wallenburg, 2013).

Blackhurst et al. (2011) generalized from case study data that relational capabilities, such as supply chain collaboration, are positively related to resilience. In this research, the relational view is the theoretical foundation for understanding how this relational capability can be a key dimension of supply chain resilience (Wieland & Wallenburg, 2013).

Critical aspects of resilience include anticipation (Hamel & Valikangas, 2003) and visibility (Pettit et al., 2010). Both these aspects can be enhanced by investing in collaborative relationships between supply chain partners to share knowledge a priori about potential changes and during actual changes. Anticipation requiring knowledge about potential changes enhances supply chain robustness (Zsidisin & Wagner, 2010), while visibility requiring knowledge about current changes promotes supply chain resilience (Christopher & Peck, 2004). In addition, preparedness (Ponomarov & Holcomb, 2009) and timeliness (Manuj & Mentzer, 2008) are two other key dimensions of supply chain resilience that can be enhanced by investments in collaborative relationships among supply chain partners to address change proactively or reactively (Wieland & Wallenburg, 2013).

- **Resource-based perspective**

The resource-based perspective (RBP) argues that an organization can achieve a competitive advantage, exploit opportunities and/or mitigate threats by creating strategic sets of resources and capabilities (Barney, 2012). In SCM research, the RBP has been used to study the achievement of competitive advantage through the supply chain based on a combination of valuable, scarce, inimitable and non-substitutable resources and capabilities (Barney, 2012; Hitt et al., 2016).

Hitt et al. (2016) suggested that the contribution of the RBP, as a theoretical foundation for SCM research, involves analysing supply chain activities individually and collectively (Williams et al., 2002) to decompose them into resources and capabilities to understand their contribution to the competitive advantage of the focal firm and supply chain partners (Dubey et al., 2017). Brandon-Jones et al. (2014) argued that resources and capabilities positively affect supply chain resilience and robustness. Indeed, the RBP has been used as a theoretical basis to examine the multidimensional concept of supply chain resilience.

- **Dynamic capabilities perspective**

Capabilities exist at different levels. The higher the level, the more abstract and complex they are (Schilke, 2014). Additionally, Winter (2003) defined lower-order dynamic capabilities as those that result in a change in the resource base or operational capabilities, while higher-order dynamic capabilities result from organizational learning that creates or changes lower-order dynamic capabilities. As a result, higher-order dynamic capabilities, particularly FSCR, comprise more metaphysical strategic ideas and complex capabilities that are more difficult to observe and decode (Collis, 1994).

Furthermore, higher-order dynamic capabilities generate change in the organization as a whole towards alignment with the environment (Teece, 2014). In addition, Ambrosini et al. (2009) explained that higher-order dynamic capabilities are more transformative because they directly contribute to organizational performance and the generation of lower-order dynamic capabilities, including collaboration, alertness, preparedness, visibility, robustness, flexibility and velocity of the supply chain (Hult & Ketchen, 2001).

This theory provides researchers with a strong theoretical basis for identifying the set of low-order dynamic capabilities or dimensions that form the higher-order capability of FSCR (Pettit et al., 2010). In support of the dynamic capabilities perspective (DCP), this research supports seven dimensions of FSCR considered as seven distinct lower-order dynamic capabilities. Through collaboration, alertness, preparedness, visibility, robustness, flexibility and velocity, firms combine, transform or renew resources and capabilities, at the enterprise and supply chain levels, to prevent, withstand and respond to risk events and resulting disruptions.

1.2 Dimensions of firm supply chain resilience

In this research, supply chain resilience is considered a higher-order dynamic capability and, therefore, a generator of lower-order dynamic capabilities (Hult & Ketchen, 2001; Ambrosini et al., 2009), including collaboration, alertness, visibility, preparedness, robustness, flexibility and velocity.

- **Collaboration**

Christopher and Peck (2004) recognized collaboration as one of the factors in resilience. A high level of collaboration within supply chains enables organizations to respond meaningfully and recover from disruptions (Christopher & Peck, 2004).

Moreover, supply chain resilience is a network-wide inter-organizational concept, and its formative capabilities must encompass the predisposition of partners to align their strengths in the presence of risk events (Jüttner & Maklan, 2011). Collaboration is the state in which inter-organizational partners are willing to work together by sharing information and resources to achieve collective goals (Stank et al., 2001). Collaboration among supply chain partners involves information sharing, decision synchronization, incentive alignment, goal congruence, resource sharing, collaborative communication and joint knowledge creation (Cao & Zhang, 2011).

Similarly, collaboration reduces uncertainty and improves preparedness (Cranfield School of Management, 2003). Collaboration also prevents opportunistic behaviour by individual parties that would negatively affect the overall system's capability to respond. In addition, Sheffi (2001) pointed out that collaboration is also important once the disruption has been overcome in that it allows sharing of experience among the parties. This post-disruption collaboration is likely to have an effect on the system's capability to cope with future disruptions.

Pettit et al. (2013) pointed out that supply chain collaboration can help mitigate disruptive risks through close partnerships among supply chain members, particularly information sharing. Wieland and Wallenburg (2013) suggested that collaborative relationships between supply chain partners are conducive to supply chain resilience. Accordingly, Jüttner and Maklan (2011) proposed that collaboration, including joint business continuity plans developed with suppliers, can have a positive impact on the capability to respond to unexpected supply chain disruptions (Hohenstein et al., 2015).

Supply chain collaboration is the capability to work across organizational boundaries to create and manage unique value-added processes (Fawcett et al., 2015). When the benefits of collaborative work outweigh the costs (Terjesen et al., 2012), firms are willing to develop complementary capabilities to create value that they could not achieve independently (Fawcett et al., 2015).

In light of the above, collaboration is primarily related to visibility insofar as it includes the willingness of parties to share information, even sensitive information, about risks and risk events (Nishat Faisal et al., 2006).

- **Alertness**

In military science, various conceptualizations of alertness have been introduced. Some military science researchers refer to alertness capability as situational awareness and describe it as the perception of elements of the environment in relation to time and space (Gligor et al., 2013). The speed of recognition of environmental elements is considered critical (Alberts, 2007). In combat, military forces need early awareness of potential and future threats. The sooner changes and risk events are detected, the faster the response can be deployed (Gligor et al., 2013).

In SCM research, supply chain alertness enhances its visibility and monitoring capabilities (Mandal, 2019). Also, alertness plays a key role in enabling supply chain resilience. Li et al. (2017) considered supply chain alertness as a key dimension of resilience. In a recent study, Shin and Park (2021) identified that alertness has a positive effect on improving supply chain resilience.

Moreover, alertness has been considered a fundamental dimension of supply chain agility enabling the detection of challenges and opportunities in external and internal environments (Gligor et al., 2013) and, consequently, supply chain resilience (Queiroz et al., 2022). Similarly, Li et al. (2017) added that alertness is a reactive dimension of supply chain resilience. In addition, alertness capability enables timely recognition of changes (Li et al., 2020).

Studies have highlighted several dimensions of supply chain resilience (Chowdhury & Quaddus, 2017; Cheng & Lu, 2017). In order to understand the development of supply chain resilience as a higher-order dynamic capability, it is important to understand the generation of the lower-order dynamic capabilities that comprise it (Mandal, 2019). Supply chain alertness helps inform, in real-time, supply chain partners of any upcoming emergencies through communication and information sharing (Li et al., 2017).

- **Visibility**

Several studies related to different fields in the literature have emphasized the importance of analysing the environment and anticipating changes in order to develop a resilient entity. One of the key sub-capabilities of resilient entities is to avoid the shock completely (Hamel & Valikangas, 2003). Therefore, the anticipation of potential disruptions plays a key role in total shock avoidance. Firms, as well as supply chains, cannot avoid disruptions in the absence of a capability to scan the environment and anticipate the resulting disruptions (Worline et al., 2004; Gligor et al., 2019).

Furthermore, organizational research has conceptualized vulnerability in terms of the capability to anticipate hazards (Obrist et al., 2010). Along these lines, Conner (1993) differentiated between resilient and less resilient managers by referring to their capability to anticipate changes, including disruptions.

In the SCM literature, Christopher and Peck (2004) understood environmental analysis/anticipation capability through supply chain visibility. Furthermore, Scholten and Schilder (2015) argued that supply chain resilience could be enhanced by supply chain visibility as a collective capability requiring collaboration among supply chain partners (Scholten & Schilder, 2015; Gligor et al., 2019). In this regard, Sheffi (2005) demonstrated that increasing supply chain visibility has a positive impact on supply chain resilience. Furthermore, Rivera et al. (2016) proposed that logistics clusters are a way to improve firms' capability to scan the environment and create more resilient supply chains.

Given the above, it appears that visibility is an important capability of the supply chain to prepare for events to reduce its vulnerability to disruptions (Christopher & Peck, 2004; Jüttner & Maklan, 2011). Supply chain preparedness involves the capability to recognize, anticipate and prevent disruptions before damage occurs (Chowdhury & Quaddus, 2017). Similarly, Pettit et al. (2010) mentioned that a supply chain should anticipate, identify and assess unexpected events or uncontrollable risks, monitor their deviations, and mitigate their disruptions by detecting their early signals. To this end, visibility plays an important role in reducing the severity of supply chain disruptions (Craighead et al., 2007).

In other words, supply chain visibility covers information about entities and events related to end-to-end orders, inventory, transportation and distribution, as well as any events occurring in the environment (Sheffi, 2001; Smith, 2004; Wei & Wang, 2010). In this regard, visibility is the accessibility of information deemed critical or useful to their operations and mutually beneficial within a supply chain. In addition, the capability to see from one end of the pipeline to the other is an important component of event preparedness, picking up the right signals in a timely manner (Van der Vorst & Beulens, 2002).

- **Preparedness**

Supply chain preparedness is understood as the capability of a supply chain to withstand the influence of potential changes (Tang, 2006). The organizational practice involves developing contingency plans to prepare a supply chain to function properly in a wide variety of scenarios (Christopher & Peck, 2004). Partners in a supply chain have a set of routines and protocols that should be followed by all based on mutual collaboration to respond to changes (Lee, 2004). In this regard, procedures are established and must be followed to synchronize operations within supply chains. Firstly, the practice of selecting supply chain partners influences the stability of the supply chain network under uncertain business conditions (Krause et al., 2007) through the reliability of partners and their motivation for collaboration (Cao & Zhang, 2011; Miles & Snow, 2007). Secondly, real-time information sharing among supply chain partners must be established to enable transparency of forecasts, sales data and plans (Hult et al., 2004; Ketchen & Hult, 2007). Thirdly, clear policies and guidelines need to be pre-established in order to implement transparent incentive systems (Morgan et al., 2007; Mandal, 2019).

Similarly, the organizational practice of aligning supply chain partner interests aims to prepare them to work together to withstand change (Lee, 2004). That said, alignment of interests within a supply chain network involves the selection of supply chain partners that can enhance the robustness of the supply chain network in a turbulent environment (Krause et al., 2007) through their willingness to adapt to the business objectives of the focal firm (Miles & Snow, 2007) and their reliability (Vickery et al., 2003; McCarter & Northcraft, 2007).

Supply chain preparedness is built, on the one hand, by developing contingency plans to prevent damage to core business value (Carvalho et al., 2012) and, on the other hand, by establishing an alignment of interests among supply chain members to collaboratively withstand uncontrollable risks, thereby maximizing value creation at the supply chain level (Cao & Zhang, 2011). Conversely, a firm belonging to a supply chain that is unprepared for potential changes could suffer negative consequences as a result of failures in that supply chain (Hendricks & Singhal, 2003).

- **Robustness**

In the field of psychology, studies examining resilience are referred to as developmental psychopathology, which explores the response of individuals to stress and adversity. On the other hand, research in the general field of psychology postulates that the capability for resilience is not limited to individuals. McCubbin et al. (1998) considered resilience as ‘‘the characteristics, dimensions and properties of families that help them resist disruption in the face of change and adapt to crisis situations’’ (p. 247). They focused on the adaptive qualities of families when faced with stress and, in particular, on processes that promote resistance and survival (Gligor et al., 2019).

In the field of management, organizational research has also raised the capability to resist/survive disruptions as one of the key aspects of resilience. Fiksel (2006) introduced a conceptualization of resilience by defining resilience as an organization's capability to survive in the face of turbulent change. Valentine and Feinauer (1993) proposed a similar definition of resilience and refer to it as the power or capability to survive stress and overcome disadvantages.

More recently, SCM studies have also recognized resistance to/survival of disruptions as a dimension of resilience (Ponomarov & Holcomb, 2009). The capability to resist/survive disruptions is considered a key dimension of resilience (Gligor et al., 2019).

Supply chain robustness is its capability to withstand changes without adjusting its initial stable configuration (Wieland & Wallenburg, 2013). Resistance typically involves redundancy, including reserves or backup options (Durach et al., 2015). Mackay et al. (2020) suggested that robustness leads to resilience as an absorptive capability consisting of two dimensions: resistance and avoidance. Similarly, Wieland and Wallenburg (2013) stated that anticipation and preparedness of supply chain members are necessary for the generation of resistance capability.

- **Flexibility**

The literature on ecological resilience has recognized the importance of flexibility in achieving a resilient system. In this regard, Carpenter et al. (2001), in their description of resilience, focused on the magnitude of the disruption. The authors defined resilience as the amount of disruption that can be tolerated before a sociological system shifts to another set of processes. Walker et al. (2004) proposed a conceptualization of resilience to provide additional insight into its flexibility dimension. The authors defined resilience as the capability of a system to absorb disruptions and reorganize itself while undergoing change so as to retain essentially the same function, structure, identity and feedback (Gligor et al., 2019).

In addition, organizational research has recognized the role of flexibility in developing a resilient organization (Worline et al., 2004). Indeed, the capability to adapt tactics and operations (flexibility) has been identified as one of the key characteristics of resilience (Gligor et al., 2019).

In the context of SCM, flexibility is the capability to adapt to new, different or changing requirements (Skipper & Hanna, 2009). Factors that enable supply chain flexibility include strong supply chain relationships, contracts that allow for changes in delivery schedules, manufacturing facilities to produce multiple products, redundancy with unused resources, and a versatile workforce (Johnson et al., 2013).

Furthermore, flexibility is an inherent part of resilience (Peck, 2004). It ensures that changes caused by the risk event are absorbed by the supply chain through effective responses (Skipper & Hanna, 2009). In addition, it has been suggested that flexibility can be an organic capability for detecting disruptions, which could enhance the risk event preparedness dimension (Sheffi & Rice, 2005). There is a consensus that supply chain flexibility should be reflected in its structure, inter-organizational processes and strategies (Tang & Tomlin, 2008).

Furthermore, several studies have indicated the important role of flexibility in improving supply chain resilience (Das & Lashkari, 2015; Tukamuhabwa et al., 2015). In addition, flexibility creates supply chain resilience via an increased capability to adapt quickly during turbulence (Christopher & Holweg, 2011). Also, Kamalahmadi and Parast (2016) state that reliability and flexibility are the capabilities required to improve supply chain resilience.

- **Velocity**

Studies in different fields have emphasized speed as a key dimension of resilience. In ecological research, researchers have placed a strong emphasis on the speed of recovery from disruption when describing resilience. Resilience has been defined as the speed of recovery to levels of control (MacGillivray et al., 1995). Fresco and Kroonenberg (1992) described resilience as the speed of restoration of the exit pattern after a disruption. This speed of restoration dimension may help entities avoid shocks completely (Berkes et al., 2008).

Similarly, organizational research has raised the role of speed in developing resilience. Ortiz-de-Mandojana and Bansal (2016) indicated that the speed of recovery from disruption is an important factor in resilience. Also, Jüttner and Maklan (2011) indicated that the speed at which supply chains recover from an uncontrollable event should be taken into consideration when assessing the resilience of a supply chain. Thus, the capability to accelerate operations has been raised as a key dimension of resilience (Gligor et al., 2019).

According to Christopher and Peck (2004), velocity is the speed of movement, action or operation. In other words, velocity in a risk event determines the loss that occurs per unit of time. Velocity, compared to flexibility, places more emphasis on efficiency than on the effectiveness of supply chain response and recovery during and after a disruption (Smith, 2004). Indeed, lead times are considered a key measure of supply chain velocity (Cranfield School of Management, 2003).

In SCM research, Manuj and Mentzer (2008) distinguished three forms of velocity: the speed at which a risk event occurs, the speed at which losses occur, and the speed at which the risk event is discovered. In a resilience context, a fourth form should be added, namely, the speed at which a supply chain can recover from a risk event. Some authors have proposed that firms can achieve a more desirable state and strengthen their competitiveness via faster recovery relative to their competitors during disruptions (Christopher & Peck, 2004; Sheffi & Rice, 2005; Pettit et al., 2013). A slower recovery time after a disruption could damage customer relationships and have lasting impacts (Sheffi & Rice, 2005).

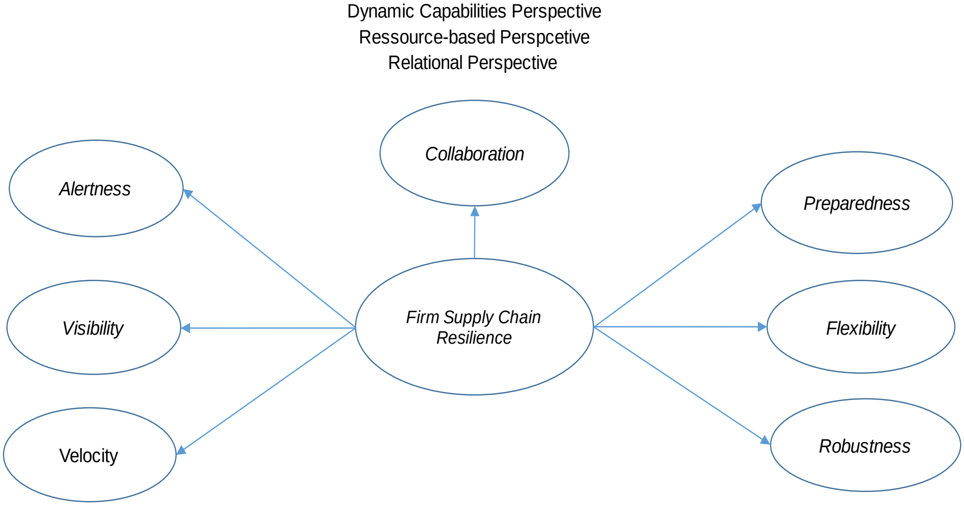
In light of the above, velocity is the speed of supply chain activities critical to maintaining competitive advantage, among others, the speed of response to customers (Chiang et al., 2015), the speed of purchasing decisions (Kaufmann & Gaeckler, 2015) and the speed of product launches (Vickery et al., 2015). Therefore, supply chain velocity can be improved by streamlining processes, reducing time to arrival and reducing non-value-added time (Christopher & Peck, 2004).

2 Research Methodology

2.1 Instrument development and validation

An effective measurement instrument must cover the content domain of each construct (Churchill, 1979; Nunnally, 1978). Items measuring a construct must agree with each other (convergence), and items in one construct must disagree with items in other constructs (discrimination). Also, each construct must be reliable, concise and easy to use. The development and refinement of the measurement scales follow a two-step approach.

Figure 1 | Dimensions of firm supply chain resilience



Source: authors

- **Scale development**

The development of the measurement scale followed the procedures and guidelines recommended by Churchill (1979), DeVellis (1991), Hinkin (1995), Mentzer and Flint (1997) and Garver and Mentzer (1999). Each dimension of the second-order construct is measured by a multi-item scale in order to increase reliability, decrease measurement error, ensure greater variability among survey participants and improve validity (Churchill, 1979). Following a review of the literature detailed above, a set of 26 items was derived to reflect each dimension of FSCR, as presented in Table 1. Also, to avoid any proliferation of measurement scales, this research adopted existing scales already validated by previous studies whenever possible (Bruner, 2003).

- **Survey design**

After determining the survey items, the procedures suggested by Dillman (2007) for survey design were used. All variables of interest were estimated by respondents' perceptual evaluation on a 7-point Likert scale: response categories for each item were anchored by 1 (strongly disagree) and 7 (strongly agree).

- **Pretesting the measurement scale**

To increase reliability, reduce measurement error and improve construct validity, the scale items were pretested (Dillman, 2007). This objective was achieved by using the online software Q-methodology. Two steps were followed to conduct this pretest, the first of which was conducted with a sample of academics and the second with a sample of supply chain managers.

In the first phase of the pretest, a personalized email containing a link to a Q-sort electronic document based on Q Method Software was sent to a group of 15 international academics

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and researchers. In addition, academics and researchers were targeted based on their research interests, areas of expertise and industry experience. Potential respondents were asked to evaluate the Q-sort statements related to the relevance of the concept dimensions and, subsequently, the items within each dimension.

Table 1 | Final measurement scale

Dimensions and items	Status and references
Firm supply chain resilience – collaboration:	
CL1. My firm and supply chain partners collaborate in developing new markets and customer responses.	Adapted from Wu et al. (2014), Cao & Zhang, (2011) and Simatupang & Sridharan (2008).
CL2. My firm and supply chain partners set up a communication plan for action.	
CL3. My firm and supply chain partners collaborate in designing their processes or products.	
CL4. My firm and supply chain partners collaborate in implementing their operational processes.	
CL5. My firm and supply chain partners have frequent interactions when problems occur.	Item 5: Eliminated – CFA method.
Firm supply chain resilience – alertness:	
AL1. My firm and supply chain partners detect threats to supply networks.	Adapted from Li et al. (2017), Christopher & Peck (2004), Lee (2004) and Sambamurthy et al. (2003).
AL2. My firm and supply chain partners detect sudden changes in demand.	
AL3. My firm and supply chain partners detect unexpected changes in the physical flow throughout supply chains.	
AL4. My firm and supply chain partners track macroeconomic changes.	Item 4: Eliminated – CFA method.
Firm supply chain resilience – visibility:	Adapted from Dubey et al. (2018) and Barratt & Oke (2007).
VI1. Inventory levels are visible to my firm and supply chain partners throughout the supply chain.	
VI2. Demand levels are visible to my firm and supply chain partners throughout the supply chain.	
VI3. My firm and supply chain partners identify new technologies for supply chain management that increase supply chain visibility.	Item 3: Newly added – Q-sort proposals.
VI4. My firm and supply chain partners have frequent communications.	Item 4: Eliminated - Q-sort proposals.
Firm supply chain resilience – preparedness:	
PR1. My firm and supply chain partners select firms that are easy to work with (i.e., willing to accommodate the focal firm's business objectives) as supply chain partners.	Adapted from Li et al., 2017), Cao & Zhang (2011), Ketchen & Hult (2007), Christopher & Peck (2004) and Lee (2004).
PR2. My firm and supply chain partners choose reliable firms to establish supply chain partnerships.	
PR3. My firm and supply chain partners develop contingency plans to increase supply chain stability.	
PR4. My firm and supply chain partners provide supply chain partners with equal access to forecasts, sales data and plans.	Item 4: Eliminated – Q-sort proposals.
PR5. My firm and supply chain partners build up a reward structure to align the incentives of supply chain partners.	Item 5: Eliminated – CFA method.

Firm supply chain resilience – robustness:	
RO1. For a long time, our supply chain retains the same stable situation as it had before disruptions occurred. RO2. When disruptions occur, our supply chain grants us enough time to consider a reasonable reaction. RO3. Without adaptations being necessary, our supply chain performs well over a wide variety of possible scenarios. RO4. For a long time, our supply chain is able to carry out its functions despite some damage done to it.	Adapted from El Baz & Ruel (2021), Wieland & Wallenburg (2012), Asbjørnslett (2009) and Meepetchdee & Shah (2007). Item 4: Eliminated – CFA method.
Firm supply chain resilience – flexibility:	
FL1. Our supply chain can adjust manufacturing facilities, processes and operations. FL2. Our supply chain can rationalize, through information systems, the management of transport and distribution. FL3. Our supply chain can adjust its delivery lead times. FL4. Our supply chain can adjust the size of orders.	Adapted from Juan et al. (2022) and Rojo et al. (2018). Items 3 and 4: Newly added – Q-sort proposals.
Firm supply chain resilience – velocity:	
VE1. Our supply chain reacts faster to make supply chain decisions. VE2. Our supply chain can quickly launch new products to meet customers' demands. VE3. Our supply chain can quickly deliver products to customers before the due date.	Adapted from Juan et al. (2022), Kaufmann & Gaeckler (2015), Vickery et al. (2015) and Chiang et al. (2015).

Source: authors

Ten responses were received, representing an effective response rate of 66.6%. These participants constitute a structured sample of respondents who are theoretically relevant to the problem being studied and are expected to have a clear and distinct perspective on the problem (Van Exel & De Graaf, 2005). Based on the respondents' ratings of the various Q-sort statements and the qualitative comments received from international academics and researchers, it appears that all dimensions were maintained. However, some items were reworded, while others were eliminated or newly added (Table 1). The objective of the Q-sort was to identify less relevant dimensions and items as well, rather than to create a new measurement scale for the FSCR construct (Clifford Defee et al., 2009).

In the second pretest phase, a procedure similar to the first pretest phase was deployed by sending personalized emails, with links to a Q-sort electronic document based on Q Method Software, to a sample of 35 managers. The survey instrument was pretested again with this random sample of logistics, supply chain and operations managers with a higher or intermediate level of knowledge and belonging to foreign companies based in Morocco. Twenty-one responses were received for a response rate of 60%. The managers represent a wide range of industry sectors. In addition, the period of professional experience was longer than 5 years for 39% of the respondents.

Results from the second Q-sort pretest indicated that all items had placement ratios exceeding the recommended level of 0.70 (Moore & Benbasat, 1991), which is considered acceptable for content validity. In addition, the inter-judge agreement exceeded the

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recommended value of 0.65 (Perreault & Leigh, 1989). Based on the results and the qualitative feedback received from the supply chain managers who responded to the Q-sort, one additional item was reworded and one was eliminated.

Finally, five items were used to measure collaboration, four items to measure alertness, three items to measure visibility, three items to measure readiness, four items to measure robustness, four items to measure flexibility and three items to measure velocity. These twenty-six items were used for the final test of the model, as shown in Table 1.

2.2 Data collection and sampling

The unit of analysis for this research is the company, and therefore, the preferred target respondents are senior or middle managers with knowledge of supply chain processes and activities as well as direct involvement in operational and strategic decision-making.

Purposive sampling was used to achieve a moderate level of external validity and to ensure generalizability of the results (Campbell & Cook, 1979). Potential respondents were identified through the use of a Ministry of Industry and Commerce database. This database contained, among other things, contact information (name, telephone number, e-mail address and title) of managers of foreign firms operating in Morocco and belonging to a diverse set of industries. An email was sent to all the contacts in the database asking them to participate in the study. From this database, a Q methodology survey was conducted in 2022 in three primary languages: French, Spanish or English, based on the potential respondent's native language or, if applicable, the official language. The initial sample included informants involved in general management and business functions related to SCM in foreign manufacturing companies based in Morocco. After eliminating mailing errors, the sample contained 650 contacts. At the end of the survey period, we received completed questionnaires from 150 respondents, which represents a response rate of 23%. Of these respondents, 75% belonged to foreign companies from Southern and Western Europe, specifically French, Spanish, German and Portuguese companies. The rest of the respondents worked for US and Japanese companies. Table 2 presents the demographics of the final test respondents.

This study adopted simple imputation using the expectation maximization (EM) algorithm as a common approach to deal with missing data (Tackney et al., 2022) using SPSS Statistics 25. Based on a procedure suggested by Armstrong and Overton (1977) regarding the likelihood of late response bias, the results of t-tests suggested no difference at the 0.05 level between early and late respondents, indicating a minimal risk of response bias. Harman's one-factor test was used to test for common method bias.

Table 2 | Respondent profile summary

Structure of the sample	Frequency	Valid %
Firm size (in terms of employees):		
• Less than 100	75	50%
• 101–200	25	16.7%
• 201–300	35	23.3%
• 301–400	15	10.0%
Manufacturing industry type:		
• Automotive industry	41	27.3%
• Aeronautics and aerospace industry	37	24.7%
• Food industry	29	19.3%
• Pharmaceutical industry	25	16.7%
• Electronic and electrical components industry	15	10.0%
• Rubber and plastic products industry	3	2.0%
Respondent designation:		
• Top management	55	36.7%
• Middle management	50	33.3%
• Lower management	45	30.0%
Respondent experience:		
• Less than 3 years	25	16.7%
• 3–6 years	31	20.7%
• 6–9 years	43	28.6%
• More than 9 years	51	34.0%
Total	**150**	**100%**

Source: authors

2.3 Scale purification

A confirmatory factor analysis (CFA) was undertaken using the Amos 22 software, as one of the main approaches for the purification of measurement items, together with the maximum likelihood estimation method to iteratively improve the parameter estimates to minimize a specified fit function. In addition to the statistical analyses, a theoretical assessment was made prior to the final deletion of any measurement items.

After purification of the measurement instrument, the 24 items used to measure the dimensions of supply chain resilience were retained, comprising four items to measure collaboration, three items to measure alertness, three items to measure visibility, three items to measure preparedness, four items to measure robustness, four items to measure flexibility and three items to measure velocity.

3 Data Analysis and Results

3.1 Reliability and validity

In this research, a CFA was conducted to determine composite reliability (CR), as well as convergent and discriminant validity.

- **Reliability**

Reliability was assessed using Cronbach's alpha, with an alpha greater than 0.70 indicating a good correlation between the item and the true scores, while lower alpha levels suggest that the sample of items is a poor indicator of the construct (Churchill, 1979). Because the alpha coefficient tends to underestimate the reliability of the scale and, therefore, has some limitations, this research followed the guidelines suggested by Garver and Mentzer (1999). If the reliability of the construct is greater than 0.70, and the average variance extracted (AVE) is 0.50 or greater, reliability is confirmed. In this regard, the results presented in Table 3 reveal that for all dimensions, the alpha coefficient and CR exceed the recommended value of 0.70. Similarly, the AVEs for all the dimensions exceed the recommended value of 0.50.

- **Validity**

Only items with loadings greater than 0.50 with their latent variables were considered for content validity. Table 3 shows values of factor loadings greater than 0.50. CR values showed acceptable internal consistency (CR > 0.775), while convergent validity was ensured due to all loadings being similar or greater than 0.5 and AVE values being acceptable (AVE > 0.542). The measurement model provided an acceptable fit to the data (x^2/df = 367.847/234 = 1.572, GFI = 0.837, SRMR = 0.0707, RMSEA = 0.062, CFI = 0.950).

Furthermore, the results contained in Table 4 revealed that all the constructs met the Fornell and Larcker (1981) criterion since the square roots of the AVEs inherent in the particular constructs had higher values than the other respective constructs. Therefore, the constructs in the study comply with the Fornell & Larcker criterion for discriminant validity.

Table 3 | Reliability and convergent validity results and fit indices

Scale/item	Cronbach alpha	CR	Item loadings	AVE	Fit indices
Collaboration					
CL1			0.933		
CL2	0.939	0.940	0.935	0.796	x^2/df (chi-square) = 367.847/234 = 1.572 GFI = 0.837 SRMR = 0.0707 RMSEA = 0.062 CFI = 0.950
CL3			0.865		
CL4			0.831		

Alertness				
AL1			0.845	
AL2	0.839	0.859	0.915	0.675
AL3			0.653	
Visibility				
VI1			0.769	
VI2	0.805	0.824	0.857	0.611
VI3			0.710	
Preparedness				
PR1			0.676	
PR2	0.873	0.780	0.872	0.545
PR3			0.646	
Robustness				
RO1			0.904	
RO2	0.886	0.893	0.716	0.677
RO3			0.809	
RO4			0.843	
Flexibility				
FL1			0.863	
FL2	0.897	0.890	0.828	0.671
FL3			0.783	
FL4			0.788	
Velocity				
VE1			0.754	
VE2	0.761	0.775	0.861	0.542
VE3			0.561	

Notes: CR = construct reliability; AVE = average variance extracted; GFI = goodness of fit index; SRMR = standardized root mean square residual; RMSEA = root mean squared error of approximation; CFI = comparative fit index.

Source: authors

Table 4 | Inter-construct correlation estimates and related AVEs

Constructs	FL	CL	AL	VI	PR	RO	VE
Flexibility (FL)	**0.819**						
Collaboration (CL)	0.689	**0.892**					
Alertness (AL)	0.478	0.371	**0.822**				
Visibility (VI)	0.681	0.588	0.524	**0.782**			
Preparedness (PR)	0.506	0.518	0.320	0.528	**0.739**		
Robustness (RO)	0.602	0.800	0.207	0.587	0.506	**0.823**	
Velocity (VE)	0.183	0.200	0.223	0.232	0.176	0.204	**0.736**

Note: Square roots of the AVE are shown on the diagonal.

Source: authors

3.2 Specification of second-order measurement model

Second-order CFA is a statistical technique that "ensures that the dimensions estimated by first-order factors define a larger, more abstract construct estimated by a second-order factor(s)" (Roussel et al., 2002, p. 310). The second-order CFA performed for the FSCR construct showed a fairly good quality of fit. Also, the correlation coefficients between the sub-dimensions and the second-order construct are also high and statistically significant. Table 5 shows that the relations between the second-order construct and its dimensions are all significant with high correlation coefficients.

Table 5 | Correlation coefficients, indicators of significance and critical ratios

First-order factors		Second-order factor	Correlation coefficients	P	CR
Collaboration	<---	*FSCR*	0.881	----	---
Robustness	<---	*FSCR*	*0.837*	***	*80.579*
Flexibility	<---	*FSCR*	*0.799*	***	*80.342*
Visibility	<---	*FSCR*	*0.749*	***	*70.133*
Preparedness	<---	*FSCR*	*0.616*	***	*40.758*
Alertness	<---	*FSCR*	*0.477*	***	*40.793*
Velocity	<---	*FSCR*	*0.254*	*	*20.571*

***Notes:** *** p<0.001; ** p<0.01; * p<0.1; CR = critical ratio.*

Source: authors

4 Discussion and Conclusion

4.1 Theoretical implications

This research represents an attempt to develop and validate a structured and comprehensive measurement scale for the FSCR construct. The most important novelty of this research is that it provides a validated measurement instrument via a rigorous approach for empirical data collection in future studies.

The proposed construct takes into account the methodological steps necessary to provide a coherent scale by testing validity, identifying the dimensions and their component items, and performing exploratory and confirmatory statistical analyses to support the methodological proposal. With respect to validity, the analyses considered in this study include content and convergent validity, reliability and discriminant validity. The statistical results were obtained through the participation of 150 supply chain managers with solid experience in the field.

The results of this study make several contributions to the SCM literature. It introduces a multidimensional measurement model of the FSCR construct. The validated FSCR measurement scale responds to the current lack of knowledge on the specificity of the dynamic capability dedicated to combating challenges associated with perturbations in supply chains.

The DCP and the RBP postulate an accumulation of resources and capabilities to meet challenges at the organizational level in times of disruptions. However, the impact of environmental challenges is no longer confined to the boundaries of an organization but extends across the entire supply chain. In this research, it was hypothesized that supply chains of organizations need to generate or reconfigure proactive and reactive lower-order dynamic capabilities in order to develop FSCR as a higher-order dynamic capability to deal with disruptive events caused by unavoidable risks.

The empirically validated FSCR measurement model extends the scope of the DCP, RBP and RP, in terms of specificity of capabilities, resources and measurement indicators, to the scale of the supply chain in order to combat challenges arising from environmental uncertainty. In support of a multi-perspective approach, this study enriches the body of knowledge and, in particular, the FSCR.

One of the main gaps in the research is the lack of a comprehensive scale for measuring FSCR based on sound theoretical foundations. The present study considered FSCR as a higher-order dynamic capability and took a multi-perspective and multi-disciplinary approach to propose a multidimensional measurement model of the construct in question, thereby extending and expanding previous studies in a comprehensive manner.

This research contributes to theory building by illuminating the confusion inherent in the dimensions of FSCR. It builds on previous work to explore the multidimensional nature of this construct. Collaboration, vigilance, visibility, preparedness, robustness, flexibility and velocity were examined as potential dimensions of FSCR. In this regard, the results of this research provide sufficient evidence to consider all seven dimensions as distinct from FSCR. The final measurement model showed satisfactory evidence of convergent and discriminant validities, indicating that the suggested dimensions capture the variance of the FSCR construct well and are distinct from each other.

The identification of the 24 items of the FSCR provided guidance for further theoretical testing of the construct. This is an important contribution because the dimensional and measurement confusions surrounding this construct pose a threat to its utility as a theoretical construct.

4.2 Managerial implications

The results suggest that supply chain managers should adopt proactive and reactive approaches to generate or reconfigure the dynamic capabilities needed for FSCR development to quickly recover from vulnerabilities induced by unavoidable risk events. In addition, these managers can use the validated measurement scale as a diagnostic tool to identify areas that require specific improvements. Supply chain managers operating in different industries will receive knowledge about the factors necessary to ensure FSCR. As a result, this study helps supply chain managers identify the dynamic capabilities and key resources that can enable the development of FSCR to cope with disruptions caused by unavoidable risk events.

In addition, supply chain managers can refer to the list of seven dimensions examined in this study to determine what aspects of their operations and tactics should be improved to strengthen the resilience of their supply chains. Once managers have identified the failures associated with any of the seven dimensions, corrective actions can be taken to reduce or eliminate the vulnerabilities and strengthen the level of FSCR as a result.

Also, decision-making could be facilitated and better informed by empirical evidence that can be based on the measurement tested and validated by this study. Specifically, supply chain managers would be able to improve their understanding of the dimensions of the concept, enabling them to assess their current levels of implementation of the FSCR. Also, they would be able to better identify the specific strengths and weaknesses of their FSCR.

It is easier to manage reality if there is a reliable and secure measure to provide quantitative results of its true size and scope. This scale is a tool that managers and practitioners can consider to assess the current implementations of FSCR in their supply chains.

4.3 Limitations and future directions

This research is essentially a methodological proposal that will only be useful if it is complemented by other research.

This study will, therefore, only be fully understood if it is used in the context of other theoretical and, especially, empirical analyses. Although most of the statistical analyses pertaining to construct validity have been completed, further analyses to test predictive validity could provide improvements.

To establish statistical generalizability, the research presented in this article must be replicated with new population samples. A study can only address statistical generalizability through results beyond its sample. Although this research sought to generalize the study to several industries, future research could focus on specific industries, including the automotive industry and the aviation and aerospace industry.

As part of the generalization of the FSCR scale developed in this study to other business environments, it should be tested in other countries. Although the results of our study show that the FSCR is a multidimensional construct, it would be useful in future studies to explore other possible distinct dimensions.

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