Maturity and resilience in supply chains: a systematic review of the literature

Luiz Carlos Roque Júnior and Guilherme F. Frederico
School of Management, Federal University of Paraná, Curitiba, Brazil, and
Maykon Luiz Nascimento Costa
Institute of Molecular Biology of Paraná, Curitiba, Brazil

Received 3 August 2022
Revised 20 November 2022
Accepted 21 November 2022

Abstract

Purpose – A globalized world demands proactive tactics from organizational supply chains. Companies should be capable of mitigating the impacts of natural and manmade disasters, which requires that they understand their stages of maturity and resilience. This study develops a theoretical model of the relationship between maturity and resilience, seeking to guide decision-making about aligning these two concepts.
Design/methodology/approach – A systematic literature review was conducted to identify the constructs that form the basis for our proposed maturity and resilience model.
Findings – The authors identified the key constructs related to maturity and resilience by analyzing the existing literature and selected 13 constructs and 3 maturity stages to construct our maturity and resilience model.
Research limitations/implications – This research contributes to the supply chain management literature, especially that involving the themes of maturity and resilience. It can encourage research to develop future empirical research in the field to validate and overcome the limitations of the initial model the authors propose.
Practical implications – The authors' proposed model supports supply chain managers in establishing strategies to increase resilience based on the maturity of the chains they manage, enabling them to face crises such as the coronavirus disease 2019 (COVID-19) pandemic.
Originality/value – The model presents a holistic view of maturity and resilience in supply chains contributing to supply chain theory by examining the alignment between the two themes.

Keywords Maturity, Resilience, Supply chains, Disruptions, Logistics, Pandemic, COVID-19, Systematic review, Sustainability, Integrating

Paper type Literature review

1. Introduction

Resilience in supply chains has been extensively studied from the strategic, tactical and operational perspectives in the context of diverse events including natural disasters like tsunamis, fires, floods, snow, rain, hurricanes and earthquakes, and human interventions like wars, terrorist attacks, maritime blockages, discontinuation of suppliers, strikes, equipment failures, industrial accidents, large swings in supply or demand and geopolitical crises (Dixit *et al.*, 2016; Hecht *et al.*, 2019; Hou *et al.*, 2018; Khalili *et al.*, 2017; Lim-Camacho *et al.*, 2017; Papadopoulos *et al.*, 2017; Pettit *et al.*, 2019; Shao and Jin, 2020; Tan *et al.*, 2020; Szyliowicz and Zamparini, 2022). According to a review, supply chain resilience has been actively researched in recent years, especially focusing on developed countries; few studies have been conducted

International Journal of Industrial Engineering and Operations Management
Vol. 5 No. 1, 2023
pp. 1-25
Emerald Publishing Limited
e-ISSN: 2690-6104
p-ISSN: 2690-6090
DOI 10.1108/IJIEOM-08-2022-0035

in developing countries, even though they are more intensely affected by the supply chain risks arising due to a lack of social, political or human resource structures (Tukamuhabwa *et al.*, 2015). While examining supply chain risks and disruptions, Kochan and Nowicki's (2018) review identified studies of industry segments such as agri-food, automotive, chemical and petrochemical, coal, counterfeiting, humanitarian aid, electronics, energy, health, military and retail.

The search for resilience in supply chains can have multiple motivations (Lücker and Seifert, 2017; Pettit *et al.*, 2019; Szyliowicz and Zamparini, 2022). As one of the biggest challenges managers face, the need for resilience can be directly linked to the impact of a disruption in a supply chain and its ripple effects. Some studies (Chowdhury and Quaddus, 2016; Purvis *et al.*, 2016; Ivanov, 2018; Pettit *et al.*, 2019; Szyliowicz and Zamparini, 2022, Sprecher *et al.*, 2017; Szyliowicz and Zamparini, 2022) present three salient points regarding resilient supply chains: first, disruptions of chains can occur at various points and are strongly influenced by supply or demand; second, sustainability through use of the circular economy does not affect supply chain resilience; and third, supply chain complexity is due to the "us" of globalized chains. Globalized chains can face events in multiple countries, and these events may or may not be linked. A supply chain is complex due to its multiple nodes and connections such as supply carriers, warehouses and stock. Each point is a node; therefore, more nodes increase complexity because they require information, people, products and more. Sprecher *et al.* (2017) highlight the need to analyze other supply chains. This is consistent with Pettit *et al.* (2019) and Szyliowicz and Zamparini (2022) who state that a company's resilience is linked beyond its supply chains to the contextual environment, which comprises communities and governments, and that these linkages need to be considered.

Resilience has been presented as an advantage of the supply chain maturity model. According to Alicke *et al.* (2020), lack of maturity is a vulnerability that organizations must resolve. Júnior *et al.*'s (2019) supply chain maturity and complexity model contribute to this view, adding a key factor to the internal, interface and external complexity. It shows that a supply chain is a living organism that can be influenced and must constantly and agilely adapt to avoid disruptions. Maturity models of supply chains are not a new concept; although they have been scarcely explored in the literature, their contributions are significant (Benmoussa *et al.*, 2015; Domingues *et al.*, 2016; Fischer *et al.*, 2016; Frederico and Martins, 2012; Júnior *et al.*, 2019).

On March 11, 2020, the Director-General of the World Health Organization (WHO), Tedros Adhanom Ghebreyesus, announced that the coronavirus disease 2019 (COVID-19) was a pandemic (OPAS, 2020). It was not the first pandemic declared by WHO in recent years, as the world has seen the emergence of the 2009 H1N1 (swine flu) pandemic and the 2014 Ebola virus epidemic (Patel *et al.*, 2017). The effects of the glut were repeated in supply chains as demand and production capacity were low, there was heavy dependence on Chinese suppliers and there was a risk of supply cuts. These consequences were also identified in China during the SARS outbreak in 2003 and during COVID-19 in 2020, as per Wang *et al.* (2016), unfortunately, millions of lives were lost in this event. Thus, we identified a gap in the literature regarding the direct link between resilience and maturity, leading to the following research question:

RQ1. How can the resilience and maturity constructs contribute to avoiding or reducing damages arising from supply chain disruptions?

The maturity and resilience model presented in this study fills a gap identified in the literature. This study proposes a model of supply chain maturity and resilience to address the lack of a model that considers these two constructs in this context. While these themes have been studied separately, they are related. Therefore, this study conducted a systematic review of the literature and constructed a theoretical model. Two systematic literature

reviews were conducted to facilitate exploring and analyzing both perspectives and to respond clearly and objectively regarding the focus areas for businesses and governments to prepare for disruptive events. The objective of this research is to identify the maturity and resilience constructs and how they can contribute to the evolution of the supply chain. The work by Shishodia *et al.* (2021) and Wilden *et al.* (2022) highlights that the existing literature tends to react to problems within the supply chain instead of proactively seeking improvements to increase performance, it also cites the limitation of the literature on the fact of not using proactive methodologies to support the advancement of the supply chain, this work seeks to shed light on this gap with the maturity and resilience model, a proactive methodology that directly contributes to improvements in chain performance of supplies by providing a guide to managers and a guide in decision-making to create resilience with each improvement in the capabilities and maturity of the constructs.

We first present a macro view of the subject using the VOSviewer tool and report the findings of the systematic literature review, which explores the resilience and maturity constructs in supply chains. Further, construction of the maturity and resilience model is addressed. Finally, the conclusions and an agenda for future research are presented.

2. Methodology: systematic literature review

In recent years, numerous studies have been disseminated in scientific repositories that are now electronic, facilitating the research process in the era of growth in big data and information. Thus, to conduct effective research, it is necessary to review the literature (Tranfield *et al.*, 2003; Lima *et al.*, 2018).

Based on the guidelines elaborated by Tranfield *et al.* (2003), we followed the research methodology depicted in Figure 1.

As a starting point for the study, the first step was to define the scope of research identified by the authors. We detailed this process by creating a research methodology flowchart. The criterion for the search process was to select studies published between April 11, 2015, and November 02, 2022. The Web of Science (WoS) database was used due to the ability to access 9,000 journals and 12 million articles, allowing substantial international access to high-quality peer-reviewed papers.

In the second step–conducting the review–the keywords "resilience," "supply" and "chain" were combined. This yielded 192 articles from the WoS during the study period, which were subsequently screened. Using the exclusion criterion of article impact, 67 articles were removed at Q2 and Q3 levels. After reading the article abstracts and full text, 9 and 130 articles, respectively, were disqualified for not meeting the study's scope and objective. After review, articles not identified in the initial database search were added; these were nominated by peer researchers and considered relevant to the study topic.

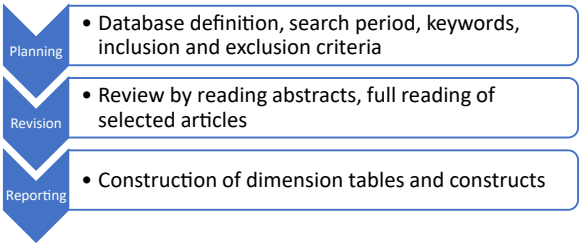

Figure 1.
Search roadmap

The article list was shared with peer researchers for a second analysis to consider some of the articles excluded in the first phases. The study search and selection process is depicted in Figure 2.

Due to the volume of data extracted from the WoS database on the theme of supply chain resilience, it was considered necessary to add a data pre-analysis stage within the literature review planning stage. The VOSviewer version 1.6.16 system was used for data analysis in the extraction stage to obtain reliable results. An analysis was performed of all articles presented in the WoS database per the review's protocol to find associations with the terms "supply chain" and "resilience." The VOSviewer keyword co-occurrence criteria were used with varying occurrence rates. A total of 989 keywords associated with the articles in this study were found, and only 156 had at least three occurrences.

Figure 3 presents a word cloud that highlights the most cited words in the first articles consulted. The most cited word is the most prominent in the central part of the figure. The less frequent the occurrence of a word, the smaller its size.

After identifying the main keywords, we identified that the theme is growing rapidly, with research being performed in recent years; the newest themes are in yellow (Figure 4).

Figure 5 presents the 104 journals relevant articles were published in, including articles related to resilient supply chains in the top journal, the *International Journal of Production*, which accounts for 26 articles and 498 citations. This shows the relevance of the theme and the impact of this journal on future publications.

The same review process was used to systematically review the supply chain maturity models. Using April 11, 2020 as the base date and considering articles published over the previous five years, the combined keywords were "Model NEAR/2 Supply Chain Maturity". In this case, the search included two more databases due to the low number of articles found in the WoS database. The Emerald and Elsevier databases were included, as both are consolidated databases with international relevance; over 207 articles were identified. After reading the abstracts and conclusions, 180 articles were excluded for not meeting the scope and objective of the work, with 37 articles considered for full-text reading. Since the number of articles was low, by the recommendation of peer researchers, the Springer database was included, using the same keyword and period. Considering only articles, 10 articles were located; after reading the abstracts and conclusions, only 3 were further considered. The impact criteria Q1, Q2 and Q3 were not applied to this review due to the low incidence of articles focusing on the theme. The phases in the search and selection process are illustrated in Figure 6.

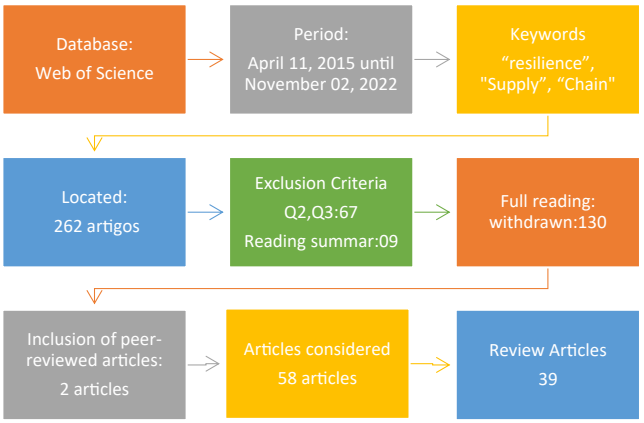

Figure 2.
Review process

Figure 3.
Keyword cloud

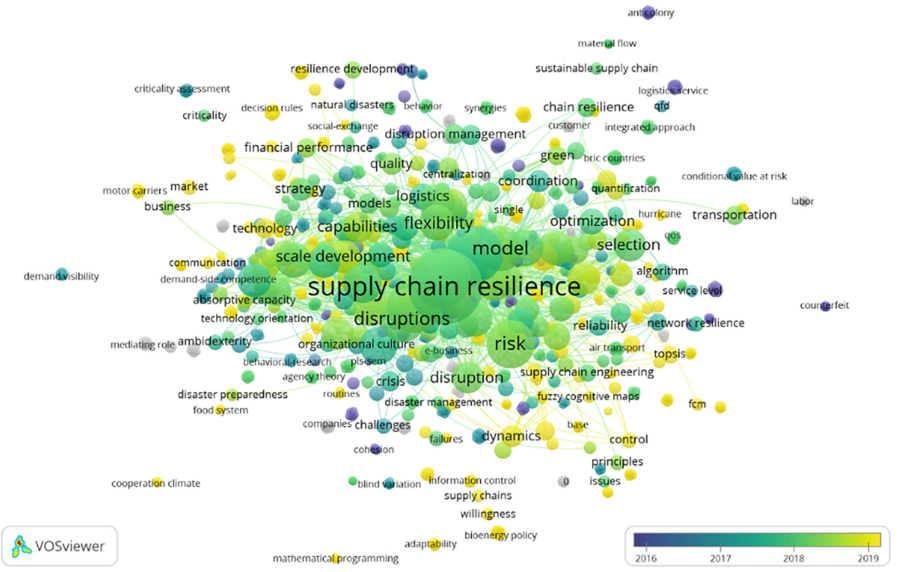

Figure 4.
Most cited keywords and year of publication

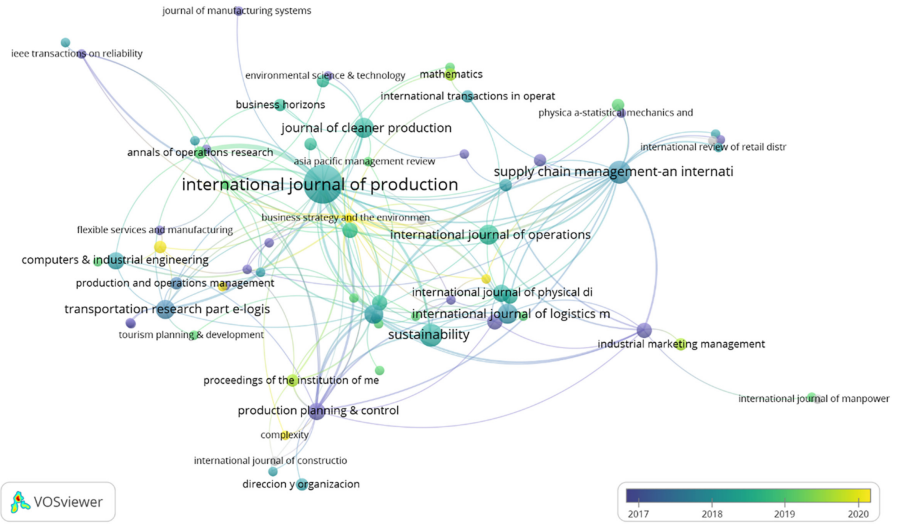

Figure 5.
Place of publication of articles on resilience

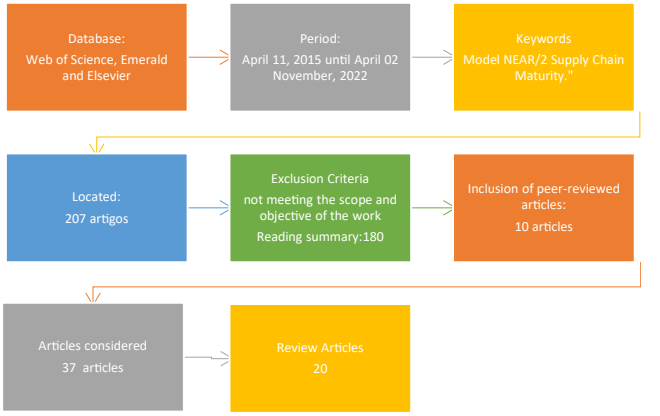

Figure 6.
Review process

In addition to the points described, the review was limited to peer-reviewed journals and published articles to ensure the study's high quality.

The next section presents the definition of resilience based on a systematic review of the literature to align this study's definition with the universe of definitions found.

3. Findings from the systematic literature review

3.1 Resilience constructs obtained from the systematic literature review

Resilience has been widely studied in the last 20 years, but the field still lacks research on mapping, creating and analyzing the links of the key resilience constructs (Macdonald *et al.*, 2018; Kochan and Nowicki, 2018). A systematic literature review was conducted to facilitate this mapping process, as shown in Table 1.

After conducting a systematic literature review according to Tranfield *et al.* (2003) and Webster and Watson (2002), we sought to use the matrix to determine the main constructs

Author	Methodology	Findings
Thomas *et al.* (2016)	Qualitative methodological approach with data triangulation. Tools applied: questionnaires, observations, semi-structured interviews and focus groups	Key factors of resilience: technology, supply chain integration, quality, marketing, organizational behaviors, definitions of leadership and direction, systems reconfigurability, supply chain reengineering, agility, commercial flexibility, manufacturing strategies and new developments, effective change management, products, practices and strategies
Lam and Bai (2016)	Qualitative methodological approach: a case study	Contingency plan, monitoring and maintenance and supply chain relationship management
Dabhilkar *et al.* (2016)	Mixed methodological approach	Quality, flexibility, reliability, cost, speed
Rajesh (2016)	Quantitative methodological approach: big data	Collaboration to increase information sharing, cross-functional teams to handle risk events, inventory management using safety stocks and available buffers, contingency plans to reduce errors, redundancies in the form of multiple vendors and insufficient resources, and visibility in the form of early warning indicators and financial monitoring
Hosseini *et al.* (2016)	Quantitative methodological approach: an empirical model	Absorbing capacity, adaptive capacity and restorative capacity
Purvis *et al.* (2016)	Qualitative methodological approach: a case study	Robust, agile, lean and flexible
Chowdhury and Quaddus (2016)	Mixed methodological approach	Supporting factors: learning and development, supply chain risk management culture, supply chain guidance
Mandal *et al.* (2016)	Quantitative methodological approach: an empirical model	Flexibility, speed, visibility and collaboration
Papadopoulos *et al.* (2017)	Quantitative methodological approach: big data	Trust, quality information sharing and publishing, partnership, infrastructure, community resilience, resources, big data
Brusset and Teller (2017)	Qualitative methodological approach: survey	Integration, flexibility, human resources, organization, capital resource
Ivanov (2017)	Quantitative methodological approach: simulation	Inventory redundancies and transport flexibility
Chowdhury and Quaddus (2017)	Mixed methodological approach	Supply chain readiness, flexibility, reserve capacity, integration, efficiency, market strength, financial strength and supply chain design
Rajesh (2017)	Quantitative methodological approach: an empirical model	Ability to modify SC design, agile features, collaboration, flexibility, inventory, deferral, standardization level, capability enhancement, product replacement, pricing features, planning features
Jain *et al.* (2017)	Quantitative methodological approach: an empirical model	Adaptive ability, collaboration, trust, sustainability, risk and revenue sharing, information sharing, supply chain structure, market sensitivity, supply chain agility, supply chain visibility, risk management culture, minimize uncertainty, technological capacity between partners
Datta (2017)	Qualitative methodological approach: systematic literature review	Communications, team building and leadership, supplier development, supply decisions and contracts, handling trade-offs, trust, information sharing
Lücker and Seifert (2017)	Qualitative methodological approach: a case study	Agility capability and risk mitigation inventory
Ali *et al.* (2017a, b)	Qualitative methodological approach: systematic literature review	Ability to anticipate, ability to adapt and recover, ability to create, ability to respond, ability to learn

(*continued*)

Table 1.
Summary of articles on resilience

Author	Methodology	Findings
Ali *et al.* (2017a, b)	Qualitative methodological approach, case study	Business certifications, globalization, vertical integration, training and development, quality management, responsiveness to customer needs, responsiveness to competitors' strategies, multi-sourcing, public–private collaboration
Ivanov (2018)	Quantitative methodological approach: simulation	Dual-source policies, risk-sharing contracts, backup providers, alternative transportation channels
Namdar *et al.* (2018)	Quantitative methodological approach: simulation	Visibility and collaboration, backup provider, contract, multiple sources
Altay *et al.* (2018)	Quantitative methodological approach: empirical models	Agility and flexibility
Gunessee *et al.* (2018)	Quantitative methodological approach: empirical models	Agility, flexibility, lean management
Kochan and Nowicki (2018)	Qualitative methodological approach: systematic literature review	Agility, flexibility, delivery, agility and flexibility of service, visibility, speed, redundancy, anticipation, efficiency, dispersion, market position, collaboration, financial strength, organization culture, anticipation, recovery, adaptability, revenue management
Liu *et al.* (2018)	Quantitative methodological approach: an empirical model	Risk management culture, agility, integration and supply chain reengineering
Lima *et al.* (2018)	Qualitative methodological approach: systematic literature review	Collaboration, visibility, flexibility, agility, redundancy, reengineering, information sharing, trust, SCR culture, innovation, leadership, sensing, information security
Singh *et al.* (2018)	Quantitative methodological approach: modeling	Government support and policy formulation, assessment of project progress, collaboration and coordination among stakeholders, skilled and competent workforce, application of technology and information systems, problem assessment, integrated logistical management, agility in processes, early delivery humanitarian aid, timely inspection and quality verification
Mancheri *et al.* (2018)	Qualitative, exploratory methodological approach	Speed, strength and flexibility
Rasouli (2019)	Qualitative methodological approach: systematic literature review	Dynamic partnership, collaborative process, collaborative process architecture, collaborative process engagement, data-driven methodologies
Sabahi and Parast (2019)	Qualitative methodological approach: systematic literature review	Sharing knowledge, agility and flexibility
Hecht *et al.* (2019)	Qualitative methodological approach: questionnaire	Formal emergency planning, employee training, service team, redundancy of food suppliers, infrastructure, location and service providers, insurance
Ivanov *et al.* (2019)	Qualitative methodological approach	Digital technologies, simulation, industry 4.0, additive manufacturing, big data, real-time tracking system
Aboah *et al.* (2019)	Qualitative methodological approach, case study	Flexibility, collaboration, features and adaptability
Chowdhury *et al.* (2019)	Qualitative methodological approach, case study	Flexibility, redundancy, visibility and collaboration
Aggarwal and Srivastava (2019)	Quantitative methodological approach: modeling	Collaborative culture, vulnerability, information sharing, resilience goal alignment, resilient supplier development, top management commitment, resource sharing for recovery, adaptive co transformation, resilient system design

Table 1. (*continued*)

Author	Methodology	Findings
Ekanayake *et al.* (2020)	Qualitative methodological approach: systematic literature review	Flexibility, capacity, efficiency, visibility, adaptability, anticipation, recovery, dispersion, collaboration, market position, security and financial strength
Anas *et al.* (2021)	Qualitative methodological approach: meta-analytical review	Organizational capability, supply chain flexibility, supply chain integration, internal integration, external integration, proactive resilience, reactive resilience, dynamic resilience, financial performance, non-financial performance
Shishodia *et al.* (2021)	Qualitative methodological approach: systematic literature review	Networks, focus, risk assessment to avoid breakdowns/disruptions, measuring resilience approaches/drivers to improve SC performance, building resilient capabilities by integrating other SC dimensions
Best and Williams (2021)	Qualitative methodological approach: systematic literature review	Agile and sustainable, leadership planning, transparency, the significance of collaboration and relationship building
Szyliowicz and Zamparini (2022)	Qualitative methodological approach: systematic literature review	Sustainability, redesigning, managing risks, multiple sourcing, safety stock, facility/supplier fortification, node density, complexity, and criticality, node density, complexity, and criticality, lateral transshipment, lateral transshipment, lateral transshipment, demand coverage, segregation/dispersion (suppliers/facilities), flexible capacity at the facilities, reassigning of customers, expansion of facility capacity
Naz *et al.* (2022)	Qualitative methodological approach: systematic literature review	IA, AI techniques, data driven, decision model, network design, machine learning, optimization algorithm, risk mitigation

Table 1.

by analyzing the keywords of the articles linked to the study's subject. Further, the most cited words in Table 1 were analyzed to group them according to taxonomy. Mapping constructs aims to avoid ambiguity and various meanings to facilitate constructing the theme. Table 2 presents the main resilience constructs found in the systematic review. These were compiled based on an analysis of the most cited words in Table 1 and the keywords in Figures 3 and 4, combined with Webster and Watson's (2002) recommendations.

A synthesis of all articles and the keywords found in the methodological process are summarized in Table 2 to facilitate a better understanding of each resilience construct. Based on 39 articles regarding supply chain resilience, we identified the competencies, skills or capacities within each construct that contribute to generating resilience. The elements that contribute to building resilience are described below.

Flexibility: This element includes process flexibility, response flexibility, flexible and time-based management, and strategic flexibility.

Agility: Adaptation, anticipation, recovery, restoration, absorption, dispersion, delaying and responsiveness are part of agility.

Collaboration: Collaboration is described in several ways; however, we highlight this skill as sharing resources, knowledge, strategies and information about risks; integration between companies, governments, society and third sector organizations (also called non-governmental organizations [NGOs]); relationship quality; collaborative forecasting; risk and revenue sharing; information sharing; technological capability among partners; and collaboration and coordination among stakeholders.

Table 2.
Resilience constructs and authors

Construct Authors	Flexibility	Agility	Collaboration	Visibility	Innovation and knowledge culture	Measurement of indicators and performance	Capabilities and resources	Management	Strategy	Environment	Process	Technology and tools
Thomas *et al.* (2016)	X	X			X			X	X		X	X
Lam and Bai (2016)			X			X		X				
Dabhilkar *et al.* (2016)	X	X			X		X	X				
Rajesh (2016)			X	X		X	X	X	X			
Hosseini *et al.* (2016)		X										
Purvis *et al.* (2016)	X	X					X	X				
Chowdhury and Quaddus (2016)					X			X	X			
Mandal *et al.* (2016)	X	X	X	X								
Papadopoulos *et al.* (2017)	X	X	X	X			X	X		X		X
Brusset and Teller (2017)	X						X	X			X	
Ivanov (2017)	X						X	X	X			
Chowdhury and Quaddus (2017)	X	X							X	X	X	
Rajesh (2017)	X	X	X		X		X	X	X		X	
Jain *et al.* (2017)	X	X	X	X	X				X	X		X
Datta (2017)			X					X	X			
Lücker and Seifert (2017)		X							X			
Ali *et al.* (2017a)		X			X							
Ali *et al.* (2017b)		X			X			X	X	X	X	
Ivanov (2018)	X				X		X	X	X			
Namdar *et al.* (2018)	X		X	X				X				
Altay *et al.* (2018)	X	X										
Gunessee *et al.* (2018)	X	X						X				

(*continued*)

Construct Authors	Flexibility	Agility	Collaboration	Visibility	Innovation and knowledge culture	Measurement of indicators and performance	Capabilities and resources	Management	Strategy	Environment	Process	Technology and tools
Kochan and Nowicki (2018)	X	X	X	X	X		X			X		
Liu *et al.* (2018)		X			X				X		X	
Lima *et al.* (2018)	X	X	X	X	X			X	X			X
Singh *et al.* (2018)					X	X	X	X	X	X	X	X
Mancheri *et al.* (2018)	X	X										
Rasouli (2019)			X					X	X		X	X
Sabahi and Parast (2019)	X	X	X		X							
Hecht *et al.* (2019)							X	X	X			
Ivanov *et al.* (2019)												X
Aboah *et al.* (2019)	X	X	X				X					
Chowdhury *et al.* (2019)	X		X	X					X			
Aggarwal and Srivastava (2019)			X		X	X	X	X				
Ekanayake *et al.* (2020)	X	X	X	X			X	X		X		
Anas *et al.* (2021)	X	X	X	X	X	X	X		X			
Shishodia *et al.* (2021)	X	X	X	X	X	X	X	X	X	X	X	X
Best and Williams (2021)			X		X		X					
Szyliowicz and Zamparini (2022)	X	X							X	X		
Naz *et al.* (2022)		X	X	X	X	X	X			X		X

Table 2.

Visibility: Supply chain visibility involves putting a set of actions into play, highlighting predictive analytics, market visibility, supplier visibility, technology visibility and scenario building.

Culture: Culture is explored in various ways in the findings. It appears as organizational, corporate, risk management and collaborative cultures; organizational behavior, trust, support factors, and learning and commitment development; and represents a key factor for creating resilience.

Performance measurement: Performance measurement can be achieved through several indicators, including measures of financial, business, supply chain, sustainability, risk resilience, operations and sustainability performance; performance innovation; measurement of resilience barriers and project progress evaluation.

Capabilities and resources: An organization's capabilities and resources provide essential foundations for developing resilience. These capabilities appear in the literature in terms of security and financial strength; social capital; investment capacity; employee training; absorption, dynamic and technological capacities; logistical capabilities; communication; knowledge; coordination; costs; capacity to develop products, services and resilience; green development; capacities for corporate efficiency, innovation, integration, anticipation, preparation and robustness; climate change adaptation capabilities; rapid emergency response capability; human capital; decision-making capacity; supplier selection; technological capability; supplier development; ability to learn; a skilled and competent workforce; and resource sharing for recovery.

Management: The management field is vast, but some actions are presented as vital for building resilience. They include managing partnerships, suppliers, supply chains, supply chain risk, resilience, operations, humanitarian, strategy, disasters, top management support, setting leadership and direction, quality, marketing, ambidextrous, commitment, trust, interruptions, information, service levels, self-leadership, competency, inventory, environment, performance, reputation, sustainability, governance, team resilience, suppliers, lean management, agility, team building and leadership, revenues, cross-functional teams and top management commitment.

Strategy: Companies have numerous strategies for creating resilience, including strategies for manufacturing and new product development, coping, competing, change management and supply chain design; data-driven strategies, reengineering of supply chains, system reconfigurability, inventory redundancies, infrastructure, location, insurance, information technology strategies, supply decisions and contracts, handling trade-offs, supply chain guidance, certifications and internationalization.

Environment: The environment includes the firm's market position, sustainability, energy policy, sustainable innovation, environmental management policies, bioenergy policy, risk propensity policies, disaster resilience, innovation resilience and chain resilience. All are part of this construct, as are community, social and socio-ecological resilience; market sensitivity; government support and policy formulation; and public-private collaboration.

Processes: This element includes optimization, integration, agile manufacturing, additive manufacturing, cloud-based manufacturing and lean processes.

Technology and tools: The use of technology and tools has been instrumental in building resilience, especially big data tools, blockchains, data science, artificial intelligence, Industry 4.0, the Internet, additive manufacturing, modeling, adaptive cycles, information technology, e-business, electric vehicles and decision support systems.

3.2 Maturity constructs obtained from the systematic literature review

We now present the supply chain maturity constructs based on a systematic review of the literature. We show the number of published articles and characteristics mentioned by the authors, based on Webster and Watson's (2002) reading and matrix technique.

Several models have been created over the years in attempts to show the status of companies; for example, Júnior *et al.* (2019) conducted a systematic review of the literature. As every review seeks to shed light on a specific theme, a new systematic review was conducted, continuing the work of Júnior *et al.* (2019) up to 2016. Table 3 was compiled based on studies that have not been addressed and the associated constructs.

Based on our systematic review of the literature, we identified that the constructs are aligned with Frederico and Martins's (2012) model. Moreover, many of the constructs presented in the review are characteristics, and the new characteristics that were not addressed by Frederico and Martins (2012) are included. The descriptions of these new features associated with the maturity constructs are given below based on Frederico *et al.* (2020). We emphasize that the process involved reading the articles in full and searching for

Author	Constructs
Benmoussa *et al.* (2015)	Planning, scheduling, execution, control and correction proposition, standardization, capitalization, goal setting, performance monitoring and improvement
Mendes *et al.* (2016)	Demand forecast management, sales, and operations planning, collaborative planning, forecasting, and replenishment, vendor-managed inventory, supply management and purchasing operations, manufacturing, warehousing, distribution, customer service, senior management support, PLM, the supply chain for risk assessment and management, product tracking and visibility, portfolio optimization, top management support
Wang *et al.* (2016)	Functional, process, collaborative, agile, sustainable
Fischer *et al.* (2016)	Collaboration, information flow, information technology, types of internal flexibility, performance measurement
Domingues *et al.* (2016)	Focus, leadership, involvement, process approach, systemic approach, continuous improvement, evidence-based decisions, mutually beneficial relationships
Tontini *et al.* (2016)	Scope of supply area activities, material standardization, receiving process, storage process, distribution process, inventory policy, inventory turnover to control, demand forecast, purchase, replenishment, planning, purchase lead time, process quotation, urgent purchase process, supplier selection, and qualification, supplier evaluation
Radosavljevic *et al.* (2016)	Strategy and planning, leadership and culture, human resources, suppliers and inventory, processes, customers, information technology, performance measurement
Barra and Ladeira (2017)	Process documentation, process measurement, process traceability, good farming practices, good processing practices, process sustainability
Asdecker and Felch (2018)	Order processing, storage, shipping
Dissanayake and Cross (2018)	Reliability, responsiveness, agility, and asset management
Miri *et al.* (2019)	Organization, supply chain strategy, control, processes, materials, resources, information
Sanae *et al.* (2019)	Purchase and supply, production, storage and distribution, sales
Frederico *et al.* (2020)	Capacity and management, support, technology levers, process performance requirements, and strategic results
Zouari *et al.* (2021)	Flexibility in sourcing, flexibility in order fulfillment, capacity, efficiency, visibility, adaptability, anticipation, recovery, dispersion, collaboration, organization, market position, security, financial strength
Yasanur *et al.* (2022)	Economic, environmental, social, policy, process, product, strategy, technology
Honorato and De Melo (2022)	Supply chain, manufacturing, delivery, after sales, P&D

Table 3.
Maturity constructs

the keywords identified in the review and the model presented, performing the correlation indicated in the table.

(1) **Costs**: This is associated with the level of costs and inventories in the supply chain, stock policy and stock turnover, economic.

(2) **Customers**: This feature is associated with the focus given to customers within chain management and the level of customer satisfaction.

(3) **Processes**: This refers to the formalization, integration and structuring of processes within the chain; planning, programming, execution, control and correction, and standardization.

(4) **Technology and tools**: This is associated with the existence of information systems and tools to support chain management, such as statistical tools for forecasting demand and information systems for managing the chain, including activities such as sales and operations planning, collaborative planning, forecasting and replenishment, vendor-managed inventory and evidence-based decisions.

(5) **Collaboration**: This refers to sharing information, gains and resources among chain members; communication and other joint action initiatives within a chain, such as product development and planning, and mutually beneficial relationships.

(6) **Management**: This is associated with the level of excellence in project management within a supply chain, risk management, and the management team's level of awareness and training in supply chain management, managing supplies and purchasing operations, manufacturing, warehousing, distribution, customer service, product lifecycle management (PLM), agility, goal setting and asset management.

(7) **Performance measurement**: This is associated with the extent of performance measurement in supply chain management, delivery, after sales.

(8) **Strategic focus**: This refers to the strategic intention provided to supply chain management by the chain's focus company and its members, research and development (R&D).

(9) **Responsiveness**: This is associated with the speed at which the supply chain responds to changes in the environment, demanding service in terms of volume and the mix of products it supplies with agility.

(10) **Resources**: This is associated with the types of resources used in the supply chain that are common (required for executing processes within the chain) and competitive (generate a competitive advantage and difficult for competing chains to use due to their differentials); top management support, focus, leadership and involvement.

(11) **Environment**: This refers to regulation issues and credit incentives that favor better supply chain performance and sustainability.

Table 4 presents the relationship between the maturity constructs discussed in the literature and the authors, according to Webster and Watson's (2002) technique. The correlation is relevant for constructing the study's final model, as well as for demonstrating the evolution of this theme in recent years.

Constructs Authors	Cost	Customers	Process	Technology and tools	Collaboration	Management	Performance measurement	Strategic focus	Responsiveness	Resource	Environments
Benmoussa *et al.* (2015)			x			x	x				
Mendes *et al.* (2016)				x		x				x	
Wang *et al.* (2016)					x		x				X
Fischer *et al.* (2016)				x	x		x		x		
Domingues *et al.* (2016)			x	x	x				x		
Tontini *et al.* (2016)	x		x	x			x				
Radosavljevic *et al.* (2016)		x		x		x		x			
Barra and Ladeira (2017)			x				x				X
Asdecker and Felch (2018)			x								
Dissanayake and Cross (2018)					x	x			x		
Miri *et al.* (2019)			x	x				x			
Yahiaoui *et al.* (2019)			x								
Frederico *et al.* (2020)				x		x	x	x			
Zouari *et al.* (2021)	x			x	x		x	x	x	X	x
Yasanur *et al.* (2022)		x	x	x		x		x		x	x
Honorato and De Melo (2022)		x	x	x						x	

Table 4.
Maturity constructs and authors

4. Alignment between supply chain resilience and maturity constructs

This section presents the supply chain maturity and resilience model, derived from the results of the systematic literature reviews, following the motto that "[a] review should identify critical knowledge gaps and thus motivate researchers to close this gap" (Webster and Watson, 2002).

In the systematic reviews of the resilience and maturity literature, similarities and gaps were identified in some constructs and their characteristics. To facilitate understanding, we defined the constructs as a macrostructure or construct, as the characteristics describe the skills or competencies expected for the construct. Such a definition is essential to avoid mixing the constructs with the characteristics that comprise them.

We ruled out that the findings in Table 2 are incorporated into the maturity and resilience model, contributing to the construction of a robust and comprehensive model in terms of constructs and characteristics, this view broadens the horizon of managers for better decision-making.

To develop a model linking the two themes, the constructs and characteristics were analyzed according to Tables 1–4; the gaps in each model are shown in Table 5, with similar constructs depicted in green.

The maturity model was constructed through a qualitative data analysis, comparing the findings and gaps in the construct stages and characteristic stages, as shown in Tables 1–5. Next, we present the maturity and resilience model with its constructs and characteristics, as shown in Table 6.

MATURITY MODEL	RESILIENCE MODEL
ENVIRONMENTS	AGILITY
CUSTOMERS	ENVIRONMENTS
COLLABORATION	CAPABILITIES AND RESOURCES
COST	COLLABORATION
STRATEGIC FOCUS	CULTURE OF INNOVATION AND KNOWLEDGE
MANAGEMENT	STRATEGY
PERFORMANCE MEASUREMENT	FLEXIBILITY
PROCESS	MANAGEMENT
RESOURCES	MEASUREMENT OF INDICATORS AND PERFORMANCE
RESPONSIBILITY	PROCESS
TECHNOLOGY AND TOOLS	TECHNOLOGY AND TOOLS
	VISIBILITY

Table 5.
Interaction of maturity and resilience models

Constructs	Characteristics
Agility and Responsibility	Agility includes adapting, anticipating, recovering, restoring, absorbing, dispersing, delaying, responsive skills. It is associated with the speed with which the supply chain responds to changes in the environment, requiring service in terms of volume and the mix of products it supplies
Environments	This refers to issues of regulation and credit incentives that favor better supply chain performance and supply chain sustainability
Capabilities and resources	This is associated with the types of resources used in the supply chain, which are common (required for the execution of processes within the chain) and competitive (they generate a competitive advantage and are difficult for competing chains to use due to their differentials). It also includes top management support, focus, leadership, and involvement. The capabilities and resources of an organization are important foundations for developing resilience. These capabilities appear in the literature as security and financial strength, social capital, investment capacity, employee training, absorption capacity, dynamic capacity, technological capacity, logistical capacities, communication, knowledge, coordination, costs, capacity for developing products, services, resilience, green development, capacity for corporate efficiency, capacity for innovation, capacity for integration, capacity for anticipation, capacity for preparation, capacity for robustness, capacity for adaptation climate change, rapid emergency response capacity, human capital, decision-making capacity, supplier selection, technological capability, supplier development, ability to learn, a skilled and competent workforce, sharing of resources for recovery
Customers	This is associated with the focus given to customers within chain management as well as the level of customer satisfaction
Collaboration	This refers to sharing of information, gains, and resources among supply chain members; communication and other joint action initiatives within the chain, such as product development and planning; mutually beneficial relationships. Collaboration is described in several ways. We highlight this ability as sharing of resources, knowledge, strategies, and information about risks; integration between companies, governments, society, and third sector organizations; relationship quality; collaborative forecasting; risk and revenue sharing; information sharing; technological capability among partners; and collaboration and coordination among stakeholders
Cost	This is associated with the level of costs and inventories in the supply chain; stock policy, stock turnover
Culture of innovation and knowledge	Culture appears in various forms in the findings: as organizational culture, corporate culture, risk management culture and collaborative culture; organizational behavior, trust, learning support factors, and commitment development, presenting a key factor in creating resilience
Strategic focus	This refers to the strategic intention that is given to supply chain management by the supply chain's focus company and its members. Companies have numerous strategies for creating resilience, including manufacturing and new product development, coping strategies, competing strategies, change management strategies, data-driven strategies, supply chain design strategies, supply chain reengineering, supplies, systems reconfigurability, inventory redundancies, infrastructure, location, insurance, information technology strategy, supply decisions and contracts, handling trade-offs, supply chain guidance, certifications, internationalization
Flexibility	Process flexibility, response flexibility, flexibility and time-based management, strategic flexibility

(*continued*)

Table 6.
Maturity and resilience model characteristics

Constructs	Characteristics
Management	This is associated with the level of excellence in project management within the supply chain, risk management, and the management team's level of awareness and training in supply chain management; management of supplies and purchasing operations, manufacturing, warehousing, distribution, customer service, PLM, agile, goal setting, asset management
Measurement of indicators and performance	This is associated with the extent to which supply chain management performance is measured
Process	This is associated with the extent of measurement of supply chain management performance; optimization, integration, agile manufacturing, additive manufacturing, cloud-based manufacturing and lean processes
Technology and tools	This is associated with the existence of information systems and tools to support supply chain management, such as statistical tools for forecasting demand and information systems for managing the chain, among other activities; sales and operations planning (S&OP), collaborative planning, forecasting, and replenishment (CPFR), vendor-managed inventory (VMI), information and evidence-based decisions
Visibility	Supply chain visibility is composed of putting a set of actions into place, highlighting predictive analytics, market visibility, supplier visibility, technology visibility and scenario building

Table 6.

4.1 Maturity model of the alignment between supply chain resilience and maturity

The supply chain maturity and resilience model seek to cover all organizations in 13 constructs, as shown in Figure 7. Each construct is composed of numerous characteristics,

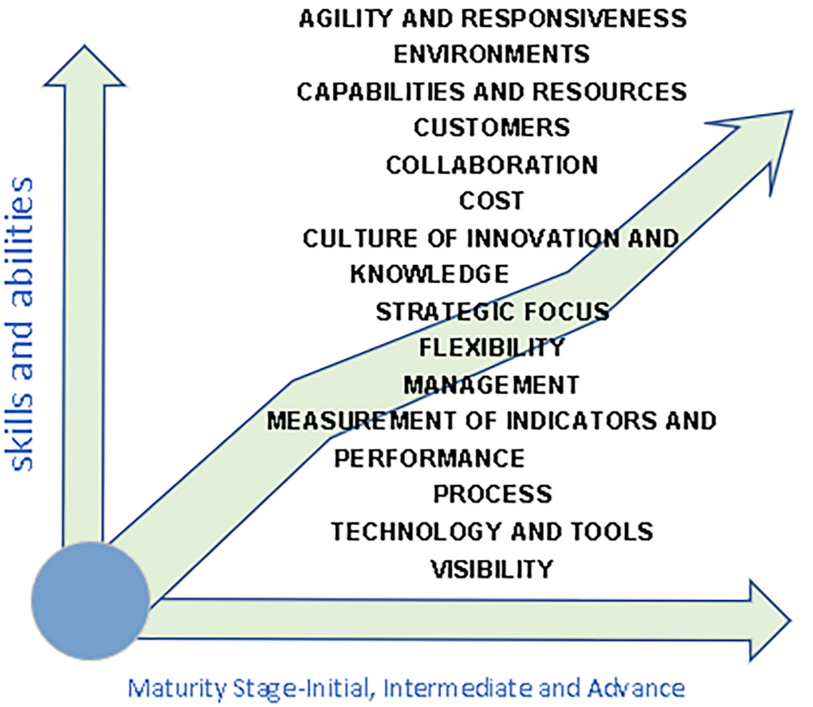

Figure 7.
Maturity and resilience framework

according to Table 6, that can be found in small to large companies. However, not all characteristics will always be present in all companies, as each company's focus will be different, affecting characteristic identification. However, even if some characteristics are lacking, the constructs will be present. Another important point regarding the model is that the maturity phases start in the initial stage, move on to the intermediate stage, and finally, progress to the advanced stage.

(1) Initial stage: This is defined as the application or development of some of the constructs through the company's performance in the characteristics, whether or not the company is aware of maturity, resilience or complexity in supply chains.

(2) Intermediate stage: The company is already aware of maturity, resilience or complexity in supply chains and seeks to master one or several constructs.

(3) Advanced stage: The company has a broad domain of skills and capabilities and uses constructs effectively as competitive differentials in the market in which it operates; the company makes decisions based on data supported by decision-making systems; its systems recognize risk patterns and act immediately to mitigate them; risk management is a living organism within the organization, fed by internal and external data with trained teams; risk management cuts across all levels from strategic to operational. The company knows to act proactively, reactively or simultaneously at the three stages of an event.

5. Discussion

On the future agenda regarding maturity and resilience, it is necessary to mention the impact of the COVID-19 pandemic, an event with the highest impact on supply chains to date. It has impacted countries and companies, as entire supply chains were paralyzed overnight, generating a mismatch between supply and demand. Such effects and impacts could have been mitigated or even eliminated. It is expected that more mature and resilient companies have been affected, but their recovery has been faster and perhaps more complete than that of their competitors. Many companies and managers who have not had the opportunity to prepare their operations in recent years due to previous events that affected their supply chains are being assessed in the ongoing crisis of the COVID-19 pandemic. Therefore, the theoretical model has been proposed for practical implementation to avoid further disruptions. The work of Shishodia *et al.* (2021) and Wilden *et al.* (2022) collaborates with the findings in this article by concluding that the existing literature tends to react to problems within the supply chain rather than proactively seeking improvements to increase performance. The same author highlights as a limitation of the literature that it does not use proactive methodologies to support the advancement of the supply chain, with the maturity and resilience model being this proactive methodology that directly contributes to improvements in the performance of supply chains by providing resilience with each improvement in capabilities and maturities of constructs.

The presented model of maturity and resilience constituted a map for strategic orientation for organizations, enabling the creation of strategies based on the constructs of Figure 7. Therefore, the model presented contributes to create resilience and, simultaneously, increase the maturity of an organization, which must be considered for successful implementation and management. The model presents the evolution of the stages through which a company passes and thus seeks its evolution in resilience and maturity, Frederico *et al.* (2020). The maturity and resilience model presented in Figure 7 fills the gap identified in the literature of the absence of an integrated model of the dimensions of resilience and maturity. In a process of building resilience, we emphasize that such capabilities take some time to develop, showing that the process of resilience and maturity development considers a long-term vision so that the impact is recognized Negri *et al.* (2021) and Thanos *et al.* (2022). For Sarkar *et al.* (2022), the survivability of the supply chain can

be achieved by combining supply chain resilience and supply chain viability measures, such findings are also part of the developed model that brings integrated constructs the which already demonstrate in the capabilities the development opportunities for finally resilience, showing that resilience is achieved together with the development of maturity. Shishodia *et al.* (2021), in their 32-year work of systematic literature review, collaborates with the findings for the creation of resilience, but does not mention maturity. Finally, the scope of this systematic review is limited to the identification of constructs and capabilities and the construction of the model presented in Figure 7, which summarizes the great competencies needed for maturity and resilience in today's world and in the complexity that awaits in the coming years.

When it comes to the limitations of this review, extending the search criteria from Q1 to Q2, Q3 would have resulted in a larger set of articles to be included, extending the scope of the review and could have offered insights into the peripheral literature. Finally, this study has identified relevant and urgent topics, given the challenging scenarios in supply chains that present themselves every day, which need to be incorporated into new research on the topic addressed. Is digitizing supply chains the future for more resilience? How will small- and medium-sized companies compete with large companies in this process (Márquez *et al.*, 2021)? How can companies in regions far from capital cities and with little access to infrastructures, such as electricity, water and the Internet, be resilient (Da Silva *et al.*, 2020)? Will risk management or contingency planning be part of most companies' day-to-day lives (Márquez *et al.*, 2021)? Will the circular economy and sustainability bring more resilience to supply chains (Majumdar *et al.*, 2020; Márquez *et al.*, 2021; Negri *et al.*, 2021)? How will supply chain 4.0 make companies more resilient (Márquez *et al.*, 2021; Ivanov and Dolgui, 2020; Thanos *et al.*, 2022; Sahoo *et al.*, 2022)?

6. Conclusions

Our review and results contributed to the existing literature and practices, offering insights into aspects of resilience and maturity, maturity and resilience needed to operate in the ever-changing world. This study contributes to the constructs of integration and maturity of resilience, presenting a holistic view of supply chains and their complexities. Only by understanding the characteristics and constructs presented will it be possible to seek ways to shield supply chain operations from future disruptions so that, in case of disruption, the company can overcome its effects as quickly as possible. This study provides visibility into the constructs and underlying supply chain maturity and resilience. A systematic literature review was performed for each of the supply chain resilience and maturity concepts. The VOSviewer tool was used to analyze networks of keywords and co-occurrences, and the model was built from 13 of the constructs identified in the literature review, organized into three stages of maturity. We believe that our study makes a significant contribution to the literature, as our model can be used by supply chain managers from anywhere in the world to develop strategies, improvement plans, contingencies or visions for their supply chains, such as model can still contribute as a basis for incorporating the appropriate Industry 4.0 into their businesses using the model to increase resilience based on the maturity of the chains they manage, allowing them to deal with crises such as the COVID-19 pandemic. Companies that do not develop supply chain maturity are at a fatal risk, with their low resilience, any disruption will have a severe impact.

References

Aboah, J., Wilson, M.M.J., Rich, K.M. and Lyne, M.C. (2019), "Operationalising resilience in tropical agricultural value chains", *Supply Chain Management*, Vol. 24 No. 2, pp. 271-300, doi: 10.1108/SCM-05-2018-0204.

Aggarwal, S. and Srivastava, M.K. (2019), "A grey-based DEMATEL model for building collaborative resilience in supply chain", *International Journal of Quality and Reliability Management*, Vol. 36 No. 8, pp. 1409-1437, doi: 10.1108/IJQRM-03-2018-0059.

Ali, A., Mahfouz, A. and Arisha, A. (2017a), "Analysing supply chain resilience: integrating the constructs in a concept mapping framework via a systematic literature review", *Supply Chain Management*, Vol. 22 No. 1, pp. 16-39, doi: 10.1108/SCM-06-2016-0197.

Ali, I., Nagalingam, S. and Gurd, B. (2017b), "Building resilience in SMEs of perishable product supply chains: enablers, barriers and risks", *Production Planning and Control*, Vol. 28 No. 15, pp. 1236-1250, doi: 10.1080/09537287.2017.1362487.

Alicke, K., Azcue, X. and Barriball, E. (2020), *Supply-Chain Recovery in Coronavirus Times—Plan for Now and the Future*, McKinsey, New York, pp. 1-18, 18 March.

Altay, N., Gunasekaran, A., Dubey, R. and Childe, S.J. (2018), "Agility and resilience as antecedents of supply chain performance under moderating effects of organizational culture within the humanitarian setting: a dynamic capability view", *Production Planning and Control*, Vol. 29 No. 14, pp. 1158-1174, doi: 10.1080/09537287.2018.1542174.

Anas, I., Purvis, L. and Giannoccaro, I. (2021), "A meta-analytical review of antecedents and outcomes of firm resilience", *Journal of Business Research*, Vol. 135, pp. 408-425, ISSN: 0148-2963, doi: 10.1016/j.jbusres.2021.06.048.

Asdecker, B. and Felch, V. (2018), "Development of an Industry 4.0 maturity model for the delivery process in supply chains", *Journal of Modelling in Management*, Vol. 13 No. 4, pp. 840-883, doi: 10.1108/JM2-03-2018-0042.

Barra, G.M.J. and Ladeira, M.B. (2017), "Modelo de maturidade para processos de certificação no sistema agroindustrial do café", *REGE - Revista de Gestão*, Vol. 24 No. 2, pp. 134-148, doi: 10.1016/j.rege.2017.03.004.

Benmoussa, R., Abdelkabir, C., Abd, A. and Hassou, M. (2015), "Capability/maturity based model for logistics processes assessment: application to distribution processes", *International Journal of Productivity and Performance Management*, Vol. 64 No. 1, pp. 28-51, doi: 10.1108/IJPPM-08-2012-0084.

Best, S. and Williams, S.J. (2021), "What have we learnt about the sourcing of personal protective equipment during pandemics? Leadership and management in healthcare supply chain management: a scoping review", *Frontiers in Public Health*, Vol. 9, p. 765501, doi: 10.3389/fpubh.2021.765501.

Brusset, X. and Teller, C. (2017), "Supply chain capabilities, risks, and resilience", *International Journal of Production Economics*, Vol. 184, pp. 59-68, doi: 10.1016/j.ijpe.2016.09.008.

Chowdhury, M.M.H. and Quaddus, M. (2016), "Supply chain readiness, response and recovery for resilience", *Supply Chain Management*, Vol. 21 No. 6, pp. 709-731, doi: 10.1108/SCM-12-2015-0463.

Chowdhury, M.M.H. and Quaddus, M. (2017), "Supply chain resilience: conceptualization and scale development using dynamic capability theory", *International Journal of Production Economics*, Vol. 188, pp. 185-204, doi: 10.1016/j.ijpe.2017.03.020.

Chowdhury, M.M.H., Quaddus, M. and Agarwal, R. (2019), "Supply chain resilience for performance: role of relational practices and network complexities", *Supply Chain Management*, Vol. 24 No. 5, pp. 659-676, doi: 10.1108/SCM-09-2018-0332.

Da Silva, R.J., dos Santos, J.P.G., Viana, F.M.F., Oler, J.R.L. and Steward, A.M. (2020), "Impactos da Covid-19 nas cadeias produtivas e no cotidiano de comunidades tradicionais na Amazônia Central", *Mundo Amazónico*, Vol. 11 No. 2, pp. 75-92, doi: 10.15446/ma.v11n2.88436.

Dabhilkar, M., Birkie, S.E. and Kaulio, M. (2016), "Supply-side resilience as practice bundles: a critical incident study", *International Journal of Operations and Production Management*, Vol. 36 No. 8, pp. 948-970, doi: 10.1108/IJOPM-12-2014-0614.

Datta, P. (2017), "Supply network resilience: a systematic literature review and future research", *International Journal of Logistics Management*, Vol. 28 No. 4, pp. 1387-1424, doi: 10.1108/IJLM-03-2016-0064.

Dissanayake, C.K. and Cross, J.A. (2018), "Systematic mechanism for identifying the relative impact of supply chain performance areas on the overall supply chain performance using SCOR model and SEM", *International Journal of Production Economics*, Vol. 201, pp. 102-115, doi: 10.1016/j.ijpe.2018.04.027.

Dixit, V., Seshadrinath, N. and Tiwari, M.K. (2016), "Performance measures based optimization of supply chain network resilience: a NSGA-II + Co-Kriging approach", *Computers and Industrial Engineering*, Vol. 93, pp. 205-214, doi: 10.1016/j.cie.2015.12.029.

Domingues, P., Sampaio, P. and Arezes, P.M. (2016), "Integrated management systems assessment: a maturity model proposal", *Journal of Cleaner Production*, Vol. 124, pp. 164-174, doi: 10.1016/j.jclepro.2016.02.103.

Ekanayake, E.M.A.C., Shen, G.Q.P. and Kumaraswamy, M.M. (2020), "Identifying supply chain capabilities of construction firms in industrialized construction", *Production Planning and Control*, Vol. 32 No. 4, pp. 303-321, doi: 10.1080/09537287.2020.1732494.

Fischer, J.H., Thomé, A.M.T., Scavarda, L.F., Hellingrath, B. and Martins, R. (2016), "Development and application of a maturity measurement framework for supply chain flexibility", *Procedia CIRP*, Vol. 41, pp. 514-519, doi: 10.1016/j.procir.2015.12.107.

Frederico, G.F. and Martins, R.A. (2012), "Model for alignment between the maturity of performance measurement systems and the maturity of supply chain management", *Gestão and Produção*, Vol. 19 No. 4, pp. 857-871, doi: 10.1590/s0104-530x2012000400014.

Frederico, G.F., Garza-Reyes, J.A., Anosike, A. and Kumar, V. (2020), "Supply Chain 4.0: concepts, maturity and research agenda", *Supply Chain Management*, Vol. 25 No. 2, pp. 262-282, doi: 10.1108/SCM-09-2018-0339.

Gunessee, S., Subramanian, N. and Ning, K. (2018), "Natural disasters, PC supply chain and corporate performance", *International Journal of Operations and Production Management*, Vol. 38 No. 9, pp. 1796-1814, doi: 10.1108/IJOPM-12-2016-0705.

Hecht, A.A., Biehl, E., Barnett, D.J. and Neff, R.A. (2019), "Urban food supply chain resilience for crises threatening food security: a qualitative study", *Journal of the Academy of Nutrition and Dietetics*, Vol. 119 No. 2, pp. 211-224, doi: 10.1016/j.jand.2018.09.001.

Honorato, C. and De Melo, F.C.L. (2022), "Industry 4.0: the case-study of a global supply chain company", *Journal of Industrial Integration and Management*. doi: 10.1142/s2424862222500269.

Hosseini, S., Al Khaled, A. and Sarder, M.D. (2016), "A general framework for assessing system resilience using Bayesian networks: a case study of sulfuric acid manufacturer", *Journal of Manufacturing Systems*, Vol. 41, pp. 211-227, doi: 10.1016/j.jmsy.2016.09.006.

Hou, Y., Wang, X., Wu, Y.J. and He, P. (2018), "How does the trust affect the topology of supply chain network and its resilience? An agent-based approach", *Transportation Research Part E: Logistics and Transportation Review*, Vol. 116, pp. 229-241, doi: 10.1016/j.tre.2018.07.001.

Ivanov, D. (2017), "Simulation-based ripple effect modelling in the supply chain", *International Journal of Production Research*, Vol. 55 No. 7, pp. 2083-2101, doi: 10.1080/00207543.2016.1275873.

Ivanov, D. (2018), "Revealing interfaces of supply chain resilience and sustainability: a simulation study", *International Journal of Production Research*, Vol. 56 No. 10, pp. 3507-3523, doi: 10.1080/00207543.2017.1343507.

Ivanov, D. and Dolgui, A. (2020), "A digital supply chain twin for managing the disruption risks and resilience in the era of Industry 4.0", *Production Planning and Control*, Vol. 32 No. 9, pp. 757-788, doi: 10.1080/09537287.2020.1768450.

Ivanov, D., Dolgui, A. and Sokolov, B. (2019), "The impact of digital technology and Industry 4.0 on the ripple effect and supply chain risk analytics", *International Journal of Production Research*, Vol. 57 No. 3, pp. 829-846, doi: 10.1080/00207543.2018.1488086.

Jain, V., Kumar, S., Soni, U. and Chandra, C. (2017), "Supply chain resilience: model development and empirical analysis", *International Journal of Production Research*, Vol. 55 No. 22, pp. 6779-6800, doi: 10.1080/00207543.2017.1349947.

Júnior, L.C.R., Frederico, G.F. and Costa, M.L.N. (2019), "Supply chain management maturity and complexity: findings from a case study at a health biotechnology company in Brazil", *International Journal of Logistics Systems and Management*, Vol. 33 No. 1, p. 1, doi: 10.1504/IJLSM.2019.099658.

Khalili, S.M., Jolai, F. and Torabi, S.A. (2017), "Integrated production–distribution planning in two-echelon systems: a resilience view", *International Journal of Production Research*, Vol. 55 No. 4, pp. 1040-1064, doi: 10.1080/00207543.2016.1213446.

Kochan, C.G. and Nowicki, D.R. (2018), "Supply chain resilience: a systematic literature review and typological framework", *International Journal of Physical Distribution and Logistics Management*, Vol. 48 No. 8, pp. 842-865, doi: 10.1108/IJPDLM-02-2017-0099.

Lam, J.S.L. and Bai, X. (2016), "A quality function deployment approach to improve maritime supply chain resilience", *Transportation Research Part E: Logistics and Transportation Review*, Vol. 92, pp. 16-27, doi: 10.1016/j.tre.2016.01.012.

Lim-Camacho, L., Plagányi, É.E., Crimp, S., Hodgkinson, J.H., Hobday, A.J., Howden, S.M. and Loechel, B. (2017), "Complex resource supply chains display higher resilience to simulated climate shocks", *Global Environmental Change*, Vol. 46, pp. 126-138, doi: 10.1016/j.gloenvcha.2017.08.011.

Lima, F.R.P.D., Da Silva, A.L., Godinho Filho, M. and Dias, E.M. (2018), "Systematic review: resilience enablers to combat counterfeit medicines", *Supply Chain Management*, Vol. 12 No. 3, pp. 117-135, doi: 10.1108/SCM-04-2017-0155.

Liu, C.L., Shang, K.C., Lirn, T.C., Lai, K.H. and Lun, Y.H.V. (2018), "Supply chain resilience, firm performance, and management policies in the liner shipping industry", *Transportation Research Part A: Policy and Practice*, Vol. 110, pp. 202-219, doi: 10.1016/j.tra.2017.02.004.

Lücker, F. and Seifert, R.W. (2017), "Building up resilience in a pharmaceutical supply chain through inventory, dual sourcing and agility capacity", *Omega*, Vol. 73, pp. 114-124, doi: 10.1016/j.omega.2017.01.001.

Macdonald, J.R., Zobel, C.W., Melnyk, S.A. and Griffis, S.E. (2018), "Supply chain risk and resilience: theory building through structured experiments and simulation", *International Journal of Production Research*, Vol. 56 No. 12, pp. 4337-4355, doi: 10.1080/00207543.2017.1421787.

Majumdar, A., Shaw, M. and Sinha, S.K. (2020), "COVID-19 debunks the myth of socially sustainable supply chain: a case of the clothing industry in South Asian countries", *Sustainable Production and Consumption*, Vol. 24, pp. 150-155, doi: 10.1016/j.spc.2020.07.001.

Mancheri, N.A., Sprecher, B., Deetman, S., Young, S.B., Bleischwitz, R., Dong, L., Kleijn, R. and Tukker, A. (2018), "Resilience in the tantalum supply chain", *Resources, Conservation and Recycling*, Vol. 129, pp. 56-69, doi: 10.1016/j.resconrec.2017.10.018.

Mandal, S., Sarathy, R., Korasiga, V.R., Bhattacharya, S. and Dastidar, S.G. (2016), "Achieving supply chain resilience: the contribution of logistics and supply chain capabilities", *International Journal of Disaster Resilience in the Built Environment*, Vol. 7 No. 5, pp. 544-562, doi: 10.1108/IJDRBE-04-2016-0010.

Márquez, R., Tolosa, L. and Celis, M.T. (2021), "Understanding COVID-19 effect on the U.S. supply chain of strategic products: important factors, current situation, and future perspective, [Entendiendo el efecto de COVID-19 en las cadenas de suministro de productos estratégicos en EE.UU: factores clave, situación actual y perspectivas para el future]", *Artículo de Investigación. Revista Ciencia e Ingeniería*, Vol. 42 No. 1, pp. 53-62.

Mendes, P. Jr, Leal, J.E. and Thomé, A.M.T. (2016), "A maturity model for demand-driven supply chains in the consumer product goods industry", *International Journal of Production Economics*, Vol. 179, pp. 153-165, doi: 10.1016/j.ijpe.2016.06.004.

Miri, F., Shahabi, N. and Asadipour, E. (2019), "Relationship between learning organization and creativity in teaching hospitals", *International Transaction Journal of Engineering Management and Applied Sciences and Technologies*, Vol. 10 No. 10, p. 6, doi: 10.14456/ITJEMAST.2019.129.

Namdar, J., Li, X., Sawhney, R. and Pradhan, N. (2018), "Supply chain resilience for single and multiple sourcing in the presence of disruption risks", *International Journal of Production Research*, Vol. 56 No. 6, pp. 2339-2360, doi: 10.1080/00207543.2017.1370149.

Naz, F., Kumar, A., Majumdar, A. and Agrawal, R. (2022), "Is artificial intelligence an enabler of supply chain resiliency post COVID-19? An exploratory state-of-the-art review for future research", *Operation Management Research*, Vol. 15, pp. 378-398, doi: 10.1007/s12063-021-00208-w.

Negri, M., Cagno, E., Colicchia, C. and Sarkis, J. (2021), "Integrating sustainability and resilience in the supply chain: a systematic literature review and a research agenda", *Business Strategy and the Environment*, Vol. 30, pp. 2858-2886, doi: 10.1002/bse.2776.

OPAS (2020), "WHO says COVID-19 is now characterized as a pandemic", available at: https://www.paho.org/bra/index.php?option=com_content&view=article&id=6120:oms-afirma-que-covid-19-e-agora-caracterizada-como-pandemia&Itemid=812 (accessed 1 May 2020).

Papadopoulos, T., Gunasekaran, A., Dubey, R., Altay, N., Childe, S.J. and Fosso-Wamba, S. (2017), "The role of Big Data in explaining disaster resilience in supply chains for sustainability", *Journal of Cleaner Production*, Vol. 142, pp. 1108-1118, doi: 10.1016/j.jclepro.2016.03.059.

Patel, A., D'Allessandro, M.M., Ireland, K.J., Burel, W.G., Wencil, E.B. and Rasmussen, S.A. (2017), "Personal protective equipment supply chain: lessons learned from recent public health emergency responses", *Health Security*, Vol. 15 No. 3, pp. 244-252, doi: 10.1089/hs.2016.0129.

Pettit, T.J., Croxton, K.L. and Fiksel, J. (2019), "The evolution of resilience in supply chain management: a retrospective on ensuring supply chain resilience", *Journal of Business Logistics*, Vol. 40 No. 1, pp. 56-65, doi: 10.1111/jbl.12202.

Purvis, L., Spall, S., Naim, M. and Spiegler, V. (2016), "Developing a resilient supply chain strategy during 'boom' and 'bust'", *Production Planning and Control*, Vol. 27 Nos 7-8, pp. 579-590, doi: 10.1080/09537287.2016.1165306.

Radosavljevic, M., Barac, N., Jankovic-Milic, V. and Andjelkovic, A. (2016), "Supply chain management maturity assessment: challenges of the enterprises in Serbia", *Journal of Business Economics and Management*, Vol. 17 No. 6, pp. 848-864, doi: 10.3846/16111699.2016.1191038.

Rajesh, R. (2016), "Forecasting supply chain resilience performance using grey prediction", *Electronic Commerce Research and Applications*, Vol. 20, pp. 42-58, doi: 10.1016/j.elerap.2016.09.006.

Rajesh, R. (2017), "Technological capabilities and supply chain resilience of firms: a relational analysis using Total Interpretive Structural Modeling (TISM)", *Technological Forecasting and Social Change*, Vol. 118, pp. 161-169, doi: 10.1016/j.techfore.2017.02.017.

Rasouli, M.R. (2019), "Intelligent process-aware information systems to support agility in disaster relief operations: a survey of emerging approaches", *International Journal of Production Research*, Vol. 57 No. 6, pp. 1857-1872, doi: 10.1080/00207543.2018.1509392.

Sabahi, S. and Parast, M.M. (2019), "Firm innovation and supply chain resilience: a dynamic capability perspective", *International Journal of Logistics Research and Applications*, Vol. 23 No. 3, pp. 254-269, doi: 10.1080/13675567.2019.1683522.

Sahoo, P., Saraf, P.K. and Uchil, R. (2022), "Identification of critical success factors for leveraging Industry 4.0 technology and research agenda: a systematic literature review using PRISMA protocol", *Asia-Pacific Journal of Business Administration*, Vol. ahead-of-print No. ahead-of-print. doi: 10.1108/BIJ-12-2018-0428.

Sanae, Y., Faycal, F. and Ahmed, M. (2019), "A supply chain maturity model for automotive SMEs: a case study", *IFAC-PapersOnLine*, Vol. 52 No. 13, pp. 2044-2049, doi: 10.1016/j.ifacol.2019.11.506.

Sarkar, P., Mohamed Ismail, M.W. and Tkachev, T. (2022), "Bridging the supply chain resilience research and practice gaps: pre and post COVID-19 perspectives", *Journal of Global Operations and Strategic Sourcing*, Vol. 15 No. 4, pp. 599-627, doi: 10.1108/JGOSS-09-2021-0082.

Shao, L. and Jin, S. (2020), "Resilience assessment of the lithium supply chain in China under impact of new energy vehicles and supply interruption", *Journal of Cleaner Production*, Vol. 252, 119624, doi: 10.1016/j.jclepro.2019.119624.

Shishodia, A., Sharma, R., Rajesh, R. and Munim, Z.H. (2021), "Supply chain resilience: a review, conceptual framework and future research", *The International Journal of Logistics Management*, Vol. ahead-of-print No. ahead-of-print. doi: 10.1108/IJLM-03-2021-0169.

Singh, R.K., Gupta, A. and Gunasekaran, A. (2018), "Analysing the interaction of factors for resilient humanitarian supply chain", *International Journal of Production Research*, Vol. 56 No. 21, pp. 6809-6827, doi: 10.1080/00207543.2018.1424373.

Sprecher, B., Daigo, I., Spekkink, W., Vos, M., Kleijn, R., Murakami, S. and Kramer, G.J. (2017), "Novel indicators for the quantification of resilience in critical material supply chains, with a 2010 rare earth crisis case study", *Environmental Science and Technology*, Vol. 51 No. 7, pp. 3860-3870, doi: 10.1021/acs.est.6b05751.

Szyliowicz, J. and Zamparini, L. (2022), "Freight transport security and the robustness of global supply chains", *Transport Reviews*, Vol. 42, pp. 717-724, doi: 10.1080/01441647.2022.2127243.

Tan, W.J., Cai, W. and Zhang, A.N. (2020), "Structural-aware simulation analysis of supply chain resilience", *International Journal of Production Research*, Vol. 58 No. 17, pp. 5175-5195, doi: 10.1080/00207543.2019.1705421.

Thanos, P., Sivarajah, U., Spanaki, K., Despoudi, S. and Gunasekaran, A. (2022), "Editorial: artificial Intelligence (AI) and data sharing in manufacturing, production and operations management research", *International Journal of Production Research*, Vol. 60:14, pp. 4361-4364, doi: 10.1080/00207543.2021.2010979.

Thomas, A., Byard, P., Francis, M., Fisher, R. and White, G.R.T. (2016), "Profiling the resiliency and sustainability of UK manufacturing companies", *Journal of Manufacturing Technology Management*, Vol. 27 No. 1, pp. 82-99, doi: 10.1108/JMTM-06-2014-0086.

Tontini, G., de Carvalho, L.C., Schlindwein, N.F.d.C. and Tomarevski, V. (2016), "Maturity model of procurement and supply management in small and medium-size enterprises: a benchmarking of hospitals and metal-mechanic companies", *International Journal of Quality and Service Sciences*, Vol. 8 No. 3, pp. 315-333, doi: 10.1108/IJQSS-04-2016-0036.

Tranfield, D., Denyer, D. and Smart, P. (2003), "Towards a methodology for developing evidence-informed management knowledge by means of systematic review", *British Journal of Management*, Vol. 14 No. 3, pp. 207-222, doi: 10.1111/1467-8551.00375.

Tukamuhabwa, B.R., Stevenson, M., Busby, J. and Zorzini, M. (2015), "Supply chain resilience: definition, review and theoretical foundations for further study", *International Journal of Production Research*, Vol. 53 No. 18, pp. 5592-5623, doi: 10.1080/00207543.2015.1037934.

Wang, G., Gunasekaran, A., Ngai, E.W.T. and Papadopoulos, T. (2016), "Big data analytics in logistics and supply chain management: certain investigations for research and applications", *International Journal of Production Economics*, Vol. 176, pp. 98-110, doi: 10.1016/j.ijpe.2016.03.014.

Webster, J. and Watson, R. (2002), "Analyzing the past to prepare for the future: writing a literature review", *MIS Quarterly*, Vol. 26 No. 2, pp. 13-23, available at: https://www.jstor.org/stable/4132319.

Wilden, D., Hopkins, J. and Sadler, I. (2022), "The prevalence of systems thinking in supply chain management: a systematic literature review", *Systemic Practice and Action Research*, Vol. 35, pp. 491-526, doi: 10.1007/s11213-021-09578-5.

Yahiaoui, S., Fedouaki, F. and Mouchtachi, E.a. (2019), "A supply chain maturity model for automotive SMEs: a case study", *IFAC-PapersOnLine*, Vol. 52 No. 13, pp. 2044-2049, doi: 10.1016/j.ifacol.2019.11.506.

Yasanur, K., Kazancoglu, Y., Gozacan-Chase, N., Lafci, C. and Batista, L. (2022), "Assessing smart circular supply chain readiness and maturity level of small and medium-sized enterprises", *Journal of Business Research*, Vol. 149 No. 2022, pp. 375-392, ISSN: 0148-2963, doi: 10.1016/j.jbusres.2022.05.042.

Zouari, D., Ruel, S. and Viale, L. (2021), "Does digitalising the supply chain contribute to its resilience?", *International Journal of Physical Distribution and Logistics Management*, Vol. 51, pp. 149-180, doi: 10.1108/IJPDLM-01-2020-0038.

Corresponding author
Guilherme F. Frederico can be contacted at: guilherme.frederico@ufpr.br