Management Review Quarterly
https://doi.org/10.1007/s11301-025-00534-4

Overcoming threats to supply chain continuity: a meta-analysis and 9R capability evaluation tool

Rowland Chen[1] · **Saroj Koul**[2] · **Ajaygopal Kandukuri Venugopal**[3] · **Rakesh Verma**[4]

Received: 9 September 2024 / Accepted: 28 May 2025

Abstract

This study examines the evolution of supply chain continuity (SCC) and unveils a novel 9R capability framework for manufacturing industries to understand their positioning to improve SCC and, thus, reduce the risks of disruptions caused by internal and external factors to their firms. We follow a comprehensive two-step methodology. First, we apply a machine learning algorithm on 3077 papers, revealing three clusters—risk, disruption and disaster followed by a review unravelling nine critical capabilities (*9R capabilities*)—*Reliability*, *Resilience*, *Readiness*, *Rapidity*, *Remediation*, *Reengineering*, *Relationship*, *Reinforcement*, and *Responsibility*. Second, the framework was validated by administering a structured survey on a focus group comprising members from 17 distinct manufacturing industries. This organized approach, derived from empirical assessments, offers actionable insights for organizations aiming to survive and thrive amid disruptions. Three common themes emerge when investigating the evolutionary development of SCC using machine learning tools: risk, disruption, and disaster. Upon classifying the collection of papers into the three themes, it was observed that they could be overcome by leveraging the nine capabilities. It offers a systematic and comprehensive approach to assessing, managing, and ultimately reducing the risks associated with disruptions in the flow of goods. By employing this novel framework, manufacturing companies can evaluate their SCC performance and proactively safeguard against disruptions despite constantly changing challenges. Also, this helps identify the limitations and counteractions a firm must take to improve its SCC. This study has implications for academia and business, allowing companies to improve their supply chains differently. Potential future work includes refinement of the framework by adding other capabilities (such as Reasoning). Further, longitudinal studies can be extended to the service sector.

Keywords Supply chain continuity · Resilience strategies · Disruption management · Supply chain risk · Supply chain management · Performance improvement

Extended author information available on the last page of the article

Published online: 21 July 2025

1 Introduction

In the constantly changing world economy, supply lines significantly impact the success of both manufacturing companies and countries. The seamless functioning of supply chains, as measured by the timely and complete delivery of goods, holds the key to customer satisfaction and resonates throughout the value chain (Hausman 2004). This, in turn, dictates the rhythm of revenue flow, making it clear that the performance of supply chains is more than a logistical concern. In an era where customer expectations continually evolve, the proactive maintenance of a supply chain becomes critical for companies aspiring to hold or gain a competitive edge.

Modern organizations are leveraging blockchain, Internet of Things (IoT), and artificial intelligence (AI) to overcome supply chain management (SCM) challenges (Dess et al. 2019). Additionally, these technologies predict disruptions and ensure transparency across value chains. Strategic integration enhances competitiveness and aligns with responsible sustainability practices, establishing them as indispensable components of the contemporary supply chain fabric. As we progress through the digital age, the resilience of the supply chain with continuous operations emerges not just as a logistical necessity but as a strategic imperative in the global supply chain market.

The severe impact of supply chain disruptions became apparent throughout the 2020 COVID-19 pandemic. Industries worldwide grappled with geopolitical uncertainties, shortages of critical components, and disruptions in supply lines, leading to varying degrees of success in responses across diverse sectors (Hausman 2004; Ramanathan 2014). This turbulent period underscored the vital role of continuous supply chain operations in maintaining an organization's performance, reputation, and financial resilience. The consequences of any disruption, be they a result of pandemics, conflicts, or natural disasters, reverberate through the complex network of supply chains, resulting in delays, out-of-stock scenarios, and, ultimately, damaged customer trust, satisfaction, and brand loyalty (Ganesan et al. 2009). The aftermath of such discontinuities often takes place during extended periods, necessitating substantial time for recovery.

Supply Chain Continuity (SCC) refers to the uninterrupted movement of goods and services amid the supply chain. Defined as a 'seamless flow of goods and services' throughout each phase of the supply chain (Blos et al. 2010, 2015), SCC stands out as a critical mitigator of revenue risks and a keystone for operational resilience. Recent scientific contributions, such as Bellamy and Basole's integrative framework (2013), illuminate the complexities of supply chain systems. They underscore the importance of the physical components and the relational embeddedness within the supply chain. Basole and Bellamy (2014) investigate global supply chains' nonlinear, multi-scale character, focusing on how network structure and visibility affect risk diffusion and recovery. Shekarian and Parast (2021) further dissect supply chain risks, highlighting the distinctions between flexibility and agility dimensions.

To understand the subtle dynamics of SCC, this study provides a comprehensive analysis of studies undertaken over the past two decades. How did it begin?

(Appendix A: supplementary companion). The company, WaterMark Sports (WMS), USA, attempted an 8R collective approach (with one of the co-authors as their lead consultant) retrospectively to their situation in 2003. It highlights the critical role of proactive risk management in SCC initiatives and a culture of continuous improvement in achieving long-term financial stability. However, the issue remains whether a collective approach employed by WMS could be sufficient to capture all the essential elements of SCC. Therefore, we particularly address the following research questions:

RQ1. What key dimensions influenced the evolution of SCC in supply chains?
RQ2. How do these dimensions enhance the understanding of SCC?
RQ3. How can the manufacturing sector use these dimensions to assess and improve its SCC in a constantly changing environment?

The main goal is to thoroughly analyze the obstacles that affect SCC and suggest a robust framework for its assessment. Our exploration begins with a detailed literature review, utilizing insights from a meta-analysis introduced by Zhang et al. (2020) to establish the definition and context of SCC in Sect. 2 and suggest *9R capabilities* to strengthen SCC. In Sect. 3, the authors describe a two-step methodology. With the findings, Sect. 4 introduces a 9R evaluation tool used as a focused survey instrument. Section 5 discusses the implications of the *9R capabilities* and the evaluation tool based on the survey results. As we approach the conclusion in Sect. 6, the authors synthesize the insights obtained from our exploration. Through this study, we aim to offer valuable insights to scholars, practitioners, and policymakers, contributing an additional layer of understanding to the evolving SCC research landscape.

2 The literature review

2.1 Overview of existing literature on SCC and related solutions

Articles were collected from WOS and SCOPUS databases from 2003 to 2023 (30 June) using a search string {"*Supply Chain*" AND "*Continuity*"}, revealing 3077 papers after inclusion and exclusion criteria (Appendix B: supplementary companion). Of all the words found, 'risk' was mentioned the most (225 times), demonstrating how important it is to evaluate and reduce risks to ensure a robust company. The word 'disaster' is used 189 times, suggesting the significance of comprehending and managing the impacts of disruptive incidents on supply chain operations. The term 'disruption' is mentioned 34 times, indicating its effect on SCC and related literature. The way these words appear shows that the examined documents mainly focus on *risk*, *disruption*, and *disaster*. In a similar vein, Fig. 1 presents the publication trends for this period, both pre- and post-COVID.

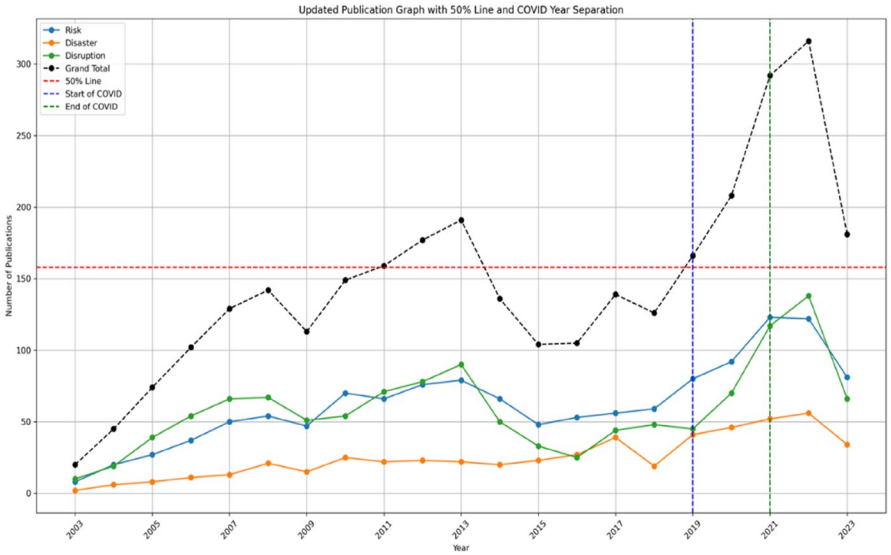

Fig. 1 Publication trend in the domains of SCC Risk, disruption and disaster

2.2 Discussion of relevant meta-analyses and frameworks in the field

Meta-analysis is a comprehensive study of many analyses (Glass 1976). Additionally, it is a valuable statistical method for assessing the extent to which a specific finding is evident in multiple replications within a particular subject area (Eden 2002). It involves the systematic review and synthesis of existing research studies to understand specific topics within the domain comprehensively. In SCM, meta-analyses can help identify best practices, evaluate the effectiveness of different strategies, and guide decision-making processes by providing a consolidated view of the available evidence. This approach enhances the credibility and generalizability of findings, contributing to advancing knowledge and improving supply chain practices. Zhang et al. (2020) introduced a novel meta-analysis approach best suited for the SCM domain (Appendix C: supplementary companion).

2.2.1 Risk

In SCM, the widespread issue of risk and uncertainty presents a substantial danger to the smooth and uninterrupted flow of operations (Pettit et al. 2019). According to several articles (Pettit et al. 2019; Fitzgerald et al. 2018), the complex character of risk within the supply chain is evident. These articles highlight the dynamic landscape that requires ongoing development to meet growing risks. Resilience is portrayed not as static but as an adaptive journey, necessitating proactive and anticipatory measures (Fitzgerald et al. 2018).

Studies on the Indonesian trucking supply chain and logistical SCC planning show that specific industries face unique challenges that underscore the *one-size-fits-all* inadequacy (Sugianto et al. 2023; Ojha and Gokhale 2009) strategy. These titles shed light on the practical difficulties of transportation-related supply chains, emphasizing the need for tailored approaches to planning disruptions in these sectors. Advanced technological solutions like blockchain and secure cloud computing (Thekdi and Santos 2016; Geiger 2010) have been proposed to mitigate risks. However, the interconnectedness of risks in control policies, where one set of risks may introduce others, emphasizes the delicate balance required in risk management (Jun and Rowley 2014).

Resilience is a recurring motif in various articles, emphasizing that a resilient supply chain weathers disruptions and emerges stronger (Sánchez and De-Batista 2023; Chen et al. 2021). The ability to adjust, recuperate, and acquire knowledge from disturbances is acknowledged as a fundamental attribute of a resilient supply chain (Yeh 2005). Identifying and comprehending the dimensions that influence SCC is essential to managing the risks effectively. One must consider the aspects that can affect the continuity of cooperative interactions (Yeh 2005).

The effect of "autonomous vehicle technology" on the likelihood of a product recall highlights the advantages and disadvantages of new technology (Murphy et al. 2019). While these technologies may enhance efficiency, they also introduce unique challenges, such as increased product recall risks and the need for efficient reverse logistics capabilities. This dynamic interplay between technological advancements and associated risks underscores the need for supply chain managers to remain cautious of industry trends and to address potential disruptions.

Cultural, organizational, and integrative aspects are highlighted in an article on the value of supply chain resilience, suggesting that resilience is not solely a technological concern but deeply intertwined with these aspects across the supply chain (Chunsheng et al. 2020). This holistic approach demands a comprehensive and integrated strategy for resilience. Empirical assessments of supply chain disruptions provide tangible evidence of vulnerabilities, emphasizing the practical application of theoretical frameworks and proactive strategies (Azadegan et al. 2020).

The COVID-19 outbreak substantially influenced numerous supply networks, as demonstrated by the study by Belhadi et al. (2021), which also emphasizes the interconnectedness of global supply chains and the necessity of resilience in industrial and service supply chains. Dynamic capabilities emerge as a crucial factor in ensuring resilience, as discussed in an empirical study on their role in pursuing SCC (Buzzao and Rizzi 2023). The article advocates for an organizational mindset that embraces change and innovation as a core component of resilience, highlighting the temper of supply chain challenges.

Ali et al. (2021) call for knowledge-sharing practices for agri-food supply chains and cultivating a culture attuned to potential risks. In the same vein, Wang et al. (2021) shed light on how technological integration contributes to the performance of resilient and sustainable supply chains, emphasizing the need for a strategic alignment of technology with sustainability goals.

Autry and Bobbitt (2008) underline the importance of a security-oriented mindset in supply chain operations, which has been addressed in the conceptual development

of their proposed framework. As supply chains become increasingly digitized, securing the flow of information and goods becomes imperative, making this framework a valuable contribution to risk management practices. The impact of government measures is investigated on how COVID-19 measures have influenced manufacturers' stock market valuations (Chen et al. 2023a, b).

The landscape provided by risk and uncertainty is a formidable challenge to SCC. This challenge necessitates an adaptive approach to risk management, incorporating innovative methodologies, industry-specific strategies, and advanced technological solutions. A recurring theme that emerges is resilience, which underscores the importance of knowledge management, adaptability, and dynamic capabilities in successfully navigating the intricacies of supply chain operations. As industries evolve and global uncertainties persist, a proactive and innovative stance towards risk management remains crucial to ensure the continuous flow of goods and services across supply chains.

2.2.2 Disruption

SCM operates in a dynamic landscape filled with challenges and disruptions that significantly threaten the seamless continuity of operations. A recurring theme across various studies underscores the importance of customer engagement in resilience-building efforts for ensuring SCC (Kaur et al. 2022; Brown et al. 2022). In the aftermath of unprecedented events like COVID-19, supply chains must actively adapt to evolving customer needs and expectations. Engaging with customers is a foundational element, providing stability and a platform for recovery. Supply chain network design emerges as a critical aspect of navigating disruptions and addressing operational complexities and unforeseen events (Zhalechian et al. 2018; Sadghiani et al. 2015). The emphasis on creating networks that can survive daily difficulties highlights the strategic importance of improved adaptability and promptness. Implementing a proactive approach is essential for reducing supply chain disruptions.

Technological advancements, such as Industry 4.0, foster resilience and ensure continuity (Buzzao and Rizzi 2023; Hussain et al. 2021). These innovations build adaptive capabilities within the supply chain, empowering organizations to respond effectively to disruptions. Integrating advanced technologies quickly into a resilient supply chain is crucial. Customized recovery mechanisms gain prominence in the face of disruptions and the need for tailored approaches (Hishamuddin et al. 2014). Recognizing that a universally applied recovery strategy may not suffice, supply chain managers are encouraged to consider unique aspects of their operations when formulating recovery plans. This emphasis on customization and flexibility in recovery planning allows a more effective response to disruptive events.

Learning from real-world experiences, Chen et al. (2019) provide valuable insights for post-disruption recovery. The adaptability required in the face of rapid technological changes becomes a key takeaway, emphasizing the importance of drawing parallels between industry-specific challenges and broader supply chain considerations. Innovation emerges as a high-impact factor during disruptive periods, encompassing technological advancements, organizational system changes, and knowledge management practices (Miao et al. 2021). Additive manufacturing,

or 3D printing, emerges as a transformative technology that enhances supply chain resilience (Naghshineh and Carvalho 2022). This holistic approach to innovation becomes essential for organizations seeking to recover from disruptions and thrive in uncertainty.

Resilience strategies, viewed holistically, become crucial for mitigating disruptions (Alikhani et al. 2023; Sahebjamnia 2020). Closed-loop supply chain design, incorporating environmental considerations, emphasizes the broader impact of supply chain practices (Torabi et al. 2016). This approach recognizes the growing awareness about sustainability and aligns with the need for reliable information. Subsequently, robust decision-making frameworks, supported by digital technologies, become imperative for companies responding to disruptions (Margherita et al. 2023). This digital transformation in decision-making is required for organizations seeking to respond swiftly and effectively to disruptions. Simulation as a tool for SCC planning within a factory setting offers a risk-free environment for testing and refining strategies (Tan and Takakuwa 2011). Insights gained from simulation exercises provide valuable guidance for minimizing the impact of disruptions in real-world scenarios and addressing vulnerabilities in supply chain processes.

SCC principles, applicable across diverse industries, highlight the need for continuity planning (Hills 2016). Organizations seeking continuity during interruptions must adhere to these principles regardless of their business. The emphasis on principles provides a universal framework for continuity planning. The assessment of critical infrastructure during the COVID-19 pandemic highlights difficulties encountered by the infrastructure services (Rostek et al. 2022). This focus on critical infrastructure emphasizes the need for tailored strategies that consider the specific challenges posed by essential services.

Humanitarian response during crises, exemplified by Medecins Sans Frontieres, underscores the adaptability and modularity required in supply chain processes (Saïah et al. 2023). Adapting and modularising supply chain processes has become essential for organizations responding to crises, particularly in humanitarian settings. The knowledge gained from these experiences helps develop resilient supply chains. A novel approach to reducing risk is shown by blockchain technology that helps build supply chains and makes them more resilient (Li et al. 2020). The emphasis on firm performance highlights that leveraging blockchain goes beyond risk mitigation, contributing to overall supply chain success.

The resilience strategies employed by automobile manufacturers offer valuable insights into the impact of sustainability (Singh et al. 2023). As a sector often at the forefront of supply chain challenges, the automotive industry teaches how resilience strategies impact sustainability. Resilience coupled with elasticity is a powerful combination for ensuring continuous service-based processes (Truong and Zhang 2021). Organizations must balance resilience with the ability to adapt swiftly to changing circumstances. The reaction of the Philippine private sector to economic recovery post-COVID-19 highlights the intricate relationship between state-supply chain relations and post-pandemic growth (Reyes 2022). Collaboration with governmental entities becomes pivotal for economic recovery, emphasizing the interconnectedness between the private sector and state policies.

Torabi et al.'s (2014) framework for *supply chain impact analysis* introduces a different perspective on assessing the consequences of disruptions. Robust impact analysis becomes a critical factor for effective SCC management. Enhanced AI-based decision-making frameworks empower leaders with data-driven insights during disruptions (Unhelkar and Gonsalves 2020). Integrating AI becomes an increasingly important factor for informed decision-making in times of crisis.

Predictive analytics, focusing on cyber threat prediction, underscores a proactive approach to enhancing cyber supply chain security (Yeboah-Ofori et al. 2021). Organizations can take preemptive measures to secure their digital supply chains by predicting potential information security threats. Systemic implementation of SCC management introduces a comprehensive framework for embedding continuity measures within the organizational structure (Bajgoric 2014). This systemic approach indicates that continuity measures should be integrated rather than treated as isolated initiatives. This integration becomes crucial for ensuring the effectiveness of SCC efforts.

The diverse nature of disruptions within the supply chain necessitates a proactive approach to ensure continuity. Customer engagement, supply chain network design, technological advancements, and innovation are pivotal in building strategies and tactics to combat disruptive forces. Customized recovery mechanisms, real-world learning experiences, and a focus on sustainability further enhance the ability of organizations to navigate disruptions successfully.

2.2.3 Disaster

Supply chain managers grapple with various challenges, none more challenging than disasters, as explored in the following cited articles. From natural disasters to pandemics to technological failures, the articles shed light on the multifaceted nature of disasters and their devastating effects on SCC. The 2011 earthquake in Japan is a stark reminder of the vulnerability to unexpected shocks, prompting a reevaluation of modelling approaches (Park et al. 2013; Diaz et al. 2019).

Organizational contexts are crucial in shaping SCC, with considerations extending beyond physical aspects to encompass organizational structures and processes (Vanichchinchai 2023). Specialized planning in critical sectors, as highlighted by the CHEST Consensus Statement, emphasizes the intersection of healthcare and SCC (Tosh et al. 2014). The importance of nursing schools as crucial components in the healthcare supply chain (Zerwic and Rosen 2016) highlights the necessity for specialized planning in the field. Several examples of the recovery conditions of enterprises after disasters provide valuable insights, particularly for small and medium-sized enterprises (SMEs) facing unique challenges (Nakatani et al. 2016; Guidry et al. 2015).

Distinguishing between disaster recovery and SCC is crucial, with the latter adopting a holistic approach encompassing proactive measures to ensure ongoing operations (Costello 2012). Stakeholder-based perspectives reveal how firms respond to natural disasters, emphasizing the interconnectedness of supply chains, communities, and governments (Sawalha 2021), strengthening societal resilience.

Collaboration and information-sharing are highlighted during disasters (McKnight and Linnenluecke 2016).

Technological advancements are pivotal in enhancing SCC, as seen in integrating SCC and disaster recovery into maintenance services (Duncan et al. 2011). Social media's role in SMEs for SCC is explored, showcasing the tenuous state of communication and information dissemination during disruptions (Mortell and Nicholls 2013). Robust evaluation methodologies for assessing the Readiness of supply chains are emphasized in studies utilizing fuzzy analytic hierarchy processes and risk quantification models (Johnson et al. 2018; Kudo et al. 2013).

Global trends in SCC, overseas market trends, and the role of lifeline losses underscore the global nature of disruptions and the need for coordinated international efforts (Ueno 2006; Orhan 2014). A historical review of SCC management practices and drivers provides insight into its evolution, emphasizing the need for supply chain managers to adapt and evolve their continuity strategies (Kurihara 2006). Quantifying preparedness risks requires a forward-looking approach, with predictive failure analysis and fuzzy cost–benefit analysis offering strategic foresight (Sasaki et al. 2020; Russo et al. 2022). Private sector preparedness and continuity planning are influenced by collaborative partnerships, highlighting the dependence among organizations during crises (Sahebjamnia 2020). The human factor in SCC is emphasized, with the importance of justice and trust in fostering employee resilience (Seyedin et al. 2011). Personnel training for the supply chain regarding the response to stranded persons further underscores the human factor in SCC (Bajgoric and Moon 2009).

The role of technology in disaster recovery and SCC, as well as the psychological impact of disasters, is explored, highlighting the need for comprehensive approaches addressing physical and emotional aspects (Li et al. 2020; Herbane 2010). Post-disaster supply chain recovery and sustainable development underscore the relationship between recovery efforts and sustainable development goals (Ma et al. 2023). The role of managed services in supporting SCC emphasizes outsourcing critical business functions to ensure resilience (Jrad et al. 2004).

The economic impact of disruptions' spillover effects emphasizes the need for supply chain managers to assess, address, and continuously improve their strategies (Dunne-Sosa and Cotter 2019; Hipple 2008). The integration of SCC and disaster management in healthcare settings exemplifies the challenges hospitals face and the importance of strategic planning (Yoshida et al. 2006). The intersection of SCC and transportation demand management requires a comprehensive approach considering transportation infrastructure and SCC (Huang et al. 2018). Analyzing post-disaster damage and disruptive impacts on small supply chains highlights smaller enterprises' unique challenges (Ogata et al. 2006).

An article on SCC and security in data centre interconnection highlights the role of secure data management (Wang et al. 2022). The field survey of an emergency power supply-related SCC highlights the importance of reliable power sources after a volcanic disaster, showcasing meticulous planning in disaster recovery (Rabbani et al. 2016). Public institutions' crisis responses emphasize trust's role in maintaining SCC (Chen et al. 2023a, b). Realizing the swift solution to full-scale SCC needs underscores the role of information systems (Lenzen et al. 2019). Post-disaster

surveillance evaluates the resilience of communities and supply systems (Gin et al. 2018).

2.2.4 *9R Capabilities*

The articles in this collection collectively emphasize the multifaceted nature of *disaster* as a challenge to SCC. Lessons learned from past events underscore the need for proactive and adaptable supply chain strategies for disaster response, management, and recovery. Effective management requires a holistic approach, considering physical aspects, organizational contexts, stakeholder perspectives, and the human factor. Collaboration, technological advancements, and data management are pivotal in enhancing resilience. As supply chains integrate SCC and disaster management, global supply chains' interconnectedness necessitates collaborative efforts worldwide. Proactive planning, robust risk assessment, and integrating technology and human expertise enable supply chains to survive disruptions and emerge more robust and resilient (Fig. 1).

As such, we introduce a set of *9R capabilities*. These capabilities, strategically identified from the recurring themes of *risk, disruption, and disaster*, are fundamental attributes that firms can leverage to navigate and overcome challenges in supply chain operations. The descriptions of the *9R capabilities* are displayed in Table 1.

3 Methodology

The methodology utilized by the authors is a two-step process: (1) identification of attributes that comprise each of the nine R's in the *9R framework* and (2) validated the framework through a focus group discussion with experienced supply chain professionals.

Figure 2 presents the detailed methodological framework and the overview of the study

3.1 Step-I: Identification of attributes comprising the 9R framework

To provide a diagnostic tool for company executives, for example, heads of supply chains, to assess their firms' performance in SCC, each of the 9Rs was decomposed into four attributes, totalling thirty-six. These attributes are to provide individual R Scores (one for *Reliability*, one for *resilience*, etc.) and a single 9R Score in aggregate. Drawing on the comprehensive literature review highlighting critical attributes of *9R capabilities* within the supply chain context, the authors developed a robust framework for evaluation, as presented in Table 2.

From Table 2, the *9R framework* provides a structured and holistic approach for organizations to assess their supply chain performance across these dimensions. By incorporating key elements such as trust-building, responsiveness, adaptability, and responsibility, the evaluation framework becomes a significant tool for organizations

Table 1 Definition and interpretation of *9R capabilities* [Source: Author's Compilation]

Sr. no	Capability	Definition/interpretation
1	Reliability	The consistent and dependable performance of the supply chain operations. The concept includes evaluating dependability of suppliers, transportation providers, and essential parties involved to guarantee products are delivered on time and fulfil the desired quality criteria
2	Resilience	The ability to rapidly come out of the disruptions, such as natural disasters, cyber-attacks, or internal failures. An agile and resilient supply chain is vital for sustaining operations amid unforeseen challenges
3	Readiness	The level of preparation and planning an organization possesses to manage supply chain disruptions effectively. This includes the development of contingency plans and a prompt response to unexpected events
4	Rapidity	The speed at which a company can address and mitigate supply chain disruptions. It involves swift problem identification, efficient contingency plan implementation, and rapid adaptive responses
5	Remediation	The actions a company takes to rectify supply chain disruptions once they occur. This invotves repairing damaged infrastructure, identifying alternative suppliers, and implementing measures to ensure continuous supply chain functionality
6	Reengineering	Redesigning a company's supply chain operations to enhance efficiency, effectiveness, and sustainability. This includes streamlining processes, adopting new technologies, and finding avenues to reduce costs
7	Relationship	Strong partnerships and collaborations between companies and their suppliers, transportation providers, and other key stakeholders are essential. Strong relationships foster shared goals and mutual investment in its success
8	Reinforcement	There is a need for continuous monitoring and evaluation of a company's supply chain operations. This involves identifying areas for improvement and implementing measures to fortify the supply chain continually
9	Responsibility	The need to take ownership of their supply chain operations and ensure ethical and sustainable practices. This includes suppliers adhering to ethical guidelines and producing products responsibly

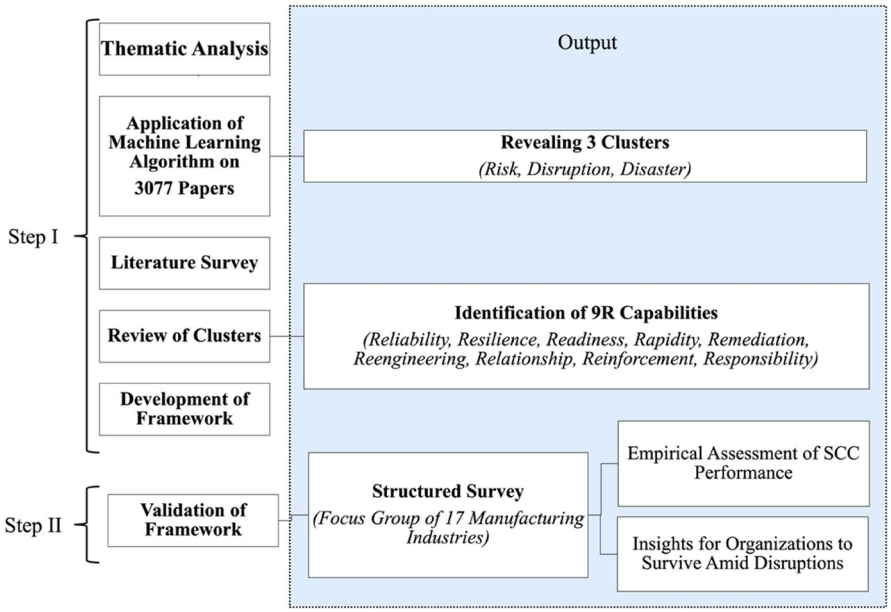

Fig. 2 Author's overview of the study

to assess their strengths and weaknesses, identify areas for improvement, and boost overall supply chain resilience.

3.2 Step-II: Validation by Focus Group Discussions

The focus group research method involves a group interview approach that leverages group interaction dynamics and jointly constructs yielding valuable consumer insights on a specific topic (Welman et al. 2005; Kress and Shoffner 2007). This interaction fosters the exchange and evaluation of ideas (Raby 2010; Baruah and Paulus 2009), and the interplay among respondents, along with their diverse views and perspectives, stimulates creative thought (Zikmund and Babin 2013). Additionally, the multivocality in focus group discussions provides a comprehensive breadth of information on the topic under discussion (Stokes and Bergin 2006), with the collaboration among participants enhancing the collective outcome beyond the sum of individual contributions (Baruah and Paulus 2009; Hartman 2004). These benefits have established the focus group research method as an efficient, practical, and applied approach for gathering qualitative research data (Kress and Shoffner 2007).

Primarily, focus groups aim to understand the meanings and interpretations of a select group of people concerning specific issues or topics (Kitzinger 2005; Liamputtong 2011). The group dynamics inherent in this method, absent in one-to-one interviews, often generate deeper and richer data (Rabiee 2004). While the findings from focus groups can inform theoretical generalizability, they are not statistically validated (Barbour 2005). Nonetheless, focus group outcomes are valuable for

Table 2 Author-identified 9R attributes

The specific R	9R attributes	References
1. Reliability	Demonstrated ability to meet contractual service level agreements and other commitments (e.g., 95% on-time/in-full delivery of products)	Sjodin et al. (2020)
	Trustworthiness in the minds of customers	Chen and Rau (2020)
	Trustworthiness in the minds of suppliers	Chen and Rau (2020)
	Trustworthiness in the minds of internal stakeholders	Chen and Rau (2020)
2. Resilience	Capability to cope with fluctuations in supply and demand	Katsaliaki et al. (2022)
	Demonstrated ability to recover control of a disrupted supply chain	Katsaliaki et al. (2021)
	Ability to minimize damage to customers' supply chains	Shishodia et al. (2023)
	Budget available for "just-in-case" requirements	Shishodia et al. (2023)
3. Readiness	Continuous assessment of potential supply shortages	Okeagu et al. (2021)
	Agreed upon criteria to rate levels of severity	*Identified by authors*
	Tactical scenario plans in place, including clear roles and responsibilities	Okeagu et al. (2021)
	Predictive analytics for potential external and internal disturbances	Ivanov and Dolgui (2021)
4. Rapidity	Optimized response based on level of severity and risk	Kusrini and Maswadi (2021)
	Flawless execution in a complex and dynamic environment	Chib and Kosarka (2022)
	Proactive and transparent internal and external communication	Lin and Huang (2014)
	Ability to learn from response experiences	Chowdhury and Quaddus (2016)
5. Remediation	Medium-term, methodical corrective actions	Xue (2023)
	Known root causes of discontinuities	Xue (2023)
	Actions to remove or minimize the impact of root causes	Milton et al. (2023)
	'Clear understanding among people across the entire value chain	Milton et al. (2023)
6. Reengineering	Re-formulation of long-term supply chain strategies	Rauch and Borz (2020)
	Changes to policies impacting suppliers and customers	Rauch and Borz (2020)
	People, processes, and systems are examined and redesigned in line with a business case	Patrucco et al. (2020)
	Transformation from a current-state supply chain to a future-state supply chain	Patrucco et al. (2020)

Table 2 (continued)

The specific R	9R attributes	References
7. Relationship	Company supports its customers' SCC initiatives, and customers know about it	Das and Hassan (2022)
	Brand loyalty with direct customers and end-users	Yeh et al. (2020)
	Maintenance of high-priority allocation with suppliers of goods, including strategic components	Qazi et al. (2022)
	Service providers aligned with service excellence requirements	Qazi et al (2022)
8. Reinforcement	Backward-looking metrics to rate past performance	Nguyen et al. (2023)
	Current-looking metrics to monitor day-to-day operations and risks	Lopez et al. (2022)
	Future-looking metrics to forecast and predict SCC issues	Lakhal (2017)
	Systems enabling closed-loop feedback for continuous improvement	Cheng and Lu (2017)
9. Responsibility	Ecological and environmental responsibility	Spence and Bourlakis (2009)
	Social and societal/community well-being responsibility	Spence and Bourlakis (2009)
	Employee well-being responsibility	Boyd et al. (2007)
	Supply chain partner behaviour responsibility	Govindan et al. (2019)

(post-) positivist studies, aligning with Johnson and Onwuegbuzie's (2004) rationale for sequential study conduct. According to Halldórsson and Aastrup (2003), this method corresponds with participants' constructed realities, offering insights into the perceptions of participants representing firms and other agents concerning supply chain finance. This approach primarily emphasizes evaluating constructs and their interrelationships.

4 Results

This study leverages the *9R framework* to develop a comprehensive tool for supply chain professionals to measure and reflect on their companies' capabilities to avoid and manage disruptions to supply chains. Key findings related to the thirty-six attributes and overall 9R scores are detailed below:

4.1 Key findings: a meta-analysis of literature on the thirty-six attributes

***Reliability*:** Supply chain *Reliability* refers to consistently delivering products on time and in full to meet committed delivery times and customer expectations. *Reliability*, an element of effective SCM, is characterized by meeting contractual service level agreements and building stakeholder trust (Sjödin et al. 2020; Chen and Rau 2020). Sjodin et al. (2020) highlight the significance of meeting on-time/in-full delivery commitments, highlighting its positive impact on customer trust. On-time delivery is crucial for customer satisfaction as it helps to maintain a good relationship between the supplier and the customer. On-time/in-full delivery also impacts a customer's supply chain *Reliability*. This aligns with Chen and Rau's (2020) exploration of trustworthiness within the supply chain, focusing on the importance of fostering trust with customers, suppliers, and internal stakeholders; this trust's advancement contributes to the overall Reliability.

Resilience: Supply chain resilience refers to maintaining stability and recovering from internal and external disturbances. These disturbances can come in many forms, such as internal organizational dysfunction or external factors (pandemics, natural disasters, geopolitical events, and fluctuating demand). Katsaliaki et al. (2022) characterize the capacity to successfully recover from disturbances and deal with variations in demand and supply. Similarly, Shishodia et al. (2023) bring out the significance of resilience in dispelling harm to customers' supply chains. It aligns with Katsaliaki et al. (2022) comprehensive review, which emphasizes organizations' need to allocate budgets for unforeseen requirements, thus enhancing their *resilience* against disruptions. Further, it includes regularly assessing the supply chain for vulnerabilities, monitoring key indicators and metrics, and implementing a comprehensive disaster recovery plan.

***Readiness*:** Supply Chain *Readiness* is the capability to plan for and respond to internal and external disturbances that might impact continuity. This involves having robust risk management practices, conducting simulations and scenario planning to prepare for potential disruptions, and continuously monitoring the supply chain for

vulnerabilities. Ensuring *Readiness* in the supply chain involves continuous assessment, agreed-upon severity criteria, tactical scenario plans, and predictive analytics (Okeagu et al. 2021; Ivanov and Dolgui 2021). Okeagu et al. (2021) recommend a proactive approach, emphasizing predictive analytics's importance in anticipating potential internal and external disturbances. This aligns with Ivanov and Dolgui's (2021) insights on tactical scenario plans, emphasizing clear roles and responsibilities in preparing for potential disruptions.

***Rapidity*:** Supply structure *Rapidity* pertains to the capacity of a supply chain to respond to internal and external disruptions promptly and efficiently. *Rapidity* is characterized by optimized responses, faultless execution, proactive communication, and the capacity to learn from past mistakes (Kusrini and Maswadi 2021; Chib and Kosarka 2022; Lin and Huang 2014; Chowdhury and Quaddus 2016). Kusrini and Maswadi (2021) highlight the importance of a swift response based on the severity and risk level, emphasizing the need for a proactive and transparent communication strategy. This resonates with Chib and Kosarka's (2022) exploration of challenges and expectations related to supply chain *Rapidity*, emphasizing the necessity of learning from response experiences.

***Remediation*:** *Remediation* is vital to ensure the near to medium-term continuity of a business's supply chain. This process involves medium-term, methodical corrective actions and a clear understanding across the value chain (Xue 2023; Milton et al. 2023). Xue's (2023) dissertation emphasizes the importance of known root causes and actions to remove or minimize their impact. This aligns with Milton et al.'s (2023) focus on understanding and collaboration in effective supply chain *Remediation* across the entire value chain. Companies ensure their business's long-term success by taking preventive actions to address supply chain risks and vulnerabilities (Milton et al. 2023).

***Reengineering*:** *Reengineering* is a comprehensive approach to enhancing the long-term performance of a supply chain. It involves transforming the supply chain's policies, processes, people, and systems to create a more integrated and efficient operation (Rauch and Borz 2020). *Reengineering* the supply chain encompasses reformulating long-term strategies, changing suppliers, and redesigning people, processes, and systems (Patrucco et al. 2020). Rauch and Borz (2020) highlight a holistic approach to *Reengineering*, focusing on the Romanian timber supply chain. This aligns with the study of Patrucco et al. (2020), which emphasizes examining and redesigning various supply chain elements.

***Relationship*:** Building robust *Relationships* within the supply chain is vital for continuity, encompassing customer support, brand loyalty, high-priority allocation with suppliers, and alignment with service excellence requirements (Das and Hassan 2022; Yeh et al. 2020; Qazi et al. 2022). Das and Hassan (2022) stress the impact of supporting customers' SCC initiatives, contributing to a robust *Relationship*. Yeh et al. (2020) highlight the significance of maintaining stable *Relationships* and how they impact the integration of internal processes, suppliers, and customers. One way to build trusted *Relationships* is to include suppliers and customers in the manufacturer's SCC initiatives. This inclusion fosters trust and partnership with suppliers, ensuring high-priority allocation of goods and aligning suppliers of services with service excellence requirements for long-term success.

***Reinforcement*:** Supply chain *Reinforcement* involves metrics, dashboards, and scorecards to monitor and improve performance. *Reinforcement* involves backward, current, and future-looking metrics to monitor and improve performance in closed-loop feedback systems (Nguyen et al. 2023; Lakhal 2017; Cheng and Lu 2017). The data collected through metrics and displayed on scorecards and dashboards can be used to develop predictive models that help companies anticipate future supply chain challenges and take proactive measures to mitigate them (López et al. 2022; Lakhal 2017), ensuring continuity of the operations and improvement in customer satisfaction. Also, the 'digital twin' approach in reinforcing supply chain *Resilience* through simulation (Nguyen et al. 2023) aligns with the focus on predictive models and continuous improvement, as highlighted by Lakhal (2017) and Cheng and Lu (2017).

***Responsibility*:** Supply chain *Responsibility* is critical tomodern business practices, encompassing multiple dimensions of ethical and sustainable operations. Supply chain *Responsibility* encompasses ecological and environmental, social and societal/community well-being, employee well-being and responsible behaviour among the partners (Spence and Bourlakis 2009; Boyd et al. 2007; Govindan et al. 2019). Spence and Bourlakis (2009) document the transition from 'corporate social responsibility' to supply chain accountability, highlighting the significance of environmental and social factors. This aligns with Boyd et al.'s (2007) procedural justice perspective, emphasizing ethical labour practices. Govindan et al.'s (2019) focus on environmental management partner selection for sustainable collaboration. By embracing responsible supply chain practices, companies can positively impact the environment, society, employees, and supply chain partners and contribute to a more sustainable and inclusive business ecosystem.

4.2 Validation of Framework

To validate the relevance of the target lists and establish if any targets were missing the 9R capabilities and their attributes, they were provided to a focus group of 27 members. A description of the Focus Group participants is in Table 3. According to Ritchie et al. (2003), typical focus groups involve 6–8 people who meet once. However, the optimum group size depends on diversity in opinion on the issue, and a large group is more effective than a small one. The group confirmed that the identified 9R capabilities and their corresponding 36 attributes were most relevant. A 9R Score evaluation tool was developed to capture the level of SCC from the participating companies (Appendix D: supplementary companion). The focus group was provided with a survey comprising ten questions, and Question 6 was related explicitly to expressing their importance over the 36 attributes of 9R capabilities. The survey questionnaire and detailed results are in Appendix E: supplementary companion.

The responses strengthened the validity of the *9R capability* framework. However, they differed in their opinion regarding the importance of specific *9R capabilities* contributing to SCC. Most group members highlighted the significant roles of Reliability, Readiness, and Relationship in withholding SCC (refer to Fig. 3). The research validates the *9R framework* through the Focus Group Discussions (FGDs), which involved various roles of manufacturing companies in different regions, including the United

Table 3 The focus group

Unique product	Role and responsibility	Experience
Sportswear	Supply planning head	> 10 years
Energy drinks	Zonal demand planning manager	> 10 years
Electronics	Procurement manager	6–10 years
Steel	Distribution manager (regional logistics head)	6–10 years
Personal care products	Chief executive officer	> 10 years
Snacks	Operations manager	> 10 years
Fashion accessories	Operations senior manager	6–10 years
Industrial machinery	Managing director	> 10 years
Home appliances	Vice president	> 10 years
Medical devices	Director	> 10 years
Packaging materials	General manager—supply chain	> 10 years
Automobile	Deputy manager	> 10 years
Prescription drugs	Head of logistics	6–10 years
Nutritional supplements	Procurement associate	6–10 years
Laptops	Supply chain program manager	> 10 years
Smartphones	Supply chain strategy and sustainability leader	> 10 years
Wearable devices	Head of procurement	> 10 years

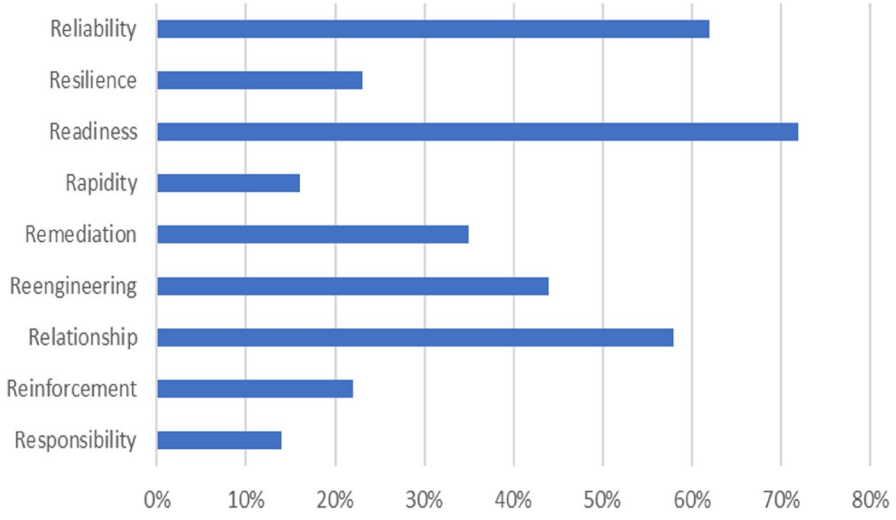

Fig. 3 Importance shown by the focus group towards each R capability

States, Canada, India, Germany, UAE, and Nepal. The framework validation process included diverse perspectives and areas, aligning with best practices for FGDs (Ritchie et al. 2003). The results showed consensus among stakeholders regarding the potential and usability of the proposed *9R framework* in reducing risks, recovering from disruptions and handling disasters to SCC.

5 Discussion

The 9R capabilities framework, developed through a comprehensive meta-analysis of existing literature on threats to Supply Chain Continuity—namely *Risk, Disruption, and Disaster*—offers a structured approach for companies to measure and enhance their capability to maintain the flow of material and money. Each capability focuses on specific aspects of SCM and collectively contributes to a robust defence against various types of hindrances to SCC. This discussion categorizes these capabilities according to the identified threats: *Preventing Risks, Managing Disruptions, and Recovering from Disasters.*

The capabilities within the Preventing Risks category—Reliability, Reinforcement, and Responsibility—collectively create a stable and predictable supply chain environment. Together, these capabilities establish a robust foundation that prevents potential threats from materializing into significant disruptions.

Preventing Risks includes Reliability, ensuring trust in suppliers and stakeholders to avoid delays or bottlenecks; Reinforcement, focusing on monitoring and improving processes to detect vulnerabilities; and Responsibility, embedding ethical and sustainable practices in supply chain strategies. These capabilities establish a robust foundation to avert potential threats.

Managing Disruptions focuses on resilience through advanced technologies like AI and blockchain, readiness through strategic planning and training, and rapidity by enabling swift responses to unforeseen events. These capabilities ensure agility and continuity during disruptions, as demonstrated by their effectiveness during crises like the COVID-19 pandemic.

Recovering from Disasters encompasses Remediation, which prioritizes corrective actions and learning from disruptions; Reengineering, leveraging digital transformation and automation for long-term stability; and Relationships, fostering trust and collaboration among stakeholders. These capabilities support recovery from significant disruptions, enabling companies to rebuild and enhance their supply chain resilience.

By implementing these capabilities, companies can measure and enhance their ability to withstand and thrive amidst the ever-evolving challenges of the global supply chain landscape.

6 Conclusion

The development of the *9R capabilities* framework marks a significant advancement in the field of SCM, offering a comprehensive tool for assessing and improving a firm's capability to maintain its Supply Chain Continuity. This framework was meticulously developed through a two-step process. To address the first research question (RQ1), in the first step, we apply a machine learning algorithm to identify the three major themes, followed by an in-depth literature review to establish its theoretical foundation. This was followed by the identification of the 9Rs, which answered our second research question (RQ2) through the development of a

comprehensive framework using the 9R capabilities. Field research was conducted on a focused group of supply chain professionals, where insights from the focused group were gathered via a structured survey, enabling the refinement of a novel framework to ensure its practicality and relevance in real-world scenarios, thus answering the third research question (RQ3). The validation of the *9R framework* by subject matter experts underscores its effectiveness and utility.

The *9R framework* is vital for manufacturing companies, empowering them to proactively manage their supply chains with elevated continuity amidst an intricate and challenging global environment. With the 9R ratings and scores, a supply chain team and company executives can understand the strengths and shortcomings of their supply chain operation's capabilities. Teams can then take the next step to leverage strengths, address deficiencies, and better manage disturbances in their supply chains.

6.1 Future directions

To further explore the utility of the *9R framework*, the authors suggest conducting additional field research to include individual follow-up conversations with each of the seventeen respondents to share the results of the field research (to date). The conversations will explicitly ask: (1) "Are the *9Rs* relevant to your supply chain operations?" (2) "Would the diagnostic be a valuable ongoing supply chain management tool?"; and (3) "Are there any other suggested improvements to the framework?".

Additionally, follow-up conversations would allow us to hear from those surveyed about any progress made to ensure SCC, particularly for those initiatives included in the survey (results of which are not discussed in this paper, again, to maintain a focus on the *9R framework*). Other topics to cover would be current supply chain performance and improvements to SCC since the survey.

Between formulating the *9R framework* and completing the initial field research discussed in this paper, another R has demonstrated its impact on SCC—*Reasoning*. *Reasoning* through artificial means, or artificial Reasoning (AR), has emerged as an instrumental tool in fortifying SCC, for example, through predictive analytics. These systems, powered by advanced algorithms and machine learning techniques, can analyze vast amounts of data from different points in the supply chain.

Finally, continued field research could include an update to the 9R Supply Chain Continuity capabilities framework into a *10R framework* with the inclusion of *Reasoning*. As with the other 9Rs, *Reasoning* is decomposed into four attributes: (1) computer-aided decision support, (2) robotics, (3) generative artificial intelligence, and (4) experimentation. The authors suggest conducting another survey using a revised instrument incorporating the new 10R framework to explore how, if at all, companies are using artificial intelligence in managing Supply Chain Continuity.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s11301-025-00534-4.

Acknowledgements The authors wish to acknowledge the early valuable words of encouragement of Charles Fine, Chrysler Leaders for Global Operations Professor of Management, MIT, Sloan School of Management. The authors thank the supply chain professionals for their participation in the field research.

Author contributions "All authors contributed to the study. Idea conceptualization was by RC and SK. Literature search and formal analysis by SK and AKV. Preparation of Survey Questionnaire and Data curation by RC, SK and AKV. Investigation by SK and AKV but in steady discussion and revision with RC and RV. Writing—original draft RC and AKV, and all authors commented on previous versions of the draft manuscript. RV constantly collaborated in writing, and RC helped structure the work and wrote parts of the introduction and findings. SK revised all sections with a focus on the overall fit of the paper. All authors read and approved the final manuscript.

Funding No funding was received to conduct this study.

Data availability The data supporting this study's findings are available from the corresponding author upon request.

Declarations

Conflict of interest The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. The authors declare no conflicts of interest.

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Authors and Affiliations

Rowland Chen[1] · Saroj Koul[2] · Ajaygopal Kandukuri Venugopal[3] · Rakesh Verma[4]

✉ Saroj Koul
skoul@jgu.edu.in

Rowland Chen
rchen@thesvlab.com

Ajaygopal Kandukuri Venugopal
ajaygopal.2020@iimmumbai.ac.in; ajaygopal.kv@chanakyauniversity.edu.in

Rakesh Verma
rakeshverma@iimmumbai.ac.in

[1] The Silicon Valley Laboratory Inc., San Jose, CA, USA

[2] Jindal Global Business School, OP Jindal Global University, Sonipat, Haryana, India

[3] Chanakya University, Bangalore, Karnataka, India

[4] Indian Institute of Management Mumbai, Mumbai, Maharashtra, India