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# A Systematic Literature Review of the Capabilities and Performance Metrics of Supply Chain Resilience

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## Abstract

Research on supply chain resilience (SCRE) capabilities and its performance measurement has been growing in recent years. However, the investigation of these concepts has primarily been conducted independently despite the interdependence of these concepts. A systematic literature review of 153 papers was conducted based on the principles of rigour, transparency and replicability required by the methodology. For the first time, we structurally reviewed the 11 SCRE performance metrics categories and its capabilities in SCRE Capabilities-Performance Metrics Framework (SCPM) developed based on the 3 resilience dimensions (readiness, response and recovery). The framework enables researchers to seek fundamental knowledge and to pursue further research regarding SCRE assessment. This study also provides practical value offering a guidance for decision-makers considering the trade-off among different capabilities and performance metrics.

*Keywords*: Supply chain, Resilience, Capabilities, Performance metrics, Systematic literature review

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## 1. Introduction

Supply chain resilience (SCRE) has attracted strong interest from researchers and practitioners because of the multiplicity of disruptive events and potential impacts on business competitiveness and continuity (Christopher and Peck, 2004; Jüttner and Maklan, 2011; Sheffi and Rice, 2005). For example, routing operation interruptions, such as extreme weather disasters, information system failures and industrial disputes, can affect supply chain robustness and stability (Elliott, Swartz, and Herbane, 2010). Supply chain managers are forced to adopt more resilient approaches to insulate the supply chain from disturbance (Christopher and Holweg, 2011; Christopher and Lee, 2004). Among the current SCRE definitions in the literature, a core concept is that SCRE is multidimensional and related to the system's ability to eventually return to stabilisation (Day, 2014; Hohenstein et al., 2015; Kamalahmadi and Parast, 2016; Ponomarov and Holcomb, 2009). Building SCRE requires one to continuously adopt and develop capabilities (Pettit, Croxton and Fiksel, 2013; Ponomarov and Holcomb, 2009). Further development of SCRE requires information on its efficiency and a comparison with previous performances by evaluating it via established performance metrics (Van Hoek, 1998; Sillanpää, 2015).

In terms of capabilities, it is recognised that it should be classified and integrated to make significant effects on formatting SCRE (Ponomarov and Holcomb, 2009). Important studies in the SCRE field researched a variety of capabilities (Jüttner and Maklan, 2011; Pettit, Fiksel, and Croxton, 2010; Christopher and Peck, 2004; Sheffi and Rice, 2005). Some applied literature reviews such as Ali et al. (2017) reviewed and classified SCRE capabilities based on proactive, concurrent and reactive strategies. Some other extant studies focused on specific capabilities. For example, Fiskel et al. (2015) studied visibility, Ivanov et al. (2018) emphasised redundancy and Ivanov et al. (2014) examined the importance of agility.

Regarding performance metrics, it is significant for organisations to conduct SCRE evaluation to facilitate the understanding of risk exposure in supply chains and to evaluate resilience and risk mitigation strategies (Soni, Jain and Kumar, 2014). Researchers have investigated the measurement of SCRE by evaluating, for example, density (Smith et al., 2016),

stock level (Cabral, Grilo, and Cruz-Machado, 2012), service level, lead time and costs (Cabral, Grilo and Cruz-Machado, 2012). However, studies on SCRE performance metrics remain scarce (Chowdhury and Quaddus, 2016; Kamlahmadi and Parast, 2016; Spiegler, Naim and Wikner, 2012), as only a few articles have discussed SCRE measurement. Without understanding the level of resilience of a system, it would be difficult to assess the response and reaction of the supply chain during disruptions. According to Ponomarov and Holcomb (2009), the potential of SCRE measurements is stated as a valuable research stream that can offer essential knowledge of SCRE and its outcomes.

Neely at al. (1995) defined performance measurement as the process of quantifying the efficiency and effectiveness of action. It reflects the most essential parts of a process and shows the aspects needing further improvement. Well-established performance metrics are essential to measure SCRE effectiveness. Performance metrics are important managerial mechanisms and support strategy implementation, communication, information and the control of processes (Kaplan and Norton, 2000; Wouters and Sportel, 2005). A measurement system states what is relevant and to be reviewed and not; it provides signals for where management has to intervene. Based on these grounds, studying change and evolution in performance metrics is highly important. Significant positive relationships exist among supply chain management capabilities, and business performance has been expounded in many extant studies (Ponomorov and Holcomb, 2009; Liao and Kuo, 2014; Chowdhury and Quaddus, 2016). Capabilities are essential in the establishment of SCRE and therefore improve the performance of organisations when facing disruptive events (Pettit, Croxton and Fiksel, 2013); at the same time, appropriate performance metrics are necessary for evaluating SCRE performance to achieve further improvement (Sillanpää, 2015). A systematic literature review by Hohenstein et al. (2015) analysed eight studies on SCRE measurement and proposed a way to measure SCRE through readiness, responsiveness and recovery. Ponomorov and Holcomb (2009) developed a framework of measuring logistical capabilities based on pre- and post-disruption aspects; Chowdhury and Quaddus (2016) extended the measurement to readiness, response and recovery capabilities specifically. It could be seen that SCRE performance could be measured through specific capabilities. We therefore propose the existence of connections between the

two topics and that they can be classified in a single framework. However, such connection between SCRE capabilities and performance metrics are ambiguous and requires sufficient understanding to explore the capabilities that deserve extra attention from the perspective of performance metrics, which indicates where the management should focus and intervene (Hald and Mouritsen, 2018).

Extant literature reviews have mainly focused on three perspectives. First is the analysis of SCRE definition and identification of capabilities (e.g. Hohenstein et al., 2015; Ali et al., 2017; Kochan and Nowicki, 2018; Kamalahmadi and Parast, 2016). The second is the review on the evolution of SCRE research and identification of future directions (e.g. Pettit, Croxton and Fiksel, 2019; Ali and Gölgeci, 2019). The other perspective is the review of research methods, such as quantitative modelling methods applied in analysing SCRE (e.g. Hosseini, Ivanov and Dolgui, 2019; Pires Ribeiro and Barbosa-Povoa, 2019). The purpose of this paper is to provide a systematic review and develop a framework to explore the aspects that contribute more to SCRE performance measurement through systematically studying the extant articles of SCRE capabilities and performance metrics and the link between them. This will build fundamental knowledge for SCRE measurement by evaluating specific capabilities that have not been sufficiently researched in the existing literature reviews.

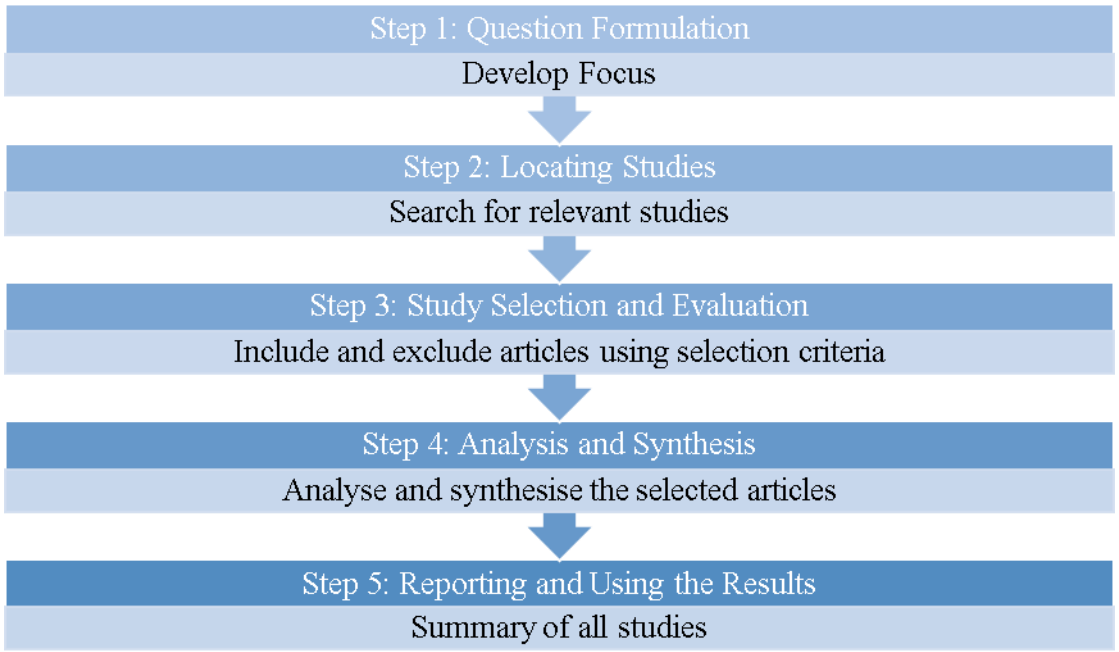
The remainder of the paper is structured as follows. Section 2 provides an explanation of the research methodology, research questions and the evaluation and selection criteria for the articles. The results of the systematic review are presented in section 3. This study concludes with a discussion of key findings, implications, limitations and recommendations for future research in section 4.

## 2. Methodology

A systematic literature review (SLR) aims to acquire all evidence to address a specific research question for a given topic and involves a reproducible and thorough search of the literature and critical evaluation of eligible studies (Briner and Denyer, 2012). An SLR is useful in synthesising the results and evidence from existing studies to create new knowledge (Light and

Pillermer, 1984; Tranfield, Denyer and Smart, 2003), and it always offers an objective assessment of the whole literature, minimising bias and errors through its strong focus on objective observation and the repeatability of results (Tranfield, Denyer and Smart, 2003; Denyer and Tranfield, 2009). Hence, an SLR is applied in this study. This research adopts Denyer and Tranfield's (2009) five-step guidelines. This method has also been applied by other literature review studies focusing on SCRE, such as Ali et al. (2017) and Hohenstein et al. (2015) (see **Figure 1**). Furthermore, the organisation of the literature review and analysis follows the important features of SLR reported in Thomé, Scavarda, and Scavarda (2016) and Torraco (2005).

Figure 1: Five steps of an SLR (adapted from Denyer and Tranfield (2009)




***Step 1: Question Formulation***

The first step of an SLR is to define the scope to develop a clear focus for the study (Booth, Papaioannou and Sutton, 2012; Light and Pillemer, 1984). As explained, this study intends to enhance the understanding of SCRE performance evaluation and therefore identify the most important capabilities in the evaluation process through a systematic summary of the literature on SCRE performance metrics, as well as capabilities that especially ensure the consistency of

time range and databases. Therefore, this study proposes and attempts to address the following questions (from 2003 to 2019):

Q1: What are the capabilities in building SCRE that are normally discussed?

Q2: What are the performance metrics of SCRE?

Q3: How can SCRE be measured through capabilities and evaluation dimensions?

***Step 2: Locating Studies***

The second step of SLR is to locate, select, assess and list the core contributions related to the review questions (Ali et al., 2017; Denyer and Tranfield, 2009). To minimise bias and cover a wide range of sources and information, this study searched key online academic databases including Emerald, Science Direct, ABI/Inform, Taylor and Francis and Wiley Online. These databases were selected based on their availability in academic institutions and having been considered in other similar studies.

Consistent with other systematic reviews in management, especially SCRE (Colicchia and Strozzi, 2012; Hohenstein et al., 2015), several keywords were defined as search criteria. To obtain broader coverage from the literature, we also adopted approaches used by Chen et al. (2012) and other well-structured literature review approaches (e.g. Short, 2009; Sheng et al., 2017; Gupta et al., 2018). The keywords consisted of the phrase 'supply chain' combined with at least one of the following: 'resilience', 'resiliency', 'resilient', 'measurement', 'performance', 'assess', 'indices' and 'capabilities'; an example is the phrase 'supply chain' with 'resilience' in the abstract and the keywords and 'performance' in a full-text search. This literature study considers peer reviewed academic articles published in 2003–2019. SCRE capabilities and performance metrics both have their critical years within this period. In 2003, the first crucial study on the capabilities of SCRE was published (Rice and Caniato, 2003) – a turning point for SCM research. In addition, the first study that quantitatively researched SCRE performance metrics was published in 2007 (Datta, Allen, and Christopher, 2007; Hohenstein et al., 2015). Given that the first paper was published in 2003, this review collected studies since then.

The search and locating of studies were started in December 2017, and were repeated in November 2018, October 2019, and March 2020.The review process was conducted interactively with frequent communications among the research teams which resulted a high level of agreement. The importance of extending the search beyond the keywords were considered for inclusiveness by including backward and forward searches (Thomé, Scavarda, and Scavarda, 2016). Literatures from the articles resulted from keyword search are reviewed for the backward search. Forward search was conducted through reviewing additional sources resulted from cited references of selected studies. No further studies were located during the process.

***Step 3: Study Selection and Evaluation***

Explicit selection criteria (see **Table 1**) were applied for the inclusion and exclusion of relevant studies to maintain the transparency of the process (see **Figure 2**). Titles and abstracts of 722 papers were read in the first screening. All documents that did not meet the selection criteria or were duplicates were excluded; 302 articles remained for the next process of selection.

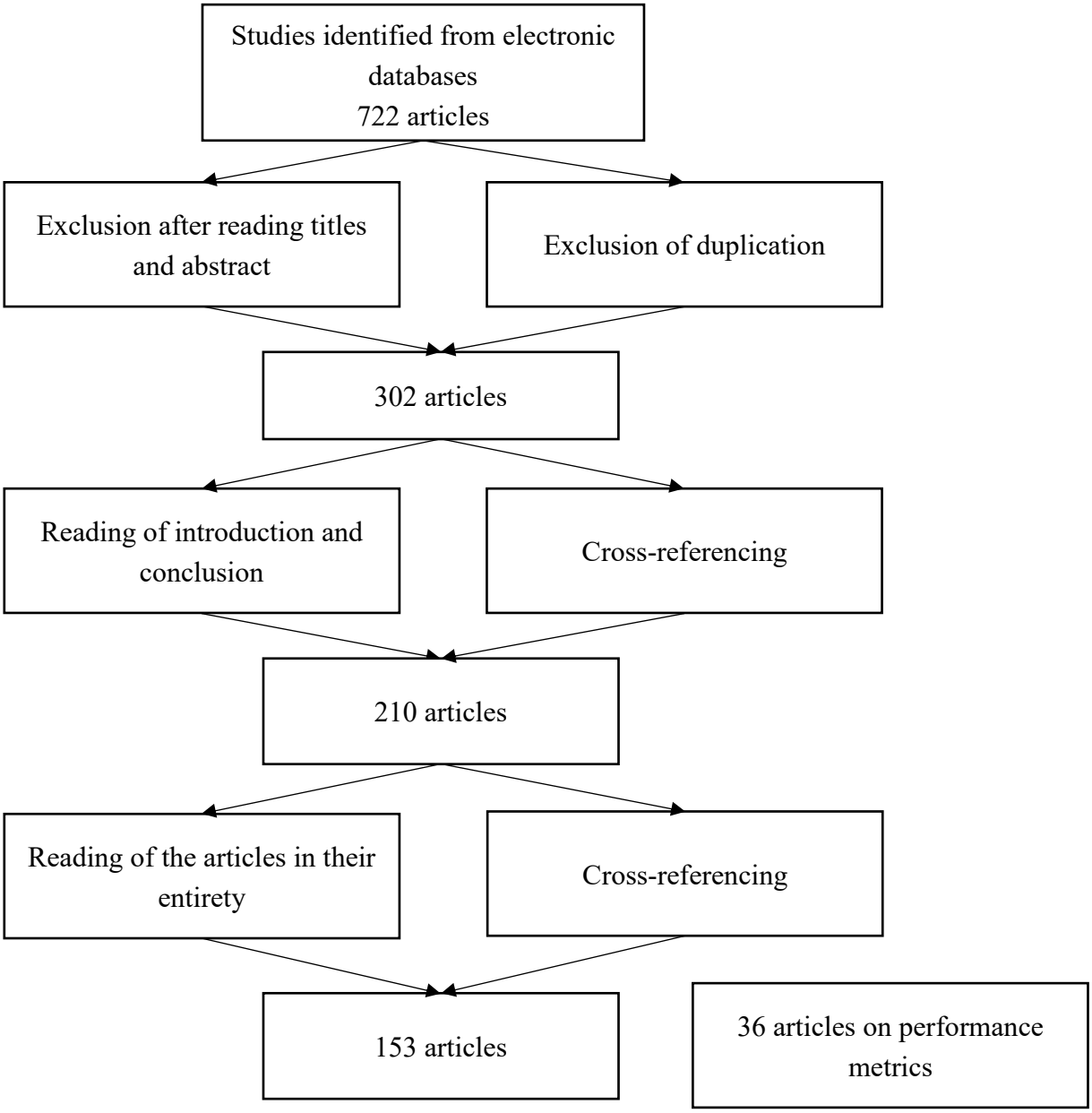
Table 1: Inclusion criteria

| **Inclusion Criteria** | **Rationale** |
|---|---|
| Papers that discuss performance metrics of resilience | This study aims to review papers that include a discussion on SCRE performance metrics |
| Papers that discuss the capabilities of resilience | This study aims to review papers that include a discussion on SCRE capabilities |
| Published in English language | The dominant language in the field of supply chain management |
| Different article types (e.g. empirical, conceptual and literature review) | To evaluate and synthesise the various research approaches |

The third screening involved reading the introductions and conclusions of the remaining articles, excluding 98 documents because of their irrelevance to the review questions. However,

six articles were added as a result of cross-referencing citations, leaving 210 articles for the final screening. The final screening involved reading the articles in their entirety. This stage excluded research papers that did not provide related information in terms of the purpose of this literature review. In total, 153 articles were selected for analysis, 36 of which discuss SCRE performance metrics, either with capabilities or simply the performance metrics themselves, while the other 117 merely concerned capabilities.

Figure 2: Review process for study selection (adopted from Moher et al., 2009)



## 3. Analysis and Findings

This section discusses the analysis and findings of the review. First, a descriptive analysis is presented on the development and current situation of SCRE literature. The publication year, journal and methodologies of the 153 articles from 2003 to 2019 are discussed in detail. Second, SCRE capabilities and performance metrics are identified and reviewed. The integrated analysis thoroughly examined the connection among reviewed capabilities and performance metrics by discussing their underlying definitions and relevant practices.

### *3.1. Descriptive Analysis*

**Figure 3** presents trends in the number of articles published in 2003–2019. In general, the number of articles related to SCRE increased dramatically during those 17 years. As noted, only a few attempted to analytically measure SCRE; most only briefly discussed SCRE performance metrics. The first attempt to analytically assess SCRE was that of Datta, Allen and Christopher (2007), which evaluated the impact of different strategies when considering the dynamics of demand, production and distribution functions. They considered customer service level, average inventory level and production change over time to assess operational resilience.

Figure 3: Number of papers on SCRE, 2003–2019

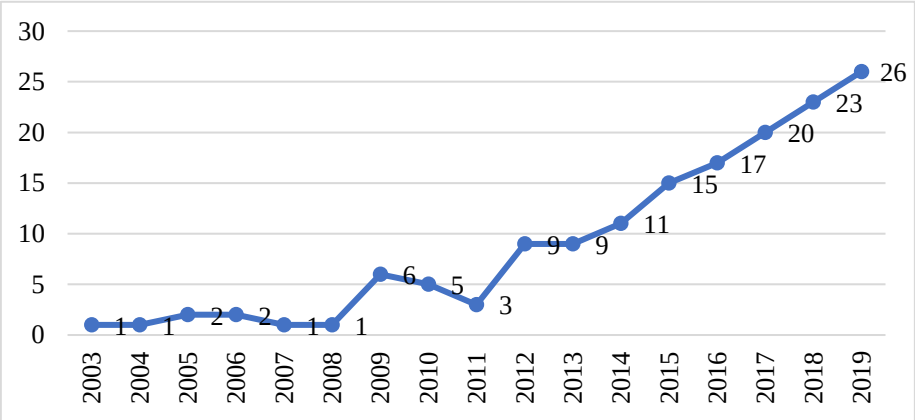



**Table 2** summarises the number of papers published in different academic journals and the methodologies applied by these articles. The 153 selected articles were published in 50 interdisciplinary academic journals, but nearly 50% were published in the 8 leading journals in

the area of supply chain management (marked with * in **Table 2**). Among the leading academic journals, the *International Journal of Production Research* accounted for the highest share of articles published. Further, the diverse research themes of the journals (e.g. production, business logistics and transportation) are evidence of the multidisciplinary nature of the research topic and the increasing attention from various research communities.

Table 2: Number of papers published in academic journals and methodology applied

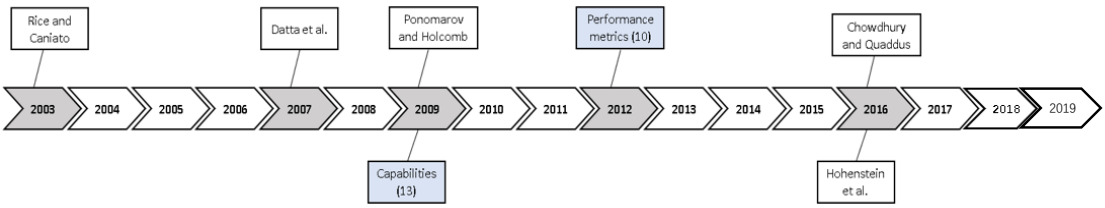
| Academic journal | No. of papers | Frequency (% rounded) | Methodology | | | |
|---|---|---|---|---|---|---|
| | | | Conceptual | Empirical | Case study | Literature review |
| *International Journal of Production Research** | 30 | 19.6% | 17 | 8 | | 5 |
| *Supply Chain Management: An International Journal** | 10 | 6.5% | 2 | 1 | 5 | 2 |
| *International Journal of Physical Distribution and Logistics Management** | 6 | 4.0% | | 2 | 1 | 3 |
| *International Journal of Production Economics** | 11 | 7.2% | 5 | 3 | 2 | 1 |
| *MIT Sloan Management Review** | 5 | 3.3% | 3 | 1 | 1 | |
| *International Journal of Logistics: Research and Application** | 3 | 2.0% | 3 | | | |
| *Journal of Business Logistics** | 4 | 2.6% | 1 | 3 | | |
| *Journal of Operation Management** | 7 | 4.6% | 2 | 5 | | |
| *Transportation Research Part E: Logistics and Transportation Review* | 4 | 2.6% | 1 | 2 | 1 | |
| *The International Journal of Logistics Management* | 6 | 4.0% | 2 | 2 | | 2 |

| | | | | | | |
|---|---|---|---|---|---|---|
| *Journal of Supply Chain Management* | 1 | 0.7% | | 1 | | |
| Others | 66 | 43.1% | 35 | 17 | 8 | 6 |
| Total | 153 | 100% | 71 | 45 | 18 | 19 |

Various research methodologies have been applied in the literature to address the research topic. Referring to **Table 2**, four types of research methodologies are commonly used, including conceptual and empirical research, case study and literature review. About 50% of the papers conducted conceptual research to study SCRE capabilities and performance metrics. Each paper was classified under its primary research methodologies although a few papers applied a mixed research method. For example, Manning and Soon (2016) applied a mixed method including a literature review and conceptual research. However, this paper is classified here as a literature review paper because this was the primary research method adopted by the study.

**Figure 4** provides a clearer view of the trends and development in this academic area, with the key times when study of SCRE capabilities and performance metrics were developing rapidly highlighted. In 2003, the first work on SCRE capabilities was published (Rice and Caniato, 2003), discussing crucial SCRE elements including security, redundancy, flexibility and knowledge management. Later, Datta, Allen and Christopher (2007) published the first quantitative study on performance metrics. The year 2009 saw a significant increase in not only the number of SCRE capability–related studies but also the types of capabilities discussed. Ponomarov and Holcomb (2009) developed the first definition highlighting preparation (readiness dimension) for unexpected events. Scholars started paying attention to performance metrics from 2012. Another important year was 2016, with two key papers published: Chowdhury and Quaddus (2016), which applied a straightforward approach to measuring SCRE by directly evaluating the performance of capabilities, and Hohenstein et al. (2015), which is, to the best of our knowledge, the first literature review study on performance metrics (though numbers were limited).

Figure 4: Timeline of the development of SCRE capabilities and performance metrics




### *3.2 SCRE Definition*

The definition of SCRE is examined in a considerable number of published studies. However, there is no commonly accepted definition although many definitions from different studies are similar. What is commonly agreed is that SCRE is a multidisciplinary concept. To name a few important studies that contributed to defining SCRE, Rice and Caniato (2003) described SCRE as an organisational ability to react to unexpected events and restore normal operations, Christopher and Peck (2004) proposed that SCRE is an ability to return to one's original state after disruptions. A more comprehensive definition that can reflect the integrated multiple disciplines is from Ponomarov and Holcomb (2009, p. 131), who stated that SCRE is an adaptive ability of the supply chain to prepare for, respond to and recover from unexpected events by maintaining the continuity of a desired level of operations and control over structure and function. Literature review studies, such as Ali et al. (2017) and Hohenstein et al. (2015), worked on reviewing the definitions proposed by current literature to find an appropriate SCRE definition. Most of the definitions noted that SCRE is developed to prepare for, respond to and recover from supply chain disruptions. Thus, this paper adopts the dimensions of readiness, response and recovery to address the research questions.

#### *3.2.1 SCRE Dimensions for Capabilities and Performance Evaluation*

Ponomarov and Holcomb (2009) clearly indicated the readiness, response and recovery dimensions as directly related to SCRE with regard to disruptions. **Readiness** is important for the supply chain to prepare for events to reduce its susceptibility to disruptions (Christopher and Peck, 2004; Jüttner and Maklan, 2011). Supply chain readiness implies the capabilities to recognise, anticipate and prevent risks and disruptions before damage occurs (Chowdhury and

Quaddus, 2016). Pettit, Fiksel and Croxton (2010) also mentioned that a supply chain should forecast, identify and assess risks, monitor deviations and mitigate disruptions by sensing early signals of risks. Readiness for unexpected events first appeared in the work of Datta, Allen and Christopher (2007). Meanwhile, **Response** implies the ability to respond quickly to critical situations – an important variable that determines a company's resilience (Chowdhury and Quaddus, 2016; Sheffi and Rice, 2005). Response was mentioned by Rice and Caniato (2003); since then, it has been considered a fundamental and reactive part of SCRE and is thus frequently discussed and stressed in SCRE definitions (Hohenstein et al., 2015). In the competitive business environment, companies that can respond quickly have the opportunity to gain market share and solidify or enhance their position in the industry (Sheffi and Rice, 2005). Similar to response, **Recovery** is also mentioned by Rice and Caniato (2003) and has since been a fundamental and reactive part of SCRE (Hohenstein et al., 2015). Recovery refers to the aftershock of an event to restore and return to normal operations. In the literature, recovery is mostly related to recovery time (Christopher and Peck, 2004; Ponomarov and Holcomb, 2009; Sheffi and Rice, 2005); the ability to recover implies a speediness in the supply chain to return to its original state (Christopher and Peck, 2004; Losada, Scaparra and O'Hanley, 2012).

### *3.3 SCRE Capabilities*

During the review process of analysing SCRE capability, we found an inconsistency in the terminologies. Some authors used the term 'capabilities' (Pettit, Fiksel, and Croxton, 2010; Pettit, Croxton and Fiksel, 2013; Jüttner and Maklan, 2011) while others referred to 'elements' (Christopher and Peck, 2004), 'antecedents' (Ponomarov and Holcomb, 2009), or 'competencies' (Wieland and Wallenburg, 2013). This study uses 'capabilities', which is also suggested by Jüttner and Maklan (2011), and in line with that formative resilience, elements should be captured at a capability level.

To consolidate the various SCRE capabilities into the dimensions of readiness, response and recovery, based on rigorous previous studies grounded in theory (Ponomorov and Holcomb, 2009), 11 capabilities were considered essential in constituting SCRE; they matched the three dimensions and attracted the largest number of SCM studies in past decades. We rigorously

reviewed and identified four resilience capabilities (situation awareness, visibility, security and redundancy) in the readiness dimension, four (agility, flexibility, collaboration and leadership) in the response dimension and three (knowledge management, contingency planning and market position) in the recovery dimension (see **Appendix**).

The readiness dimension contains four capabilities: situation awareness, visibility, security and redundancy. **Redundancy** entails maintaining excess capacity, safety stock, multiple suppliers and backup sites (Dabhilkar, Bengtsson and Lakemond, 2016; Hasani and Khosrojerdi, 2016; Manning and Soon, 2016; Ivanov, 2018; Ivanov and Dolgui, 2019). It is expected to improve the ability to respond to disruption via the strategic use of excess resources (Sheffi and Rice, 2005; Wieland and Wallenburg, 2013). **Visibility** involves the use of information technology to enable transparency of information and awareness of the current supply chain situation (Fiksel et al., 2015; Jüttner and Maklan, 2011; Pettit, Fiksel and Croxton, 2010; Melnyk et al., 2010). **Security**, is helpful in areas such as personnel security, physical security and cyber-security. **Situation awareness** is the ability to sense and forecast a possible disruption; such capability requires knowledge of supply chain vulnerabilities and the sharing of information (Ali et al., 2017; Chowdhury and Quaddus, 2017; Eltantawy, 2016).

In terms of response, four capabilities were identified and reviewed. **Flexibility** was widely discussed as the ability to adapt and adjust to a disruption rapidly rather than merely withstand the damage of the disruption (Ishfaq, 2012; Jüttner and Maklan, 2011; Ponis and Koronis, 2012; Wieland and Wallenburg, 2013; Dolgui, Ivanov and Sokolov, 2018). **Collaboration** is what integrates the supply chain network, allowing the holistic decision to build a resilient supply chain (Scholten, Sharkey and Fynes, 2014; Sheffi, 2001). According to Christopher and Peck (2004), collaboration concerns the exchange of information and the application of shared knowledge to decrease uncertainty and increase visibility and customer service (Scholten, Sharkey and Fynes, 2014). **Agility** is the ability to rapidly respond to unpredictable changes in demand or supply in the marketplace since customer requirements are continuously changing (Carvalho, Duarte and Machado, 2011; Christopher and Peck, 2004). Quick reactions through agility will help the supply chain to reduce the damage of disruption (Cabral, Grilo and Cruz-Machado, 2012). **Leadership** refers to the execution of management in companies, which

requires support from top management, engagement of employees and high-quality decision-making (Seville, Opstal and Vargo, 2015; Manning and Soon, 2016).

As for the recovery dimension, three capabilities were identified and reviewed – knowledge management, contingency planning and market position. **Knowledge management** is the ability to learn from feedback from a disruption to develop better plans and solutions for future ones (Ponomarov and Holcomb, 2009). **Contingency planning** enhances the ability to recover by assessing processes such as supply chain reconfiguration, scenario analysis and resource reconfiguration (Birkie, Trucco and Campos, 2017; Boone et al., 2013; Ponomarov and Holcomb, 2009; Zsidisin and Wagner, 2010; Pavlov et al., 2018). **Market position** is related to financial perspectives, including financial strength, market share and loss absorption (Day, 2014; Fiksel et al., 2015; Wu et al., 2013); for example, a strong market position will ensure a high market share that allows for more investment in SCRE (Sheffi and Rice, 2005).

### *3.4 Identification and Categorisation of SCRE Performance Metrics*

SCRE performance metrics focus on the evaluation of the impact of resilience. We identified 36 papers studying the performance metrics of supply resilience, applying different research methods and perspectives (see **Appendix 2** for a detailed summary of SCRE performance metrics). Most of the studies had their own measurement models and identified specific performance metrics for SCRE. However, from the results of the literature review, no common agreement on a measurement model has been achieved; the assessment of SCRE performance was studied structurally using SCRE dimensions or phases in most published SCRE measurement studies.

To improve understanding and conceptual clarity, we first integrated and consolidated various performance metrics and primarily categorised them into 11 categories according to the underlying definitions of the performance metrics in **Table 3** (see **Appendix 3** with listed performance metrics from the 36 studies of SCRE measurement). The performance metrics adopted by each article are listed in **Table 3**, and the details can be found in **Appendix 2**. We found that the assessment of SCRE is rigorously studied by scholars from variety of

perspectives. For example, in 2016, Ivanov, Pavlov, and Sokolov attempted quantifying reliability from the managerial perspective, which enables supply chain managers to assess and compare the reliability of different supply chain settings. Later, Ivanov (2018) and Kinra et al. (2019) contribute in measuring ripple effect. The former study is a simulation-based research which identifies the sustainability factors that mitigate or enhance the ripple effect. The latter study develops a model based on possible maximum loss in assessing the ripple effect of a supplier disruption. Hosseini and Ivanov (2019) also looks at the ripple effect and examine resilience by using a Bayesian network and real-life case study. The research quantifies the resilience through a multi-stage assessment of suppliers' proneness to disruptive events and the supply chain exposure to ripple effect. Pavlov et al. (2018) assesses the total structural resilience for a given reconfiguration path. Using a hybrid fuzzy-probabilistic approach, the authors suggest a method of comparing resilience of different supply chain design, considering both the disruption propagation and recovery strategies. Ivanov, Dolgui and Sokolov (2018) analyses the control policy performance by measuring service level and profit under different scenarios. If both performance indicators are above the minimum bounds for all possible disruptions, the supply chain can be considered resilient within the analysed perturbation range.

Table 3: Categorisation of performance metrics of SCRE

| Category | Studies (e.g.) |
|---|---|
| Performance of maintaining customer satisfaction | Cabral, Grilo and Cruz-Machado, 2012； Rajesh, 2016; Chen et al., 2017; Schmitt et al., 2017; Ivanov, Dolgui and Sokolov, 2018; Kinra et al., 2019 |
| Efficiency of completing supply chain processes | Day, 2014; Rajesh, 2016; Azevedo, Carvalho and Cruz-Machado, 2016; Schmitt et al., 2017 |
| Efficiency of recovering to normality | Todo, Nakajima and Matous, 2015; Chowdhury and Quaddus, 2016; Zeng and Yen, 2017; Chen et al., 2017; Hosseini and Ivanov, 2019; Chang and Lin, 2019; Tan, Cai and Zhang, 2019 |
| Performance of production and inventory | Azevedo, Carvalho and Cruz-Machado, 2016; Wicher et al., 2016; Lücker and Seifert, 2017; Ivanov, 2018; Tan, Zhang and Cai, 2019 |
| Performance of relationship management | Chowdhury and Quaddus, 2016; Rajesh, 2016; Wicher et al., 2016; Li et al., 2017 |

| | |
|---|---|
| Financial performance | Ambulkar, Blackhurst and Grawe, 2015; Dixit, Seshadrinath and Tiwari, 2016; Rajesh, 2016; Loh and Thai, 2016; Wicher et al., 2016; Ivanov, Dolgui and Sokolov, 2018; |
| Performance of overseeing the supply chain situation | Azevedo, Carvalho and Cruz-Machado, 2016; Ivanov, Pavlov, and Sokolov, 2016 |
| Performance of discerning possible disruptions | Cabral, Grilo and Cruz-Machado, 2012; Rajesh, 2016; Li et al., 2017; Chen et al., 2017; Hosseini and Ivanov, 2019 |
| Damage of disruptions | Munoz and Dunbar, 2015; Ambulkar, Blackhurst and Grawe, 2015; Ivanov, 2018; Kinra et al., 2019 |
| Efficiency of responding the disruptions | Chowdhury and Quaddus, 2016; Rajesh, 2016; Wicher et al., 2016; Li et al., 2017; Chang and Lin, 2019 |
| Reconstruction of the supply chain | Ambulkar, Blackhurst and Grawe, 2015; Loh and Thai, 2016; Lam and Bai, 2016; Pavlov et al., 2018 |

Based on analysing the categories of these studies on performance measurement, this paper attempts to link SCRE capabilities and performance metrics to consolidate them into the SCRE evaluation framework as illustrated in Section 3.5. Subsequently, we have carefully reviewed and analysed the selected scientific articles and explained the categories specifically for SCRE evaluation as follows:

1. **Performance of maintaining customer satisfaction** refers to the measurement with regards to the performance of managing customer satisfaction particularly during disruption periods (Cabral, Grilo and Cruz-Machado, 2012; Datta, Allen and Christopher 2007; Loh and Thai, 2016; Rajesh, 2016). Under disruption risks, many companies try to develop an efficient manner to maximize customer service level and seek better metrics to measure their performance in order to enhance services in a customer-driven supply chain environment (Rajesh, 2016; Sawik, 2016). For instance, Sawik (2014) developed an integrated measurement model to equitably optimize expected cost and expected customer service level to improve selection of supply portfolio and scheduling of customer orders in a global supply chain under disruption risks.

2. **Efficiency in completing a certain supply chain process** concerns the time and efficiency between the initiation and the execution of a process during the time of disruptions (Azevedo, Carvalho and Cruz-Machado, 2016; Pettit, Croxton and Fiksel, 2013; Rajesh, 2016). For example, lead time is used to measure the time needed to deliver the product to market to complete customers' requirement. Companies usually strive to reduce lead time; if the production lead time increases, the total lead time and cost will increase (Cabral, Grilo and Cruz-Machado, 2012). Previous literature (e.g. Chopra and Sodhi, 2014; Rumyantsev and Netessine, 2007) indicates that lead time has a positive relationship with companies' preparation to absorb the impact of a disruption. The method aims to eliminate potential duplicate and improve work flows within production and responsiveness of suppliers to end users during any disruption events. Therefore, companies should develop effective metrics for lead time in determining companies' resilience performance when businesses are exposed to a greater risk of disruptions (Carvalho et al., 2012).

3. **Efficiency of recovery to normality** refers to the speed of the supply chain to fully recover to its normal operation after a disruption (Pant et al., 2014; Raj et al., 2015; Todo, Nakajima and Matous, 2015). It is different from the efficiency in responding to disruptions that focuses on the speed of taking responses and actions at the beginning of an event. For example, Pant et al. (2014) proposed 'the time to full system service' resilience to measure the time from when recovery activities commence to the time when the system is completely restored.

4. **Performance of production and inventory capacity** concerns the measure of stock level and capacity during disruptions. Inventory levels increase material availability, allowing for a quicker response to unexpected demand (Cabral, Grilo and Cruz-Machado, 2012). Normally, if the inventory level of critical materials is low, the supply chain is more vulnerable to unexpected events that affect the supply of these materials (Carvalho, Duarte and Machado, 2011).

5. **Performance of relationship management** refers to performance metrics such as extent of connection and interaction (Smith et al., 2016) and the quality of relationships in the supply chain network under disruptive conditions (Lam and Bai, 2016). For instance, building flexible relationships with suppliers is one of the effective ways to respond to uncertainty of productions such as supply and demand volatility (Ivanov and Dolgui, 2019; Ivanov, Das and Choi, 2018). According to Smith et al. (2016), there are many dimensions to measure flexibility of suppliers' relationships (such as connectivity or adaptability), and this measurement is essential to effectively respond to supply chain networks under disruptions.

6. **Financial performance** mainly includes the evaluation of cost, profits, financial benefits, fines and penalties that occurred during the disruption (Cabral, Grilo and Cruz-Machado, 2012; Loh and Thai, 2016). In other words, it measures whether the supply chain has the ability to maximise the profits and minimise the costs during the time of disruptions.

7. **Performance of overseeing the supply chain situation** concerns the assessment of the quality in monitoring the supply chain situation to enable a longer preparation time for the supply chain before the disturbances take place (Chen et al., 2017; Li et al., 2017; Rajesh, 2016). This indicator measures specifically the performance of the supply chain in the overall monitoring and control of the conditions from the beginning to the end of disruption.

8. **Performance of discerning possible disruptions** measures the supply chain's ability to sense and interpret events through assessing, for example, the quality of forecast (Rajesh, 2016). Unlike the performance of overseeing the supply chain that focus on the situation during the disruption happening, this indicator targets specifically on whether the supply chain has the ability or has sufficient ability to forecast a disruptive even before it happens.

9. **Damage from disruptions** relates to the assessment of the severity of the event, which focus only on the calculation and measurement of the loss caused by the disruption.

This is also an appropriate indicator to assess the final results of a company's resilience building. For example, Ambulkar, Blackhurst and Grawe (2015) adopted a disruption impact measure to capture how supply chain disruptions reported by respondents affected their firm's overall efficiency of operations, delivery reliability to customers and procurement costs.

10. **Efficiency in responding to disruptions** evaluates specifically on how quick the supply chain (e.g. time, speed) can recognise a disruptive event and start taking actions when a disruption appears. It is different from the Efficiency of recovery to normality, which emphasise on the post-disruption recovery. According to the literature, for example, it can relate to the assessment of the ability to provide quick, appropriate resources to meet dynamically shifting needs (Chen et al., 2017; Li et al., 2017; Rajesh, 2016) that allows for sufficient adaptability to external influences and unforeseen problems, which can improve overall relief effort performance (Day, 2014; Pettit and Beresford, 2005).

11. **Reconstruction of the supply chain** involves the redesign and restructure of the system and the reconfiguration and realignment of resources after the impact of disruptions (Ambulkar, Blackhurst and Grawe, 2015; Loh and Thai, 2016; Ivanov, Dolgui and Sokolov, 2018). Ambulkar, Blackhurst and Grawe (2015) applied a seven-point Likert scale to evaluate resource reconfiguration, renewal and restructure in response to the dynamic environment and to react to the changing business environment (Ambulkar, Blackhurst and Grawe, 2015; Munoz and Dunbar, 2015).

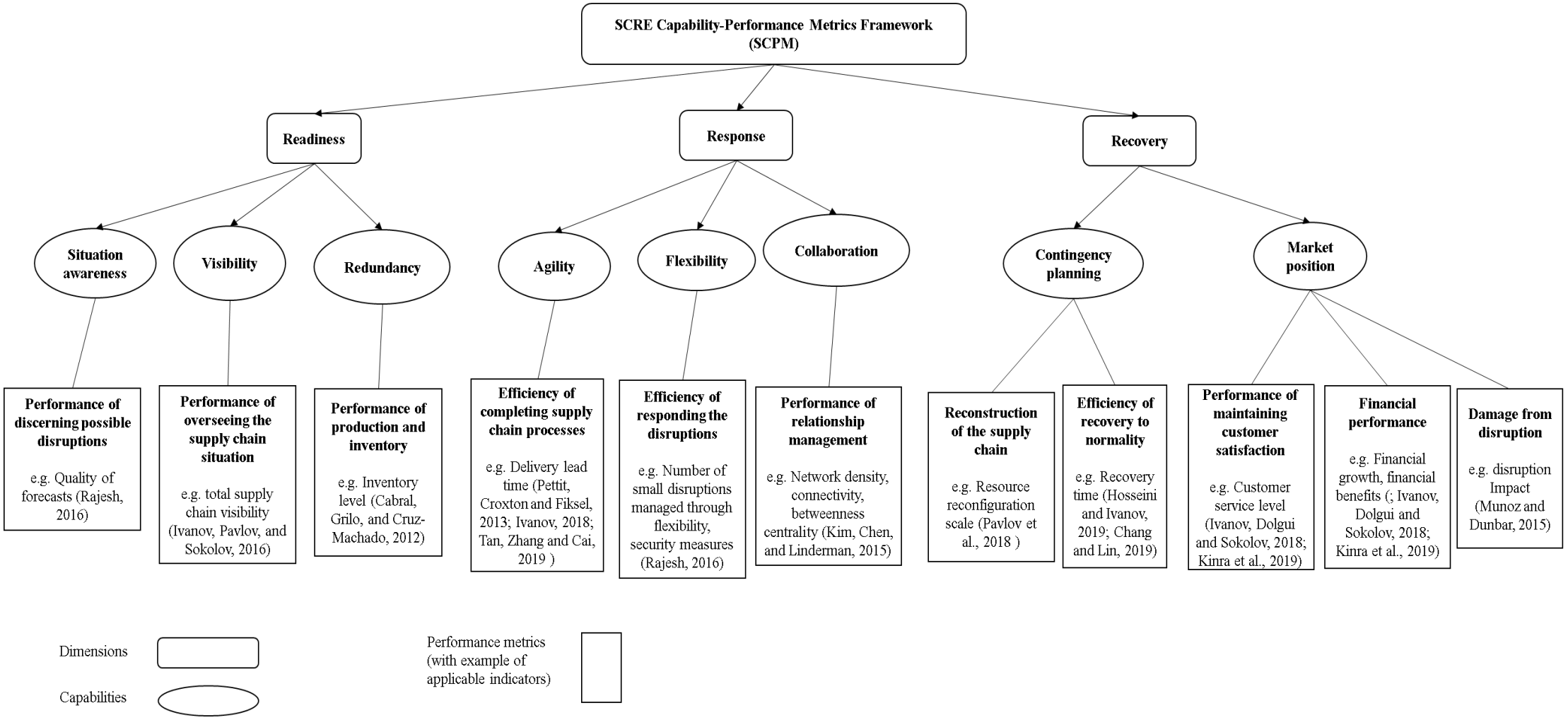
### *3.5 SCRE Evaluation Framework*

The literature review conducted by Hohenstein et al. (2015) proposed that the assessment of readiness, response and recovery should be based on robustness measures (e.g. inventory holding, multiple sourcing), reaction time to disturbance and time to recover to normal performance, respectively. The authors further revealed that the overall SCRE performance could be assessed through customer service, market share and financial performance. However,

through our review of SCRE capabilities and performance metrics from 2003 to 2019, it is clear that extant studies on SCRE assessment focused on more aspects, and it could be noticed that SCRE capabilities and different categories of performance metrics share similar underlying concepts; in other words, they are conceptually connected. This section intends to illustrate such connection and hence present capabilities and performance metrics in a single framework. Furthermore, to identify the most crucial SCRE aspects in the studies' perspective, this review allocates capabilities and performance metrics correspondingly using dimensions including readiness, response and recovery. Building certain SCRE capabilities is expected to enable better SCRE performance, and the corresponding performance metrics can measure SCRE performance resulting from the establishment of capabilities.

According to the explanation of different capabilities and performance metrics (refer to Appendix 1–3 and sections 3.3–3.4.), for example, situation awareness is the ability to forecast a possible disruption (Birkie, Trucco and Campos, 2017; Eltantawy, 2016; Rajesh and Ravi, 2015) while the ability to discern possible disruptions involves the assessment of accuracy and quality in forecasting the disruptive events (Chen et al., 2017; Li et al., 2017; Rajesh, 2016). Similarly, redundancy is the resilience capability of having excess inventory, multiple suppliers, backup sites and capacity (Dabhilkar, Bengtsson and Lakemond, 2016; Hasani and Khosrojerdi, 2016; Manning and Soon, 2016). Contingency plans appear as a key SCRE capability, including the practices of resource reconfiguration and restoration plans, while the category of performance metrics of the reconstruction of the supply chain also seeks to measure supply chain reconfiguration and redesign. The efficiency of completing certain supply chain process evaluates, for example, lead time, which refers to the amount of time needed to deliver the product to market. Both scholars and industries strongly suggest the importance of reducing lead time (Christopher and Peck, 2004; Vonderembse et al., 2006).

Figure 5: SCRE Capability-Performance Metrics Framework (SCPM)



Built upon the three SCRE dimensions (readiness, response and recovery), capabilities associated with SCRE and the categories of performance metrics identified from previous studies, this paper presents the SCRE Capability-Performance Metrics Framework (SCPM) which comprehensively demonstrates the overall SCRE structure (as in **Figure 5**). Through the literature review and linking the capabilities and performance metrics, we were able to identify the 8 capabilities that are frequently measured using corresponding performance metrics. Building on the literature, this framework provides a comprehensive and holistic view of the development of SCRE research and a guideline associated with capabilities development and performance metrics. Two important implications of the SCPM are therefore:

-It indicates that the SCRE performance can be measured from a capability perspective and the SCRE performance measurement framework reveals how such measurement is achieved.

-It bridges the two academic areas, SCRE capabilities and SCRE performance metrics, that are used to be independently researched in most of the literatures. SCPM suggests that the two areas should be considered and discussed as a whole for successful SCRE development.

After the review and analysis, 3 capabilities are found to be left out by the SCPM, namely security, leadership, and knowledge management. This is mainly because the corresponding performance metrics for evaluating the three capabilities are not located during the review process. However, it is not suggesting to overlook the importance of these capabilities as the advancement of technologies, management skills, globalisation, etc. could imply a starting point for researchers to conduct further research into these capabilities and establish relationships with SCRE performance metrics. We therefore suggest the future studies to pay specific attention to the measurement of security, leadership, and knowledge management.

According to the review, research on SCRE capabilities exhibits a mature and unified framework. The development of performance metrics is still far from that of capabilities. We argue in this study that capabilities enable SCRE development, and performance metrics are needed to evaluate SCRE and future improvement. Therefore, we suggest that future studies conduct research on performance metrics directly based on SCRE capabilities to offer a more

straightforward approach to demonstrate how SCRE performance is measured and guides companies to focus on crucial capabilities to improve performance. To provide a simple example, if an organisation adopted capabilities including flexibility, collaboration, redundancy and visibility to enable the building of SCRE, it could apply available performance metrics that directly target these four capabilities. This would provide a clear view of the requirements to improve these capabilities and enable better SCRE performance.

## 4. Concluding remarks

### *4.1 Implications*

The distinctiveness of this literature review focuses on the connection between SCRE capabilities and performance metrics and establishment of the SCPM framework to offer a better conceptual framework for these important research topics in supply chain management. Practitioners can benefit from the findings and develop a better understanding of what capabilities they need to develop and further improve using performance metrics. Young researchers can have a comprehensive understanding and knowledge about this research area, which can conceptually help them build their knowledge base. For senior researchers, this literature review suggests that future studies on SCRE performance metrics can conduct the study based on the conceptual connectedness between SCRE performance metrics and capabilities.

#### *4.1.1 Academic Implications*

Building on previous research, this study contributes to the analysis of supply chain capabilities and performance metrics guided by an SLR covering studies undertaken over a period of 17 years (2003–2019). First, this study identified SCRE capabilities from 2003 to 2019 which provides researchers the updated knowledge of relevant studies. Second, this paper addresses the gap of lacking studies on SCRE measurement by offering the first structured review on extant studies; this provides future researchers a clearer structure and picture of current research in this area. Most of all, this paper is the first attempt that structurally reviews performance metrics for SCRE measurement and contributes as the first review study in

providing structured knowledge involving SCRE capabilities and performance metrics to future research. The development of the SCPM framework reveals the important capabilities reflected from the measurement perspective. The framework points to a research direction and provides an efficient approach of SCRE performance evaluation. Assessing readiness, situation awareness, visibility, and redundancy measures fosters the SCRE to quickly prepare for the shock. Responses can be measured by evaluating agility-, collaboration- and flexibility-related indicators to analyse the performance level of reacting to disruptions. The assessment on contingency planning and market position can indicate the supply chain's performance in maintaining operation status. Meanwhile, overall SCRE performance can be reflected through the damage caused by the events.

### *4.1.2 Practical Implications*

This review of capabilities and performance metrics can help managers towards a better understanding of the requirements of building a resilient supply chain. This literature review indicates that if companies intend to develop and improve certain SCRE capabilities such as flexibility (the category of efficiency of responding to disruptions), performance metrics related to flexibility should be applied. Eleven SCRE capabilities were identified, which encompass a wide range of supply chain dimensions to manage disruptions (readiness, response and recovery). Therefore, this can offer companies a framework for cultivating and building their capabilities based on real situations. Managers now have a clear picture of the evaluation of their SCRE capabilities and potential for further improvement. For example, managers could directly refer to performance metrics such as level of capacity and inventory to evaluate the capability of redundancy.

Further, SCRE is a relatively new terminology to some developing countries. For example, companies in China have only begun to realise the value and importance of improving supply chains in recent years. The Belt and Road project, which is currently under the spotlight, is an example of applying SCRE strategies to build sustainable business models (Sheu and Kundu, 2017). Therefore, this literature review could serve as a good set of instructions for understanding the establishment, evaluation and improvement of SCRE. A similar case can be

found in India, as Indian firms and their partners within the country are seeking global competitiveness, and a better understanding of resilience building and risk mitigation strategies is crucial (Rogers et al., 2016).

Moreover, this study emphasises and reminds the public about the critical role of resilience in supply chain disruption management in the current special period of COVID-19 and future epidemic outbreaks. Epidemic outbreaks start with small scale, but scale up fast and disperse over many geographic regions with great uncertainty which makes it difficult to fully understand the impacts of epidemic outbreaks on supply chains and take appropriate measures to response (Ivanov, 2020). This makes it even more important and urgent for not only businesses, but also authorities and government sectors to invest in establishment of core capabilities of resilient supply chains to enhance the performance in such a crisis. Thus, this systematic review would serve as a strong fundamental and comprehensive knowledge for the development of a more robust supply chain resilience framework in responding to emergencies such as the COVID-19.

### *4.2 Recommendations for Future Research*

Through this study, important paths for future research can be highlighted with following research agendas.

From a general perspective of SCRE research, the review has found sufficient conceptual research observing and analysing existing SCRE related concepts and definitions. Therefore, more rigorous and exploratory empirical studies are needed to justify SCRE capabilities and performance metrics with practical evidence. Case studies have been proven particularly useful in exploring the right direction to understand the relationships between SCRE capabilities and performance metrics (Stuart et al. 2002). We suggest empirical studies such as case study in combination with quantitative methods to validate both theoretical concepts and practical models would be effective methodological approaches. We encourage researchers to further investigate all the elements provided in the SCPM framework to discover specific measures for SCRE in various industries. For instance, researchers could conduct empirical research focusing

on different countries and industries that requires significant exploration from competitive advantage and sustainable perspectives. Given that the COVID-19 has not only immensely affected all areas of economy and society, but also put the SCRE to the test, we suggest that the future research focuses more on extending the constructs of SCRE capabilities and performance measurements to tackle unknown disruptions and systemic threats. For example, Ivanov and Dolgui, (2020) introduces the term 'Intertwined Supply Network' (ISN) that encapsulates entireties of interconnected supply chains which secure the provision of society and markets with goods and services, and elaborates on the integrity of ISNs and viability to ensure the survivability. Future studies may continuously work on measuring the impact of epidemic outbreaks (e.g. COVID-19), and supply chain capabilities that need to be developed and improved to achieve a quicker recovery from the epidemic outbreaks to enhance the SCRE performance.

We also suggest researchers to follow up the SCRE research for deeper understanding on how the SCRE capabilities and performance metrics can be effectively generated and developed. In our study, the SCPM framework developed in this study enhances the understanding of relationships among the SCRE dimensions, SCRE capabilities and their associated enabling business practice factors, and the performance metrics (as presented in Figure 5 and Appendix 1). For instance, the development of collaboration relies on information sharing, collaborative forecasting, and communication as seen in Appendix 1. We believe that further investigation about these relationships with strengthened forms, e.g. differentiated priorities or ranked proximity, etc. would add significant value to building key capabilities and evaluate critical measures for improving SCRE in businesses. An effective option for such research would be, a step further from the breadth-oriented study presented in this paper, developing depth-oriented studies on the literature, e.g. identifying the strength of the relevant relationships through content analysis. As a widely adopted method for qualitative research, content analysis may be used to "inference about matters of importance" (Stemler, 2000) of the enabling business practice elements to relevant SCRE capabilities. Through identifying the concurring frequency of coded key capability terms and business practice factors in selected literature with proper tools, the targeted relationships with various level of interest would be

revealed reflecting their importance of the practice factors to building relevant capabilities and improving SCRE performance. Such a study would help to develop theoretical or practical frameworks for SCRE management with more tangible sense.

Furthermore, the study on SCRE measurement and related capabilities can be extended by taking the implementation and operationalisation factors into account. From the perspective of SCRE measurement, firstly, this study only identified a limited number of articles on performance metrics (Chowdhury and Quaddus, 2016; Kamlahmadi and Parast, 2016) further studies can be conducted among variety of research types, theoretically and empirically. As a future research agenda, researchers could examine SCRE capabilities for assessing the resilience status and most importantly for the design of a sustainable SCRE framework with reasonable and practical procedures. Secondly, security, leadership, and knowledge management are not included in the SCPM framework because corresponding performance metrics for these capabilities were not identified in this study. However, according to Chowdhury and Quaddus (2017) and Manning and Soon (2016), these three important capabilities have values associated with the ability to synthesize research and can provide a fundamental understanding of SCRE phenomenon and create further research advancement. For example, evaluating the performance of security related to information and data would be promising in SCRE research in the big data era (Richey et al., 2016). Therefore, we suggest future research to pay extra attention to the measurement of the three capabilities.

From the perspective of SCRE capabilities, it is observed during the review process that apart from the 11 capabilities selected, there are many other capabilities whose definitions are similar to or same as the identified capabilities in this paper, but using different terminologies. It is widely recognised that opinions and discussions among many concepts within SCRE are still divided (Pettit, Croxton and Fiksel, 2013; Jüttner and Maklan, 2011; Christopher and Peck, 2004; Ponomarov and Holcomb, 2009). Therefore, though studies through literature review help with summarisation and comprehensive understanding of the topics, further conceptual or empirical studies are urgently needed to clarify the variety of SCRE capabilities. In practice, building capabilities for performance could be expensive. For instance, redundancy, a SCRE capability that is characterised by holding excess stock, facilities, multiple suppliers, etc., is

widely discussed as an efficient way of achieving SCRE (e.g. Rajesh and Ravi, 2015; Zsidisin and Wagner, 2010). However, Tukamuhabwa et al. (2015) notes that building redundancy could be an expensive method to achieve SCRE. Zsidisin and Wagner (2010) also found that the benefits of holding redundant resources might be overestimated by firms, as this may not reduce frequency of disruptive events. Therefore, it is important for future research to pay extra attention to the investment into SCRE capability building, so that plausible balance between the benefits and costs of developing certain SCRE capabilities can be explored.

### *4.3 Limitations*

This study has certain limitations. First, it only covers literature over the past 17 years drawn from key electronic academic databases. Second, the articles selected for review and analysis are limited to peer-reviewed academic journal articles that provide higher quality. Other types of texts, such as conference papers and book chapters, are ignored; these sources might offer a deeper understanding of this topic.

## Appendix

### *Appendix 1: SCRE Capabilities from Selected Articles*

| Resilience dimensions | Capability | Number of articles | Related business practices | Authors |
|---|---|---|---|---|
| Readiness | Situation awareness | 14 | Sensing events, forecasts, continuity planning, warning strategies | Christopher and Peck (2004); Stecke and Kumar (2009); Ponomarov and Holcomb (2009); Pettit, Fiksel and Croxton (2010); Sawik (2013); Rajesh and Ravi (2015); Birkie, Trucco and Campos (2017); Eltantawy (2016); Ali et al. (2017); Chowdhury and Quaddus (2017); Machado, Paiva and Silva (2018); Stone and Rahimifard (2018); Lima et al. (2018); Yu et al. (2019) |
| | Visibility | 26 | Tracking and monitoring, information technology capabilities, information exchange, transportation | Christopher and Peck (2004); Stecke and Kumar (2009); Pettit, Fiksel and Croxton (2010); Jüttner and Maklan (2011); Ponis et al. (2012); Aigbogun, Zulkipli and |

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| | | | visibility, information transparency, perceiving potential opportunities | Radzuan (2014); Brandon-Jones et al. (2014); Fiksel et al. (2015); Rajesh and Ravi (2015); Thekdi and Santos (2016); Dabhilkar, Bengtsson and Lakemond (2016); Ivanov, Mason and Hartl (2018); Tukamuhabwa, Stevenson and Busby (2017); Ali et al. (2017); Parkouhi and Ghadikolaei (2017); Aigbogun, Zulkipli and Radzuan (2017); Gunessee, Subamanian and Ning (2018); Machado, Paiva and Silva (2018); Namdar et al. (2018); Gunasekaran, Subramanian and Rahman (2015); Stone and Rahimifard (2018); Lima et al. (2018); Singh, Soni, and Badhotiya (2019); Dubey et al. (2019); López and Ishizaka (2019); Kumar and Anbanandam (2019) |
| | Security | 17 | Access restriction, cyber-security, personnel security, layered defence, security partnership, public–private partnership, physical security | Rice and Caniato (2003); Sarathy (2006); Stecke and Kumar (2009); Williams, Ponder and Autry (2009); Pettit, Fiksel and Croxton (2010); Voss and Williams (2013); Ivanov and Sokolov (2013); Fiksel et al. (2015); Rajesh and Ravi (2015); Thekdi and Santos (2016); Ali et al. (2017); Chowdhury and Quaddus (2017); Kochan and Nowichi (2018); Stone and Rahimifard (2018); Lima et al. (2018); Singh, Soni, and Badhotiya (2019); López and Ishizaka (2019) |
| | Redundancy | 53 | Safety stock, multiple suppliers, multiple sourcing, multiple production locations, backup sites, capacity, transportation capacity | Rice and Caniato (2003); Sheffi and Rice (2005); Tang (2006); Stecke and Kumar (2009); Klibi, Martel and Guitouni (2010); Pettit, Fiksel and Croxton (2010); Zsidisin and Wagner (2010); Thun, Drüke, and Hoenig (2011); Ponis and Koronis (2012); Mandal (2012); Klibi and Martel (2012); Schmitt and Singh (2012); Boone et al. (2013); Wu et al. (2013); Wieland and Wallenburg (2013); Ivanov and Sokolov (2013); Ivanov, Sokolov and Dolgui (2014); Pereira, Christopher and Silva (2014); Sáenz and Revilla (2014); Urciuoli et al. (2014); Aigbogun, Zulkipli and Radzuan |

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| | | | | (2014); Fiksel et al. (2015); Matsuo (2015); Tukamuhabwa et al. (2015); Manning and Soon (2016); Hasani and Khosrojerdi (2016); Dabhilkar, Bengtsson and Lakemond (2016); Tukamuhabwa, Stevenson and Busby (2017); Ali et al. (2017); Parkouhi and Ghadikolaei (2017); Chowdhury and Quaddus (2017); Ivanov (2017); Ivanov et al. (2017); Aigbogun, Zulkipli and Radzuan (2017); Beheshtian et al. (2017); Schmitt et al. (2017); Rajesh (2017); Sharma and George (2018); Adobor and McMullen (2018); Machado, Paiva and Silva (2018); Kochan and Nowichi (2018); Ivanov and Dolgui (2019); Ivanov (2018); Dolgui, Ivanov and Sokolov (2018); Ivanov, Dolgui and Sokolov (2018); Namdar et al. (2018); Stone and Rahimifard (2018); Lima et al. (2018); Tan, Cai and Zhang (2019); Dolgui, Ivanov, and Rozhkov (2019); Hosseini et al. (2019); Thomas and Mahanty (2019) |
| Response | Agility | 25 | Velocity, channel to detect change, execution of supply chain activities, fast reaction to perceived change | Pereira (2009); Ponomarov and Holcomb (2009); Ismail, Poolton and Sharifi (2011); Jüttner and Maklan (2011); Khan, Christopher and Creazza (2012); Mandal (2012); Ponis and Koronis (2012); Wieland and Wallenburg (2013); Kristianto et al. (2014); Durach, Wieland and Machuca (2015); Rajesh and Ravi (2015); Tukamuhabwa et al. (2015); Thekdi and Santos (2016); Ali et al. (2017); Parkouhi and Ghadikolaei (2017); Machado, Paiva and Silva (2018); Kochan and Nowichi (2018); Stone and Rahimifard (2018); Lima et al. (2018); Abeysekara, Wang, and Kuruppuarachchi (2019); Singh, Soni, and Badhotiya (2019); Vishnu et al. (2019); Kumar and Anbanandam (2019); Gligor et al. (2019); Sridharan, Gunasekaran, and Ram Kumar (2019) |

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|---|---|---|---|---|
| | Collaboration | 48 | Information sharing, collaborative forecasting, communication, risk sharing, joint knowledge creation, joint relationship effort, employee engagement, connecting people in dynamic ways, trust, business relationships, joint decision-making | Christopher and Peck (2004); Pereira (2009); Pettit, Fiksel and Croxton (2010), Jüttner and Maklan (2011); Mandal (2012); Ponis and Koronis (2012); Voss and Williams (2013); Leat and Revoredo-Giha (2013); Urciuoli et al. (2014); Aigbogun, Zulkipli and Radzuan (2014); Fiksel et al. (2015); Rajesh and Ravi (2015); Tukamuhabwa et al. (2015); Erica et al. (2015); Scholten and Schilder (2015); Dabhilkar, Bengtsson and Lakemond (2016); Tukamuhabwa, Stevenson and Busby (2017); Ali et al. (2017); Papadopoulos et al. (2017); Chowdhury and Quaddus (2017); Brusset and Teller (2017); Zeng and Yen (2017); Aigbogun, Zulkipli and Radzuan (2017); Chen et al. (2017); Rajesh (2017); Botes, Niemann and Kotze (2017); Liu and Lee (2018); Adobor and McMullen (2018); Turner, Aitken and Bozarth (2018); Durach and Machuca (2018); Friday et al. (2018); Machado, Paiva and Silva (2018); Kochan and Nowichi (2018); Namdar et al. (2018); Gunasekaran, Subramanian and Rahman (2015); Stone and Rahimifard (2018); Lima et al. (2018); Ivanov, Mason and Hartl (2018); Abeysekara, Wang, and Kuruppuarachchi (2019); Singh, Soni, and Badhotiya (2019); Kim and Bui (2019); Dubey et al. (2019); Lawson et al. (2019); Hendry et al. (2019); Li et al. (2019); López and Ishizaka (2019); Kumar and Anbanandam (2019); Chunsheng et al. (2019) |
| | Flexibility | 56 | Auditing supplier process, monitoring, flexibility in sourcing, flexibility in order fulfilment, flexible products | Rice and Caniato (2003); Sheffi and Rice (2005); Tang (2006); Tang and Tomlin (2008); Pereira (2009); Stecke and Kumar (2009); Yang and Yang (2010); Pettit, Fiksel and Croxton (2010); Zsidisin and Wagner (2010); Jüttner and Maklan (2011); Thun, Drüke, and Hoenig (2011); Ponis and Koronis |

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|---|---|---|---|---|
| | | | | (2012); Khan, Christopher and Creazza (2012); Ishfaq (2012); Wieland and Wallenburg (2013); Ivanov and Sokolov (2013); Aigbogun, Zulkipli and Radzuan (2014); Ivanov, Sokolov and Dolgui (2014); Urciuoli et al. (2014); Chopra and Sodhi (2014); Mari et al. (2015); Rajesh and Ravi (2015); Gunasekaran, Subramanian and Rahman (2015); Tukamuhabwa et al. (2015); Sokolov et al. (2016); Ivanov et al. (2016); Tukamuhabwa, Stevenson and Busby (2017); Ali et al. (2017); Parkouhi and Ghadikolaei (2017); Chowdhury and Quaddus (2017); Brusset and Teller (2017); Aigbogun, Zulkipli and Radzuan (2017); Beheshtian et al. (2017); Rajesh (2017); Adobor and McMullen (2018); Turner, Aitken and Bozarth (2018); Gunessee, Subamanian and Ning (2018); Machado, Paiva and Silva (2018); Kochan and Nowichi (2018); Ivanov and Dolgui (2019); Ivanov, Das and Choi (2018); Dolgui, Ivanov and Sokolov (2018); Kumar et al. (2018); Stone and Rahimifard (2018); Lima et al. (2018); Ivanov, Mason and Hartl (2018); Singh, Soni, and Badhotiya (2019); Dubey et al. (2019); Li et al. (2019); Vishnu et al. (2019); López and Ishizaka (2019); Thomas and Mahanty (2019); Bag, Gupta, and Foropon (2019); Kumar and Anbanandam (2019); Chunsheng et al. (2019); Sridharan, Gunasekaran, and Ram Kumar (2019) |
| | Leadership | 5 | Top management support, sound decision-making, execution of decisions, staff engagement | Erica et al. (2015); Manning and Soon (2016); Adobor and McMullen (2018); Stone and Rahimifard (2018); Lima et al. (2018) |
| Recovery | Knowledge management | 12 | Learning, innovation, education and training | Rice and Caniato (2003); Ponomarov and Holcomb (2009); Dowty and Wallace (2010); Pereira, Christopher and Silva (2014); Rajesh and Ravi (2015); Manning and Soon (2016); Birkie, |

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| | | | | Trucco and Campos (2017); Eltantawy (2016); Tukamuhabwa, Stevenson and Busby (2017); Cheng and Lu (2017); Ali et al. (2017); Stone and Rahimifard (2018) |
| | Contingency planning | 11 | Supply contingency plans, supply chain reconfiguration, scenario analysis | Blackhurst et al. (2005); Ponomarov and Holcomb (2009); Khan, Christopher and Creazza (2012); Boone et al. (2013); Zsidisin and Wagner (2010); Birkie, Trucco and Campos (2017); Adobor and McMullen (2018); Stone and Rahimifard (2018); Vlajic, Vorst and Dragan, (2019); Abeysekara, Wang and Kuruppuarachchi (2019); Tan, Cai and Zhang (2019) |
| | Market position | 11 | Financial strength, market share, cost efficiency, loss absorption | Sheffi and Rice (2005); Pettit, Fiksel and Croxton (2010); Boone et al. (2013); Wu et al. (2013); Day (2014); Fiksel et al. (2015); Adobor and McMullen (2018); Kochan and Nowichi (2018); Stone and Rahimifard (2018); López and Ishizaka (2019); Kumar and Anbanandam (2019) |

## *Appendix 1: SCRE Performance Metrics from Selected Articles*

| Measures | Explanation | | Authors |
|---|---|---|---|
| Customer service level | Total quantity sold to the end customer over the total quantity ordered, averaged across all products, all markets and the entire time horizon | | Datta, Allen and Christopher (2007) |
| Production change over time and average production run length | Planning of production, how long it should be produced for | | |
| Average inventory at each distribution centre | Total on-hand stock level in the whole network across all distribution centres and products averaged over the time horizon | | |
| Total average inventory across all distribution centres | Average number of days the system takes to attend to a large drop in inventory | | |
| Operational performance | Inventory level, quality, customer satisfaction, time | Just in time<br>Supplier relationships<br>Cycle/setup time reduction | Cabral, Grilo and Cruz-Machado (2012) |
| Economic performance | Cost, environmental cost, cash-to-cash cycle | Speed in improving responsiveness to changing market needs<br>Producing in large or small batches | |
| Environmental performance | Business waste | Ability to change delivery times of supplier's order<br>Developing visibility for a clear view of upstream inventories and supply conditions<br>Lead time reduction<br>Demand-based management<br>Reduction in the variety of materials employed in manufacturing the products<br>Working with product designers and suppliers to reduce environmental impacts | |
| Lead time ratio | Ratio between actual and promised lead time | | Carvalho et al. (2012) |
| Total cost | Evaluate all costs associated with each supply chain entity on a time period | | |
| Actual inventory or cover time in the MTS (market-to-stock) | MTS system products are produced based on a demand forecast; the customer is more interested in the amount of inventory still available | | Spiegler, Naim and |

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| Delivery lead time or the order book in the MTO (market-to-order) system | | MTO products are manufactured only after an order is confirmed. Hence, MTO supply chains are concerned with delivering the orders in a minimum reasonable time | Wikner (2012) |
| Availability<br>Inventories<br>Delivery lead time<br>Order accuracy<br>Customer complaints | | Tested with seven global manufacturing and service companies. Needs a longitudinal study | Pettit, Croxton and Fiksel (2013) |
| Agility, collaboration, information sharing, sustainability, risk and revenue sharing, trust, visibility, risk management culture, adaptive capability and structure | | Using graph theory to explain the interdependence of enablers and select the values of the enablers | Soni, Jain and Kumar (2014) |
| Transient recovery | Recovery | Records the time required for performance to return to 95% from the time of impact where performance first falls below 95% | Munoz and Dunbar (2015) |
| | Impact | Severity of the impact, the difference between the initial performance level and the performance at full onset | |
| | Profile length | The length of the recovery curve, measured from the time of the full onset of the disruption until the performance level returns to 95% | |
| | Performance loss | The area above the performance curve from the time of the initial performance drop until the time at which the system returns to 95% performance, | |
| Contingency plan | | Achieving redundancy, maintaining response capacity | Lam and Bai (2016) |
| Forecast accuracy | | Increase visibility and responsiveness | |
| Strategic alliance | | Establishment of collaborative programs | |
| Supply chain relationship | | Development and maintenance of good supply chain relationships | |
| Advanced IT system (real-time tracking) | | Synchronising the flow of goods with the flow of information | |
| Monitoring and maintenance | | Control and monitoring activities to ensure the performance of employee and suppliers | |
| Supply chain disruption scale | | Alertness to disruptions, analysis of disruption | |

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| Risk management infrastructure | The presence of a person/department in risk management, use of information system, use of KPIs and metric in risk monitoring | Ambulkar, Blackhurst and Grawe (2015) |
| Resource reconfiguration scale | Ability to realign, reconfigure, restructure, renew the resource | |
| Disruption impact | How disruption impacts the overall efficiency of operation, delivery reliability, procurement cost | |
| Speed | Speed of critical activities | Day (2014) |
| Efficiency | Reasonable costs, balance between efficiency and effectiveness | |
| Responsiveness | Ability to provide appropriate resource quickly | |
| Time to total system restoration | Total time spent from the point when recovery activities commence to the time when all recovery activities are finalised | Pant et al. (2014) |
| Time to full system service resilience | Total time spent from the point when recovery activities are started to the exact time when system service is completely restored | |
| Time to a *100% resilience | Total time spent from the point when recovery activities commence to the exact time when the system service is restored to au(t0) | |
| Recovery time | Based on the CoxPH model, the variables represent various sources of disruptions, the input variable represents an event (failure event), and the output variable is the time | Raj et al. (2015) |
| Network density | Ratio of the total existing arcs to possible arcs in the network | Kim, Chen and Linderman (2015) |
| Average degree | Average number of possible arcs in the network | |
| Average, maximum, minimum walk length | The average, maximum and minimum length of the identified multiple walks | |
| Connectivity | Minimum number of nodes/arcs that must be removed to disconnect the network | |
| Betweenness centrality | How often the nodes in a network lie on the shortest path between all combinations of pairs of nodes | |
| Recovery | Number of days before resulting production (number of suppliers in/outside of the affected area, number of workers and sales per work) | Todo, Nakajima and Matous (2015) |
| Scale | The extent to which production and distribution is locally/nationally/globally located | Smith et al. (2016) |

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| Density | The number of social, economic and environmental actors, skills, functions | |
| Responsiveness | Speed of the reaction (flexibility, efficiency, adaptability and learning) | |
| Cohesion | Extent of connection and interaction | |
| Percentage of unfulfilled demand<br>Total transportation cost post-disaster | Analyses resilience of a supply chain network while addressing trade-off between the two performance measures | Dixit, Seshadrinath and Tiwari (2016) |
| Disaster preparation | Readiness training, readiness resource, early-warning signal, contingency planning | Chowdhury and Quaddus (2016) |
| Flexibility | Production flexibility, customisation, multi-skilled workforce, contract flexibility, sourcing flexibility, distribution flexibility | |
| Redundancy | Reserve capacity, stock, backup utility | |
| Visibility | Information sharing, track of information on operation, business intelligence, flow of real-time information | |
| Collaboration | Collaborative demand forecasting, collaborative decision, investing in supplier's plant | |
| Response | Quick response, effective response, response team | |
| Recovery | Quick recovery, loss absorption, reduction of impact, recovery cost | |
| Flexibility indicators | Stock-out rate, inventory accurate rate, number of small disruptions managed through flexibility, percentage increase in sales from design flexibility | Rajesh (2016) |
| Responsiveness indicators | On-time delivery ratio, contract issue time, contract approval time, put-away time ratio | |
| Quality indicators | Quality of forecasts, testing quality, shipping accuracy, security measures | |
| Productivity indicators | Order compliance, fill rate, storage space utilisation, units moved per person-hour | |
| Accessibility indicators | Dealer accessibility, retailer accessibility, customer accessibility, network intensity | |
| Resilient behaviour | Sourcing strategies to switch suppliers, flexible supply base, strategic stock, lead time reduction, total supply chain visibility, flexible transportation, visibility of downstream inventories and demand conditions | Azevedo, Carvalho and Cruz- |

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| | | | Machado (2016) |
| Financial perspective | | Presence of financial difficulties, financial growth, financial benefits, fines and penalties received, financial ratios and profits | Loh and Thai (2016) |
| Customer perspective | | Market share, customer retention, customer complaints, attraction of new customers, customer satisfaction | |
| Process perspective | | Ability to redesign and resume internal operations, improvement in operational efficiencies, experience in disruptions | |
| Learning perspective | | Skills and knowledge of employees, engagement in technology and acquirement of capabilities, intensity and frequency of training and learning opportunities, improvement in disruption management process, improvement in employee turnover rates | |
| Number of cooperating partners | | Number of enterprises weighted by the size of material flow | Wicher et al. (2016) |
| Investment in cooperation development | | Million per year | |
| Width of portfolio | | Number of groups in the NACE classification | |
| Alternative options to ensure production | | Percentage of own capacities | |
| Number of enterprises sharing basic information | | Number of enterprises weighted by the size of material flow | |
| Number of enterprises using an integrated ERP system | | Number of enterprises weighted by the size of material flow | |
| Reserve capacity | | Percentage of own capacities | |
| Creditworthiness index | | Kralicek's Quick Test scale | |
| Supply chain design reliability | | Use the genome concept and its dual analogue to quantify the supply chain structure reliability; allows determining the upper bound and the approximate lower bound of the supply chain reliability | Ivanov Pavlov, and Sokolov (2016) |
| Recovery rate | | Probability of the supply chain returning from chaos to normality | Zeng and Yen (2017) |
| Financial performance | Supply chain preparedness | Capability of a supply chain to endure the influence of potential changes (contingency plan and interest alignment) | Li et al., (2017) |
| | Supply chain alertness | Capability of a supply chain to detect changes | |

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| | Supply chain agility | Capability of a supply chain to respond to actual changes in a timely manner by adapting supply chain processes (reconfiguration, reduce lead time and reduce non-value action) | |
| Reliability | | Ability to satisfy immediate demand before any risk mitigating actions, preventative or post-disruption, are taken | Chen et al., (2017) |
| PEDC (pre-disruption mitigation capability) | | Ability to prognose and prevent a disruption before its occurrence | |
| PODC (post-disruption mitigation capability) | | Ability to recover from a disruption after it occurs (time allowance, safety inventory and quantity required by buyers) | |
| Operational resilience $\rho = \frac{M}{M+S}$ | | S is defined as the stock-out surface (quantity times time), surface M is the area that has been successfully mitigated | Lücker and Seifert (2017) |
| Warehouse performance measurers | Accuracy | Inventory accuracy, accuracy in order picking, accuracy in order shipping, % product transferred without transaction errors, % order/lines received with correct shipping documents | Laosirihongthong et al (2018) |
| | Resource utilisation | Space utilisation, equipment utilisation, labour productivity and utilisation | |
| | Financial outcome | Shipping cost, inventory holding cost, product damage rate, insurance cost, shortage cost | |
| | Responsiveness and flexibility | Responsiveness to urgent deliveries, transportation speed, customer query time, order size flexibility, delivery flexibility, service system flexibility | |
| Supply management resilience performance | | suppliers' flexibility, supply location flexibility and suppliers' reliability | Das (2018) |
| Production management resilience performance | | levels of production capacity flexibility, plant reliability and quality assurance performance of the product | |
| Distribution management resilience performance | | level of distribution flexibility, the provision of safely located distribution capacities and extra inventory for ensuring product distribution to a market | |
| Performance impact of disruption propagation in the supply chain | | With consideration of sustainability factors in order to design a resilient supply chain structure in regard to ripple effect mitigation and sustainability increase. | Ivanov (2018) |
| Supply chain design resilience | | Describes the total structural resilience for a given reconfiguration path by changes in the structure failure values during the reconfiguration on a certain path | Pavlov et al. (2018) |

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| J1 as service level and J2 as profit | Comparison of J1 and J2 in a disruption scenario with 'ideal' minimum values of these indicators in a disruption-free scenario with different disruption scenarios. | Ivanov, Dolgui and Sokolov (2018) |
| Suppliers' proneness to disruptions and the supply chain exposure to the ripple effect | Examine and test the developed notion of resilience as a function of supplier vulnerability and recoverability using a Bayesian network | Hosseini and Ivanov (2019) |
| Ripple effect of a supplier disruption | A risk exposure model that quantifies the ripple effect based on possible maximum loss. Comprehensively combining features such as financial, customer, and operational performance impacts | Kinra et al. (2019) |
| Crisis readiness, response effectiveness, recovery speed, and impact propagation rate | Measured under different supply chains characterized by various lead-time durations | Chang and Lin (2019) |
| Time-to-Recover | Measures the time taken to recover its operations after a disruption. | Tan, Cai and Zhang (2019) |
| Total cost | Economic consequences of disruption can be influenced by the mitigation and contingency strategies taken by the fir | |
| Redundancy | Structural redundancy is measured using graph theory | Tan, Zhang and Cai (2019) |

## *Appendix 3: Categorisation of Performance Metrics*

| Category | Number of articles | Performance metrics from the 36 papers |
|---|---|---|
| Performance of fulfilling customer requirements | 11 | Customer service level (Datta, Allen and Christopher, 2007)<br>Customer satisfaction (Cabral, Grilo and Cruz-Machado, 2012)<br>Customer complaints (Pettit, Croxton and Fiksel, 2013)<br>Demand-based management (Cabral, Grilo and Cruz-Machado, 2012)<br>Percentage of unfulfilled demand (Dixit, Seshadrinath and Tiwari, 2016)<br>Customer accessibility (Rajesh, 2016)<br>Customer perspective (e.g. customer retention, customer complaints) (Loh and Thai, 2016) |

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| | | Post-disruption mitigation capabilities (PODC) (quantity required by buyers) (Chen et al., 2017) |
| | | Service level and system expediting (Schmitt et al., 2017) |
| | | Service level (Ivanov, Dolgui and Sokolov, 2018) |
| | | Customer (service level) (Kinra et al., 2019) |
| Efficiency of completing supply chain processes | 8 | Lead time ratio (Carvalho et al., 2012) |
| | | Delivery lead time or the order book in the market-to-order (MTO) system (Spiegler, Naim and Wikner, 2012) |
| | | Delivery lead time (Pettit, Croxton and Fiksel, 2013) |
| | | Cycle/setup time reduction, lead time reduction (Cabral, Grilo and Cruz-Machado, 2012) |
| | | Speed (of critical activities) (Day, 2014) |
| | | On-time delivery ratio, contract issue time, contract approval time, put-away time ratio, shipping accuracy (Rajesh, 2016) |
| | | Lead time reduction (Azevedo, Carvalho and Cruz-Machado, 2016) |
| | | System expediting (Schmitt et al., 2017) |
| Efficiency of recovery to normality | 10 | Profile length, performance loss, recovery (Munoz and Dunbar, 2015) |
| | | Time to total system restoration, time to full system service resilience, time to *100% resilience (Pant et al., 2014) |
| | | Recovery time (Raj et al., 2015) |
| | | Recovery (days passed before resulting production) (Todo, Nakajima and Matous, 2015) |
| | | Recovery (quick recovery) (Chowdhury and Quaddus, 2016) |
| | | Recovery rate (Zeng and Yen, 2017) |
| | | Post-disruption mitigation capability (PODC) (Chen et al., 2017) |
| | | Recoverability (Hosseini and Ivanov, 2019) |
| | | Recovery speed (Chang and Lin, 2019) |
| | | Time-to-recovery (Tan, Cai and Zhang, 2019) |
| Performance of production and inventory | 15 | Production change over time, average production run length (Datta, Allen and Christopher, 2007) |
| | | Average inventory at each distribution centre, total average inventory across all distribution centres (Datta, Allen and Christopher, 2007) |
| | | Inventory level, producing in large or small batches, reduction in the variety of materials employed in manufacturing products (Cabral, Grilo and Cruz-Machado, 2012) |
| | | Actual inventory or cover time in market-to-stock (MTS) (Spiegler, Naim and Wikner, 2012) |
| | | Availability, inventories (Pettit, Croxton and Fiksel, 2013) |

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| | | Scale (Smith et al., 2016) |
| | | Stock-out rate, inventory accurate rate, order compliance, fill rate, storage space utilisation, units moved per person-hour (Rajesh, 2016) |
| | | Strategic stock (Azevedo, Carvalho and Cruz-Machado, 2016) |
| | | Reserve capacity (Wicher et al., 2016) |
| | | Operational resilience (Lücker and Seifert, 2017) |
| | | PODC (safety inventory) (Chen et al., 2017) |
| | | System inventory (Schmitt et al., 2017) |
| | | Extra inventory for ensuring product distribution to a market (Das, 2018) |
| | | Facility fortification, inventory replacement, sourcing (Ivanov, 2018) |
| | | Structural redundancy (Tan, Zhang and Cai, 2019) |
| Performance of relationship management | 10 | Collaboration, information sharing, trust, risk and revenue sharing (Soni, Jain and Kumar, 2014) |
| | | Supplier relationships, ability to change delivery times of supplier's order, working with product designers and suppliers to reduce environmental impacts (Cabral, Grilo and Cruz-Machado, 2012) |
| | | Strategic alliance, supply chain relationship (Lam and Bai, 2016) |
| | | Risk management infrastructure (Ambulkar, Blackhurst and Grawe, 2015) |
| | | Network density, average degree, average, maximum, minimum walk length, connectivity, betweenness centrality (Kim, Chen and Linderman, 2015) |
| | | Density, cohesion (Smith et al., 2016) |
| | | Collaboration (Chowdhury and Quaddus, 2016) |
| | | Dealer accessibility, retailer accessibility, customer accessibility, network intensity (Rajesh, 2016) |
| | | Number of cooperating partners, width of portfolio, number of enterprises sharing basic information, number of enterprises using an integrated ERP system, investment in cooperation development (Wicher et al., 2016) |
| | | Supply chain agility (Li et al., 2017) |
| Financial performance | 10 | Total cost (Carvalho et al., 2012) |
| | | Efficiency (reasonable costs, balance between efficiency and effectiveness) (Day, 2014) |
| | | The total transportation cost post-disaster (Dixit, Seshadrinath and Tiwari, 2016) |
| | | Percentage increase in sales from design flexibility (Rajesh, 2016) |
| | | Financial perspective (e.g. financial growth, financial benefits) (Loh and Thai, 2016) |
| | | Creditworthiness index (Wicher et al., 2016) |
| | | Financial outcome (Laosirihongthong et al., 2018) |
| | | Profit (Ivanov, Dolgui and Sokolov, 2018) |

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|---|---|---|
| | | Financial (costs, revenue) (Kinra et al., 2019) |
| | | Total cost (Tan, Cai and Zhang, 2019) |
| Performance of overseeing the supply chain situation | 7 | Order accuracy (Pettit, Croxton and Fiksel, 2013), visibility, developing visibility to a clear view of upstream inventories and supply conditions (Cabral, Grilo and Cruz-Machado, 2012) |
| | | Monitoring and maintenance (Lam and Bai, 2016) |
| | | Reliability (Ivanov, Pavlov, and Sokolov (2016) |
| | | Disaster preparation (early warning signal), visibility (Chowdhury and Quaddus, 2016) |
| | | Visibility of downstream inventories and demand conditions, total supply chain visibility (Azevedo, Carvalho and Cruz-Machado, 2016) |
| | | Accuracy (Laosirihongthong et al., 2018) |
| Performance of discerning possible disruptions | 5 | Quality of forecast (Cabral, Grilo and Cruz-Machado, 2012) |
| | | Quality of forecasts (Rajesh, 2016) |
| | | Supply chain alertness (Li et al., 2017) |
| | | Pre-disruption mitigation capability (PEDC) (Chen et al., 2017) |
| | | Disruption probability (Hosseini and Ivanov, 2019) |
| Damage of disruptions | 4 | Impact (Munoz and Dunbar, 2015) |
| | | Supply chain disruption scale, disruption impact (Ambulkar, Blackhurst and Grawe, 2015) |
| | | Ripple effect (Ivanov, 2018; Kinra et al, 2019) |
| Efficiency of responding the disruptions | 11 | Agility, adaptive capability (Soni, Jain and Kumar, 2014) |
| | | Responsiveness (ability to provide appropriate resource quickly) (Day, 2014) |
| | | Responsiveness (Smith et al., 2016) |
| | | Disaster preparation (readiness training, readiness resource, contingency planning), flexibility (production flexibility, sourcing flexibility, distribution flexibility), response (quick response, effective response, response team) (Chowdhury and Quaddus, 2016) |
| | | Number of small disruptions managed through flexibility, security measures (Rajesh, 2016) |
| | | Alternative options to ensure production (Wicher et al., 2016) |
| | | Supply chain preparedness (contingency plan), supply chain agility (Li et al., 2017) |
| | | Reliability (Chen et al., 2017) |
| | | Responsiveness and flexibility (Laosirihongthong et al., 2018), suppliers' flexibility, supply location flexibility, suppliers' reliability, production capacity flexibility, plant reliability, distribution flexibility (Das, 2018) |
| | | Response effectiveness (Chang and Lin, 2019) |

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| Reconstruction of the supply chain | 4 | Resource reconfiguration scale (Ambulkar, Blackhurst and Grawe, 2015)<br>Process perspective (e.g. ability to redesign and resume internal operations, improvement in operational efficiencies), learning perspective (e.g. skills and knowledge of employees, engagement in technology and acquirement of capabilities) (Loh and Thai, 2016)<br>Contingency plan (Lam and Bai, 2016)<br>Total structural resilience for a given reconfiguration path (Pavlov et al., 2018) |


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