ISSN 1980-5411 (On-line version)
Production, 28, e20180020, 2018
DOI: 10.1590/0103-6513.20180020

Systematic Review

Supply chain resilience and key performance indicators: a systematic literature review

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Abstract

Paper aims: The aim of this article is to explore the influence of non-financial key performance indicators (KPIs) to create supply chain resilience (SCRes).

Originality: It theoretically identifies the influence of specific non-financial KPIs when creating SCRes by monitoring them before, during and after a disruption.

Research method: A systematic literature review was conducted using 57 peer-reviewed academic papers from 2000 to 2017.

Main findings: Order and delivery lead time, on-time delivery, supplier delivery efficiency and customer satisfaction were the KPIs that had a significant influence on elements of resilience.

Implications for theory and practice: Results contribute to the theory by providing knowledge in an underexplored topic, and assist managers in practice by identifying specific KPIs to build resilience.

Keywords

Resilience. Key performance indicators. Systematic literature review.

How to cite this article: Karl, A. A., Micheluzzi, J., Leite, L. R., & Pereira, C. R. (2018). Supply chain resilience and key performance indicators: a systematic literature review. *Production*, *28*, e20180020. https://doi.org/10.1590/0103-6513.20180020.

Received: Mar. 16, 2018; Accepted: Sept. 5, 2018.

1. Introduction

According to the US Federal Emergency Management Agency (FEMA), approximately 40% of companies that are severely affected by a disruption in the supply flow go bankrupt (Federal Emergency Management Agency, 2016). Regardless of the sector and size, supply chains face a myriad of threats in global operations, which vary from cyber risks to natural disasters. As businesses enter an era of economic, geopolitical, societal, technological and environmental uncertainty (World Economic Forum, 2017), a wide range of unforeseen and unavoidable risks may incur, which might cause minor to major impacts to companies throughout supply chains.

Recognizing that market instability directly affects supply chain operations, it is acknowledged that competition is no longer between individual companies, but rather between supply chains (Christopher, 2012). In this context, building resilience is an important factor for organizations, as well as for their supply chains (Hohenstein et al., 2015). In Operations Management, resilience is defined as a set of organizational capabilities to face immediate and unexpected changes in the environment with proactive and reactive actions so as to anticipate, adapt, respond, recover and learn from any disruptive event (Kamalahmadi & Parast, 2016; Ali et al., 2017). Therefore, developing skills to manage organizational resources (tangible and intangible) is fundamental to achieve resilience in the supply chain, thereby achieving a competitive advantage.

Assuming that it is not possible to manage any resource that cannot be measured and that consumers are increasingly demanding, analyses and surveys regarding performance indicators have been increasing in recent

years (Anand & Grover, 2015). In pursuit of better operations management, managers have used Key Performance Indicators (KPIs) to monitor operations as they provide internal and external visibility, and consequently help decision making (Chae, 2009).

The literature on supply chain management is wide and extensive considering the different perspectives to explore this complex concept. There is an increasing number of studies regarding resilience (Christopher & Peck, 2004; Ponomarov & Holcomb, 2009; Ali et al., 2017) and KPIs (Chan, 2003; Cai et al., 2009; Cho et al., 2012) from a supply chain perspective. However, very few studies (Hohenstein et al., 2015) have focused on exploring the relationship between resilience and KPIs and the benefits of KPIs in building or improving supply chain resilience (SCRes).

In addressing this gap, this study conducts a systematic literature review (SLR) on KPIs and SCRes by adopting a structured and transparent methodology such as that proposed by Tranfield et al. (2003, 2004) and Thomé et al. (2016). Denyer & Tranfield (2009, p. 671) state that SLR aims to "[...] locate existing studies, to select and evaluate contributions, to analyse and synthesize data, and to report the evidence in such a way that allows reasonably clear conclusions to be reached about what it is [already] known" on a specific subject. Accordingly, this methodology has been applied in other SCM literature reviews (*e.g.* Colicchia & Strozzi, 2012; Hohenstein et al., 2015; Lima et al., 2018).

The purpose of this paper is to explore the influence of non-financial key performance indicators (KPIs) in the creation of supply chain resilience (SCRes). Recognizing that KPIs from the supply chain perspective cover a broad scope in the management area, and that any disruption primarily has an impact on the operations of any organization, this study prioritizes exploring non-financial KPIs. Moreover, we recognize that financial KPIs are just as important to organizations as to the phenomenon of SCRes, however it is mostly a result of non-financial KPIs (Ghalayini & Noble, 1996). According to Nudurupati et al. (2011, p. 281), non-financial indicators "[...] act as the leading indicators for the financial performance". This study contributes to theory by raising elements of resilience and non-financial KPIs from a fragmented literature, and combining them in order to explore the use of KPIs in building SCRes. In practice, it can assist managers by identifying specific KPIs to build resilience.

The article is structured in five sections. First, the introduction contextualizes the research problem followed by the research purpose. Second, it provides theoretical support to better understand the two main topics under study (resilience and KPIs). Third, it explains the whole process of SLR in detail. The fourth section lists the KPIs and elements that support resilience found in the literature to further discuss the influence between them. The last section summarizes the findings, highlighting limitations and opportunities for future studies.

2. Theoretical overview

This section provides theoretical support to the concepts of KPIs and resilience in the context of supply chains.

2.1. Key performance indicators

Supply chains are commonly known as a set of organizations which are connected through different processes and activities that produce value along the pipeline in the form of products and services to attend consumers' expectations (Christopher, 2012; Asgari et al., 2016). In this context, KPIs are used by organizations to manage such processes and activities (local and global). Nagyova & Pacaiova (2009) define KPIs as quantifiable (metric) aspects that reflect key factors that organizations must monitor and manage so as to achieve success. For this purpose, KPIs able to portray the current scenario of an organization and its supply chain should be established, thus helping to monitor and evaluate processes (Maestrini et al., 2017).

To capture relevant metrics for processes and needs, each company generates and specifies its own KPIs in terms of functional context, responsibilities and goals (Chan, 2003; Cai et al., 2009). In the supply chain context, integrating the objectives at their different levels is an important factor for the correct selection of KPIs, which will provide a broader view of the business.

2.2. Resilience in the supply chain

The word "resilience" originally comes from materials science, referring to the ability of a system to recover its initial state after undergoing an elastic deformation without any changes in its nature (Ponomarov & Holcomb, 2009). Therefore, due to market instability and the occurrence of environmental and manmade

disasters, the importance of incorporating this concept was emphasized in the operations management scenario (Scavarda et al., 2015).

Admitting that almost every supply chain faces disruptions of varying severity and types (Pettit et al., 2013), being prepared for any future disruptive event allows companies to respond efficiently and effectively, and therefore become less vulnerable to disruptions (Scholten et al., 2014). Thus, resilience within organizations and throughout supply chains recognises both the ability to absorb shocks in the form of extreme events and the adaptive capability to adjust to new circumstances (Brusset & Teller, 2017). Hence, it is recognised as a responsive capability for a firm's performance, as well as a key dimension of a firm's survival (Hohenstein et al., 2015).

However, not all risks and impacts are predictable (Christopher & Peck, 2004; Pereira et al., 2014). Thus, if a disruption occurs in the flow of goods or information, there must be an immediate and effective response to minimize losses (Kamalahmadi & Parast, 2017). Accordingly, to obtain adaptive capacities to better respond to disasters, companies must develop proactive and reactive actions to overcome impacts and remain competitive (Hohenstein et al., 2015). Conducting a robust systematic review, Ali et al. (2017) summarize all key concepts discussed in the supply chain resilience literature, and developed a concept mapping framework that classifies and aligns different features of resilience (phases, strategy, capability, elements, and practices). This framework will further guide the structure of the discussion between KPIs and elements that support SCRes in Section 4.1.

3. Methodology

Considering that deductive approaches are built on the existing literature (Blaikie, 2010), and that it is a first step to achieving a major contribution to research progress (Colicchia & Strozzi, 2012), a systematic literature review is a recently used method applied to operations management as a way of managing a growing number of studies and ensuring that no relevant research has been overlooked (Pereira et al., 2014). According to Thomé et al. (2016), SLR surpasses narrative reviews in the sense that it adopts a more rigorous and well-defined review process, which follows clear guidelines to ensure more transparency, reliability and reproducibility of findings.

Following orientations of Tranfield et al. (2003, 2004), Jesson et al. (2011), Colicchia & Strozzi (2012) and Thomé et al. (2016), this SLR follows five main steps which are described in the protocol (Table 1).

Table 1. SLR protocol.

Steps	Details
Question formulation	- develop review questions to achieve the aim of the study
Locating studies	- develop search queries - search on Web of Science, EBSCO and Scielo databases - search in 17-year period (Jan/2000-Mar/2017)
Study selection and evaluation	- *1st selection:* title, abstract and keywords screening; - *2nd selection*: introduction, conclusion and searching for the paper's content; - *3rd selection*: full paper's reading and assessment about four main points: quality of journal, accessibility, theoretical and empirical content, and unit of analysis;
Analysis and synthesis	- carefully read papers; - use Excel spreadsheet to code and organize the content based on what is intended to answer from the research questions; - content analysis of the selected papers by crossing data and observing the co-occurrence between non-financial KPIs and elements of resilience.
Results presentation	- answer the review questions based on what is known in the literature. - critical analysis from the findings observing the influence of KPIs from the supplier, focal company and customer perspective on the creation of SCRes before, during and after the disruption.

3.1. Question formulation

Aiming to explore the influence of non-financial KPIs when creating SCRes, three review questions (RQs) were addressed:

RQ1. What are the KPIs used for in the context of supply chains?

RQ2. What are the elements that support supply chain resilience?

RQ3. How can non-financial KPIs help create resilience in the supply chain?

RQ1 seeks to retrieve KPIs used in studies related to supply chains. At this stage, we did not limit this study to non-financial KPIs so as not to overlook articles that do not classify KPIs into financial and non-financial ones. RQ2 aims to identify elements responsible for creating resilience in the supply chain. Currently, Ali et al. (2017) have joined all the terms used to characterize factors that enable the development of resilience (such as principles, enablers and capabilities), and called them "elements". For this reason, we opted to use the term elements. Finally, RQ3 intends to explore the influence of non-financial KPIs which can help to create SCRes and answer the aim of this study. Overall, RQ1 and RQ2 are complementary questions to RQ3.

3.2. Locating studies

Based on the constructs embedded into the RQs, keywords were listed to develop search queries (Table 2). Tests were made using possible search queries before defining the final ones. To do so, searches were made in ABI/Inform and EBSCO, which are considered two of the most extensive databases in management (Khan et al., 2012; Thomé et al., 2012; Pereira et al., 2014), in addition to SCIELO which can cover searching for Brazilian studies, considering that the empirical part of this study will be conducted in Brazil.

Table 2. Search parameters.

Constructs	Keywords	Search queries
Supply Chain Resilience (SCRes)	Supply chain resilience Resilient supply chain Resilience / resilient Supply chain vulnerability Vulnerability Risk in supply chain Risk Supply chain disruption Disruption	"supply chain*" N5 (reslien* OR risk* OR disruption* OR vulnerab*)
Key Performance Indicators (KPI)	Performance indicators Performance metrics Performance measures	("supply chain*" AND ("performance" N5 (indicator* OR measure* OR metric*))
Supply Chain Resilience and Key Performance Indicators	Supply chain resilience Resilient supply chain Resilience / resilient Supply chain vulnerability Vulnerability Risk in supply chain Risk Supply chain disruption Disruption Performance indicators Performance metrics Performance measures	("supply chain*" N5 (reslien* OR risk* OR disruption* OR vulnerab*)) AND ("supply chain*" AND ("performance" N5 (indicator* OR measure* OR metric*))

3.3. Study selection and evaluation

For this search, a period of 17 years was defined (Jan/2000-Mar/2017), taking into account the beginning of publications in the area of the supply chain resilience (Pereira et al., 2014; Ali et al., 2017). From the 4,620 articles identified in the first search, 2,615 were selected after checking if the content in the titles and abstracts are related to KPIs and resilience in the supply chain, and also eliminating the duplicates (1st selection). The introductions and conclusions were then read to choose only articles that would certainly help answer the proposed RQs, reaching the number of 133 articles (2nd selection). Finally, after reading the full articles, they were evaluated into general assessment criteria (3rd selection). The criteria involved assessment about quality of journals (scholarly and peer-reviewed journals), accessibility (papers in English and Portuguese), theoretical (Resilience and KPIs within supply chain context), empirical content (qualitative and quantitative), and unit of analysis (organizations and supply chain level). At the end, 57 articles were selected to finally answer the RQs. All these steps are illustrated in Figure 1. The snowballing technique was not used in this study, as the developed search queries are very specific and structured to identify articles in the literature that help answer the proposed RQs. It, therefore, provided an adequate sample of papers (Jalali & Wohlin, 2012).

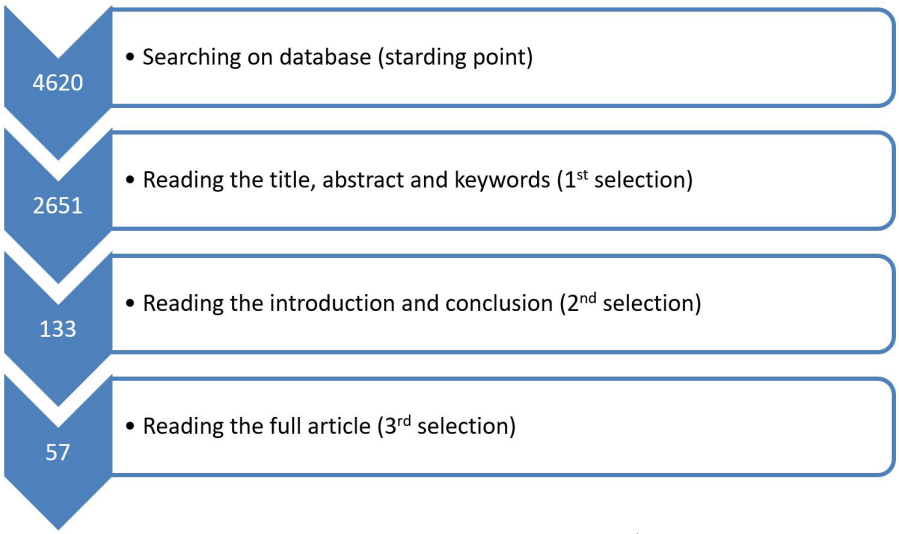

Figure 1. Systematic review process.

3.4. Analysis and synthesis

According to Thomé et al. (2016), a number of alternative approaches can be used to systematically analyse and synthesize the literature review. Data was analysed through the content analysis (Bardin, 2008; Seuring & Gold, 2012), in which codes were created by reading and extracting KPIs and elements of resilience from the literature. To ensure the validity of codes, the coding procedure was conducted by two researchers using MS Excel and then validated by two additional researchers. Codes were then analysed by the co-occurrence analysis technique. This analysis is a way of showing evidence of how one idea associates and co-occurs with another to interpret a relation between them (Kuckartz, 1999; Thomé et al., 2016). MS Excel supported the extraction, organization and analyses of the data.

3.5. Presentation of results

The final stage is presenting the findings, which answers the review questions by listing the KPIs and elements of resilience found in the literature, and then discussing the influence between them. As explained in the Introduction, we focused on non-financial KPIs as it is a previous stage of financial indicators, and as way to observe the performance of operations before, during and after the disruption. Along the same lines, we first classified the elements of resilience into pre, during and post-disruption by following a study conducted by Ali et al. (2017). However, we also added elements in different phases if there was co-occurrence between KPI and elements within a specific phase (before, during or after the disruption). Finally, a critical analysis is developed about the influence between elements and non-financial KPIs, which highlights the main contribution of this paper.

4. Findings

By reading the 57 articles, 10 non-financial KPIs and 13 elements of resilience were extracted and listed in Table 3 and Table 4, which answers the RQ1 and RQ2. From this total, only Hohenstein et al. (2015) discusses the two topics together, in which they have proposed three KPIs (*customer service, market share* and *financial performance*) that can quantify supply chain resilience. However, these KPIs are still very broad and do not explore how non-financial KPIs monitoring can help create SCRes. For this reason, these authors are not included in Table 3. Subsequently, RQ3 is answered by exploring the co-occurrence identified between non-financial KPIs and elements that support resilience. Thus, a discussion seeks to show the influence of KPIs in creating SCRes in the pre-, during- and post-disruption phases.

Table 3. Non-financial KPIs from a supply chain perspective.

Non-financial KPIs	Gunasekaran et al. (2001)	Chan (2003)	Gunasekaran et al. (2004)	Conceição & Quintão (2004)	Aragão et al. (2004)	Sellitto & Mendes (2006)	Huang & Keskar (2007)	Bhagwat & Sharma (2007)	Chae (2009)	Cai et al. (2009)	Ganga et al. (2011)	Cho et al. (2012)	Carvalho et al. (2012)	Sacomano Neto & Pires (2012)	Cedillo-Campos et al. (2014)	Avelar-Sosa et al. (2014)	Bai & Sarkis (2014)	Chelariu et al. (2014)	Gunasekaran et al. (2015)	Sjøbakk et al. (2015)	Anand & Grover (2015)	De Felice & Petrillo (2015)	Morini et al. (2015)	Katiyar et al. (2015)
Capacity utilization	✓		✓					✓				✓										✓		✓
Stock level	✓	✓						✓											✓	✓				
Quality of delivered goods	✓		✓	✓							✓	✓				✓				✓				✓
Order Lead Time	✓	✓	✓		✓			✓		✓		✓	✓	✓	✓					✓	✓	✓	✓	✓
Delivery Lead Time	✓		✓					✓				✓		✓										✓
On-time delivery of goods			✓	✓	✓	✓				✓						✓		✓						✓
Supplier delivery efficiency		✓	✓				✓		✓			✓					✓	✓						
Supplier rejection rate		✓					✓										✓							
Consumer Satisfaction		✓		✓	✓	✓				✓		✓		✓		✓		✓	✓			✓		✓
Damage return rate		✓																						✓

Table 4. The constituent elements of SCRes.

Elements of Resilience	Christopher & Peck (2004)	Pereira (2009)	Williams et al. (2009)	Oke & Gopalakrishnan (2009)	Blackhurst et al. (2011)	Zhu & Ruth (2013)	Talluri et al. (2013)	Funo et al. (2013)	Pettit et al. (2013)	Pereira et al. (2014)	Urciuoli et al. (2014)	Scholten et al. (2014)	Brandon-Jones et al. (2014)	Peng et al. (2014)	Soni et al. (2014)	Cedillo-Campos et al. (2014)	Scavarda et al. (2015)	Hohenstein et al. (2015)	Ambulkar et al. (2015)	Scholten & Schilder (2015)	Boyes (2015)	Rajesh & Ravi (2015)	Wang et al. (2016)	Ivanov et al. (2016)	Rajesh (2016)	Kamalahmadi & Parast (2016)	Lam & Bai (2016)	Kamalahmadi & Parast (2017)	Sahu et al. (2017)	Ali et al. (2017)	Brusset & Teller (2017)	Linnenluecke (2017)
Security	✓		✓								✓	✓				✓					✓						✓				✓		
Trust	✓				✓	✓				✓					✓											✓							
Robustness	✓														✓			✓		✓			✓			✓				✓			
Flexibility	✓	✓		✓	✓	✓	✓		✓	✓				✓	✓		✓	✓		✓		✓		✓	✓			✓		✓	✓	
Redundancy	✓			✓	✓		✓		✓	✓	✓			✓			✓	✓		✓			✓	✓			✓	✓		✓		
Financial Strength					✓	✓		✓		✓					✓			✓		✓						✓						
Risk Management	✓	✓			✓				✓	✓		✓	✓		✓		✓	✓		✓											✓	
Visibility	✓	✓			✓			✓	✓	✓			✓		✓		✓	✓		✓					✓		✓		✓	✓		
Information Sharing	✓	✓			✓			✓	✓	✓	✓		✓		✓	✓	✓			✓					✓	✓						
Collaboration	✓									✓		✓	✓		✓		✓	✓		✓		✓			✓	✓			✓	✓		
Agility	✓	✓				✓				✓		✓			✓	✓	✓	✓		✓		✓					✓		✓	✓		
Supply chain design	✓									✓		✓			✓			✓	✓							✓					✓	✓
Knowledge Management	✓		✓		✓			✓	✓	✓	✓	✓			✓				✓							✓			✓		✓	

4.1. Pre-disruption phase

The pre-disruption phase occurs before a possible disruption in the flow of goods or service in the supply chain. The constituent elements of resilience assigned to this phase are: security, knowledge management, visibility, information sharing, trust, risk management and robustness.

4.1.1. Security

Security is an essential element of any supply chain and should be designed in advance to mitigate the occurrence of disruptions. Developing security in operations means protecting companies against different types of breakdowns related to the manmade disruptions - cyber-attacks or physical attacks (Scholten et al., 2014; Lam

& Bai, 2016). Taking this into account, security can be built and improved by creating partnerships and/or by monitoring KPIs among members of the supply chain (Hohenstein et al., 2015; Ali et al., 2017).

On-time delivery is one of the KPIs that presented a co-occurrence to the security element in the literature. According to Chan (2003), it measures the product delivery performance by observing the percentage of orders delivered on or before the due date. The same authors highlight that for delivery industries, customers rely on time delivery for important documents or goods transfer. Thus, monitoring this KPI can help predict future disruptions by observing the delay and promptly searching for the causes. Additionally, knowing that the result of this KPI influences the level of customer service (Katiyar et al., 2015), monitoring it can verify if customers feel secure and if they are satisfied, or if there is a need to develop practices to enhance security. Ali et al. (2017) point out some security practices, such as security culture, cyber-security, layered defenses, creating public-private partnerships (PPP) and cooperative strategies with supply chain partners.

By monitoring the on-time delivery of materials, *Supplier delivery efficiency* is another metric that can help develop security by dynamically identifying if a specific supplier is not meeting the companies' target (Chae, 2009). This is important because companies typically expect their deliveries to be more important than pricing (Gunasekaran et al., 2004).

4.1.2. Knowledge management

Understanding supply chain operations, needs and threats, as well as human and capital resources are key factors to creating a resilient supply chain (Scholten et al., 2014; Ali et al., 2017). In addition, resilience must start being built in the pre-disruption phase through practices, such as education and training (Jüttner & Maklan, 2011) of knowledge acquired from past experiences (Christopher & Peck, 2004; Pereira et al., 2014).

Although all the identified KPIs can help build and enhance knowledge management by understanding the organization's environment, few KPIs presented a clear co-occurence in the literature with this element. *Capacity utilization* is a common non-financial KPI and plays an important role in determining the performance level in a supply chain by observing how well the capacity is used in the delivery of services (Katiyar et al., 2015). According to Cho et al. (2012), by understanding the *capacity utilization* throughout the months, it is possible to schedule better and use the resources to increase the efficiency of operations, and consequently reduce the product's final price with a view to increasing the market share.

Furthermore, the *quality of delivered goods* is also a key indicator since it affects *customer satisfaction* (Chan, 2003). By measuring the *supplier delivery efficiency*, it can be gauged if it is time to search for a more reliable or qualified supplier (Cho et al., 2012). Finally, Bhagwat & Sharma (2007) discuss a relationship among different KPIs, such as *capacity utilization*, *delivery lead time* and *supplier delivery efficiency*. Thus, building an understanding of the pattern of KPIs may help to develop knowledge management, and consequently SCRes.

4.1.3. Visibility

Visibility is an essential element to achieve resilience recognizing it is able to visualize conditions of inventories, demand and supply from upstream to downstream of the supply chain (Christopher & Peck, 2004). It serves as a warning strategy that provides valuable time for companies to align their capabilities to mitigate disruptive impacts (Hohenstein et al., 2015). Due to this, Ali et al. (2017) affirm that this element is achieved and enhanced by using KPIs to monitor the organizational assets (tangible and intangible).

Authors that explore visibility, such as Aragão et al. (2004), Chae (2009), Anand & Grover (2015), Hohenstein et al. (2015) and even Ali et al. (2017), affirm that this element helps to improve the supply chain performance, considering it can estimate the accuracy of supply/demand plan and assist managers to identify the key areas of improvement - whose impacts can be seen in the operation performance and, consequently, in the financial performance of the firm. Despite the fact that these authors do not point out a specific KPI for that, they affirm that a group of KPIs (financial and non-financial) can achieve an overall supply chain visibility.

4.1.4. Information sharing

Information sharing is also a widely recognized element for supply chain management under the effect of disruptions (Brandon-Jones et al., 2014). Sharing information in advance or in real time regarding organization assets or any events that might happen or have happened in a specific part of the supply chain (Ambulkar et al., 2015; Kamalahmadi & Parast, 2016) can help managers to mitigate and overcome disruptions (Urciuoli et al., 2014). This is therefore the first step to achieve visibility (Ali et al., 2017).

Cho et al. (2012) state that supply chain KPIs must be linked to *customer satisfaction*, considering this information is needed to align customer requirement for product/service design. Additionally, monitoring *stock level* from suppliers and customers is also an important KPI to avoid or mitigate the bullwhip effect (Chan, 2003). To do so, information sharing about organizational assets is required among supply chain partners in order to allow upstream and downstream visibility (such as information on new project development or online order status). It can consequently help managers to make better decisions to increase the supply chain profitability (Aragão et al., 2004). To achieve this, information technology (IT) is normally used (Chae, 2009).

4.1.5. Trust

As previously highlighted, companies that share information among each other throughout their supply chains increase their visibility, and consequently achieve better operational results than those who work isolated (Pereira, 2009; Brusset & Teller, 2017). For this to happen, they must trust each other, which promotes greater cooperation, conflict reduction, improved integration and decision-making under conditions of uncertainty and ambiguity (Christopher & Peck, 2004). Therefore, trust is considered a vital element to develop resilience due to the interdependence between organizations (Soni et al., 2014).

Although trust is stated as a conceptual idea by Chan (2003), monitoring a set of KPIs can help develop it. *Quality of delivered goods* and *On-time delivered products* are KPIs that improve this element, considering it increases customers´ trust in the company (Chan, 2003; Cho et al., 2012). *Supplier delivery efficiency* is another related KPI as it aims to measure supplier's reliability in delivering materials (Chae, 2009). Thus, any failure on the supply side may simultaneously turn into a failure in service delivery performance. To avoid such an occurrence, trustworthy relationships should be built among supply chain partners (Cho et al., 2012). Along these lines, "[...] inaccurate delivery greatly reduces the confidence of customers towards the company. It is a serious mistake that must be avoided" (Chan 2003, p. 539). For this reason, *Supplier rejection rate* is also a KPI that can monitor trust.

4.1.6. Risk management

Risk management is considered by authors (Christopher & Peck, 2004; Hohenstein et al., 2015; Scholten & Schilder, 2015) as part of the supply chain resilience, since many risks cannot be predicted or avoided. It can help reduce vulnerabilities through forecasting, monitoring and mitigating risks (Fernandes et al., 2011; Rajesh & Ravi, 2015). Thus, risk management culture must extend beyond the organization's boundaries in order to understand and share the risks among partners (Christopher & Peck, 2004).

According to Ferreira et al. (2018), there is a special characteristic of cross-company orientation in the supply chain risk management process that identifies and reduces risks not simply at the company level but rather focusing on supply chains. These authors described this process in two phases. In phase I, the risk is analyzed through Risk Identification, Risk Assessment, and Risk Evaluation, whilst phase II comprises risk control with Risk Mitigation and Risk Monitoring.

A lack of predictability and consistency in the flow of goods causes the effect of loading more inventories to avoid a lack of materials (Morini et al., 2015). Thus, monitoring the *stock level* can help managers to mitigate risk and reduce inventory costs. Risks can also be mitigated by observing the level of *order or delivery lead time*, as it is important in the context of customer service by serving as feedback to control the day-to-day operations (Chan, 2003). *Supplier delivery efficiency* is also seen as a KPI to monitor risks since it can monitor and observe a drop in supplier performance and consequent possible disruption in the flow of goods (Gunasekaran et al., 2004; Cho et al., 2012). Analyzing data from these KPIs can orientate managers to minimize the risk of supply disruptions (Chan, 2003).

4.1.7. Robustness

Robustness is characterized by Brandon-Jones et al. (2014) as the ability of the supply chain to support impacts arising from different disruptions or maintaining continuity of the process. Moreover, Scholten et al. (2014) assert that developing robustness helps companies to sustain the operations' performance by being resistance to any major disruption.

In this context, Hohenstein et al. (2015, p. 108) affirm that

> [...] to assess the level of readiness, the analysis indicated that robustness measures (e.g., inventory holding, redundancy, multiple sourcing) foster SCRes proactively to absorb sudden shocks and reduce the potential disruption impact on performance.

Therefore, monitoring the *stock level* is a way to prepare the company for major and unavoidable breaks.

4.2. During-disruption phase

When the disruption has happened, KPIs can also be useful in monitoring the impacts and taking actions. The constituent elements of resilience in this phase are: visibility, information sharing, collaboration, agility, flexibility, redundancy and supply chain design. Due to the fact that visibility and information sharing have already been discussed in the pre-disruption phase, their definition will not be mentioned in this subsection.

4.2.1. Visibility

Knowing that even a simple supply chain consists of suppliers, manufacturers, distributors and customers, any requirement or change in the customer's order can take a long time to go through from one end to another. In this case, information might be distorted on the way and many mistakes can occur (Christopher & Peck, 2004). During a disruption, information must flow efficiently so as the supply chain has a great chance to succeed. Therefore, visibility for a supply chain is important for accurate and fast delivery of information (Chan, 2003). Equally as in the pre-disruption phase, no co-occurrence has been found between a specific KPI and this element; nevertheless, it was affirmed in the literature that the management of a set of KPIs can certainly generate visibility (Aragão et al., 2004; Chae, 2009; Anand & Grover, 2015; Hohenstein et al., 2015; Ali et al., 2017).

4.2.2. Information sharing

According to Bhagwat & Sharma (2007), *stock level* and *delivery lead times* are important KPIs to be measured and monitored. Being sure about the available stock and hence knowing the average time for deliveries, managers can better observe if the impacts from the disruption are increasing or decreasing. By doing this, they keep up to date with the impacts, consequences and supply chain partners' actions (Gunasekaran et al., 2001; Cho et al., 2012). Fast service and responding properly to customers' queries are crucial for keeping *customers satisfied* (Katiyar et al., 2015), and hence develop SCRes.

4.2.3. Collaboration

According to Ali et al. (2017, p. 27), "[...] collaboration is the ability to respond to supply chain disruptions with partners through collaborative planning and information- and knowledge-sharing to coordinate the immediate response". Collaboration among all members of the supply chain is required especially in times of disruption (Scholten & Schilder, 2015). Additionally, Christopher & Peck (2004) had already stated that a high level of collaboration in supply chains can significantly help reduce risk, as the greatest challenge for managers is to create conditions in which collaborative work becomes possible.

Quality of delivered goods and *Supplier delivery efficiency* are both KPIs that have clear co-occurrence in the literature. Chan (2003) affirms that collaboration is needed to increase the quality of delivered goods as *customer satisfaction* depends on the result of this KPI. It can also be observed in Cho et al. (2012, p. 805) that "[...] suppliers contribute directly to the production of services and are usually in direct contact with customers". The same authors state that any mistake on the supply side might be replicated to the demand side. Hence *supplier delivery efficiency* is a KPI that should be monitored daily, especially during the disruption time when the rate of this indicator normally drops. *Damage return rate,* as well as supplier rejection rate are additional KPIs that require collaboration between supply chain partners in order to reduce problems and improve its operational results for all of them (Katiyar et al., 2015).

4.2.4. Agility

Agility refers to the company's ability to respond rapidly to changes, which helps reduce the impacts of disruptions and enhances the response time (Ali et al., 2017). It is recommended that managers segment markets (based on volume, product variety and demand uncertainty) to reduce costs and increase responsiveness to mitigate supply chain risks (Hohenstein et al., 2015).

Regarding this element, Bhagwat & Sharma (2007, p. 48) affirm that "[...] *capacity utilization* directly affects the speed of response to customers' demands". This is particularly important in times of disruption, considering that there might be available capacity to surplus the urgent requirements. The same authors also state that it helps to gain flexibility and deliverability. Likewise, monitoring the *stock level* is a fundamental action during disruptions so as to guarantee that available stock will certainly cover urgent orders (Chan, 2003; Bhagwat & Sharma, 2007).

According to Gunasekaran et al. (2001) and Chan (2003), a reduction in the *order lead time* leads to a reduction in the supply chain response time. In other words, it decreases the lead time from end to end of the pipeline and increases *customer satisfaction* (Morini et al., 2015). This is also true for *delivery lead time* (Katiyar et al., 2015). Thus, measuring these KPIs can help managers act during disruption, and consequently in creating SCRes.

According to Chan (2003, p. 538), "[...] time is a very important element anywhere in the world". Thus, if the organization, as well as its supply chain, can deliver a product much faster than its competitors, *customer satisfaction* will certainly increase. This is especially true in times of disruption (Scholten et al., 2014).

4.2.5. Flexibility

Flexibility is the organization's ability to meet a growing variety of customer expectations without excessive costs, organizational disruptions or performance losses (Pettit et al., 2013). This element facilitates coordination processes and allows organizations to cope with high levels of uncertainties (Talluri et al., 2013). Thus, a resilient supply chain can deal with unexpected disruptions and disasters by reaching a relevant level of flexibility (Sahu et al., 2017).

Katiyar et al. (2015) correlates and analyses different KPIs. As a result, these authors highlighted that monitoring *capacity utilization*, *on-time delivery of goods* and *delivery lead time* will help managers to flexibilize operations to rapidly attend customers' needs. *Order lead time* and *delivery lead time* also presented an interesting co-occurence for flexibility in Chan (2003)'s research. They stated that once a customer gives an order to collect a package, a collector has to draw up a flexible route to collect the package within the established lead time.

4.2.6. Redundancy

One alternative to overcome disruptions is to create redundancy of resources in the supply chain. This element is characterized by additional capacity (production, transportation, inventory and storage facility) that can rapidly replace losses during unexpected events (Christopher & Peck, 2004). Although additional stock is an opposite way of thinking to the Lean Management System, in which limited or no inventory is promoted (Kamalahmadi & Parast, 2016), the redundancy may give time to managers to come up with an effective solution (Pereira et al., 2014).

During turbulent periods, holding extra resources is a key strategy for companies to overcome critical and scarce situations caused by supply disruptions (Christopher & Peck, 2004). *Stock level* is a KPI that helps managers to visualize how long the organization can maintain its operations in case a supply breakdown occurs. In this regard, Chan (2003, p. 538) clarifies that

> [...] safety stock is necessary, as there may be a sudden increase in orders or other interruptions can occur (which should be kept as low as possible) during manufacturing. [However], it is important for the manager to determine the optimum resources necessary for every order.

Along these lines, Morini et al. (2015) also highlight that redundancy can generate agility, because customer orders can be placed immediately by means of available stock. It therefore reduces *order lead time* and hence increases *customer satisfaction* (Gunasekaran et al., 2015).

4.2.7. Supply chain design

Re-designing the supply chain is one of the elements that makes supply chains more robust, secure and agile by focusing on location strategies (Christopher & Peck, 2004). If this element is performed in real time, it is possible to mitigate risks and consequences of supply chain disruptions or even to avoid looming disruptive events (Pereira et al., 2014). Therefore, supply chains are mainly designed to achieve two objectives: cost optimization and *customer satisfaction* (Kamalahmadi & Parast, 2016).

As stated, security is an essential element of any supply chain and should be designed to mitigate the occurrence of disruptions. To build security, re-designing the supply chain is also required. Thus, by monitoring

the *quality of delivered goods*, failures can be identified from one source and then actions can be taken to reallocate to another source (Chan, 2003; Pereira et al., 2014).

According to Chan (2003), if the product is available from the warehouse, the *order lead time* can considerably decrease. However, if the slack of inventory is not possible (as discussed in the redundancy element), *order lead time* depends very much on the distribution network designed by the focal company. Therefore, during disruptions, this KPI can be kept as previously established if the supply chain is adaptable (Christopher & Peck, 2004; Ali et al., 2017).

4.3. Post-disruption phase

After disruptions, KPIs should also be used to measure and monitor the recovery and lessons learned (Hohenstein et al., 2015; Ali et al., 2017). The constituent elements of resilience in this phase are: knowledge management, information sharing, visibility, and collaboration.

4.3.1. Knowledge management

Knowledge management can be increased through optimization and control of the *supplier delivery efficiency*, considering that after disruptions, the identification of the supplier efficiency rate can help managers to make decisions about keeping the source or searching for another (Pereira et al., 2014; Ivanov et al., 2016). This rationale is also true for the *quality of delivered goods* (Lam & Bai, 2016).

According to Christopher & Peck (2004, p. 2), supply chain resilience is defined as "[...] the ability of the system to return to its original state or move to a new and more desirable state, after being disturbed". In this regard, monitoring the *order or delivery lead time* and *on-time delivery of goods* are ways to understand the supply chain behavior pre- and post-disruption, and thus develop strategies to achieve the more desirable state. Finally, Sacomano Neto & Pires (2012) explain the *customer satisfaction* measurement in the automotive sector, in which through after-sales monitoring, the assembler industry performs a diagnosis to check the critical points to be improved for future unexpected events.

4.3.2. Information sharing and visibility

Following the same rationale in the prior phases, information sharing and visibility are the basis for achieving knowledge management (Pereira et al., 2014; Ali et al., 2017). Therefore, the discussed KPIs (*stock level*, *delivery lead time and customer satisfaction*) are also beneficial (Gunasekaran et al., 2001; Cho et al., 2012; Katiyar et al., 2015) in the post-disruption phase.

4.3.3. Collaboration

To achieve a higher level of collaboration, *order/delivery lead time* and *on-time delivery* of goods should be controlled and optimized (Chan, 2003), considering that a collaborative supply chain is based on deadlines, including production and delivery times at all links in the chain (Scholten et al., 2014). Additionally, the *supplier rejection rate* can also be improved by increasing collaboration between supply chain members (Bhagwat & Sharma, 2007; Huang & Keskar, 2007).

4.4. Critical analysis of the findings

Table 5 summarizes the prior discussion. In addition to the classification of elements into pre-, during, and post-disruption, KPIs were also organized into performance indicators related to focal company, supplier and customer. In doing so, key characteristics can be observed that ensure KPIs have a positive influence when creating resilience throughout the main members of a supply chain.

From the focal company perspective, it is noted that all non-financial KPIs identified in this study can influence the creation of SCRes in the three phases of disruption. Thus, companies can make use of them to monitor operations and manage resources so as to overcome any disruptive event that might happen. This, therefore, leads to actions to add to resilience within the organization or throughout the supply chain. Furthermore, *delivery lead time*, *order lead time* and *stock level* showed great connection to the elements of resilience (more than five co-occurrence), which make them relevant to the SCRes phenomenon. Moreover, there is an intense connection between these KPIs to the during and post-disruption phases. This occurs because in the moment

Table 5. Summary of non-financial KPIs and elements of resilience.

		Focal Company						Supplier		Customer	
		Capacity utilization	*Quality of delivered goods*	*Order Lead Time*	*Delivery Lead Time*	*On-time delivery of goods*	*Stock level*	*Supplier delivery efficiency*	*Supplier rejection rate*	*Consumer Satisfaction*	*Damage return rate*
Pre-disruption	*Security*					✓		✓		✓	
	Knowledge Management	✓	✓		✓			✓		✓	
	Visibility										
	Information Sharing						✓			✓	
	Trust		✓			✓		✓	✓		
	Risk Management			✓	✓		✓	✓			
	Robustness						✓				
During-disruption	*Visibility*										
	Information Sharing				✓		✓			✓	
	Collaboration		✓					✓		✓	✓
	Agility	✓		✓	✓		✓			✓	
	Flexibility	✓		✓	✓	✓					
	Redundancy			✓			✓			✓	
	Supply chain design		✓	✓						✓	
Post-disruption	*Knowledge Management*		✓	✓	✓	✓		✓		✓	
	Visibility										
	Information Sharing				✓		✓			✓	
	Collaboration			✓	✓	✓			✓		

of a disruption, companies normally drive their attention to attend orders and meet deadlines, and one of the common strategies to achieve this is through stock (Fernandes et al., 2011; Pereira et al., 2014).

From the supplier's perspective, KPIs showed a considerable influence on the pre-disruption phase, but not many on the during and post-disruption phases, which are critical phases in resilience to maintain the operations and build a strong relationship between buyers and suppliers. With respect to the customer perspective, *customer satisfaction* showed co-occurrence with 10 elements, while *damage return rate* co-occurred only with the collaboration element. Likewise the analysis of the three KPIs above, this highlights the interest of companies in monitoring the customer's satisfaction, as it is the key for their success and survival. This analysis is especially true in the during-phase disruption, while companies have to maintain their operations to fulfill customers' requirement. Nevertheless, authors (Chan, 2003; Cho et al., 2012; Sacomano Neto & Pires, 2012) emphasize that customer satisfaction is a result of the management of other KPIs. Due to this, *customer satisfaction* is the KPI that showed more connections to the elements of resilience.

Overall, Table 5 portrays a high co-occurrence between KPIs and elements in the disruption phase, following the pre-disruption phase, and lastly post-disruption. From this result, it can be reaffirmed that the non-financial KPIs in this study are able to positively influence resilience more in the moment of the disruption instead of before or after it. Therefore, there is a lack of attention from the KPIs to monitor certain actions in order to prepare the supply chain or deal with unexpected events by means of resource management.

As important as in the pre-disruption phase, knowledge management is also required in during- and post-disruption phases, recognizing that all knowledge must be recorded to be further used to mitigate and excel any type of disruptions. Consequently, information sharing, collaboration and visibility are also elements that must be developed as it is the basis for enhancing knowledge management. Although no clear evidence was identified in the literature about the correlation of all KPIs for knowledge management element, it was observed that monitoring and managing all supply chain KPIs is a source of information to improve knowledge management. It is especially notable in the post-disruption phase as the knowledge can be used to create or enhance other elements, such as security, flexibility and risk management.

Finally, although there is much on the literature about the importance of visibility within the company and throughout the supply chain (Aragão et al., 2004; Chae, 2009; Anand & Grover, 2015; Hohenstein et al., 2015; Ali et al., 2017), no clear co-occurrence between this element and specific KPIs was found in the three phases of disruption; yet authors mentioned the creation of visibility through monitoring a set of KPIs. In addition to this, no co-occurrence was also identified between financial health (element) to any non-financial KPI (nor specific, neither generic). Although this is a common cited element by SCRes authors, we assumed that it may be certainly linked to financial KPIs instead of non-financial ones, as it requires or measures capital investment (from focal firm or suppliers) to be built.

5. Conclusion

This paper shed light on an underexplored topic which explores the influence of specific non-financial KPIs in generating SCRes. As a first step in exploring this, a systematic literature review was conducted and analysis showed a positive influence between non-financial 10 KPIs and 11 elements of resilience (Table 5). Out of 13 elements of resilience identified, visibility and financial health did not present clear co-occurrence with the KPIs discussed. Order and delivery lead time, stock level and customer satisfaction were the indicators that most co-occurred for the elements that support resilience. Notwithstanding, customer satisfaction was found to be a result of the management of other KPIs so as to achieve SCRes. Among all elements, knowledge management presented the highest co-occurrence with the KPIs (as in pre- or post-disruption), considering it is the source of knowledge to develop other elements.

This study contributes to the theory by raising elements of resilience and non-financial KPIs from a fragmented literature, and connecting them in order to explore the use of KPIs in building SCRes. To practice, it can assist managers by identifying specific KPIs that can help not only monitor the operations but also assist in the creation of organizational or supply chain resilience.

As every piece of research, it has a number of limitations. First, it is purely based on the body of knowledge presented in three databases over the past 17 years. Second, considering that the snowball search was not applied in this study, it might be interesting to check if it would identify additional relevant articles to improve the results. Third, articles in Portuguese were included in the systematic review, which may limit foreign researchers to replicate the present SLR process. However, we opted to include articles in Portuguese considering these findings will be validated through an empirical study in the Brazilian supply chains. The Brazilian context was chosen due to the increasing number of disruptive events that the entire country is facing and the lack of studies in resilience in the context. Future opportunities for research should evolve the purpose of this study by involving financial KPIs or even the impact of the operational KPIs in the financial KPIs by creating SCRes.

Acknowledgements

The authors are grateful to the financial support granted by FAPESC (Santa Catarina Research Foundation) through the processes 2017TR759.

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