Supply chain resilience and agility: a theoretical literature review

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Abstract: Current supply chain management topics, including just-in-time, cost reduction through the offshoring of production, market globalisation, economies of scale, outsourcing, consolidation of suppliers, international market volatility, technological disruptions and the global economic instability, increase the likelihood of suffering disruptions in supply networks and chains due to their international dissemination and fragmentation. Supply chains need to adopt new strategies to improve their abilities to respond quickly and effectively to unforeseen changes in markets and to the increasing levels of turbulence, thereby supporting the performance and competitiveness of companies. This article provides a review of the current literature on resilience and agility in supply chain management from the perspective of risk management in business management in global environments and proposes two approaches to resilience and agility. The perspectives contemplate a risk management, by means of the previous preparation to the disruptive event, a mitigation of the impact, a phase of recovery and finally the one of stabilisation.

Keywords: supply chain management; resilience; agility; operations strategy; risk management; supply chain disruptions.

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1 Introduction

Among the responsibilities of the supply chain management (SCM) is to maintain a secure supply chain that is capable of managing any disruption, minimising its impact on the organisational capacity to supply products and services, and ensuring business continuity in the new conditions. This approach includes external and internal elements of the organisation, as suppliers and outsourcing of processes (Bird, 2013). In 2012, the International Organization for Standardization (ISO) created the specific regulation ISO 22301: 2012 to help ensure the continuity of management systems in organisations, regardless of their size, location or activity sector (Gasiorowski-Denis, 2012).

Incidents can take many forms ranging from large-scale natural disasters, acts of terror, technology-related accidents and environmental incidents. However, although most events may be small, they can have a significant impact. Any small local crisis can lead to a disruption with global consequences, such as a 'butterfly effect' (a concept developed by the Theory of Chaos) in the ecosystem of supply chains that collaborate.

What makes business continuity management related to the supply chain relevant at all times.

Given this current issue topic in the world of business and the SCM, we were interested in learning about the most up-to-date academic literature says. And how we could compile this knowledge into a single article, to help the academic community to get an overview of the subject quickly, and to future researchers to focus your information searches.

In this paper we compile the most important theoretical contributions in the field of resilience and agility in SCM, to answer the research question: what have been the most relevant contributions according to the number of citations and main bibliometric indicators?

The review of theoretical literature helped us to establish what theories already exist, the relationships between them and develop a combined frame of the dynamics of resilience and agility that summarises our findings (Belllers and Smith, 2003; Merigó et al., 2015; University of Alabama Libraries, 2018; Nakano and Muniz, 2018; Tseng et al., 2019).

We have included quotes from the most pertinent authors about the different classifications of the risk factors, the evolutionary phases, and crisis management according to the most relevant authors. We intended to provide a compilation of significant citations from the sources that can guide researchers to those authors that are researching about most compelling topics.

2 The methodology of the bibliometric analysis of the cited literature

A semi-bibliometric analysis of the bibliographical references selected for this article – all listed in the references, was carried out in order to demonstrate that the cited scientific publications are relevant and indispensable in the study of resilience and agility in SCM. For its selection, two criteria were applied:

a A semi-bibliometric approach of academic scope: several searches related to business management (using keywords fundamentally focused on SCM) were carried out in Web of Science, Scopus, Google Scholar, ProQuest, and Emerald; publications that received a good number of citations were chosen. This approach is not considered totally bibliometric because in order not to exclude any article of interest by applying excessively strict rules, which might exclude from the selection recent articles with contributions considered important, we did not wish to establish a specific threshold of citations from which an article was chosen for consultation or not. The titles were then read and, in some cases, the abstract of each publication chosen in the first step, thereby definitively selecting a population of 64 scientific publications (specifically: 41 scientific articles, 4 book chapters, and 19 books) due to their interest and relevance for this study.

b A general scope approach: The same keywords used in the scientific databases were applied to Google, which allowed the identification other types of documents also relevant and of interest to the authors: 1 interview, 4 reports, 1 news item, 3 webpages, and 1 scientific working paper.

To confirm whether the previous bibliographic selection was adequate, the comparative bibliometric study described below was then carried out.

For this, four recognised bibliometric indicators were considered in order to measure the quality of the scientific journals, editorials, articles and quality of the authors:

a Scientific journals: The impact factor (Campanario, 2006), the impact index (Ardanuy, 2012) of Web of Science and its ranking of journals, the Journal Citation Reports.

b Scientific articles: The total number of citations they received in Web of Science. Only those scientific articles indexed in Web of Science are considered in this analysis, as we believe that the highest quality citations, or those of the highest level, are those obtained from other articles indexed in Web of Science (Ardanuy, 2012).

c Scientific quality of researchers: The h-index, currently the most common way to gauge the influence of an author in the scientific community. The h-index of a selection of authors considered relevant was calculated (Ardanuy, 2012). Given that it was not possible, within the limits and objectives of this bibliometric study, to calculate this indicator relative to each author of all the articles included in the bibliography, the following criterion for choosing outstanding authors related to the subject of this study was applied: to include in this study those authors who have published a scientific article exceeding 500 citations in Web of Science.

The detailed description of the results of bibliographic analysis can be found in the appendix.

3 Introduction to current topics in SCM

Current topics in SCM, including *just-in-time*, cost reduction through production offshoring, the globalisation of markets, economies of scale, outsourcing and the consolidation of suppliers, increase the chances of suffering disruptions in networks and supply chains through their international dissemination and atomisation (Christopher, 2011). For Zsidisin and Wagner (2010), "The concern and study of supply risk and supply continuity has recently come to the forefront in managing business and conducting research".

Carvalho et al. (2012) conclude that supply chains need to adopt new strategies to improve their abilities in order to respond quickly and effectively in terms of costs to unforeseen changes in markets and the increasing level of turbulence, and link these abilities to company performance and competitiveness. They propose a conceptual framework that allows the resilience and agility of the supply chains to be related to the performance and competitiveness of a company. Christopher and Peck (2004) developed a strategic taxonomy for the design of resilience in the supply chain that includes its relationship with agility, which, according to Sheffi (2007), is directly related to speed, acceleration and visibility, i.e., the speed of recovery. In the global context, companies compete with each other in an ecosystem formed by their supply chains (Batra, 2012).

Wagner and Bode (2008) cite a series of pre-2008 crises that impacted supply chains and that have attracted the attention of academics – Hurricane Katrina in the USA (2005),

the 2001 terrorist attack in New York, and the 2003 SARS epidemic in Asia –, and state that supply chains are increasingly vulnerable, as companies have been increasingly suffering from competitor pressure on a global scale in recent decades. This increase in disruptive crises and the sensitivity of supply chains means that special attention should be paid to the resilience of companies and how they manage risks (Wagner and Bode, 2008).

Kainuma (2012) suggests conducting future research on the relationship between SCM and the performance, resilience and agility of companies through the use of financial metrics. Gunasekaran and Kobu (2007) suggest the design of a series of both traditional and new metrics, while Stock and Boyer (2009) state categorically that scientists should investigate and examine the background, consequences and negative impacts of disruptions and uncertainties in supply chains.

4 Risk management in SCM: resilience and agility

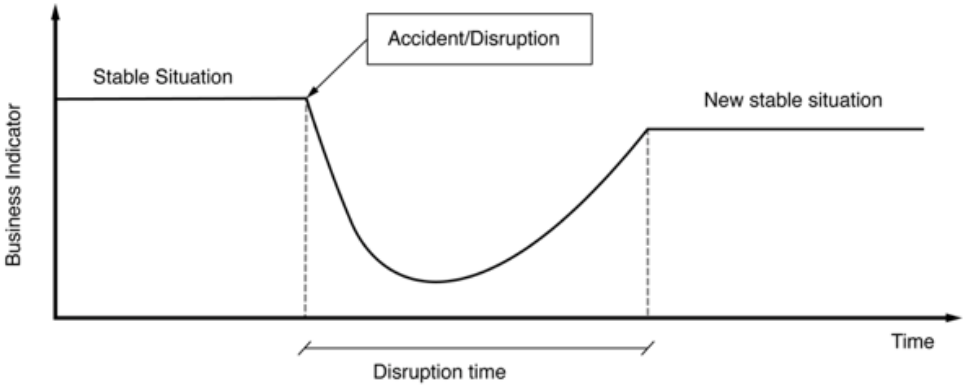
One of the responsibilities of SCM is to maintain a secure supply chain capable of managing any disruption, thereby minimising its impact on the company's capacity to supply products and services and ensuring business continuity under the new conditions. This includes external and internal components of the organisation, such as suppliers and the outsourcing of processes. Faced with this responsibility, defined by the Business Continuity Institute to ensure business continuity (Bird, 2013), the ISO in 2012 created regulation ISO 22301:2012 specifically to help ensure the continuity of management systems in organisations, regardless of their size, location or activity sector.

Incidents can disrupt an organisation at any moment and the application of ISO 22301 will ensure that organisations can respond and continue their operations. Incidents can take many forms, ranging from large-scale natural disasters, acts of terror, technology-related accidents and environmental incidents. However, although most incidents might be small, they can have a significant impact, which makes the management of business continuity relevant at all times (Gasiorowski-Denis, 2012).

Many countries have already incorporated ISO 22301 into their legislation. Among the first were the United Kingdom and Singapore. According to Dr. Stefan Tangen, secretary of the ISO Technical Committee: "Organizations that implement ISO 22301 will be able to demonstrate to legislators, regulators, clients, potential clients and other interested parties that they have adhered to good practices in Business Continuity Management" (Tangen and Austin, 2012). It can also be used as an organisational measure of the level of application of good practices within the organisation, which will be of interest to auditors who have to report on the quality of management (Gasiorowski-Denis, 2012).

Current SCM topics, such as *just-in-time*, cost reduction due to the offshoring of production, globalisation, economies of scale, outsourcing and the consolidation of suppliers, increase the chances of suffering disruptions in supply networks and chains due to their international dissemination and fragmentation (Christopher, 2011). Any local crisis can lead to disruption with global consequences through a 'butterfly effect' (a concept developed by the Chaos Theory) in the ecosystem of supply chains that work together. Whilst there is no control over the cause, a company does have the ability to mitigate them (World Economic Forum, 2008).

Figure 1 Curve of the impact on business of the crisis and disruptive period



Source: Asbjørnslett and Rausand (1997)

Figure 1 shows the dynamics of the impact of a disruptive crisis on the stability of the economic-financial environment, as studied by Asbjørnslett and Rausand (1997), Asbjørnslett (1999), Sheffi (2001, 2005a, 2005b, 2007, 2015), Sheffi and Rice (2005), Ritchie and Brindley (2004), Tomlin (2006), Briano et al. (2009) and Kouvelis et al. (2012) among others, who define resilience as the ability "to better withstand the unpredictability of world trade by gaining a competitive advantage and by being able to do more and faster than competitors when a catastrophe occurs".

For Viner (2008) and Kouvelis et al. (2012), the main objective is to identify and control the risks that operations may suffer, to the extent reasonably possible, not by simply following literally each and every regulation of industrial sectors, even though they have no direct relationship with the scope of the organisation. They highlight three classes of risks associated with SCM:

1 strategic risks: those associated with the company's business plan and its strategies and decisions

2 financial risks: those affected by decisions influenced by changes in markets, liquidity and credit risk classification

3 operational risks: those related to processes, personnel, systems, assets and external factors.

According to Lee (2004), "the best supply chains are not only cost effective; they are also agile and adaptable [...] the most efficient supply chains can become uncompetitive if they do not adapt to structural changes". A number references highlight the improvements to SCM performance and competitiveness when strategies that allow a better and faster response to changes in the needs of customers in changing environments are jointly managed. "Many of the characteristics that make companies successful in the current economic context are the same characteristics that make these companies resilient" (Sheffi, 2007). Sheffi (2015) adds that resilience helps companies compete by establishing within the organisation a culture of systems and processes for surveillance and of sensitivity and flexibility in order to detect and respond quickly and effectively to disruptive crises.

Supply chains must be more resilient and agile and better able to deal with unpredictable disruptive events, that is, to be resilient, in order to cushion the negative impacts of crises (Carvalho et al., 2012) and agile in order to recover rapidly (Lee, 2004), something that should be considered imperative at present.

Risk management in the supply chain is an imperative in the current state of market volatility, although very few organisations are adequately prepared to deal with disruption. These risk factors can range from an increase in the cost of raw materials, especially energy, (and their unavailability) and those related to natural disasters, such as earthquakes and floods, and political changes (Siegfried, 2008).

Asbjørnslett and Rausand (1997) and Asbjørnslett (1999) establish three key phases in supply chain risk:

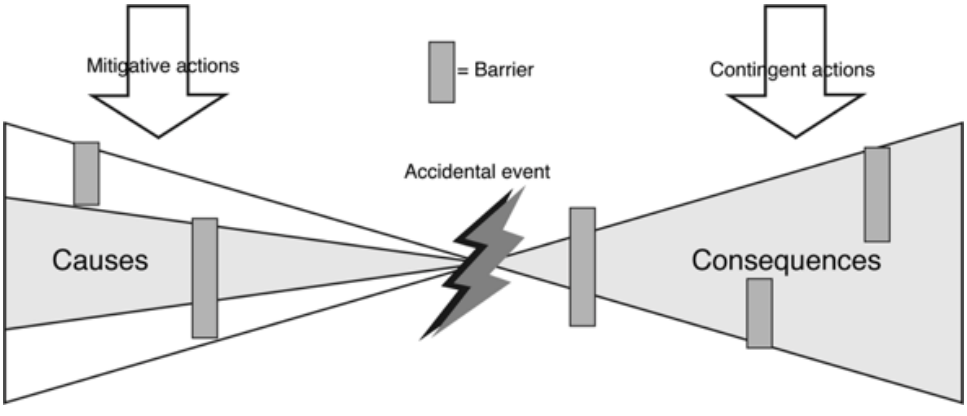
1 concern about the crisis: mitigation actions

2 crisis detection: rapid analysis of the causes and consequences

3 mitigation actions.

Figure 2 shows these three phases together with the potential barriers that impede actions.

Figure 2 Phases of crisis and disruption



Source: Asbjørnslett and Rausand (1997)

Sheffi (2007) details more precisely the various phases of a crisis in the supply chain and its impact on performance as a function of time. These phases, shown in Figure 3, are:

1 preparation and alertness

2 disruptive event

3 first response

4 delayed impact

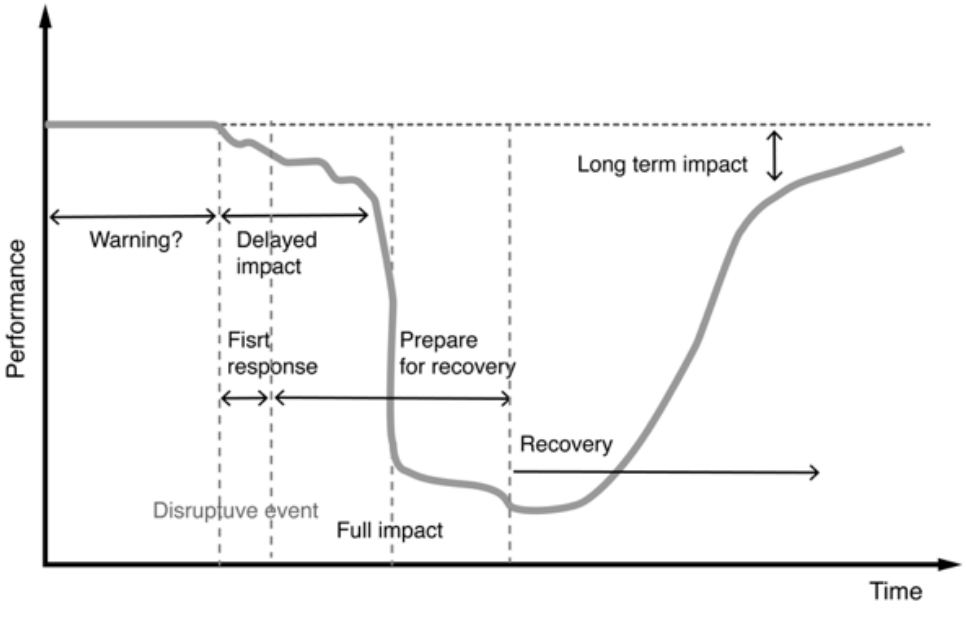
5 full impact

6 preparation for recovery

7 recovery

8 long-term impact.

Figure 3 Profile of disruption



Source: Sheffi (2007)

We can classify the types of risk, and their action barriers, into three categories (Loach, 2000):

1 external factors: environmental, political, legal, regulatory, competitors, customers, etc.

2 internal factors: operations and processes

3 decision factors: lack of information, wrong decisions, lack of support, failed execution.

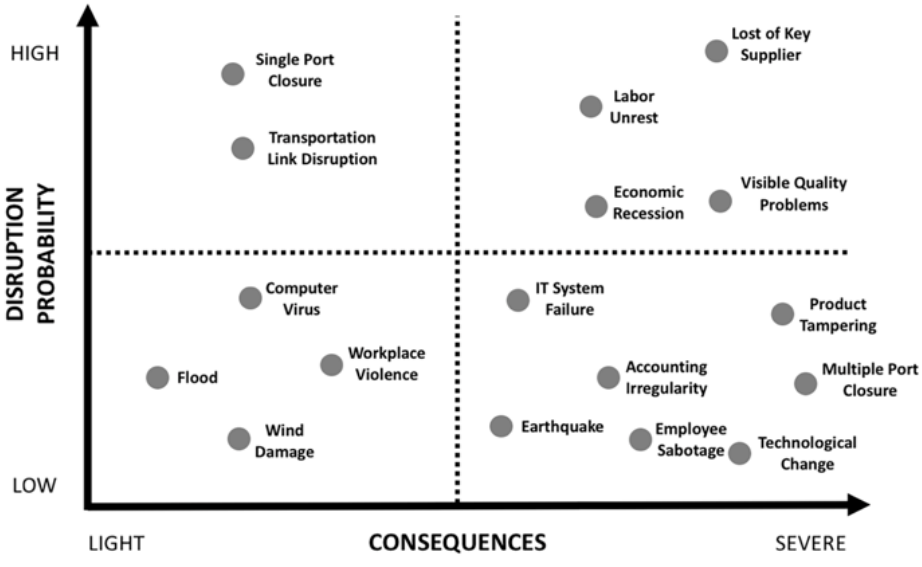
Manuj and Mentzer (2008) classify them into two categories:

1 Risks inherent in the supply chain:
   a supplies
   b operations
   c demand
   d security.

2 Environmental risks:
   a macro: economic crises, recessions, labour costs, exchange rates, trade agreements, tariffs, etc.
   b political: actions and sanctions of governments, changes in legislation, conflicts, etc.
   c competition: uncertainty regarding competitors' movements, bad practices
   d resources: lack of human resources, lack of capital or technology, etc.

Sheffi (2015) and Myerson (2015) classify these risks in the form of a Cartesian coordinate map according to risk impact criteria and their probability based on historical studies, demonstrating that different disruptions have different probabilities and impacts. Many experts categorise the risks of the supply chain using a 2 × 2 matrix (Sheffi, 2015), which consists of four quadrants showing several hypothetical types of disruption, including events according to their causes (floods, gales, recessions, etc.) and effects (the loss of a key supplier, IT systems crash, closure of a transport centre, etc.), as shown in Figure 4.

Figure 4 Map of the vulnerability of the supply chain



Source: Sheffi (2007)

Risk management strategies should therefore be defined taking into account the sources of risk, their consequences and the aforementioned risk factors. Christopher and Peck (2004) divide the risks into three factors that cover five categories:

1 Internal factors:
   - processes
   - control
2 External factors that form part of the supply chain:
   - demand
   - supply
3 Factors external to the business network:
   - environment.

According to Loach (2000), strategies to mitigate the impact of risk can be classified according to four objectives:

1 avoid
2 transfer
3 reduce
4 retain.

Manuj and Mentzer (2008) list seven such strategies:

1 avoid risk: leaving or delaying entry to the market or product
2 postpone risk: delay commitments with suppliers or maintain flexibility as much as possible
3 speculate risk: take risks to gain competitive advantage
4 spread risk: between suppliers, customers and facilities
5 control risk: vertical and lateral integration of suppliers and business partners
6 transfer risk: outsourcing, offshoring, subcontracting
7 security: identify and protect the company from risk to prevent it from affecting the organisation.

For Craighead et al. (2007), a good capacity to mitigate risk is based on the ability to adapt – the capacity to recover – and the ability to share information visibly and transparently – capacity to warn.

The absence of contingency plans and mitigation actions means that the supply chain can become highly vulnerable based on the probability of risk and the magnitude of its consequences (Asbjørnslett and Rausand, 1997). Christopher and Peck (2004) provide a definition of the vulnerability of the supply chain: "an exposure to serious disturbances, resulting in risks to the supply chain, as well as risks outside the supply chain". For Christopher and Peck (2004), risks within the supply chain and external risks cannot be differentiated and should be in the same category, as they are interrelated.

Based on the studies of Asbjørnslett and Rausand (1997), Sheffi (2007) developed a vulnerability map (Figure 4) in which the two axes represent the consequences and probabilities of disruption versus their magnitudes. It is striking that risks that are unlikely but with great consequences, such as earthquakes, should be mitigated. As too should malicious risks such as terrorist acts or sabotage.

There are multiple ways to classify risks in the supply chain (Briano et al., 2009) and Mason-Jones and Towill (1998) provide a simplification, later developed by Peck (2003) and Christopher and Peck (2004), which categorises the risks as either external and internal, with the external risks being those associated with suppliers and those that would affect demand, while internal risks would imply processes and the control of the supply chain. Of the most relevant internal processes, the most critical are those that add value in the chain, while the risks derived from control are those related to the systems, standards and commitment of the members.

Bendig (2015) states that risk in the supply chain affects the financial performance of the company, both in terms of assets, inventories and properties, and cash flow. Bendig also states that the relationship between the volatility of operations and finances is characterised by providing feedback between the two in extreme situations of risk.

Clear volatility in the level of inventories indicates that the company is in a situation of risk, which may include changes or disruptions in supplies, uncertainty in demand and changes or disruptions in logistics.

Instability in operations implies a need for more working capital, such that the stability of metrics such as net profit, ROA and earnings before interest and taxes (EBIT) reflect company performance, while the sum of dividend payments and net present value (NPV) reflect future cash flows. Shareholders prefer low cash flow volatility, as stability would reduce capital costs. According to numerous published studies, a correlation exists between inventory growth and a negative impact on dividends or dividend per share (DPS) (Bendig, 2015).

Economists specialised in mathematical modelling (Gangnes et al., 2014; Alessandria et al., 2010; Chen and Lee, 2009; Hull, 2005) who have studied the impact of economic changes on supply chains, such as the effects of the 2008–2009 crisis, define the repercussion in the increase in inventories or in supply ruptures as representing the elasticity of the supply chain.

Alessandria et al. (2010) argue that the characteristics of supply chains can influence the elasticity of the earnings of the global value chain, with larger consequences than those caused by normal trade, for example, those caused by an accumulation of inventories or a breakdown in stock. This is because the rapid growth of the global economy has increased the number of suppliers from different countries, since the Internet has facilitated the localisation of supplies with competitive prices anywhere in the world (Hull, 2005; Bacos, 1998). Hull (2005) and Bacos (1998) have developed theoretical models of performance analysis based on elasticity to study the implications of economic theory in the performance of supply chains, mainly in the management of inventories and the amplifying effect, referred to as the *bullwhip* effect, in the changes in demand on inventories and production capacity.

Chopra and Shodi (2004) studied and described nine different categories of risk that can affect SCM and its repercussions, and concluded that knowing these can enable a better mitigation strategy to be developed:

1 disruptions
2 delays
3 systems
4 forecasts
5 intellectual property
6 supplies
7 customer receivables
8 capacity.

They state that while many companies protect themselves from recurrent risks that have a low impact on the supply chain, many ignore the high-impact but low probability risks, such as a system crisis or a natural disaster.

Kouvelis et al. (2012) differentiate between risk and ambiguity in their research conducted subsequent to other traditional studies on risk, and state that academic studies on ambiguity models are of growing interest due to the increasing economic and financial

ambiguity in the context of SCM. In their mathematical modelling of ambiguity, they take as their basis the European School, which states that, "who makes the decision knows the probability distribution of random effects" (Kouvelis et al., 2012). However, they argue that this game theory, which is based on random results, should be expanded and that other ambiguity models, such as Aumman's Subjective Expected Utility model and Ellsberg's Paradox, which questions those theories, should be considered in order to have a more eclectic framework. Kouvelis et al. (2012) conclude that, although ambiguity has been widely studied in the economic and financial literature, this concept has been little explored in the context of SCM. They propose five different strategies to manage risk in supply chain operations:

1 a backup inventory of finished products that can be used to meet the demand even if the supplies have been interrupted

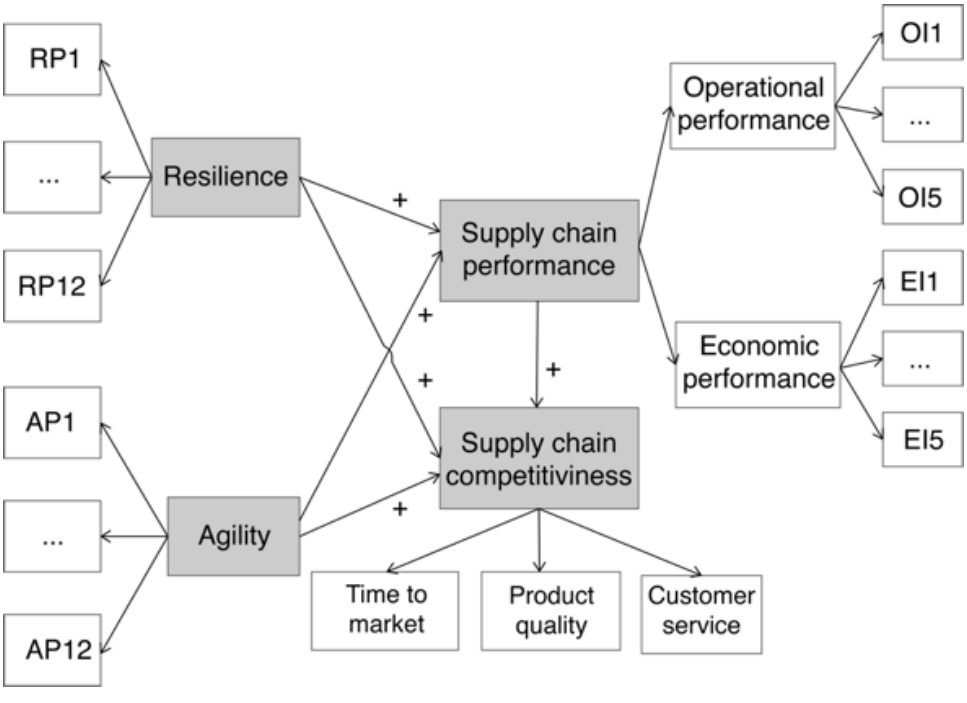
2 diversify suppliers, so that if a supplier suffers problems, others in the supply chain that have not been affected can be used

3 backup substitute suppliers, which can be used if necessary

4 demand management: influence the demand in order to opt for substitute products

5 strengthen the supply chain: collaborate with suppliers and partners in the supply chain to reduce the frequency and impact of possible disruptions.

Figure 5 Resilience and agility taxonomy



Source: Carvalho et al. (2012)

Carvalho et al. (2012) conclude that supply chains need to adopt new strategies to improve their abilities in order to respond quickly and effectively in terms of costs to unforeseen changes in markets and the increasing level of turbulence, and link these abilities to company performance and competitiveness. They propose a conceptual framework that allows the resilience and agility of supply chains to be related with the performance and competitiveness of a company, and subdivide operational and economic performance, something we are particularly interested in highlighting (see Figure 5). This conceptual framework, or taxonomy, serves as a model to observe the relationships between components of the system with the aim of achieving improvements through the implementation of practices that lead to greater resilience and agility. The variables $RP_{1–12}$ and $AP_{1–12}$ represent the practices aimed at improving resilience and those aimed at improving agility, respectively, with 12 categories each. Variables $OI_{1–15}$ and $EI_{1–15}$ represent the key indicators of operational performance and economic performance, respectively, with 15 indicators.

Carvalho et al. (2012) classify economic performance indicators associated with resilience and agility into six categories:

1 cost

2 economic value added (EVA)

3 net operating profit

4 return on assets

5 cash cycle

6 cost efficiency.

Raz (2008), from the point of view of uncertainty in demand according to the type of product managed by the supply chain and based on the contributions of Lee (2002), which relate the instability of product demand with the instability of supply chains, classifies them into four categories:

1 efficient supply chains: those that generate high efficiencies and performance

2 supply chains oriented to risk management: designed to manage potential disruptions

3 supply chains sensitive to changes: designed to adapt to changes in customer preferences

4 agile supply chains: those that are designed to be sensitive and flexible while managing possible potential disruptions through the rapid adequate management of inventories and other resources.

Singhal (2011) is cited by Decovny (2011) vis-à-vis the immediate consequences for a company's value when suffering a disruption in its supply chain:

Interruptions in the supply chain can occur internally or in suppliers or end customers. Vinod Singhal, professor of operations management at the Georgia Institute of Technology, has conducted extensive research on how disruptions affect shareholder value and profitability. After reviewing approximately a thousand cases of disturbances experienced by publicly traded companies, it was found that, on average, shareholders lose about 7% of the value of their shares on the day news is made public regarding supply chain interruptions.

During the three years around the time of the interruption, the performance of the shares of the company is on average 33–40% lower than its competitors. In the year after the interruption, the volatility in share prices is 13.5% higher compared to that in the year before the interruption. Interruptions represent a toll on profitability. In the year leading up to the interruption, the average effect is a 107% decrease in operating income, a 93% decrease in the return on assets, a 7% decrease in sales growth, and an 11% increase in costs. Most importantly, companies do not recover quickly from interruptions: they will continue to operate at a lower performance level for at least two years after experiencing interruptions. Singhal (2011) points out that companies with good risk management in the supply chain experience fewer interruptions and react faster when they occur (Decovny, 2011).

For Decovny (2011), risk management in supply chains is of growing importance for organisations, especially those that operate in emerging global markets. Bendig (2015) concludes that the impact of risks associated with operations is greater for manufacturing companies, followed by retail chain stores and thirdly, mining companies.

Wagner and Bode (2008) classify five potential large-impact risks on SCM performance:

1 demand risks
2 supply risks
3 legal and bureaucratic risks
4 infrastructure risks
5 catastrophe risks, corroborating the negative association between risks related to the supply chain and their performance.

Singhal (2011) states that the earthquake that affected Japan in 2011 was a wake-up call for many companies that believed they would never be exposed to such a great risk. Some of the affected companies were suppliers of large global companies who saw their supply chains suffer a sudden disruption that affected their operations.

The importance of the impacts on operations due to disruptive changes in the environment is highlighted by Hoberg and Alicke (2013), who analysed the impact of the 2008–2009 financial crisis, in which the four largest investment banks declared bankruptcy at the same time, through the annual growth rate of orders in US industrial sectors between 2008–2009 and showed that these sectors suffered significant reductions in order volumes. The sectors that suffered the greatest impact were those related to transport equipment (–42.3%), basic metals (–40.3%) and machinery (–31.9%), while those of minor, but considerable impact included electrical equipment and appliances (–21.8%) and consumer electronics (–18.6%), which led to global instability. Briano et al. (2009), citing Tang and Tomli (2008) and various other authors, confirmed that alignment, adaptability and agility are the basic ingredients for risk management in the supply chain, affirming hat agility (flexibility) improves the resilience capacity of the supply chain. However, it is not clear yet how much flexibility is necessary to mitigate the risk. Yusuf et al. (2014) found in their study an increase in the competitive advantage of companies in which a combination of their capacities was observed in integrated supply chain networks.

The next sections describe the two most significant approaches to resilience and agility, noting that “numerous scientific articles have been published on resilience and

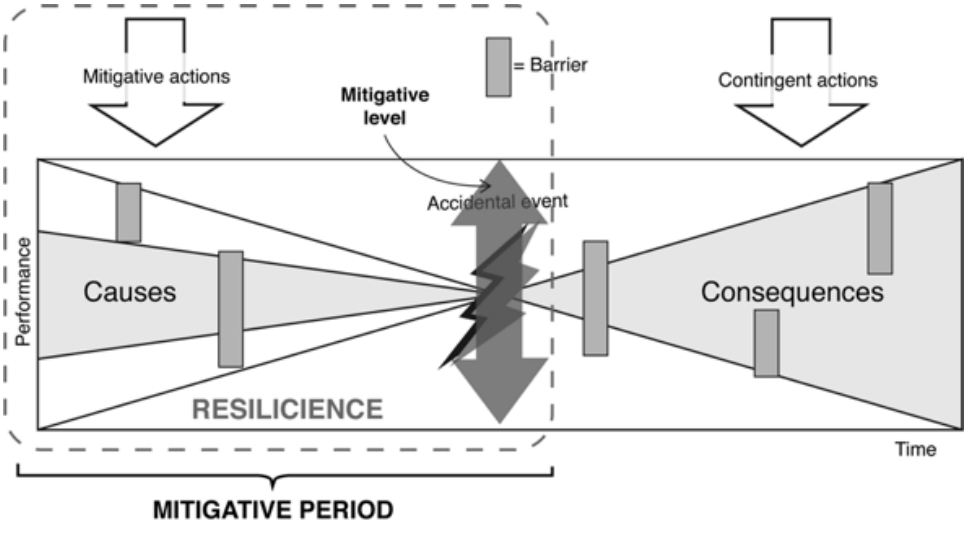
agility separately but very few relate them or provide an analysis of their impact on the performance of SCM" (Carvalho et al., 2012).

5 Approach to resilience in SCM

Following the study of several authors, Carvalho et al. (2012) proposed a definition of resilience in SCM that resonates with the perspective of this doctoral thesis report: "the ability of supply chains to cope with unforeseen shocks". In other words, the mitigation of the impact of an unforeseen disruptive event, with 'rigidity' as a concept opposite to 'resilience' (Smith and Smith, 2014). As such, resilience is associated with effectiveness in mitigation and the actions or plans prior to the crisis.

In the crisis and disruption model proposed by Asbjørnslett (1999), we can place resilience on the left in a preliminary phase in which the company designs and executes previous mitigation activities that allow it to face a crisis, thereby cushioning its negative impact (Figure 6).

Figure 6 Scope of the first phase of the damping effect of resilience according to the Asbjørnslett model



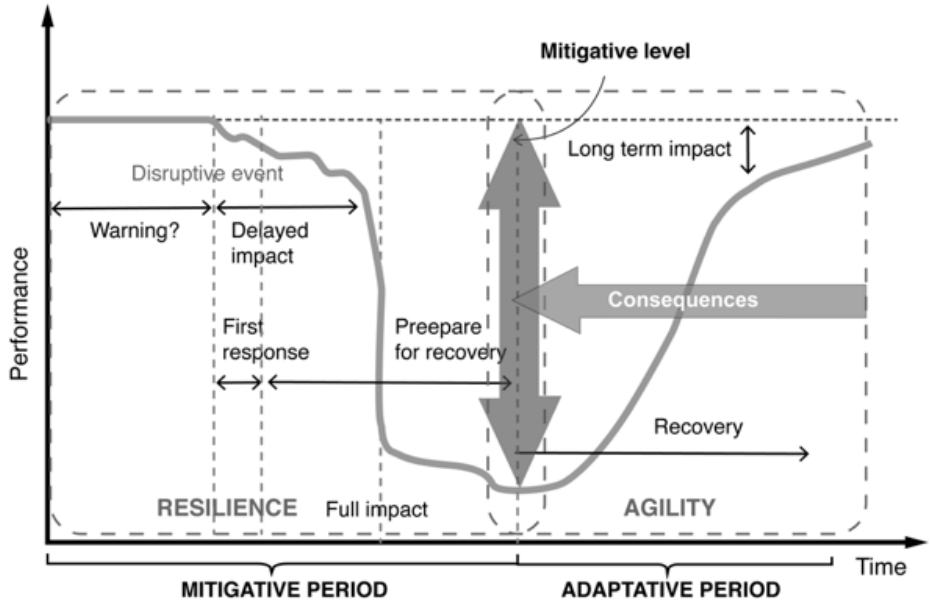
Source: Author based on Asbjørnslett (1999)

Similarly, in the model developed by Sheffi, resilience would be placed before and up until the moment of experiencing the full impact of the crisis (Figure 7).

According to Decovny (2011), based on a study carried out by Gartner (2011), factors such as speed, agility, efficiency, responsiveness and innovation are still critical; however, equally important is a flexible supply chain. The ability to deliver predictable results, even under volatile business conditions, has become a priority for large companies: Cisco, Dow Chemical, RIM and Unilever actively develop the design of structures, processes and methodologies to create and expand the capacity of resilience in their own supply chains and their business partners.

Smith and Smith (2014) state that low resilience capacity affects both operations and finances and sales, thereby reducing the levels of service quality, inventory yield and gross margin, and that together these lead to higher capital consumption, which can lead to financial chaos, destroying ROI. Therefore, a series of metrics, both financial and non-financial, should be implemented that constantly monitor the evolution of investments, with particular focus on operating expenses and inventory buffers.

Figure 7 Scope of the first phase of the damping effect of resilience according to the Sheffi model



Source: Author based on Sheffi (2007)

The potential for disruption forces companies to carry out an analysis of the resilience capacity of their supply chains. The frequency with which these analyses are carried out can provide an idea of the importance the organisation gives to risk management. In a study of 196 companies from 22 industries, 51% of the companies usually perform annual reviews, while 40% carry them out sporadically or after having suffered a serious incident; 5% never conduct any. The 78% of companies that have suffered a disruption due to natural disasters, extreme weather conditions or drastic political changes confirm that recovery required the attention of every one of the company's top executives (Partida, 2013).

The Business Continuity Institute (2012) points in the same direction with its study carried out between 2009 and 2012, whose results revealed that 73% of the companies surveyed had suffered an average of five disruptions during that period. 39% of these disruptions caused a fall in basic suppliers, who needed a recovery time of two years. 52% of the disruptions seriously affected IT systems, while 59% of the respondents claimed to have suffered reductions in productivity due to some disruption (Business Continuity Institute, 2012). In its study conducted in 2014, 81% of the companies had suffered a disruption in their supply chains in the previous year, of which 58% suffered productivity losses and a 47.5% increase in labour costs, confirming that large industrial

companies are facing increasing difficulties in building resilient supply chains, while small and medium-sized companies are less sensitive to disruptions in general (Business Continuity Institute, 2014).

Wagner and Bode (2008) analysed crises that occurred prior to 2008 that had an impact on supply chains and that have been studied academically: Hurricane Katrina in the USA (2005), the terrorist attack in New York (2001), the SARS epidemic in Asia (2003). They concluded that supply chains are increasingly vulnerable, as companies have been suffering constant increases in competitor pressure on a global scale since the last decade. This increase in disruptive crises and the sensitivity of global supply chains means special attention should be paid to the resilience of companies and how they manage risks (Wagner and Bode, 2008).

Weick and Sutcliffe (2007) claim that resilience capacity implies three basic skills:

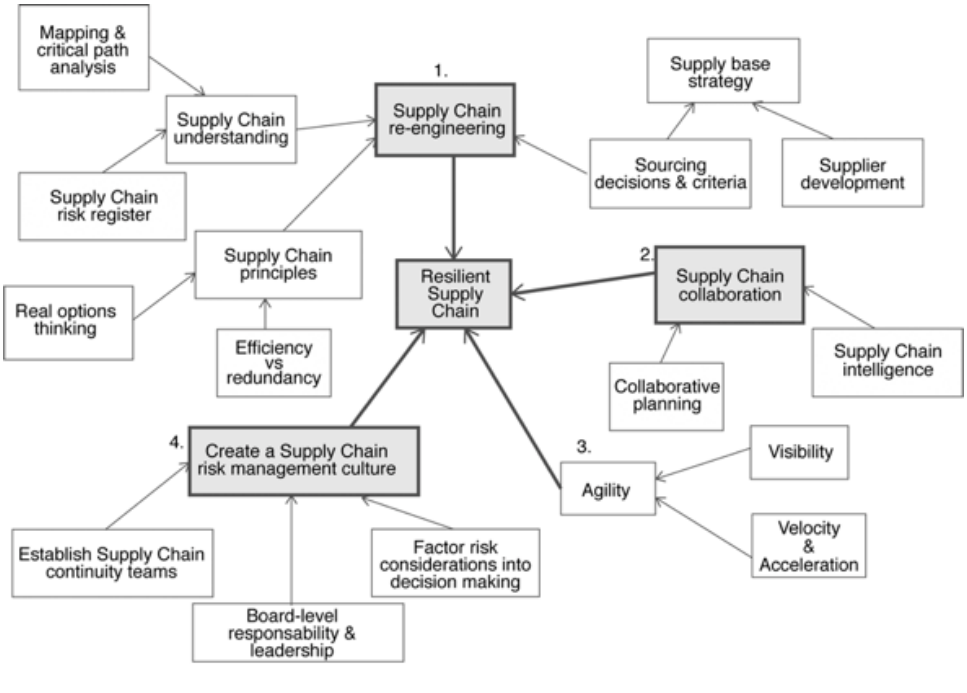
1 the ability to mitigate the impact and maintain the functions of the supply chain

2 the ability to recover quickly

3 the ability to learn from the experience and to grow from previous periods of resilience.

As discussed in the next section, the ability to mitigate impact (resilience) can, in the models of Asbjørnslett (1999), Christopher and Peck (2004) and Sheffi (2007, 2015) be attributed to the first ability proposed by Weick and Sutcliffe (2007), while the second and third abilities to accelerate recovery and grow after the crisis can be attributed to the generalised concept of 'agility' in SCM.

Figure 8 Taxonomy of the resilient and agile supply chain of Christopher



Source: Christopher and Peck (2004)

There are two fundamental perspectives in risk management strategies to develop resilience and agility (Briano et al., 2009): that of Martin Christopher and Towill (2001, 2002) and Peck (2003), and that of Sheffi (2001, 2005a, 2005b, 2007, 2015), which could generate the abilities of Weick and Sutcliffe (2007), as described in Figure 8.

Christopher and Peck (2004) developed a strategic taxonomy for the design of resilience in the supply chain, including its relationship with agility, in which the latter is directly related to speed, acceleration and visibility, that is, the speed of recovery according to Sheffi (2007). Figure 8 shows the elements of Christopher's perspective, whose strategic design requires:

1 An in-depth knowledge of the value network and how the business connects suppliers with customers and the detection of bottlenecks.

2 The definition of the supply strategy, which should not be based on concentration in a single supplier, but on reliable suppliers with several alternatives.

3 Combining efficiency and redundancy without considering them as opposite terms. Redundancy should mitigate disruptive consequences greater than its cost. For example, maintaining safe inventories or production overcapacity available in different centres.

The model proposed by Sheffi (2007, 2015) provides a series of tools to build resilience in the supply chain and represents a functional approach in key factors that should work together but that in many cases work separately without coordination:

1 the human resources that design and manage continuity plans

2 the human resources that control and maintain security

3 the computer systems that manage and support security.

According to Sheffi (2007), companies can develop resilience in three ways:

1 increase redundancies

2 develop agility

3 change corporate culture.

6 Approach to agility in SCM

We can define agility as the ability of the supply chain to respond quickly to unpredictable changes in demand or supply (Christopher and Peck, 2004), thus associating it with effectiveness in post-crisis action. For Agarwal et al. (2007), "Agility is the fundamental characteristic of a supply chain needed for survival in turbulent and volatile markets, which are becoming norms as product life cycles shorten and environmental forces create additional uncertainty resulting in higher risk in the supply chain management. Agility further helps in providing the right product, at the right time to the consumer, which is the main objective of any supply chain".

Carvalho et al. (2012) broaden the definition of 'agility' in SCM, which we take as a basic reference: "the ability of supply chains to respond quickly and cost-effectively to

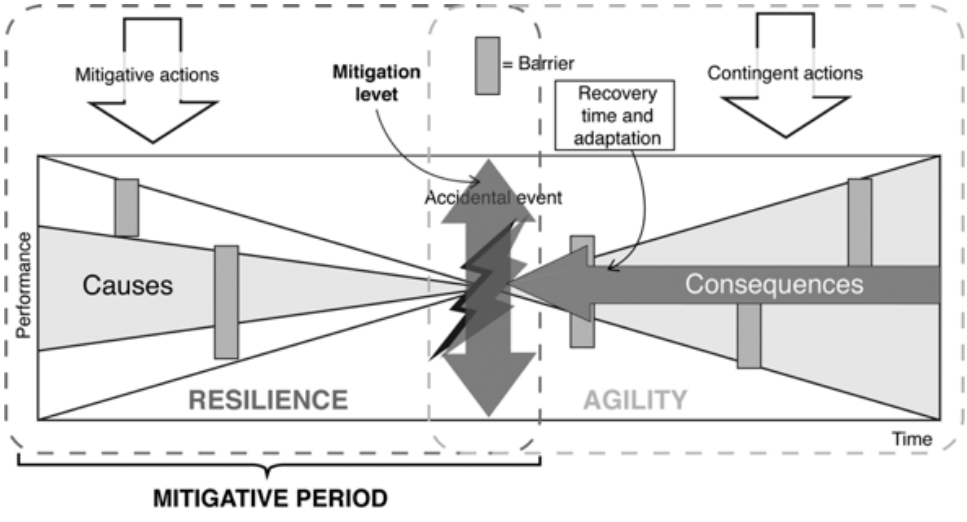
unforeseen changes in markets and turbulent environments". In this definition, the time factor – quickly – is a key factor in agility.

Some authors had previously included similar concept in their conclusions. Sheffi (2007) concludes that quick adaptation to the environment can provide competitive advantage with respect to the slowest competitors in the reaction to change. Lee (2004) approaches agility from the point of view of rapidly experienced changes and the ability of the company to smoothly manage external disruptions, suggesting that the best supply chains identify structural changes – economic, market, etc. – before they occur, by gathering the right information, filtering the noise and tracking key patterns. He also provides the example of the company Seven Eleven Japan, which was able to recover its activity in its supply chain following the 1995 Kobe earthquake through the use of seven helicopters and 125 motorcycles, which avoided the traffic jams and blockages of the highways to supply 64,000 rice balls to the inhabitants of the destroyed city.

6.1 Agility in the risks and disruption management models

In the crisis and disruption model of Asbjørnslett (1999), agility can be placed on the right in a second phase in which the company designs and executes post-crisis recovery activities that allow the recovery of normal activity, adaption to the new context and, where possible, the gaining of a competitive advantage over competitors by accelerating results (Figure 9).

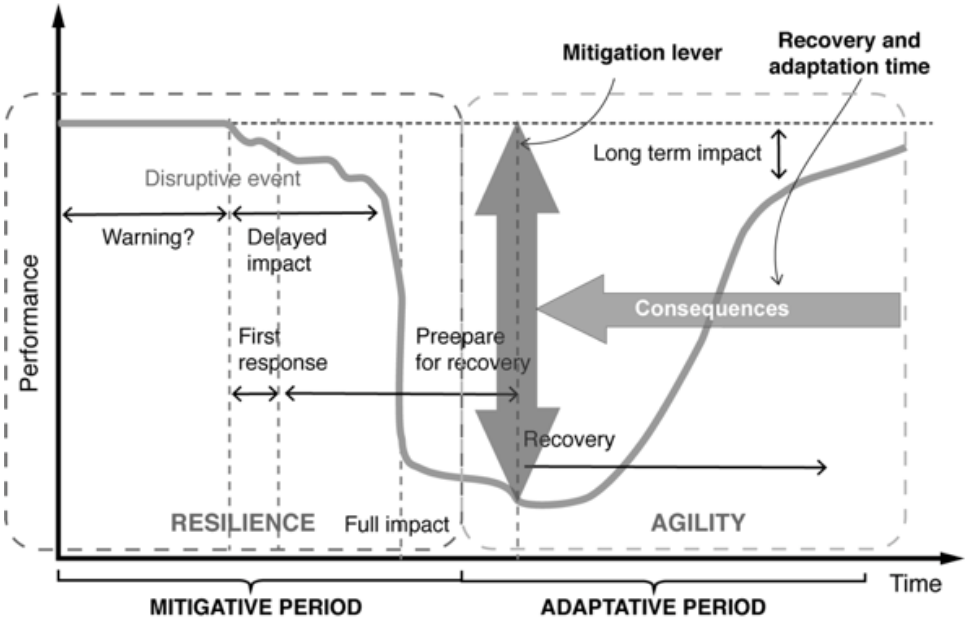
Figure 9 Scope of the first and second phases of the damping effect of resilience and recovery/adaptation in the Asbjørnslett model



Source: Author based on Asbjørnslett (1999)

Similarly, in the model elaborated by Sheffi, agility would be placed after the moment of experiencing the full impact of the crisis, and would include the recovery of normal activity and adaptation to the new environment, creating a competitive advantage through an acceleration of the results, as shown in Figure 10. This model served as a starting point for the present investigation.

Figure 10 Scope of the first and second phases of the damping effect of resilience and recovery/adaptation in the Sheffi model



Source: Author based on Sheffi (2007)

For Baramachi and Zimmers (2007), in their model of strategies to transform supply chains in order to make them agile, change management strategies should consider three factors: implementation cost, risk, and ease of application. Depending on the way in which the organisation contemplates these three factors, the level of consistency can be measured. Since these factors are prioritised, the model calculates a coefficient of consistency of the agility strategy and the capacity of the company to respond to changes. The authors conclude the following: "Nowadays, many companies need to constantly improve their agility in order to respond to changes in the business environment that are occurring increasing quickly. However, there is a general lack of understanding about how this could be achieved and what tools/methodology/techniques can be used in practice".

6.2 The role of customers in the strategy

Gulati (2010) suggests that the analysis and focus of strategies to face a crisis, thereby gaining agility, should centre on customers, not on products. The differentiation of customers, through data analysis, enables the identification of customer segments, assigning risk and impact profiles to them, and the ramifications of the supply chains that reach them. The design of recovery and adaptation strategies is thus more effective, which makes it possible to conduct both an economic-financial and value (as perceived by the client) analysis for decision-making purposes. Gulati also associates the ability to develop sustainable resilience and agility with the development of internal coordination and collaboration and with the development of products in order to face disruptive crises (modularisation, component standardisation, multifunctionality, etc.) and innovative

solutions that link the client with actions of cooperation in mitigation, recovery and adaptation. This approach to empowering the client in the management of risk of the value chain represents the total connection of the supply chain from the start – the suppliers – to the end – the clients –, transforming itself into a collaborative value chain.

6.3 The role of individuals in the management system

In this perspective of the participants in supply chain risk, Kildow (2011) states that it is very important to assign particular individuals, since both projects and plans and emergency management require time, attention and resources, which tend to be ignored or postponed by the pressure of daily activities in the absence of any sense of urgency. Kildow (2011) states that the risk management in SCM and its connection with corporate business continuity plans are infrequent and are generally guided by a circumstantial reparative vision or covered by insurance policies, not by creating value through agility. Kildow (2011) proposes that the SCM executive should work closely in partnership with the executive responsible for the business continuity plan and that there are expert risk management specialists within areas of SCM who can accurately analyse the risks, propose plans for mitigation, recovery and adaptation, and who can communicate with both internal and external members of the organisation in the definition and joint execution of a macro business continuity plan.

7 Conclusions

All the mentioned authors agree on the importance of providing supply chains with a first resilience capacity to cushion the effects of different potential crises, which can be of various kinds and due to both internal and external factors, in the face of vulnerability and uncertainties of business ecosystems, reinforcing business continuity. And subsequently, a capacity for agility to obtain a competitive advantage in the rapid adaptation to changes in a better and faster way than competitors to external factors. The perspectives contemplate a risk management, by means of the previous preparation to the disruptive event, a mitigation of the impact, a phase of recovery and finally the one of stabilisation.

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Appendix

Bibliometric analysis of cited literature

With regard to the impact factor, among all the scientific journals included in the bibliography, those indexed in the Journal Citation Reports were selected, obtaining the following results (Table A1).

Table A1 IF year and impact factor of journals by alphabetical order

Journals	*IF year*	*Impact factor*
California Management Review	2002	0.982
Decision Sciences	2007	1.435
Economics Letters	2014	0.51
Harvard Business Review	2004	1.148
Harvard Business Review	2005	1.404
IMF Economic Review	2010	0.768
Industrial Marketing Management	2000	0.42
Industrial Marketing Management	2007	0.911
International Journal of Production Economics	2004	0.879
International Journal of Production Economics	2005	1.008
International Journal of Production Economics	2008	2.026
International Journal of Production Economics	2014	2.752
International Journal of Production Research	2000	0.504
International Journal of Production Research	2007	0.560
Journal of Business Logistics	2010	3.905
Journal of the Academy of Marketing Science	2010	3.269
Management Science	2006	1.687
Management Science	2009	2.227
MIT Sloan Management Review	2004	1.013
MIT Sloan Management Review	2005	0.719
Production Planning & Control	1999	0.18

It is worth mentioning several issues related both to the analysis of the results obtained and to the nature of the data:

- Firstly, it is necessary to clarify that the impact factor was taken relative to the years in which the scientific articles referenced in the bibliography were published in their respective journals. Therefore, certain publications appear more than once, since they contain more than 1 cited article and, in addition, they have a different impact factor depending on the year.
- Turning now to the pure analysis of the results obtained, it is interesting to look more closely at those publications with a greater impact factor, namely those that received, on average, more than 1 citation per article during a period of between 1 and 2 years following its publication (reflected in Table A2).

Table A2 Ranking of impact factor of journals 2005–2010

Position	*Journals*	*IF year*	*Impact factor*
1	*Journal of Business Logistics*	2010	3.905
2	*Journal of The Academy of Marketing Science*	2010	3.269
3	*International Journal of Production Economics*	2014	2.752
4	*Management Science*	2009	2.227
5	*International Journal of Production Economics*	2008	2.026
6	*Management Science*	2006	1.687
7	*Decision Sciences*	2007	1.435
8	*Harvard Business Review*	2005	1.404
9	*Harvard Business Review*	2004	1.148
10	*MIT Sloan Management Review*	2004	1.013
11	*International Journal of Production Economics*	2005	1.008

- Foremost is the *Journal of Business Logistics*, whose impact factor considered in this bibliometric study (IF from 2010) occupies position 1 of the specific ranking generated from the impact of scientific journals included in the bibliography, obtaining approximately four citations on average for each article published in 2009 and 2010.
- Also outstanding are the results of:
  a The *Journal of the Academy of Marketing Science*, whose impact factor in this bibliometric study (IF from 2010) occupies the position 2 of the specific ranking generated from the impact of scientific journals included in the bibliography (achieving more than three citations on average for each article published in 2009 and 2010).
  b The *International Journal of Production Economics*, since three of its four impact factor measurements in this bibliometric study (IF from 2014, IF from 2008 and IF from 2005) appear respectively in positions 3, 5 and 11 of the specific ranking generated according to the impact of scientific journals included in this bibliography.
  c *Management Science*, since the two impact factor measurements considered in this bibliometric study (IF from 2009 and IF from 2006) appear respectively in positions 4 and 6 of the specific ranking generated from the impact of scientific journals included in the bibliography.

d *Harvard Business Review*, since the two impact factor measurements considered in this bibliometric study (IF from 2005 and IF from 2004) appear respectively in positions 8 and 9 of the specific ranking generated from the impact of scientific journals included in the bibliography.

Therefore, it can be said that, for researchers and professionals dedicated primarily to the study of the supply chain and business management, it is highly advisable to consult the five scientific journals highlighted in the two previous points because of their potentially interesting content in this field. Moreover, in the case of researchers, one of the objectives of their career in the medium- to long-term would logically be to publish in these journals. This is confirmed by the fact that all of these journals currently lie in the first or second quartile of their respective categories in the journal citation reports, as can be seen in Table A3.

Table A3 Journals in quartiles 1 and 2 in the journal citation report

Journals	*Category*	*IF year*	*Quartile*
Journal of Business Logistics	Management	2017	2
Journal of The Academy of Marketing Science	Business	2017	1
International Journal of Production Economics	Operations research and management science	2017	1
Management Science	Operations research and management science	2017	1
Harvard Business Review	Management	2017	1

With regard to the citations, the citations received in Web of Science by 21 of the articles included in the bibliography (specifically, all those articles in the bibliography belonging to journals indexed in WoS) were checked, yielding the following results:

- Of the 21 scientific articles, 12 received more than 100 citations. Three scientific articles did not reach ten citations.
- It should be noted that five articles were cited more than 500 times (each) in Web of Science, as can be seen in Table A4.

Table A4 Articles by number of citations received

Articles	*Citations*
Gunasekaran, A., Patel, C. and McGaughey, R.E. (2004) 'A framework for supply chain performance measurement', *International Journal of Production Economics*, Vol. 87, No. 3, pp.333–347.	709
Christopher, M. (2000) 'The agile supply chain: competing in volatile markets', *Industrial Marketing Management*, Vol. 29, No. 1, pp.37–44.	625
Chopra, S. and Sodhi, M. S. (2004) 'Managing risk to avoid supply-chain breakdown', *MIT Sloan Management Review*, Vol. 46, pp.53–61.	605
Tomlin, N. (2006) 'On the value of mitigation and contingency strategies for managing supply chain disruption risk', *Management Science*, Vol. 52, No. 5, pp.639–657.	587
Lee, H.L. (2004) 'The triple – a supply chain', *Harvard Business Review*, October.	511

- Obviously, over time following the publication of an article it is increasingly likely that it will be read, used and cited by a large number of authors, which is why the most recent of this list of most cited articles was published in May 2006, now more than 12 years ago.

- Logically, the authors of these five most relevant articles according to their citations can be considered top researchers in the field of supply chain management. These authors are: Angappa Gunasekaran, C. Patel and Ronald E. McGaughey (authors of the most cited article); Martin Christopher (author of the second most cited article); Sunil Chopra and ManMohan S. Sodhi (authors of the third most cited article); Brian Tomlin (author of the fourth most cited article); and Hau L. Lee (author of the fifth most cited article).

Consequently, the results related to citations received per article were used to select eight outstanding authors (those mentioned in the previous paragraph, who are authors of scientific articles that exceeded 500 citations received in WoS) and calculate their h-index. Angappa Gunasekaran is the author with the best h-index in Web of Science (since 49 of his articles indexed in WoS each received at least 49 citations from articles indexed in WoS). After him, the vast majority of the rest of the authors studied have an appreciable h-index (all except Patel), but they are very far behind. None of them is even close to reaching half of Gunasekaran's h-index. Special mention goes to C. Patel, who has a fairly modest h-index. This can be explained by the fact that he is the only one of these eight authors whose career is confined to the business world and not the academic field.

Comparison

The results obtained demonstrate that:

- The *Journal of Business Logistics*, the *Journal of the Academy of Marketing Science*, the *International Journal of Production Economics*, *Management Science*, and the *Harvard Business Review* are the most prominent scientific journals in the literature consulted.

- Springer, McGraw-Hill, Wiley, and Harvard University Press are the publishers in the bibliography that publish the books and chapters of greater scientific quality in the field of economics.

- The articles 'A framework for supply chain performance measurement', 'The agile supply chain: competing in volatile markets', 'Managing risk to avoid supply-chain breakdown', 'On the value of mitigation and contingency strategies for managing supply chain disruption risks', and 'The triple-A supply chain' are the scientific publications included in the bibliography that obtained the highest quality citations.

- The researchers Angappa Gunasekaran, Martin Christopher, and ManMohan S. Sodhi are the authors included in the bibliography who have published the greatest number of publications of impact on the scientific community.

However, to corroborate the extent to which these journals, articles and researchers are relevant, it is necessary to contrast these results by establishing:

1 Which journals in the specific field of supply chain management appear in the top positions of the Journal Citation Reports ranking. We have established those journals with the highest impact factor in the categories 'management', 'business', 'engineering, industrial', 'engineering, manufacturing', and 'operations research and management science' in the JCR ranking (considering the current edition of this ranking, namely the 2017 edition). In this way we demonstrate that:

   - The journal with the highest impact factor, and therefore occupying first position, in the category 'management' is the *Academy of Management Annals*, with an impact factor of 9.281.
   - The *Journal of Business Logistics*, assigned to this category ('management'), is currently in position 60 out of a total of 210 journals (with an impact factor of 2.891), which means that it lies in the second quartile (or Q2, as it is usually represented) of the category, thus showing a prominent position. However, currently 59 journals lie above it in the field of management.
   - The journal *Management Science*, also included in this category ('management'), currently lies in position 41 out of a total of 210 journals (with an impact factor of 3.544), which means that it is in the first quartile (or Q1, as it is usually represented) of the category, thus showing a very prominent position. However, currently there are 40 journals ahead of it in the field of management.
   - The *Harvard Business Review*, also included this category ('management'), is currently in position 25 out of a total of 210 journals (with an impact factor of 4.374), which means that it is in the first quartile (Q1) of the category, thus showing a very prominent position. However, currently there are 24 journals ahead of it in the field of management.
   - The journal with the highest impact factor, and therefore occupying first place, in the category 'business' is also the *Academy of Management Annals*, with an impact factor of 9.281.
   - The *Journal of the Academy of Marketing Science*, included in this category ('business'), currently lies in position 3 out of a total of 140 journals (with an impact factor of 8.488), which means that it is in the first quartile (Q1) of the category, thus showing a very prominent position. It should be noted that currently there are only two journals lying ahead of it in the field of business.
   - The *Harvard Business Review*, also included this category ('business'), is currently in position 19 of a total of 140 journals (with an impact factor of 4.374), which means that it is in the first quartile (Q1) of the category, thus showing a very prominent position. However, currently there are 18 ahead of it in the field of business.
   - The journal with the highest impact factor, and therefore occupying first place, in the 'engineering, industrial' category is *IEEE Transactions on Industrial Informatics*, with an impact factor of 5.430.

- The *International Journal of Production Economics*, also included in this category ('engineering, industrial'), currently lies in position 3 out of a total of 47 journals (with an impact factor of 4.407), which means that it is in the first quartile (Q1) of the category, thus showing a very prominent position. It should be noted that currently only two journals have impact factors higher than it in the field of industrial engineering.
- The journal with the highest impact factor, and therefore occupying first place, in the category 'engineering, manufacturing' is the *International Journal of Machine Tools & Manufacture*, with an impact factor of 5.106.
- The *International Journal of Production Economics*, assigned to this category ('engineering, manufacturing'), currently lies in position 3 out of a total of 46 journals (with an impact factor of 4.407), which means that it is in the first quartile (Q1) of the category, thus showing a very prominent position. It should be noted that currently only two journals have impact factors higher than it in the field of manufacturing engineering.
- The journal with the highest impact factor, and therefore occupying first place, in the category 'operations research and management science' is the *Journal of Operations Management*, with an impact factor of 4.899.
- The *International Journal of Production Economics*, included this category ('operations research and management science'), is currently in position 3 out of a total of 84 journals (with an impact factor of 4.407), which means that it lies in the first quartile (Q1) of the category, thus showing a very prominent position. It should be noted that currently only two journals have impact factors higher than it in the field of operations management.
- The journal *Management Science*, also assigned to this category ('operations research and management science'), currently lies in position 11 out of a total of 84 journals (with an impact factor of 3.544), which means that it is in the first quartile (Q1) of the category, thus showing a very prominent position. It should be noted that currently only ten journals lie ahead of it in the field of operations management.

2 Which articles whose subject matter concerns the supply chain are the most cited in Web of Science. We have established those articles related to the supply chain that have received the most citations in Web of Science. In this way we demonstrate that:

- The article 'Information distortion in a supply chain: the bullwhip effect' is the article related to the supply chain most cited in Web of Science. Specifically, it has received 1,819 citations in WoS as of the end of November 2018.
- A total of seven articles related to this subject have received more than 1,000 citations in Web of Science.
- The article 'A framework for supply chain performance measurement' (cited in WoS on 709 occasions) occupies position 21 of this ranking of citations related to articles concerning the supply chain.
- The article 'The agile supply chain: competing in volatile markets' (cited in WoS on 625 occasions) lies in position 30 of this ranking of citations related to articles dealing with the supply chain.

- The article 'Managing risk to avoid supply-chain breakdown' (cited in WoS on 605 occasions) occupies position 32 of this ranking of citations related to articles dealing with the supply chain.
- The article 'On the value of mitigation and contingency strategies for managing supply chain disruption risks' (cited in WoS on 587 occasions) lies in position 34 of this ranking of citations related to articles dealing with the supply chain.
- The article 'The triple-A supply chain' (cited in WoS on 511 occasions) occupies position 43 of this ranking of citations related to articles dealing with the supply chain.

3 Those authors dedicated to research in the supply chain that have a higher h-index in Web of Science than Angappa Gunasekaran, and/or Martin Christopher, and/or ManMohan S. Sodhi. Since there is no ranking related to this or any way to list authors according to their h-index (neither in Web of Science nor in Scopus), we decided to calculate the h-index of the authors of the 3 articles related to the supply chain that have received the most citations in Web of Science. In this way we show that:

- Hau L. Lee (one of the authors of the most cited article, 'Information distortion in a supply chain: the bullwhip effect'), which is included in this study, has an h-index of 15.
- Venkat N. Padmanabhan (one of the authors of the most cited article, 'Information distortion in a supply chain: the bullwhip effect') has an h-index of 20.
- Seungjin Whang (one of the authors of the most cited article, 'Information distortion in a supply chain: the bullwhip effect') has an h-index of 17.
- Stefan Seuring (one of the authors of the second most cited article, 'From a literature review to a conceptual framework for sustainable supply chain management') has an h-index of 29.
- Martin Mueller (one of the authors of the second most cited article, 'From a literature review to a conceptual framework for sustainable supply chain management') has an h-index of 5.
- Aharon Ben-Tal (one of the authors of the third most cited article, 'Robust optimisation') has an h-index of 21.
- Laurent El Ghaoui (one of the authors of the third most cited article, 'Robust optimisation') has an h-index of 1.
- Arkady Nemirovski (one of the authors of the third most cited article, 'Robust optimisation') has an h-index of 28.
- Looking at the h-indices of these eight authors, it can be stated that Angappa Gunasekaran (whose h-index is 49) is a very prominent author in the field of the supply chain and most probably the foremost researcher dedicated to this subject.
- For their part, we have confirmed that Martin Christopher (whose h-index is 19) and ManMohan S. Sodhi (whose h-index is 18) are truly important authors in this field but do not belong to this field's elite, which would consist of Gunasekaran himself and other authors such as Seuring.

- Nemirovski deserves special mention. Despite having a very high h-index – comparable to that of Seuring–, Nemirovski's scientific production concerns the supply chain tangentially and in fact focuses on research from another area, namely continuous optimisation. The same can be said of his co-authors, Ben-Tal and El Ghaoui: their scientific production does not focus on the supply chain.