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RESEARCH ARTICLE

SUPPLY CHAIN RESILIENCE, A SYSTEMATIC LITERATURE REVIEW

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Abstract

The catastrophic events of recent years have shown how global busines s is vulnerable to unexpected and disruptiveevents and have changed the concept of disaster preparedness. The World Economic Forum has published a report on the most likely and serious risks that might occur globally and it is clear that risks of different categories (economic, environmental, geopolitical, social and technological) are connected and can influence each other. For instance, the COVID-19 pandemic resulted in Supply Chain (SC) collapse in the entire world, which confirms that today's complex and lean SC design is vulnerable to severe disruption (Moosavi, Hosseini, 2021). Con-sequently, it is very likely that they cause supply disruptions, which could potentially have a large impact from small to large business during the complex global network. In this context of increasing numbers of natural and man-made disasters, the business of each sector strongly demonstrated the recent need for change in traditional strategies, especially companies depending on timely delivery of materials. Unfortunately, there is no way to avoid these risks, however, it has been noted that some organizations have overcome these eventualities better than others. These organizations share one crucial characteristic: Resilience. Althou gh Literature has discussed several ways to in-crease the resilience of a sole proprietorship that is part of the network system, it fails to capture a holistic view of the supply chain network. In this work we used a Systematic Literature Review (SLR) in order to obtain a comprehensive coverage and analysis of the related literature. As a result of this SLR we also identified the most interesting publications, authors involved and the most interesting techniques to investigate the near future. We are interested in understanding if there is a well-defined resilience structure; if there are procedures to evaluate or measure the resilience capabilities of a supply chain; which are the modelling and simulation techniques in use and and which ones to study in the next future.This topic is of fundamental importance also in the military considering the strategic utility of supply chains in the operations and for logistics.

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Introduction:-

According to the classical definition, a supply chain is a group of entities involved in a process chain concerning the acquisition of raw materials or components, their conversion or assembly into a product and the distribution of the final product to a customer.

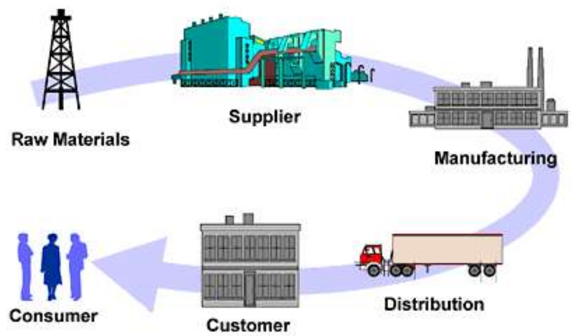


Figure 1 – typical supply chain

The world's leading industries are focusing more and more on integration, optimization and management of the entire supply chain, from component acquisition to manufacturing, inventory management and end-customer delivery distribution. In the last decades, corporate environments moved from mass production to customization, and from technology and product to market and customer. Providing a distinctive customer value has become a major business factor for companies. However, a single company is often unable to meet all customer needs, including rapidly-developing technologies, a variety of requirements of products and services and shorter product life cycles. These new developing business environments made companies look to the supply chain as an "extended enterprise" to meet end customer expectations.

Participants joining the extended enterprise will cooperate and collaborate with each other to achieve common goals, obtaining therefore competitive advantages. The efficiency of the supply chain and its interaction with the business logistics concept can determine the performance of a single company inside the extended enterprise. In many cases, a company's performance will depend largely on its upstream suppliers. The product introduction life cycle is shortening and market needs are more diversified, while there is pressure to reduce costs and product delivery times. Performance, quality and price were key factors for competitive advantage, but the service is increasingly becoming a differentiating factor. Since '90s companies can no longer maintain profitability and competitive advantage simply with good quality products and technologies in the traditional ways (Christopher M. G., 1998).

Alternative approaches now under exploration include a combined offer of products and services where the boundaries between manufacturer, seller and service provider are granted. Often, a single company can no longer compete effectively in the modern global marketplace, for this reason interest in the extended enterprise has grown. Companies took advantage from collaborative partnerships and risk and revenue sharing agreements. It is particularly important that efficient supply chain operations ensure revenue streams throughout the product life cycle, due to the high initial costs associated with development and production.

The creation of a distinctive value for the customer, requires the supply of a differentiated offer that includes short delivery times linked to a high flexibility in volume and variety of associated products and services. These requirements are often too demanding for a company to meet them entirely using only its own resources. Traditional vertical integration is no longer the solution because it would not be flexible enough to meet the variety of requirements, therefore, companies may need to deliver value to the customer in new ways, obtaining and maintaining vital business contracts. Companies tend to focus on their core business and expertise, outsourcing other areas to the extended enterprise. Christopher (Christopher M. G., 1998) argued that real competition in the market now exists between supply chains, not between companies.

All this means that an organization can no longer act as an isolated and independent entity in the competition, but the fully integrated supply chain can offer competitive advantages in the marketplace. According to Johansson (Johansson, 2002), one of the most common definition of the supply chain is "a system whose constituent parts include material suppliers, production facilities, distribution services and customers linked together via the feedforward materials and the feedback flow of information." It is commonly accepted that there are three main flows in the supply chain: material flow, information flow and cash flow. Activities involved in material flow must be delivered to the end user through the supply of raw materials, production, distribution and customer service.All these activities must be managed using appropriate information flows (see Figure 2).

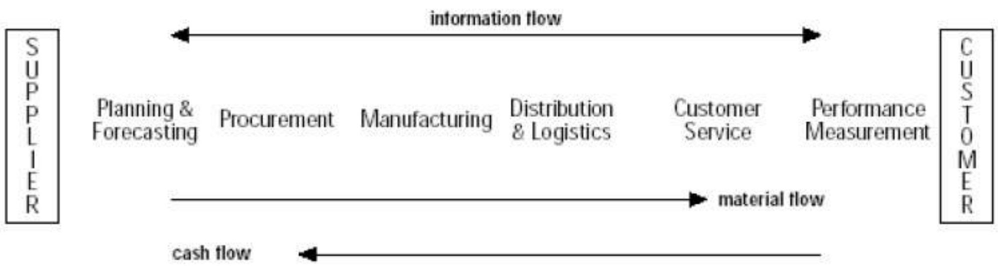


Figure 2 - flow in a supply chain

The linear representation of the supply chain, however, has started to be considered a bit simplistic (Lambert & Cooper, 2000) (Choi & Kim, 2008). Actually, materials and information flow through a complex structure of organizations, from the initial raw materials to the final consumer: it can be effectively defined as a supply network. A supply network is defined as "interconnected entities whose primary purpose is the procurement, use and transformation of resources to provide packages of goods and services ". (Harland & et al., 2001). This is therefore the set of organizations that directly and indirectly produce products and services to support specific end-consumer markets (Harland & et al., 2001).

Lambert & Cooper (2000) distinguish between primary members - those companies that carry out activities aimed at adding value for clients and end consumers - and support members - organisations that provide resources, knowledge or resources for main members. In this definition, the network is seen from the position of a focused company - a single node where products and information flow from multiple upstream suppliers to downstream customers (Harland C., 1996). This level of conceptualisation is often characterised as the highest to be considered by supply chain management (Crooms, Romano, & Giannakis, 2000) and most of the research on the supply network is from the perspective of a focused company.

However, this definition tends to overlook the interdependencies that occur between several suppliers and buyers in a supply network (Greening & Rutherford, 2001). The research on industrial networks emerged from the fields of industrial marketing and purchasing (Möller, 1995) and describes the complex interactions through an integrated network in a particular market. In literature the use of the supply network (focused company) and the industrial network (no focused company) are often used interchangeably (Miemczyk, 2012). The definition of the industrial network, however, recognises the market context of the network and those organisations operate within a complex network of interconnected business relationships, some of which exist outside the traditional supply chain links (Gadde, 2003), (Ritter, 2004).

This also applies to relations with government, NGOs, the media and other non-business organizations (Ritter et al., 2003). Figure 3 shows the structural differences between supply chain and industrial networks. In this context, no connection can be understood without reference to the wider network. Each company "gains benefits and bears costs by the network into which it is incorporated and by the investments and actions of all other companies involved" (Hakansson H. &., 2002, p.134). The examination of these wider connections is particularly important when we look at the major disruptions of supply chain nodes, where companies need to look for new connections in the wider context of the industrial network (Greening & Rutherford, 2001).

This level of analysis is also vital when examining the sustainability of practices, as the social and environmental consequences of actors' behaviour expand further and have an impact on a wider group of stakeholders than on those in the immediate supply chain (Miemczyk, 2012). The inclusion of more actors in a supply network may discover additional reasons such as social, environmental and ethical considerations that could be lost by using more isolated analysis units (Pilbeam, 2012). The Chatham House project, by its very nature, examined the food system from an industrial network perspective: there was no focused company, but it examined different organizations and their perceptions at different points of the wheat and dairy industry. This thesis, therefore, explains the word "supply network" in terms of an industrial network; so, any reference to supply networks implies this definition.

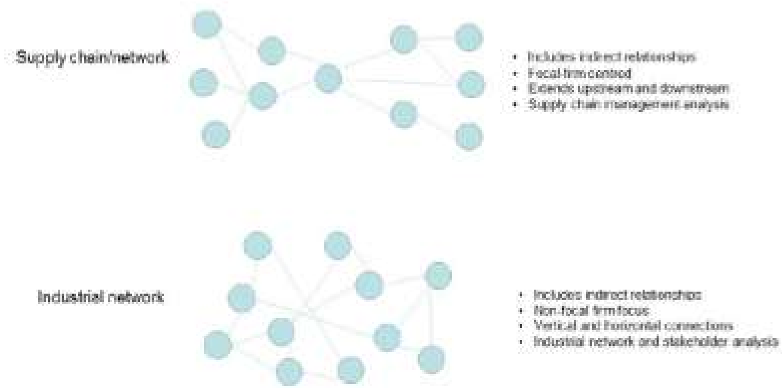


Figure 3 - Levels of supply network analysis (adapted by Miemczyk et al, 2012)

The way in which the traditional Supply Chain Management (SCM) relates to network settings and how it needs to be adapted represents an even greater challenge. From an industrial/supply network, it becomes virtually impossible for a company to control and coordinate activities through the network in the traditional sense of SCM (Ritter, 2004). Gereffi et al. (Gerreffi, 2005) identify three key factors that influence the way in which networks can be successfully governed by leading companies:

- the complexity of the information required to support a transaction, especially in terms of product and process specifications
- the way in which information can be encoded and transmitted to the parties without the need for transaction-specific investments
- the capabilities of organisations and actors in the supply network to meet the transaction requirements.

Gerreffi et al. (Gerreffi, 2005) identified five different types of governance, based on these factors. These are shown in Figure 4.

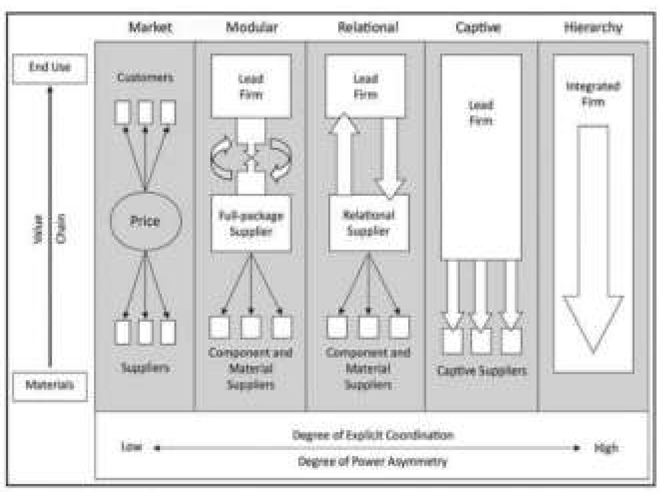


Figure 4 – Five types of global value chain governance (Gerreffi et al. (2005)

More research has begun to emerge regarding the supply. While actors with more power may have the opportunity to control parts of the network, their control is limited or difficult where there are more nodes / suppliers (Pilbeam, 2012). Where integrated SCM management concepts apply, as greater efficiency and effectiveness are the desired result, it is necessary to focus on a greater legitimacy and/or increase flexibility. In this context, SCM concepts expand from the management of serial interdependencies (direct connections) to the exploitation of the benefits of other interdependencies with a wider set of stakeholders through the network (Hakansson& Persson, 2004), (Pilbeam, 2012). This has a subtle difference to the classic EER on which it is based, rather than developing connections to protect against opportunistic behaviour and uncertainty, there are lower benefits from developing connections outside the traditional SCM model (Gadde, 2003). The definition of the supply chain focuses on the interdependencies of the actors belonging to the same supply chain (Morais, 2010): the sudden crisis, affecting one or more nodes, inevitably creates an inconvenience that can destabilize the system as a whole. One element that has become increasingly important in recent years, is the security factor.

Let us think of recent terrorist episodes that pushed some governments to invest heavily on this front, encouraging research on technologies and management tools for the security of materials, people and information flows. Although supply chain engineering methods rapidly evolved in a sophisticated way over the past two decades, the application of modeling and methods to explicitly consider and manage uncertainties and risks in supply chain activities is necessary for companies to advance to the next level of sophistication. The ability to identify, evaluate, manage, mitigate and control the impact of disruptive events within the extended supply chain is at the core of the complete supply chain risk management.

In the past, many companies attempted to improve their financial performances by implementing various supply chain initiatives. These initiatives aimed to increase revenue, reduce costs (e.g., reducing the supply base, online sourcing including e-marketplaces and online auctions, offshore production, just-in-time inventory systems, supplier-managed inventory) and reduce operations (e.g., manufacturing, information technology and logistics). These initiatives can be effective in a stable environment; however, as the number of supply chain partner increases, these global supply chains become "longer" and "more complex".

Long and complex global supply chains are usually slow to respond to change and are therefore more vulnerable to business disruption. According to a study conducted by Computer Sciences Corporation in 2004, 60% of companies reported that their supply chains are vulnerable to disruption. In today's uncertain and turbulent markets, supply chain vulnerability has become a particularly important issue for many companies. Threats to the supply chain have been intensified by long and global supply chains, increasingly shorter product lifecycles, and volatile, unpredictable markets. A vulnerability analysis is not as a risk analysis.

This latter focuses on human resources, environmental and asset impacts of an accidental event, while a vulnerability analysis focuses on the survival of the system. Vulnerability analysis has a wider range than risk analysis. In particular, the former focuses on how to weaken detected threats and reboot the system after an accidental event. Asbjørnslett and Rausand (Asbjornslett, 1997) describe the steps to conduct a vulnerability analysis. First, an assessment scenario is developed with the list of threats and the potential probability of the risk scenario. Second, a quantitative analysis of the factors previously detected is carried out, classifying threats and scenarios according to critical issues in terms of impacts on human resources, environment, trade and real estate. In his work "The Resilient Enterprise", Yossi Sheffi (Sheffi, 2005) analyses high impact / low probability interruptions. Sheffi says that in the process of creating a resilient organization, companies must first identify and prioritise types and levels of risk they face.

A company's vulnerability increases with the volatility of demand and the globalization of the supply chain. Risk factors, in addition to acting individually on vulnerabilities for companies operating in the supply chain, combine and influence each other (the uncertainty in such a market may be due to catastrophic or terrorist events). Basically, it is necessary to include in decision-making models not only risks associated with traditional processes, controls, supplies and demand, but also those related to the external environments in which the supply chain operates. For this reason the focus has shifted from a robust-oriented supply chain to a resilience-oriented supply chain.

Resilience Definition:

The origin of resilience was detected for the first time in the field of psychology, then it spread in other fields such as medicine and finally reached the economic science. A long-term survey studied children who grew up in adverse conditions in order to identify special children who were able to develop positively despite their negative environment. The result of this study showed that some children had special abilities that enabled them to cope with negative external influences. The scientific literature defined these children as "special" or "vulnerable" (Kißgen and Heinen, 2010). The literal term "resilience" was developed from a survey conducted by Werner and Smith in 1980

Resilience in Material Science:
Resilience in materials science usually refers to the ability of the material to return to its original form after temporary deflection. The degree of recovery is measured by the rate of recovery (Nagdi, 1993). The degree of resilience is also measured by the ratio of the energy returned to the energy applied to produce the deformation. The higher the ratio, the greater the recovery capacity of the material (Nagdi, 1993). This ratio can be considered proportional to the percentage of rebound.

Resilience in Engineering and Ecological Resilience:
Holling (Holling, 1996) defines and distinguishes engineering resilience and ecosystem resilience as two different and alternating paradigms. His ideas on these systems are shown in Table 1.

	Engineering Resilience	**Ecological Resilience**
Definition (focus on)	Maintaining the function	Existence of the function
Attributes (Desired for fail-proof design)	Efficiency, Constancy and Predictability	Persistence, Change, and Unpredictability
Stability	Global optimum or one equilibrium Steady State exists	More than one equilibrium states and systems flips states in case of instabilities.
Measure of Resilience	Resistance to Disturbance, and Speed of Return to equilibrium	The magnitude of disturbance the system can absorb before the system changes its structure and attain a controlled behavior.

Table 1 - Summary of Engineering Resilience and Ecological Resilience (Holling, 1996)In addition to the above, Gao (Gao, 2010) suggests a definition for engineering resilience based on the concepts of system function and damage and he distinguishes it further from resilience-like concepts such as reliability, robustness, repair, etc.

Resilience in Information and Communication Technology:
Laprie (Laprie, 2008) refers to resilience in complex information and computer systems in order to have the similar concept of ecological resilience described by Holling (Holling, 1973). For this system, he provides the following definition of resilience as "The persistence of the avoidance of failures that are unacceptably frequent or severe, when facing changes". Sterbenz et al. (Sterbenz, 2010) describes the following two disciplines that form the basis for network resilience:
a. Disciplines of tolerance that deal with the design and engineering of systems that continue to provide a service faced with the challenges.
b. Disciplines of trustworthiness that describe the measurable properties of resilient systems.

The divisions of these disciplines are shown in Table 2.

Challenge tolerance	Fault Tolerance (compensated through Redundancy)
	Survivability (requires diversity)
	Disruption tolerance
	Traffic tolerance (accommodate sudden load)
Trustworthiness	Dependability (availability and reliability)
	Security (reduce unauthorized access)
	Perform-ability

Table 2 - Basic disciplines for information and communication resilience

Business Resilience:
Hamel and Valikangas (Hamel, 2003) identified business resilience as a superior ability to reinvent a business model before circumstances change. They also suggested the following strategies for business resilience:
a. Anticipation of unforeseen failures through special attention to the business environment.
b. Investment in diversity (products or services).
c. Constant exploration of new opportunities.
d. Maintaining the balance between optimization (a research for efficiency) and the exploration of new opportunities.
Furthermore, quantitative assessments of resilience using enablers and the inter-dependencies between their dimensions are beneficial measures for managers. (Agarwal and Seth, 2021).

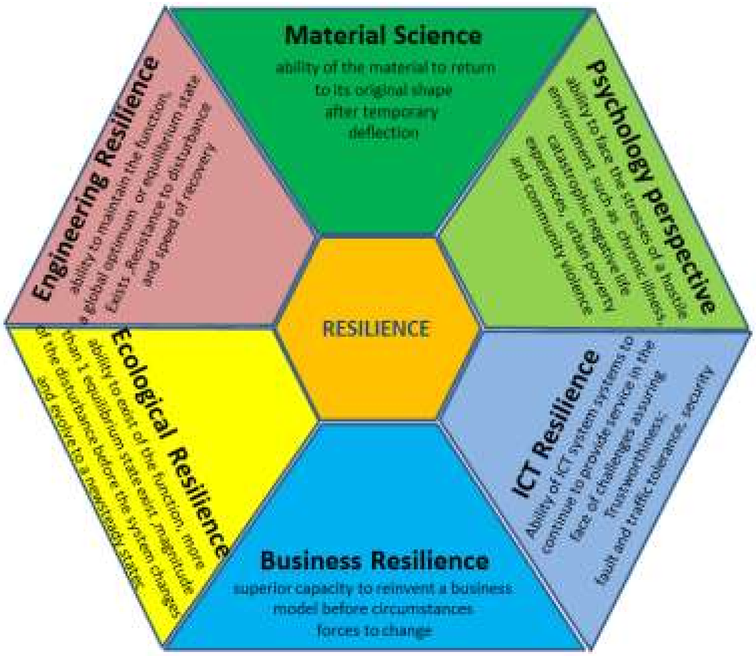


Figure 5 - Resilience: various perspectives

Generic Resilience Of The System:
The resilience definitions collected from various fields are used to describe the characteristics of a resilient system and create a complete definition. We suggest a new definition expressed, also, in a supply chain perspective.
a. Objective: the objective of the resilient system should be to survive and maintain the function (at least partially) during the interruption. In the case of the supply chain, survival can be seen as an equivalent to profit, while the function of a supply chain is described as to satisfy demand with a sufficient quantity. Here, survival and function are separated to capture a case where the supply chain meets the demand, but the demand is not enough to make a sufficient profit for its survival.
b. Anticipation: a resilient system should have continuous anticipation for all types of disruptions, paying particular attention to the continuous changes in its environment and at the same time using the knowledge learned from the destructive events of the past.
c. Estimation: to have the strong intent to estimate and prioritize the damage that could occur from the expected disruptions.
d. Preparation: a resilient system should adopt an appropriate resilient strategy or a combination of strategies as preparation for defence against possible disruptions. Some of the resilient strategies identified in the previous study on resilience in various fields are creating diversity, flexibility, redundancy, security and safety measures, collaboration and sharing of resources, etc.

The strategy selection depends on the system, context and situation. This article, as an extension of the distinction made by Holling (Holling, 1996) between engineering resilience and ecological resilience, considers that supply chain systems occupy the intersection of these two paradigms (see Table 1) as it concerns not only the social component in the form of interactions with suppliers and customers but also the engineering values during the production phase.

The combination of the above characteristics gives a generic definition of resilient system (also applicable to supply chain systems) as follows:
A resilient system is a system aimed at surviving and maintaining its function even during an interruption, with the ability to predict and assess the damage of possible interruptions, reinforced by a strong awareness of its constantly changing environment and knowledge of past events and therefore using resilient strategies for the defence against interruptions.

This definition can be seen as a combination of the definitions of Zhang and Lin (Zhang, 2010) and Hollnagel et al. (Hollnagel E. W., 2006). The behaviour of a company exposed to sudden interruptions has been well illustrated by (Sheffi, 2005). The destructive event is preceded by a "warning time" in which the company can (in some cases) predict what will happen and act to reduce the consequences. If the disruption cannot be avoided in time, it will occur in full force after a short time due to a "delayed impact". At this point the company must prepare to recover. Recovery occurs gradually after the "recovery time" and brings the company to a level of performance that is often lower than before the impact (see Figure 6).

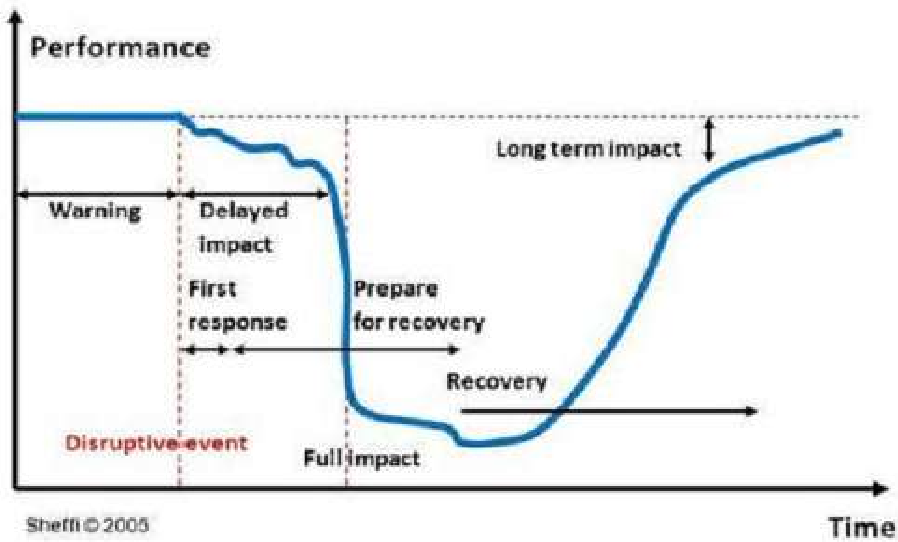


Figure 6 Performance by Time (Sheffi)

The risk is inevitable but it can be managed (Briano, Caballini, Giribone and Revetria, 2010). There are basically two main strategies to manage the risk: an attempt to reduce the risk by reducing the consequences or the impact of increasing the responsiveness of the supply chain (in other words reducing vulnerability), while the other try to reduce the possibility of occurrence, which increases its security. Recent studies showed how resilience is the best way to deal with disruptions. According to Christopher (2004), supply chain risks can be mitigated through a systematic approach to the supply chain risk management. There are 5 basic principles that allow the creation of a more resilient supply chain:
a. Understanding the supply chain: mapping tools can be useful for this.
b. Basic supply strategy: many companies reduced the number of suppliers in order to reduce production costs. It can provide a real cost reduction, but this type of strategy is dangerous in terms of resilience.
c. Supply chain collaboration: A high level of collaboration throughout the supply chain can help mitigate risks.
d. Agility: One of the most powerful ways to achieve resilience is agility. Organisations that have focused their attention on eliminating value-added steps throughout the supply chain have been shown to be more prepared to respond to unforeseen events. Agility is based on two key concepts: speed and visibility. Speed requires shorter end-to-end pipelines that depend on sourcing decisions and improved internal processes.

Visibility affects agility in several ways. First, it reduces uncertainty and achieves the goal of a demand-driven supply chain. Second, it reduces supply chain risk through shared information, both upstream and downstream of the company's activities.

e. Creating a supply chain risk management (Revetria, 2000).Sheffi (Sheffi, 2005) points out that business risk management comes in 3 forms: there are managers in charge of the business continuity plan, there is the security staff (access badges, security codes, etc.) and finally the information technology security function (e.g. data backup). These 3 functions are often independent and cannot be integrated into company strategies.

The traditional definitions of business security and continuity are only a small part of the true resilience capability. In particular, companies can develop resilience in three main ways: by increasing redundancy, by increasing flexibility and by changing the corporate culture. The first has a limited utility; the other two are essential.

Systematic Literature Review:-

The aim of our work is to produce a reliable knowledge base and highlight opportunities for the future research, identifying what is known and what is not about Supply Chain Resistance. We used the systematic literature review (SLR) approach and evidence synthesis (Briner & Denyer, 2012, Rousseau et al., 2008) to achieve this goal. Originally developed in the medical sciences, the Systematic Literature Review (SLR) has been widely recognised in management and organisational sciences as an evidence-based approach to identify, select, analyse, synthesise and report "best evidence" secondary data (Briner & Denyer, 2012); (Denyer & Tranfield, 2009; Tranfield et al., 2003). Unlike traditional reviews of narrative literature, the SLR aims to eliminate prejudices and improve the quality of the review process by ensuring accuracy, replicability and consequently relevant results (Tranfield et al., 2003). According to Denyer and Tranfield (2009) the SLR approach has four fundamental methodological principles. The SLR approach is transparent, inclusive, explanatory and heuristic.

These sets of principles are incorporated in the five review phases shown in Figure 7

1. Question Formulation;
2. Locating Studies;
3. Article Selection and Evaluation;
4. Analysis and Synthesis;
5. Reporting and Using the Results.

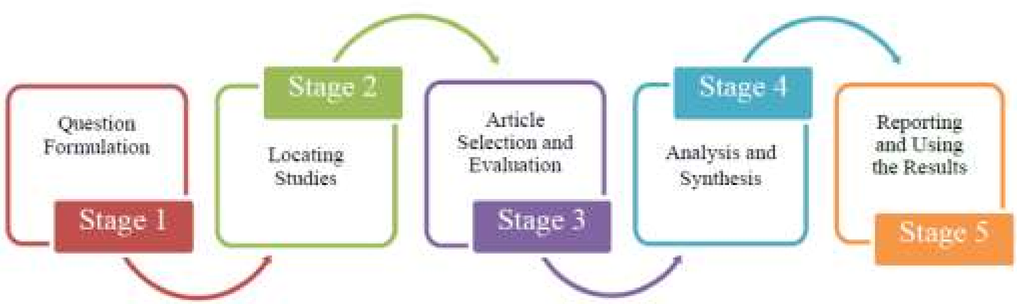


Figure 7 – SLR Methodology

The following sections will illustrate each of the five review steps to improve the validity and quality of the SLR results.

Formulation Of Questions:

A good question for systematic review should be formulated as a question that can be divided into a number of questions (Briner & Denyer, 2012). Denyer and Tranfield (2009) propose to formulate review questions using a CIMO framework consisting of context (C), intervention (I), mechanisms (M) and outcomes (O). The context questions identify which people, institutional settings or broader systems are the subject of the study. Intervention questions detect the effects of events, actions or activities. Mechanism questions identify the connections between interventions and results. Questions on results determine the effects of the intervention, the measures of the results and the expected and unforeseen effects. We adapt the CIMO logic to form our initial review question and establish a basis to summarize and report the results of the SLR approach.

As shown in Figure 8, we suggest that supply chain capabilities and vulnerabilities (I) can produce different results of the Supply Chain Resistance (O) based on different mechanisms (M) depending on specific contexts (C). We therefore use the CIMO framework to answer the following research question: how do supply chain capabilities and vulnerabilities create specific results in specific supply chain resilience contexts?

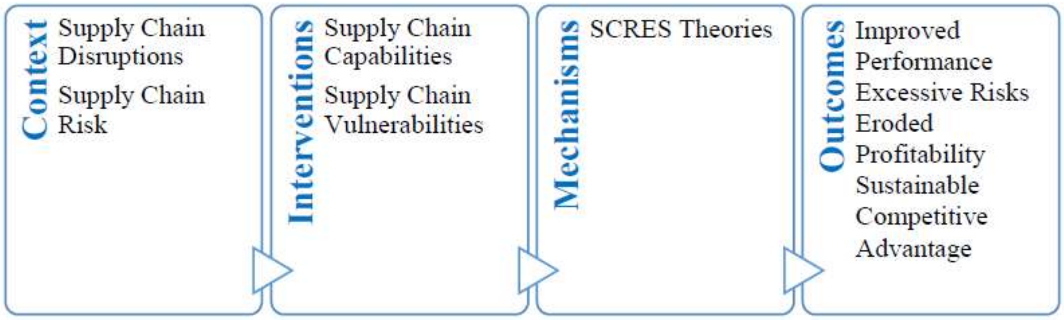


Figure 8 – CIMO Framework

Identification of Studies:

A total of 18 SCRES-related keywords and SCRES concepts have been identified. Keywords include expressions such as “supply chain resilience”, “supply chain vulnerability”, “supply chain risk”, “supply chain disruption” and “supply chain” and “resilience” in the title, keywords or articles abstract. Table 3 shows keywords, constructs and codes used in the research. In the process of refining keywords, a group of three academics with experience in the area of supply chain risk and supply chain resilience have been consulted to minimize distortion during the keyword research.

Constructs	Keywords	Codes
Supply Chain Resiliency	Supply chain resilience	"supply chain" AND "resilience"
	Supply chain resiliency	"supply chain" AND "resiliency"
	Resilient supply chain	"supply chain" AND "resilient"

Table 3 - Keywords and codes used in the research

A wide variety of free search engines have been used, including: Google scholar, Research Gate, Emerald, Science Direct, Wiley Online Library, Taylor & Francis, Springer, Elsevier, etc. (Table 4).
All these activities must be managed using appropriate information flows (see Figure 2).

Main Free Academic Search Engine	Web site URL
Google scholar	https://scholar.google.com/
Science Direct	http://www.sciencedirect.com/
Research Gate	https://www.researchgate.net/
Emerald	http://www.emeraldinsight.com/
Pro Quest free	http://www.proquest.com/
Wiley Online Library	http://onlinelibrary.wiley.com/
Taylor & Francis Online	http://www.tandfonline.com/
Springer T	http://www.springer.com/it/
Elsevier	https://www.elsevier.com/
IEE Explore	http://ieeexplore.ieee.org/
InderScience Online	http://www.inderscienceonline.com/

Table 4 - Free academic search engine mainly used

Selection And Evaluation Of The Study:

We found references that age over a period of 32 years (1990-2022, updated in February). We did not exclude chapters of books, conference proceedings and doctoral theses. Our selection has about 2100 publications. This large number of papers required some checks for accuracy and consistency. We extracted about 140 random articles and verified the precision of the extraction from the criteria adopted in the search engine (i.e. we searched the title in the keywords or in the "keywords" shown in Table 3. We found an error of about 3.5% which, from our point of view, confirms the universe of the collected data).

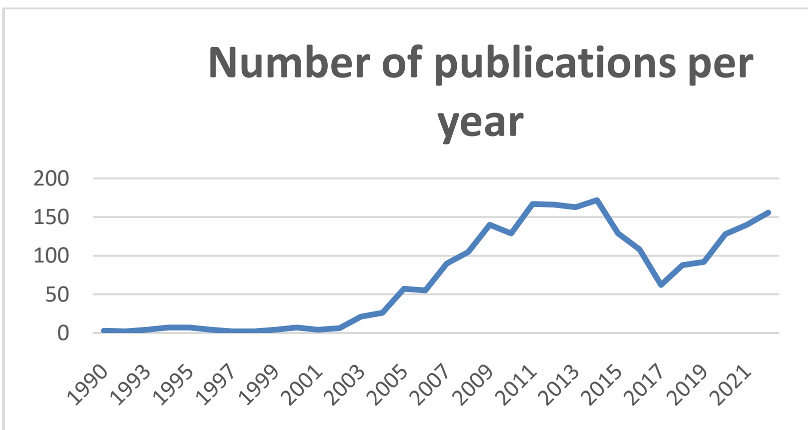
Formulation Of Questions:

According to Tranfield et al. (2003), the systematic review should summarize the results of individual studies in a new or different arrangement. Therefore, we have performed a multidimensional analysis of the collected data in order to obtain information suitable for future research.

Distribution of works per year:

A very interesting measure is the distribution of work per year. Figure 9 shows the editorial trend in the field of supply chain resilience from the 1990s to February 2022 (2022 is a linear estimate from the data collected until December). An increasing trend in the number of publications can be observed especially after 2008. However, the number of publications is significantly low compared to other supply chain management areas such as supply chain risk (Pereira et al., 2014).

In any case, we can understand that the peak in the number of research has been reached between 2012-2014, after the trend has decreased but now is increasing more than the past years. This could be explained by the fact that most have been done in the recent past to conceptualize the theory and create an adequate "resilience framework", after scholars were mainly oriented to find right "models" to measure the resilience of a supply chain or to analyze the resilient capabilities of a supply chain network but, during the COVID 19 period, has been necessary to adapt the past studies



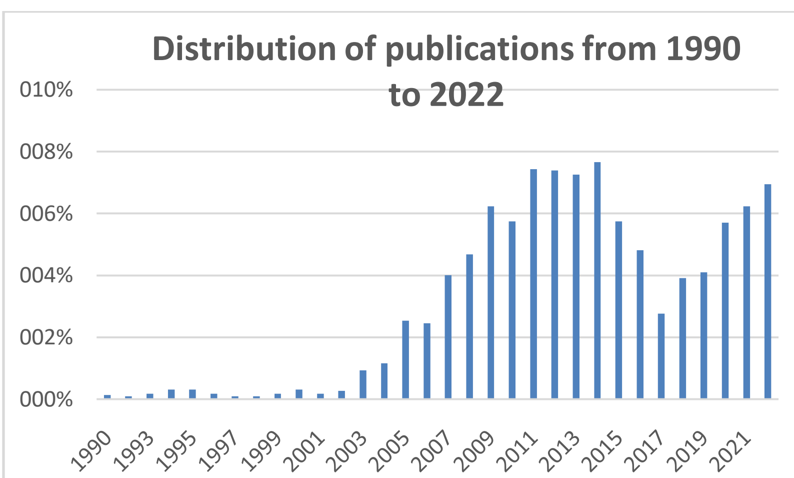


Figure 9 - Number and distribution of publications per year

Text extraction analysis:

We initially performed a text extraction analysis of the collected data. We sampled the universe by extracting about 10% of the works. The sampled subset includes 145 works, about 160,000 characters and about 70,000 words. After some monopolization and standardization we obtained the histogram of the most frequent words used in documents (Figure 10).

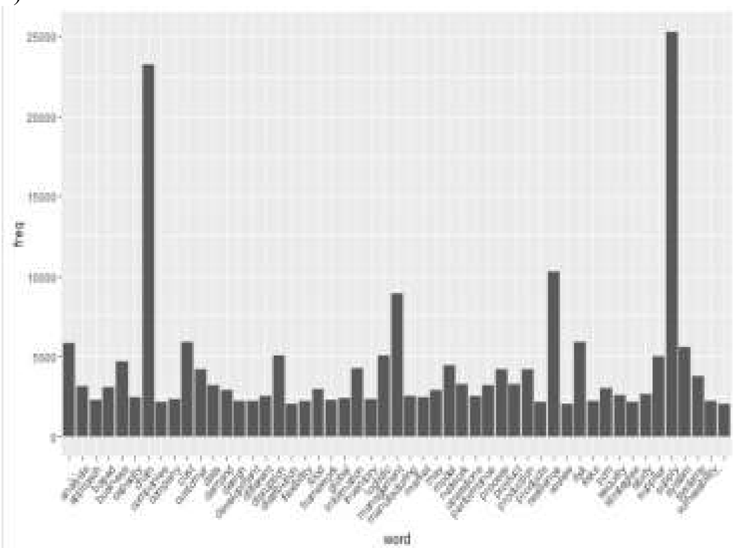


Figure 10 - chart of words frequency

It is very significant that most of the words in this chart are those we used to introduce and provide a detailed description of resilience and supply chain management. In order to have a more meaningful view we represented the most frequently used words with a word-cloud-graph: we discovered that this representation is very interesting because it gives the idea at a glance of all the concepts concerning resilience and supply chain management (Figure 11).

Figure 11 - Representation of CloudWords

This representation of words highlights the most used words that scholars used to "talk about" resilience: it will be very useful in the next steps to evaluate the recent trend and status of "resilience theory".

Reporting And Using The Results:
We report the results as a description of what is known and what is not known on the application for review. The objective of the SLR approach is to summarize the literature in a way that makes the results more understandable for professionals and researchers.

Sources:
The large amount of data collected can be used to go deeper into the universe of sources (journals, books, procedure, doctoral thesis.). As for sources, a widely used metric is the relative frequency of a single source compared to general elements. Therefore, in general, it is normal to find a table of characters ordered in descending order according to the relative frequency of the event itself. For our purposes we believe that this measure is too "weak" because it loses some important information about the "relative" importance of the source and the distribution over time of the publication.

In order to get more information, we organized all types of sources in a different way, trying to obtain information about the "presence" during years of the source and the distance (along the time axis) from now of the publications. We introduced 3 new metrics and used a more efficient tool than the normal bar graph to represent simultaneously these 3 metrics and all 647 (separate) sources collected. We used the sphere graphic tool in which the 2 main axes are respectively metrics 2 and 3 and the size of the sphere is the first metric (see Figure 12).

	Metric 1	Metric 2	Metric 3
	Mean works by year	"Centred" year	Num years more frequent
Journal X	6,52	2010	10

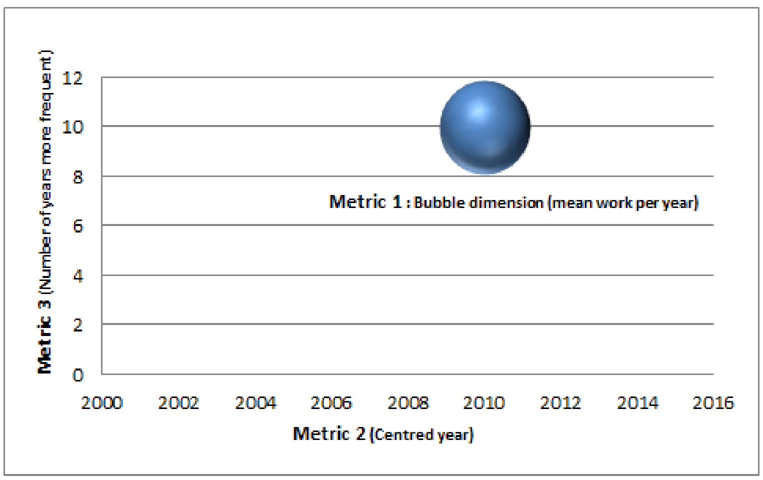


Figure 12 - Bubble chart for diary X

Our data universe has 647 different sources represented by 647 bubbles of different size and position in the chart, obviously not uniformly distributed over it. Most of the sources have a size that is really small and not "remarkable", so we can appreciate about 20-25 bubbles (the non-gray ones) which represent the most remarkable sources.

Let's isolate (see Figure 13) the cloud of notable sources from the rest (we kept also the Google Books source, but it mainly refers to books published or sold by Google).

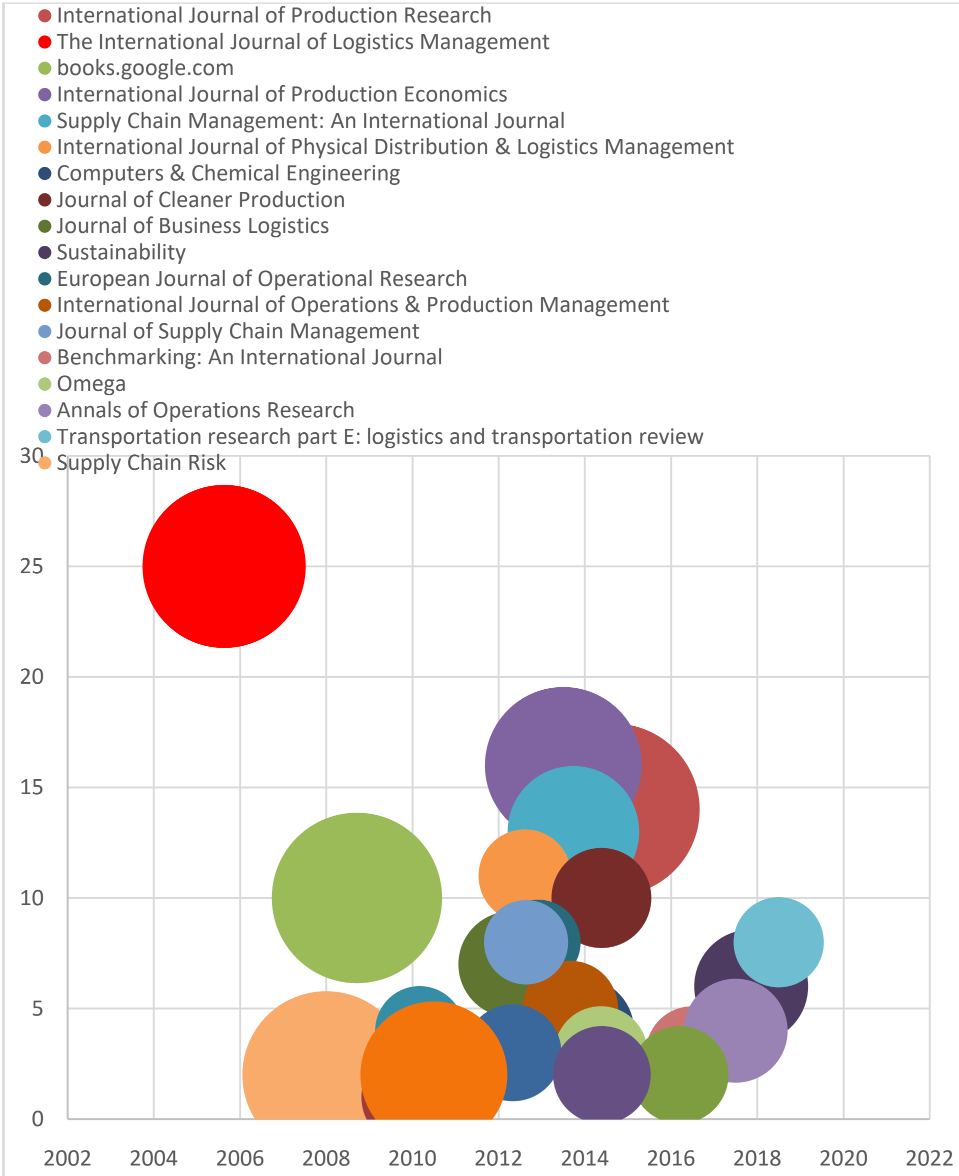


Figure 13 - Bubble chart of the first 24 sources

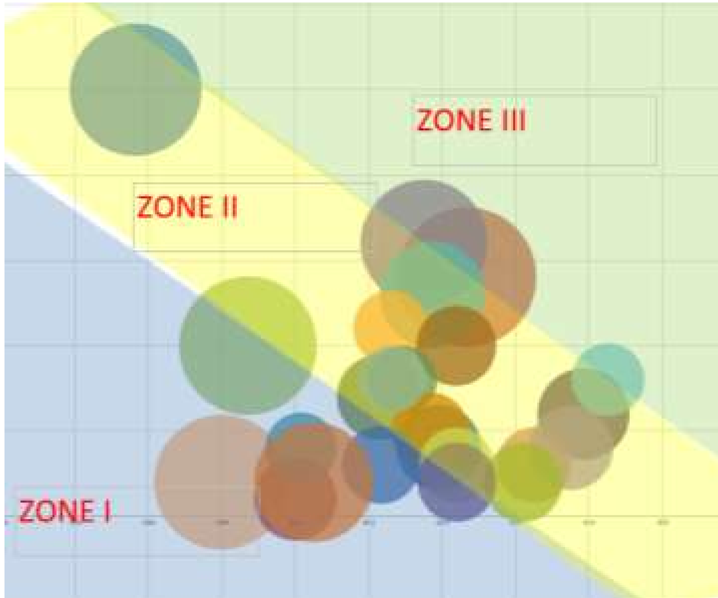
We divided the chart plan into 3 regions:

I. This is the area of the no longer active sources.

II. This is the area of active sources in the recent past, but currently they appear as inactive or with a non-significant number of jobs.

III. This is the area where there are the most active (so far) or most important sources that deal with resilience in the supply chain.

In Table 5 we summarized these 25 sources, highlighting their names (and the acronym used in this paper), their metrics and their url.



N ame	ean works by year	entred year	um years more frequent	. years in total	one
In dustrial Engineering and Engineering Management		010			
Journal of operations management	,83	010			
Ex pert Systems with Applications	,2	014			
IE EE Transactions on Engineering Management	,2	016			I
Su pply Chain Forum: An International Journal	,4	010			
Pr oduction Planning & Control	,17	012			
Su pply Chain Risk	,5	008			
Tr ansportation research part E: logistics and transportation review	,88	018			II
A nnals of Operations Research	,5	017			I

O mega		014			I
Be nchmarking: An International Journal		016			I
Jo urnal of Supply Chain Management	,64	012		1	I
Int ernational Journal of Operations & Production Management	,11	013			I
Eu ropean Journal of Operational Research	,67	012		2	I
Su stainability		017			I
Jo urnal of Business Logistics	,6	012		0	I
Jo urnal of Cleaner Production	,31	014	0	3	I
C omputers & Chemical Engineering	,58	013		2	I
Int ernational Journal of Physical Distribution & Logistics Management		012	1	8	I
Su pply Chain Management: An International Journal		013	3	5	I
Int ernational Journal of Production Economics	,69	013	6	6	II
bo oks.google.com	,71	008	0	4	
Int ernational Journal of Production Research	,87	014	4	5	
Th e International Journal of Logistics Management	,17	005	5	0	I

Table 5: List of the first 24 sources and division in zones

We grouped all the authors collected (each of whom counted 1 regardless the order of presence in the individual work, i.e. regardless whether he was the first or the fourth author). The universe of data collected counts 3667 different authors. The distribution per year is very interesting (see Figure 14):

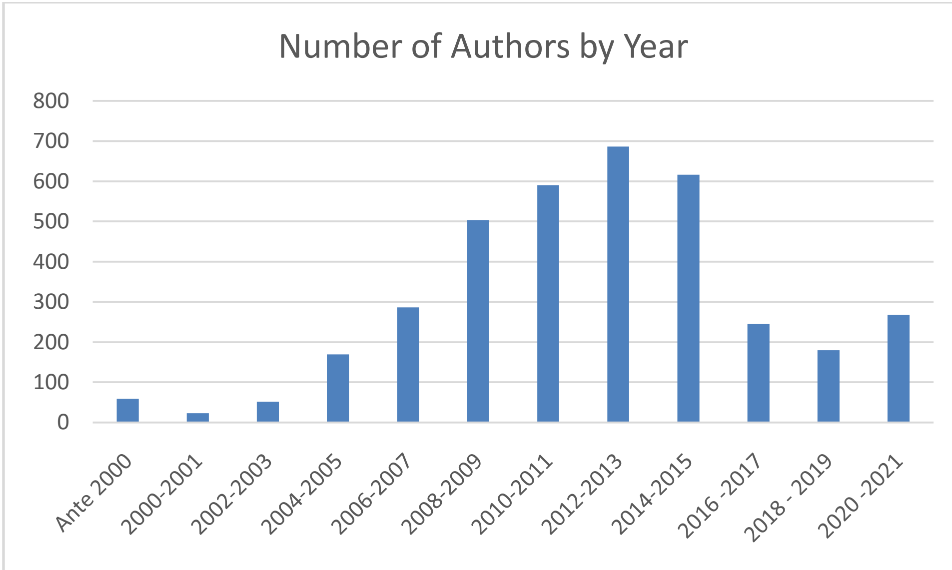


Figure 14 - Number of authors per year

State Of The Art And Complete Reading Of The Paper:
We report the results as a description of what is known and what is not known on the application for review. The objective of the SLR approach is to summarize the literature in a way that makes the results more understandable for professionals and researchers.
As a final step in our systematic review of the literature, we carried out a comprehensive analysis of all works published in recent years by the authors listed in Table 8. The results are shown in the following tables.

Purpose	**Percentage**
Theoretical	36%
Model and Simulation	36%
Review	28%
Total	00%

Purpose	Theoretical
Main Issue	**Percentage**
General Framework	75%
Measure of Resilience	25%
Total	100%

Table 6 - Aims of the complete works:
In Table 8 we summarized aims and approaches of the works published in recent years by the author of Table 7: as we can see, the interest in resilience is confirmed in the large number of works reviewed (about 30%). Therefore, the authors paid attention to the theoretical and model approach.If we go deeper into the last two we get:

Table 7 - Main theoretical problems

Purpose	Model and Simulation
Method	**Percentage**
SD modelling	52%
Stochastic Fuzzy Programming	20%
Industrial Dynamic	11%
Robust Optimization	17%
Total	**100%**

Table 8 - Model and simulation methods

We could therefore say that most of the work is about the general framework, while we can see that a lot of attention is given to SD modelling. The analysis of the authors' work gives us the possibility to write the most recent contribution on SCRs and the complete answers to the questions that represent the purpose of this thesis.

Results:-

Although supply chain resilience is cited by some scholars as a topic in its early stages, an increasing number of studies have been published on this topic along with the risk and vulnerability of the supply chain due to changes in the market and the environment. Therefore, this exploratory study has used a comprehensive review using the SLR technique to investigate the issues in the literature that scholars should address in creating supply chain resilience. We found that SCRes are actually of great interest among researchers. The peak of the research was reached between 2012-2014 (Figure 9) when the focus was on the "theoretical definition" of resilience in the supply chain: the text mining technique we used to analyse more than 640 papers helped us find the "words of the SCRs" (Figure 10, Figure 11). Today we can say that a well-defined "framework" has been described (Figure 13).

The analysis of the collected works has allowed us to obtain the most published sources on SCRes. A new method for cataloguing sources has been introduced: in this way we grouped all types of sources with a three-dimensional measurement that takes into account the number of published articles per year, the number of years of presence in this field of research and the "centred" year of publication.

By analysing the publications we obtained the most active authors on the subject. Analysing their works, we can say that in reality there is no single and unifying method of evaluation (Table 8), scholars seem to be involved in modelling the supply chain and simulating different scenarios to "evaluate" SC and improve their resilience.

Regarding this latter aspect, we believe that SD modelling and simulation is a promising technique and we will study more in the near future to obtain a more " strong " evaluation technique and measure resilience.

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